Data for Self-Assessment and External Review about Faculty Members

自己点検・外部評価資料

Contents

Particle and Nuclear Physics

Kenji Fukushima、福嶋 健二

1 Education and Professional Experiences

Education

1997	B.S. (Physics)	The University of Tokyo
1999	MSc. (Physics)	The University of Tokyo
2002	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

2002−2005	JSPS Research Fellow	The University of Tokyo
2003−2005	Visiting Scientist	Massachusetts Institute of Technology
2005−2007	Postdoctoral Fellow	RIKEN BNL Research Center
2007−2008	Assistant Professor	Yukawa Institute for Theoretical Physics
2008−2010	Associate Professor	Yukawa Institute for Theoretical Physics
2010−2013	Associate Professor	Keio University
2013−2017	Associate Professor	The University of Tokyo
2017−	Professor	The University of Tokyo

2 Research Highlights

We have been leading a research field of extreme matter out of quarks and gluons, i.e., fundamental particles in quantum chromodynamics (QCD), under various environments realized in relativistic nucleus-nucleus collision experiments, in cores of neutron stars, and even in theoretical idealization. We are covering many theoretical topics, sometimes cross-disciplinary over condensed matter systems and general physics, but it would be impractical trying to explain them all here. Below we make brief descriptions on major streams of our research.

◇ **Relativistic fermionic matter in strong fields**

In nucleus-nucleus collisions positively charged ions generate an extremely strong magnetic field, as well as achieving an extremely high temperature. QCD physicists have studied the phase diagram of QCD matter as functions of the temperature and the baryon density, and along the temperature axis our theoretical understanding has been significantly deeped thanks to successful QCD numerical simulations and high-energy nuclear experiments. About a decade ago we emphasized the importance of such strong magnetic field which affects the nature of QCD matter, and many theorists got interested in this possibility. Since then we have been pioneering strong-field physics in the context of QCD matter, and almost every year we published review articles on distinct theoretical aspects of strong-field physics. We cannot cover all our research activities within limited space, and we shall pick up some representatives onlyhere:

(1) We studied the magnetic effect on the QCD phase diagram, motivated by controversial lattice-QCD results. The origin of the mass can be explained by non-trivial QCD vacuum structures with BCS-type condensates, and usually in the BCS theory, the critical temperature should

increase if the condensates increase. In lattice-QCD simulations, however, the opposite was observed. We then successfully demonstrated our theoretical idea that the critical temperature can be decreased by fluctuations of Nambu-Goldstone bosons whose dispersions are modified by the magnetic field, and we named this new machanism the Magnetic Inhibition.

(2) Schwinger Mechanism is a pair particle production process in an external electric field. Inspired by our assertion, in our community, many started research involving the magnetic field, but not many cope with the electric field, for the electric phenomena are dynamical and far more difficult than static ones like the phase structures under an external magnetic field. We performed a rather brute-force numerical simulation to study the pair particle production, and at the same time, we utilized the world-line formalism to investigate the magnetic effect onto the Schwinger Mechanism and found a novel enhancement mechanism of the production rate assisted by the magnetic effect.

(3) One of our specialties lies in the Quantum Anomaly. Among various manifestations of the anomaly, a combination of the chirality and the magnetic field causes very interesting physics called the Chiral Magnetic Effect. We have been clarifying profound natures of this effect, and the recent discovery includes the fully field-theoretical computation of the electric conductivity in the presence of background magnetic field, which is considered for the signature of the Chiral Magnetic Effect. In this calculation the pinch singularities play an essential role, the resummation of which leads to kinetic type equations and the Kubo formula calculus eventually amounts to solving the kinetic equations. Also, our recent achievement revealed a nontrivial connection between the Chiral Magnetic Effect and the axial Ward identity through the Schwinger Mechanism. The latter is a beautiful concretization of the fact that the Chiral Magnetic Effect is an intrinsically dynamical phenomenon and it should be absent in equilibrated matter.

◇ **Chiral matter with a finite rotation**

One may say that the rotation is something like strong fields in a sense that the angular velocity is another controlling parameter. The angular velocity should be, however, not too large not to violate the causality bound. The rotation has effects similar to an external magnetic field as well as a finite baryon density. If the QCD vacuum is put into a rotating frame, it would be unnatural to anticipate any detectable change in physics, which would actually violate Einstein's equivalence principle. However, once the rotation couples with other disturbances such as the temperature, the chemical potential, the magnetic field, the finite Riemann curvature, etc, it is allowed to lead to nontrivial physics consequences. We performed explicit field-theoretical calculations for such systems and estimated the induced vector and the axial vector currents, the QCD condensates, etc. These calculations constitute important elements for a deeper understanding on recent experimental activities in relativistic nucleus-nucleus collision (in which an enormous amount of vorticity was found) as well as future signals from the neutron star that rotates with finite magnetic field and baryon density on its own. We are also extending our physics perspective from rotating field-theoretical systems to more general objects that exhibit the Barnett and the Einstein–de Haas effects. In fact we successfuly formulated the chiral Barnett effect and discovered not only a magnetization along the rotation axis but also a transverse magnetization originating from the chiral nature of matter, which might account for gigantic toroidal magnetic fields in the neutron star.

◇ **Deep machine learning analysis on the neutron star EoS**

Because of the severe sign problem it is still impossible to compute properties of dense baryonic matter even though the first principles theory is known, that is QCD. There are many model approaches to the QCD phase diagram and the equation of state (EoS). In the particular context of the neutron star physics, the EoS, i.e., a relation between the pressure and the energy density, is the most crucial information to determine the internal structures of the neutron star. The old-fashioned analysis had been the following; some model assumption is made; an EoS is calculated; then the output (in this case the mass-radius relation of the neutron star) is compared to the data to reject/accept the assumption. This trial-error attempt, however, amounts to endless iterations, and it is nowadays not really a preferred strategy. The modern approach is solving the regression problem to map the experimental data onto the most likely EoS. This is typically an ill-posed problem due to the lack of experimental data points. So far, the Bayesian analysis has been successful in the community, and as a complemental method, we proposed a new technique to utilize the machine learning with deep neural networks. Results from our new technique are as nicely contraining the EoS as the Bayesian analysis, and on top of the performance, the machine learning turns out to be far more easily adaptive to complicated dataset expected in the future multi-messanger era of the neutron star physics.

◇ **High-energy QCD processes**

QCD is an extremely interesting theory, especially at high energy, it enters a new regime where the theory is perturbative but nonlinear. Sometimes, in quantum field theories, the linearity and the perturbativity are mixed up, but they are clearly distinct. High-energy QCD is such a unique system with a small coupling constant and a large field amplitude. More interestingly, this large field amplitude gives a justification of solving the *classical* field dynamics, even though the large amplitude itself is a result of *quantum* evolution. We adopted this classical formulation, namely, the color glass condensate (CGC), to quantify the photon yields in the proton-nucleus collision and made a comparison to the available experimental data. At present the experimental data is quite limited, but our theoretical estimate should play a role as a guiding principle for the future higher-energy projects. The CGC is a profound theoretical formalism for not only this practical purpose to estimate physical observables. We established a mathematical procedure to take an expectation value of arbitrary number of the Wilson lines, which is indispensable for the correlator calculations in the CGC formalism.

3 Selected Papers

- P. Copinger, K. Fukushima et al., Physical Review Letters 121, 261602 (2018)
  This work has made an important observation that the realization of the chiral anomaly looks different in and out of equilibrium, which underlies the dynamical intrinsics of the chiral magnetic effect.

- M.G. Alford, G. Baym, K. Fukushima et al., Physical Review D99, 036004 (2019)
  This work has triggered active discussions on the deep nature of quark matter, some controversies and confusions, which are still under intensive discussions.

- Y. Fujimoto, K. Fukushima et al., Physical Review D98, 023019 (2018)
  This work has mapped the neutron star data to the EoS. This is a first successful application of the machine learning for such a purpose.

- K. Fukushima et al., Physical Review Letters 120, 162301 (2018)
  The work has clarified the field-theoretical treatment of the negative magnetoresistance for the first time that is a clear signature for the chiral magnetic effect.

- K. Fukushima et al., Physical Review Letters 110, 031601 (2013)
  This paper has been cited 145 times (INSPIRE). This work has given an explanation for a counter intuitive observation in lattice QCD under strong magnetic field.

4 Honors, Awards and Professional Society Memberships

2012 Nishinomiya Yukawa Memorial Prize, Nishinomiya City
2015 Outstanding Referee Prize, American Physical Society

5 Research Plan

Nuclear physics is now facing a sort of restructuring in the methods and even in the major physics objectives. Relativistic nucleus-nucleus collision programs have been extremely successful over almost a half century, but fundamental questions have been resolved, and remaining problems are rather technical. For the moment the active research will continue for another decade or so, but we must prepare for a paradigm shift from now, and particularly, it is of paramount importance to educate students so that they can have a wide physics perspective based on modern nuclear physics background, but not limited to it. We have already invested a lot for possible future research directions, and here, we shall introduce a couple of our future prospects.

◇ **Quantifying the electric effect in nuclear physics**

A decade ago we emphasized the importance of the magnetic field in a high-energy nuclear physics context, and since then, many theorists followed us. Now, in the QCD phase diagram research and the nucleus-nucleus collision discussions, the magnetic field is one of the most fashionable subjects. In contrast to this magnetic situation, not many are working on the electric field effects. This is mainly because the electric situation is dynamical and thus technically far more difficult, while the magnetic case is static (as long as the magnetic field is constant). We are pioneering the electric calculus, and we should definitely pursue this direction until others will follow us again. Last year we worked out a novel approach to the electric problem using the proper-time integral with a complexified contour that reflects the presence of the electric field. We are now advertising our method by showing various physical observables affected by the electric field.

◇ **Nuclear physics as a laboratory of quantum field theory**

QCD is such a fascinating theory accommodating all interesting theoretical features such as the topological states, the topological excitations, spontaneous symmetry breaking including higher-form symmetries, confinement, etc. Non-perturbative approaches developed in QCD can be applied to more general class of quantum field theory, for example, supersymmetric QCD-like theories. Recent breakthroughs include the establishment of confinement/deconfinement nature with physical degrees of freedom by calorons (i.e., finite-temperature instantons) with nontrivial holonomy that contains dyons in them. Even though the theory is not precisely QCD, we can in this way aquire many useful insights. Along these lines we are now investigating a modified QCD model to look into microscopic dynamics, which has been inspired by a question of disclosing a connection between predicsions from the 't Hooft anomaly argument and actual dynamics inherent in the theory.

◇ **Machine learning applications for the neutron star observations**

We are strongly pushing an idea to use the machine learning technique to analyze the neutron star observation. So far, we have confirmed that the performance is as good as the Bayesian analysis, but our wish is to demonstrate the advantages of the machine learning over the existing Bayesian results. Generally speaking, the advantages are found in the easy manipulation of the machine learning algorithms (and also in a less artificial choice of the prior information). In the previous works we considered the mass-radius observation data only in order to constrain the EoS and then checked the consistency with the tidal deformability hinted by the neutron star merger observations. Moreover, the constraint coming from the most massive neutron star (above the twice of the solar mass) was not taken into account for the machine training since the radius is undetermined, but we just made sure the consistency afterward. Ideally such different types of data would better be plugged into the optimization machinery from the beginning. Our future strategy is to develop a (public) library to deal with all such different data on the equal footing, which is crucially important for the forthcoming era of the multi-messanger astrophysical observations.

6 Publications and Patents

< Refereed Original Papers >

[1] P. Copinger, K. Fukushima, S. Pu, Phys. Rev. Let. **121**, 261602 (2018).

[2] S. Benić, K. Fukushima, O. Garcia-Montero, Phys. Let. B **791**, 11–16 (2019).

[3] M.G. Alford, G. Baym, K. Fukushima, T. Hatsuda, M. Tachibana, Phys. Rev. D **99**, 036004 (2019).

[4] K. Fukushima, S. Imaki, Phys. Rev. D **97**, 114003 (2018).

[5] Y. Fujimoto, K. Fukushima, K. Murase, Phys. Rev. D **98**, 023019 (2018).

[6] K. Fukushima, Y. Hidaka, Phys. Rev. Let. **120**, 162301 (2018).

[7] K. Fukushima, Y. Hidaka, JHEP **1711**, 114 (2017).

[8] H.-L. Chen, K. Fukushima, X.-G. Huang, K. Mameda, Phys. Rev. **96**, 054032 (2017).

[9] S. Ebihara, K. Fukushima, S. Pu, Phys. Rev. D **96**, 016016 (2017).

[10] K. Fukushima, K. Murase, S. Pu, Annals Phys. **386**, 76–96 (2017).

[11] A. Flachi, K. Fukushima, Phys. Rev. D **98**, 096011 (2018).

[12] S. Benić, K. Fukushima, O. Garcia-Montero, R. Venugopalan, JHEP **1701**, 115 (2017).

[13] S. Ebihara, K. Fukushima, K. Mameda, Phys. Let. B **764**, 94–99, (2017).

[14] Y. Abe, K. Fukushima, Phys. Rev. D **94**, 094506 (2016).

[15] P. Copinger, K. Fukushima, Phys. Rev. Let. **117**, 081603 (2016); Erratum-ibid. **118**, 099903 (2017).

[16] K. Fukushima, Y. Hidaka, Phys. Rev. Let. **117**, 102301 (2016).

[17] S. Benić, K. Fukushima, Nucl. Phys. A **958**, 1–24 (2017).

[18] H.-L. Chen, K. Fukushima, X.-G. Huang, K. Mameda, Phys. Rev. D **93**, 104052 (2016).

[19] K. Fukushima, K. Hattori, H.-U. Yee, Y. Yin, Phys. Rev. D **93**, 074028 (2016).

[20] S. Ebihara, K. Fukushima, T. Oka, Phys. Rev. B **93**, 155107 (2016).

[21] K. Fukushima, T. Kojo, Astrophys. J. 817, 180 (2016).

[22] K. Fukushima, Y. Tanizaki, PTEP 111A01 (2015).

[23] A. Flachi, K. Fukushima, V. Vitagliano, Phys. Rev. Let. **114**, 181601 (2015).

[24] K. Fukushima, Phys. Rev. D **92**, 054009 (2015).

[25] K. Fukushima, Phys. Rev. C **91**, 044910 (2015).

[26] A. Flachi, K. Fukushima, Phys. Rev. Let. **113**, 091102 (2014).

[27] R. Anzaki, K. Fukushima, Y. Hidaka, T. Oka, Annals Phys. **353**, 107 (2015).

[28] K. Fukushima, T. Hayata, Phys. Let. B **735**, 371–375 (2014).

[29] A. Armoni, K. Fukushima, Phys. Rev. D **89**, 105001 (2014).

[30] K. Fukushima, New. J. Phys. **16**, 073031 (2014).

[31] R. Fukuda, K. Fukushima, T. Hayata, Y. Hidaka, Phys. Rev. D **89**, 014508 (2014).

[32] K. Fukushima, Phys. Rev. C **89**, 024907 (2014).

[33] K. Fukushima, P. Morales, Phys. Rev. Let. **111**, 051601 (2013).

[34] K. Fukushima, N. Su, Phys. Rev. D **88**, 076008 (2013).

[35] K. Fukushima, Y. Hidaka, Phys. Rev. Let. **110**, 031601 (2013).

[36] K. Fukushima, K. Mameda, Phys. Rev. D **86**, 071501(R) (2012).

[37] K. Fukushima, K. Kashiwa, Phys. Let. B **723**, 360–364 (2013).

[38] K. Fukushima, Phys. Rev. D **86**, 054002 (2012).

[39] K. Fukushima, J.M. Pawlowski, Phys. Rev. D **86**, 076013 (2012).

[40] T. Kojo, Y. Hidaka, K. Fukushima, L.D. McLerran, R.D. Pisarski, Nucl. Phys. A **875**, 94–138 (2012).

[41] K. Fukushima, F. Gelis, Nucl. Phys. A **874**, 108–129 (2012).

< Conference Proceedings >

[42] K. Fukushima, Nucl. Phys. A **982**, 231–234 (2019).

[43] S. Benić, K. Fukushima, O. Garcia-Montero, R. Venugopalan, J. Phys. Conf. Ser. **1024**, 012014 (2018).

[44] K. Fukushima, Acta Phys. Polon. Supp. **10**, 577 (2017).

[45] A. Flachi, K. Fukushima, Int. J. Mod. Phys. D **26**, 1743007 (2017).

[46] S. Benić, K. Fukushima, O. Garcia-Montero, R. Venugopalan, Nucl. Part. Phys. Proc. **289-290**, 201–204 (2017).

[47] K. Hattori, K. Fukushima, H.-U. Yee, Y. Yin, Nucl. Part. Phys. Proc. **289-290**, 273–276 (2017).

[48] K. Fukushima, Nucl. Phys. A **956**, 665–668 (2016).

[49] K. Fukushima, Eur. Phys. J. A **52**, 222 (2016).

[50] K. Fukushima, Nucl. Phys. A **931**, 257–266 (2014).

< Review Papers >

[51] K. Fukushima, Prog. Part. Nucl. Phys. **107**, 167–199 (2019).

[52] K. Fukushima, V. Skokov, Prog. Part. Nucl. Phys. **96**, 154–199 (2017).

[53] K. Fukushima, Rep. Prog. Phys. **80**, 022301 (2017).

[54] K. Fukushima, C. Sasaki, Prog. Part. Nucl. Phys. **72**, 99–154 (2013).

[55] K. Fukushima, J. Phys. G **39**, 013101 (2012).

< Books >

[56] 物理学者，機械学習を使う ～ 第 9 章「深層学習による中性子星と核物質の推定」

[57] 数理科学 2016 年 9 月号 ～ 特集：摂動論を考える「摂動論と複素化」

[58] 数理科学 2015 年 5 月号 ～ 特集：物理と方程式 – 現象はいかに記述されるか

[59] 日本物理学会誌 2015 年 5 月号 ～ 現代物理のキーワード「見えないクォークを見る」

< Patent Applications >

7 Invited Presentations at International Conferences

[1] K. Fukushima, Inclusive isolated photon in pp collisions up to the next leading order with CGC, 8th International Conference on Quarks and Nuclear Physics, Nov. 14, 2018 in Tsukuba, Japan.

[2] K. Fukushima, Views of Confinement, Deconfinement, and Inbetween, Heavy Flavor Production in High Energy Nuclear Collisions and Forty Years of Quark-Gluon Plasma, Oct. 9, 2018 in CCNU, China.

[3] K. Fukushima, Chiral Physics with Optical Chirality, Quantum Anomalies and Chiral Magnetic Phenomena, Sep. 17, 2018 in NORDITA, Sweden.

[4] K. Fukushima, Schwinger Formula and the Axial Ward Identity, Quantum Chromodynamics and Its Symmetries, Sep. 14, 2018 in Oberwoelz, Austria.

[5] K. Fukushima, New View of Melting Nuclear Matter into Quark Matter, XIII Quark Confinement and the Hadron Spectrum, Aug. 3, 2018 in Dublin, Ireland.

[6] K. Fukushima, Domain-walls and vortices in dense QCD matter, NFQCD, May 31, 2018 in Kyoto, Japan.

[7] K. Fukushima, QCD Matter in Neutron Star Environments, Workshop of Recent Developments in QCD and QFT, Nov. 9, 2017 in NTU, Taiwan.

[8] K. Fukushima, Electric fluctuations and conductivity at finite density under a magnetic field, Critical Fluctuations Near the QCD Phase Boundary in Relativistic Nuclear Collisions, Oct. 11, 2017 in CCNU, China.

[9] K. Fukushima, Quantum Percolation from Nuclear to Quark Matter, Phases of QCD and BES Program with HICs, Aug. 16, 2017 in Fudan U., China.

[10] K. Fukushima, Particle Production in CGC, Saturation: Recent developments, new ideas and Measurements, April 27, 2017 in BNL, U.S.A.

[11] K. Fukushima, Chirality and Vorticity in Non-trivial Geometry at Finite Temperature, QCD in Finite Temperature and Heavy-Ion Collisions, Feb. 14, 2017 in BNL, U.S.A.

[12] K. Fukushima, Worldline Instantons and Novel Phenomena in Inhomogeneous Magnetic Fields, Gauge Topology 2016: from lattice to colliders, Nov. 8, 2016 in ECT*, Italty.

[13] K. Fukushima, Quarkyonic Matter as realized in a Quantum Percolation Picture, Quarkyonic Matter from Theory to Experiment, Oct. 27, 2016 in CCNU, China.

[14] K. Fukushima, Opportunities in Diquark Physics, JAEA/ASRC Reimei Workshop: New exotic hadron matter at J-PARC, Oct. 24, 2016 in Inha U., Korea.

[15] K. Fukushima, Extreme Matter in Strong External Electromagnetic Fields, Nuclear Physics School in Erice 2016, Setp. 19, 2016 in Erice, Italy.

[16] K. Fukushima, Holography for Hot and Dense Magnetized Quark Matter, 14th Workshop on Nonperturbative QCD, June 16, 2016 in IAP, France.

[17] K. Fukushima, Phase Diagram of QCD, QCD Phase Structure III, June 9, 2016 in CCNU, China.

[18] K. Fukushima, Magnetic Shift of the Chemical Freezeout and Electric Charge Fluctuations, Critical Point and the Onset of Deconfinement 2016, June 3, 2016 in Wroclaw U., Poland.

[19] K. Fukushima, Magnetic Shift of the Chemical Freezeout and Electric Charge Fluctuations, Workshop on Magnetic Fields in Hadron Physics, May 9, 2016 in ICTP-SAIFR, Brazil.

[20] K. Fukushima, Dynamically and Spatially Assisted CME, Chirality and Vorticity Workshop, Feb. 23, 2016 in UCLA, U.S.A.

[21] K. Fukushima, QCD in Heavy-Ion Collisions, New Progress in Heavy Ion Collision: What is Hot in the QGP, Oct. 7, 2015 in CCNU, China.

[22] K. Fukushima, QCD in Heavy-Ion Collisions (for non-experts), Student-day Lecture at Quark Matter 2015, Sep. 27, 2015 in Kobe, Japan.

[23] K. Fukushima, QCD under curvature and magnetic effects, Gauge Topology 2015: from lattice simulations and solvable methods to experiment, Aug. 18, 2015 in Stonybrook U., U.S.A.

[24] K. Fukushima, The complex Langevin and the Lefschetz thimble methods – supersymmetric Hamiltonian and the unification, Numerical approaches to the holographic principle, quantum gravity and cosmology, July 23, 2015 in YITP, Japan.

[25] K. Fukushima, New Approach to the Sign Problem, Workshop on Dense Matter from Chiral EffectiveTheory, June 27, 2015 in Jilin U., China.

[26] K. Fukushima, Geometrical Effects on Quark Matter, sQGP and Extreme QCD, May 25, 2015 in KITPC/ITP-CAS, China.

[27] K. Fukushima, Quark Production and Anomalous Currents in Strong Fields, Hadrons and Hadron Interactions in QCD 2015, March 10, 2015 in YITP, Japan.

[28] K. Fukushima, Particle Production and Current from a Topological Domain, Ab initio approaches in many-body QCD confront heavy-ion experiments, Dec. 16, 2014 in Heidelberg U., Germany.

[29] K. Fukushima, Magnetic Catalysis vs Chiral Gap Effect, Workshop on Strong Magnetic Field, Oct. 17, 2014 in Beijing, China.

[30] K. Fukushima, Study of the QGP Initial State and Its Evolution to QGP, 4th Joint Meeting of the APS and JPS, Oct. 8, 2014 in Hawaii, U.S.A.

[31] K. Fukushima, Chiral Gap Effect in Curved Space, Confinement and Hadron Spectrum 2014, Sep. 8, 2014 in St. Petersburg, Russia.

[32] K. Fukushima, QCD Phase Structure – A Theoretical Overview, Asian Heavy Ion Conference (ATHIC) 2014, Aug. 5, 2014 in Osaka U., Japan.

[33] K. Fukushima, Baryonic matter and beyond, Quark Matter 2014, May 24, 2014 in Darmstadt, Germany.

[34] K. Fukushima, Real-time Stochastic Quantization – Problems and Simulations –, The Approach to Equilibrium in Strongly Interacting Matter, April 4, 2014 in BNL, U.S.A.

[35] K. Fukushima, Spatial Modulation and Topological Current in Holographic QCD Matter, Holography and QCD, Sep. 27, 2013 in IPMU, Japan.

[36] K. Fukushima, Real-time Yang-Mills Simulation and the Thermalization Problem at RHIC and LHC, Erice Summer School for Subnuclear Physics 2013, June 26, 2013 in Erice, Italy.

[37] K. Fukushima, Classical YM Dynamics and Tubulent Diffusion, High-energy, high-temperature, high-density (3h) QCD, June 18, 2013 in ECT*, Italy.

[38] K. Fukushima, The Structure of QCD Phase Diagram – Facts and Fictions –, EMMI Workshop: Prospects and Challenges for Future Experiments in Heavy Ion Collisions, Feb. 15, 2013 in Darmstadt, Germany.

[39] K. Fukushima, QCD Phase Transitions at Finite Temperature, Density, and Magnetic Field, QCD Structure I, Oct. 11, 2012 in CCNU, China.

[40] K. Fukushima, Baryon-rich state of QCD matter, Quark Gluon Plasma meets Cold Atoms – Episode III, Aug. 27, 2012 in Hirschegg, Austria.

[41] K. Fukushima, Extreme QCD matter – Fate of chiral symmetry in strong magnetic field, International Conference on Strong and Electroweak Matter 2012, July 10, 2012 in Swansea U., UK.

[42] K. Fukushima, Photons in the Chiral Magnetic Effect, P and CP-odd Effects in Hot and Dense Matter 2012, June 25, 2012 in Stonybrook U., U.S.A.

[43] K. Fukushima, Instability in an expanding non-Abelian system, Relaxation, Turbulence, and Non-Equilibrium Dynamics of Matter Fields – RETUNE 2012 –, June 23, 2012 in Heidelberg U., Germany.

[44] K. Fukushima, Quest for the QCD phase diagram in extreme environments, 5th International Symposium on Symmetries in Subatomic Physics, June 19, 2012 in Groningen, Netherlands.

8 Teaching Accomplishment

Not in particular.

9 Contribution to Academic Community

9.1 Editorial Activities

- Chief Editor for the Proceedings Volume for Quark Matter 2015.
- Supervising Editor for Progress of Theoretical and Experimental Physics 2017−

9.2 Organization of Professional Societies

Not in particular.

9.3 Organization and Advisory of Conferences

- Member of International Advisory Committee of Initial Stages, 2018−
- Member of International Advisory Committee of XQCD, 2015−
- Chiral Matter 2016, Wako, RIKEN, 5-8 Dec., 2016. 12-16 Nov. 2012.
- Workshop on QCD in strong magnetic fields, ECT*, Trento, Italy, 12-16 Nov., 2012.

10 Outreach

Not in particular.

11 Committee Service

11.1 External Committees

- Member of the Zimanyi Medal Selection Committee, 2018−
- Member of KEK Research Plan Committee 2013−2014
- Member of YITP Future Plan Committee 2014−2014
- Member of JPS Program Committee (Nuclear Theory Division) 2014−2015
- Member (Chair) of Theoretical Nuclear Physics Committee 2016−

11.2 University Committees

理学系研究科男女共同参画委員会 委員 2016 年 –2018 年

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	4	USA, China, Chile
Doctor Course	3	USA, China, Chile
Foreign researchers hosted	3	China, Croatia
Students sent abroad	5	USA, France, Germany, Italy, China
Researchers sent abroad	0	
Foreign visitors	7	USA, France, Germany, China, Chile

Koichi Hamaguchi、濱口 幸一

1 Education and Professional Experiences

Education

1997	B.S. (Physics)	The University of Tokyo
1999	MSc. (Physics)	The University of Tokyo
2002	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

2002−2002	JSPS postdoc fellow	Tohoku University
2002−2004	Postdoc fellow	DESY Theory Group
2004−2006	Staff Member	DESY Theory Group
2006−	Associate Professor	The University of Tokyo

2 Research Highlights

I am interested in physics beyond the Standard Model of particle physics and doing research aiming at a more fundamental unified theory underlying in nature. I have worked on model building, phenomenological study, astroparticle physics and particle cosmology of models beyond the Standard Model (BSM), such as the supersymmetric models. Below, I select three subjects corresponding to the five papers in Sec. 3. In addition to them, I have worked on various topics that you can find in the Publication List in Sec. 6.

- Recently I am working on a new topic, **physics of neutron star (NS) and its application to particle physics beyond the Standard Model.** In the work [5][1], we have studied the cooling of the NS at the center of the supernova remnant Cassiopeia A (Cas A), and obtained a new bound on the axion[2] decay constant, $f_a > \mathcal{O}(10^8)$ GeV. Our new bound is as strong as the one from the supernova 1987A, which has been known to give the strongest bound so far. Our result is adopted in the Review of Particle Physics.

  In another paper [1], we have studied the NS heating by the WIMP dark matter (DM). The heating of NS by WIMP DM and its possible observational signature has been pointed out in 2007, but the studies so far have not included the heating mechanisms in the NS itself. We have included, for the first time, the effect of a heating mechanism inherent in the NS called rotochemical heating, and clarified the condition that the dark matter signal can be detected under such additional heating. In the meantime, we have also updated

[1] Here and hereafter, the numbers refer to the ones in the publication list in Sec. 6.

[2] Axion is a hypothetical particle. In the Standard Model of particle physics, there is a serious problem called "strong-CP problem", which is a fine-tuning problem in the QCD in the Standard Model. This puzzle cannot be solved within the Standard Model. The leading candidate for the solution to this puzzle, the Peccei-Quinn mechanism, predicts the existence of a very light, extremely weakly interacting particle, called axion. There have been extensive studies in both theoretical research and experimental searches for the axion.

the calculation of the NS rotochemical heating itself and wrote another paper [1904.046667, submitted to MNRAS].

- In the work [10], we proposed **a new scenario called "flaxion", which solves multiple puzzles in the Standard Model simultaneously**, (i) the hierarchical flavor structure in the quark and lepton sector (including neutrino sector), (ii) the strong CP problem, (iii) origin of dark matter, (iv) baryon asymmetry of the universe, and (v) inflation.
- I have also worked on **models beyond the Standard Model motivated by the muon anomalous magnetic moment (muon $g-2$)** [9, 23, 24, 25, 27, 28, 30, 31, 32]. There exists a more than 3-σ discrepancy between experimentally measured and theoretically predicted values of the muon $g-2$. I have constructed particle physics models, such as those in supersymmetric framework, investigated the constraints on those models, and studied prospects for testing those BSM models at the Large Hadron Collider and International Linear Collider.

3 Selected Papers

- **"Dark Matter Heating vs. Rotochemical Heating in Old Neutron Stars"** [1] ,K. Hamaguchi, N. Nagata and K. Yanagi. ,arXiv:1905.02991 [hep-ph] ,,Phys. Lett. B **795**, 484 (2019).
- **"Limit on the Axion Decay Constant from the Cooling Neutron Star in Cassiopeia A"** [5] ,K. Hamaguchi, N. Nagata, K. Yanagi and J. Zheng. ,arXiv:1806.07151 [hep-ph] ,,Phys. Rev. D **98**, no. 10, 103015 (2018).
- **"Flaxion: a minimal extension to solve puzzles in the standard model"** [10] ,Y. Ema, K. Hamaguchi, T. Moroi and K. Nakayama. ,arXiv:1612.05492 [hep-ph] ,,JHEP **1701**, 096 (2017). ,(55 citations counted in INSPIRE as of 29 Oct 2019).
- **"Muon g-2 vs LHC in Supersymmetric Models"** [25] ,M. Endo, K. Hamaguchi, S. Iwamoto and T. Yoshinaga. ,arXiv:1303.4256 [hep-ph] ,,JHEP **1401**, 123 (2014) ,(80 citations counted in INSPIRE as of 29 Oct 2019.)
- **"Constraints on Hidden Photon Models from Electron g-2 and Hydrogen Spectroscopy"** [28] ,M. Endo, K. Hamaguchi and G. Mishima. ,arXiv:1209.2558 [hep-ph] ,,Phys. Rev. D **86**, 095029 (2012) ,(119 citations counted in INSPIRE as of 29 Oct 2019.)

4 Honors, Awards and Professional Society Memberships

5 Research Plan

I will continue working on physics beyond the Standard Model of particle physics. I also plan to pay attention to the latest results from high energy experiments and astrophysical observations, and then feed them back to theoretical research. Below I list some of the on-going and near future projects.

- **BSM physics and Neutron Star (and supernova)**
  As I wrote above, recently I am interested in the physics of neutron star (NS) and its application to particle physics beyond the Standard Model. We are now working on follow-up projects of those works. Concerning the constraint from the Cas A NS [5], I would like to write a full paper including the dependence on the models of neutron-superfluidity/proton-superconductivity, envelope models, equation of state, etc. We are also planning to apply our previous work on other light dark matter candidates. As for the heating of the neutron star by WIMP Dark Matter [1], there remain several things to do, such as applications to concrete Dark Matter models, analysis including the other heating mechanisms, and study of the observational feasibility. Another interesting topic is the effect of Dark Matter (and other BSM physics) on the equation of state of the neutron star. In addition to the neutron star, I would like to study the prospects of testing BSM physics via supernova (not only the SN1987A but also the possible next nearby supernovae) and white dwarfs. I general, I believe there are many interesting topics in the area of intersection between BSM particle physics and compact stars. I would like to discuss (and hopefully collaborate) with researchers outside the particle physics, such as nuclear physics and astrophysics as well.

- **BSM models motivated by the muon anomalous magnetic moment (muon $g-2$)**
  Probably there will be a new result on the muon $g-2$ from the Fermi $g-2$ experiment within this year (2019). Another new experiment is planned at J-PARC. There are also progress on the theoretical side, such as the lattice calculation of the light-by-light contribution to the muon $g-2$. I plan to study the supersymmetric models that can explain the muon $g-2$ discrepancy, and analyze their testability at the Large Hadron Collider.

- **Leptogenesis and neutrino physics**
  The origin of the matter-antimatter asymmetry in the Universe is one of the biggest puzzles in particle physics and cosmology. Leptogenesis scenario is the most popular and the leading candidate for the solution to this puzzle. Since my Ph.D., I have intermittently worked on leptogenesis, and I would like to continue it. In particular, I would like to summarize the various detailed developments in the last decade and write a comprehensive and up-to-date public code to calculate the baryon asymmetry of the Universe from the Lagrangian. It will also have an impact on the research of neutrino physics, which will have more experimental data (such as CP-violation and hopefully lepton-number violation) in the (near) future.

6 Publications and Patents

< Refereed Original Papers >

[1] "Dark Matter Heating vs. Rotochemical Heating in Old Neutron Stars", K. Hamaguchi, N. Nagata and K. Yanagi. arXiv:1905.02991 [hep-ph], Phys. Lett. B **795**, 484 (2019).

[2] "Minimal Gauged U(1)$_{L_\alpha - L_\beta}$ Models Driven into a Corner", K. Asai, K. Hamaguchi, N. Nagata, S. Y. Tseng and K. Tsumura. arXiv:1811.07571 [hep-ph], Phys. Rev. D **99**, no. 5, 055029 (2019).

[3] "Moduli Oscillation Induced by Reheating", D. Hagihara, K. Hamaguchi and K. Nakayama. arXiv:1811.05002 [hep-ph], ,JCAP **1903**, 024 (2019).

[4] "The swampland conjecture and the Higgs expectation value", K. Hamaguchi, M. Ibe and T. Moroi. arXiv:1810.02095 [hep-th] ,JHEP **1812**, 023 (2018).

[5] "Limit on the Axion Decay Constant from the Cooling Neutron Star in Cassiopeia A" , K. Hamaguchi, N. Nagata, K. Yanagi and J. Zheng. arXiv:1806.07151 [hep-ph], Phys. Rev. D **98**, no. 10, 103015 (2018).

[6] "Supersymmetric Flaxion", Y. Ema, D. Hagihara, K. Hamaguchi, T. Moroi and K. Nakayama. arXiv:1802.07739 [hep-ph], JHEP **1804**, 094 (2018).

[7] "Gravitino/Axino as Decaying Dark Matter and Cosmological Tensions", K. Hamaguchi, K. Nakayama and Y. Tang. arXiv:1705.04521 [hep-ph], Phys. Lett. B **772**, 415 (2017).

[8] "Predictions for the neutrino parameters in the minimal gauged U(1)$_{L_\mu - L_\tau}$ model", K. Asai, K. Hamaguchi and N. Nagata. arXiv:1705.00419 [hep-ph], Eur. Phys. J. C **77**, no. 11, 763 (2017).

[9] "Probing minimal SUSY scenarios in the light of muon $g-2$ and dark matter", M. Endo, K. Hamaguchi, S. Iwamoto and K. Yanagi. arXiv:1704.05287 [hep-ph], JHEP **1706**, 031 (2017).

[10] "Flaxion: a minimal extension to solve puzzles in the standard model", Y. Ema, K. Hamaguchi, T. Moroi and K. Nakayama. arXiv:1612.05492 [hep-ph], JHEP **1701**, 096 (2017).

[11] "Affleck-Dine Leptogenesis with Varying Peccei-Quinn Scale", K. J. Bae, H. Baer, K. Hamaguchi and K. Nakayama. arXiv:1612.02511 [hep-ph], JHEP **1702**, 017 (2017).

[12] "Probing the origin of 750 GeV diphoton excess with the precision measurements at the ILC", K. J. Bae, K. Hamaguchi, T. Moroi and K. Yanagi. arXiv:1604.08307 [hep-ph], Phys. Lett. B **759**, 575 (2016).

[13] "From the 750 GeV diphoton resonance to multilepton excesses", K. J. Bae, C. R. Chen, K. Hamaguchi and I. Low. arXiv:1604.07941 [hep-ph], Phys. Rev. D **94**, 015035 (2016).

[14] "Models of a 750 GeV quarkonium and the LHC excesses", K. Hamaguchi and S. P. Liew. arXiv:1604.07828 [hep-ph], Phys. Rev. D **94**, no. 3, 035012 (2016).

[15] "Diphoton Excess and Running Couplings", K. J. Bae, M. Endo, K. Hamaguchi and T. Moroi. arXiv:1602.03653 [hep-ph], Phys. Lett. B **757**, 493 (2016).

[16] "Prospects for Higgs- and Z-resonant Neutralino Dark Matter", K. Hamaguchi and K. Ishikawa. arXiv:1510.05378 [hep-ph], Phys. Rev. D **93**, no. 5, 055009 (2016).

[17] "How to decontaminate overlapping fat jets", K. Hamaguchi, S. P. Liew and M. Stoll. arXiv:1505.02930 [hep-ph], Phys. Rev. D **92**, no. 1, 015012 (2015)

[18] "AMS-02 Antiprotons from Annihilating or Decaying Dark Matter", K. Hamaguchi, T. Moroi and K. Nakayama. arXiv:1504.05937 [hep-ph], Phys. Lett. B **747**, 523 (2015).

[19] "Reconstruction of Vector-like Top Partner from Fully Hadronic Final States", M. Endo, K. Hamaguchi, K. Ishikawa and M. Stoll. arXiv:1405.2677 [hep-ph], Phys. Rev. D **90**, no. 5, 055027 (2014).

[20] "Complexified Starobinsky Inflation in Supergravity in the Light of Recent BICEP2 Result", K. Hamaguchi, T. Moroi and T. Terada. arXiv:1403.7521 [hep-ph], Phys. Lett. B **733**, 305 (2014).

[21] "Testing the Minimal Direct Gauge Mediation at the LHC", K. Hamaguchi, M. Ibe, T. T. Yanagida and N. Yokozaki. arXiv:1403.1398 [hep-ph], Phys. Rev. D **90**, no. 1, 015027 (2014).

[22] "Isospin-Violating Dark Matter with Colored Mediators", K. Hamaguchi, S. P. Liew, T. Moroi and Y. Yamamoto. arXiv:1403.0324 [hep-ph], JHEP **1405**, 086 (2014).

[23] "Reconstructing Supersymmetric Contribution to Muon Anomalous Magnetic Dipole Moment at ILC", M. Endo, K. Hamaguchi, S. Iwamoto, T. Kitahara and T. Moroi. arXiv:1310.4496 [hep-ph], Phys. Lett. B **728**, 274 (2014).

[24] "Probing Bino contribution to muon $g-2$", M. Endo, K. Hamaguchi, T. Kitahara and T. Yoshinaga. arXiv:1309.3065 [hep-ph], JHEP **1311**, 013 (2013).

[25] "Muon g-2 vs LHC in Supersymmetric Models", M. Endo, K. Hamaguchi, S. Iwamoto and T. Yoshinaga. arXiv:1303.4256 [hep-ph], JHEP **1401**, 123 (2014).

[26] "Axino dark matter with R-parity violation and 130 GeV gamma-ray line", M. Endo, K. Hamaguchi, S. P. Liew, K. Mukaida and K. Nakayama. arXiv:1301.7536 [hep-ph], Phys. Lett. B **721**, 111 (2013).

[27] "Gauge Mediation Models with Vectorlike Matters at the LHC", M. Endo, K. Hamaguchi, K. Ishikawa, S. Iwamoto and N. Yokozaki. arXiv:1212.3935 [hep-ph], JHEP **1301**, 181 (2013).

[28] "Constraints on Hidden Photon Models from Electron g-2 and Hydrogen Spectroscopy", M. Endo, K. Hamaguchi and G. Mishima. arXiv:1209.2558 [hep-ph], Phys. Rev. D **86**, 095029 (2012).

[29] "Scalar Decay into Gravitinos in the Presence of D-term SUSY Breaking", M. Endo, K. Hamaguchi and T. Terada. arXiv:1208.4432 [hep-ph], Phys. Rev. D **86**, 083543 (2012).

[30] "Vacuum Stability Bound on Extended GMSB Models", M. Endo, K. Hamaguchi, S. Iwamoto and N. Yokozaki. arXiv:1202.2751 [hep-ph], JHEP **1206**, 060 (2012).

[31] "Higgs mass and muon anomalous magnetic moment in the U(1) extended MSSM", M. Endo, K. Hamaguchi, S. Iwamoto, K. Nakayama and N. Yokozaki. arXiv:1112.6412 [hep-ph], Phys. Rev. D **85**, 095006 (2012).

[32] "Higgs mass, muon g-2, and LHC prospects in gauge mediation models with vector-like matters", M. Endo, K. Hamaguchi, S. Iwamoto and N. Yokozaki. arXiv:1112.5653 [hep-ph], Phys. Rev. D **85**, 095012 (2012).

[33] "Boltzmann equation for non-equilibrium particles and its application to non-thermal dark matter production", K. Hamaguchi, T. Moroi and K. Mukaida. arXiv:1111.4594 [hep-ph], JHEP **1201**, 083 (2012).

[34] "A Solution to the mu/Bmu Problem in Gauge Mediation with Hidden Gauge Symmetry", K. Hamaguchi, K. Nakayama and N. Yokozaki. arXiv:1111.1601 [hep-ph], JHEP **1208**, 006 (2012).

[35] "NMSSM in gauge-mediated SUSY breaking without domain wall problem", K. Hamaguchi, K. Nakayama and N. Yokozaki. arXiv:1107.4760 [hep-ph], Phys. Lett. B **708**, 100 (2012).

< **Conference Proceedings** >

< **Review Papers** >

< **Books** >

< **Patent Applications** >

7 Invited Presentations at International Conferences

[1] "Discussion: Astrophysical signatures of / bounds on axions, A Limit on Axion from the Cooling Neutron Star in Cassiopeia A", Axions in the Lab and in the Cosmos, 2019.07.19, CERN.

[2] "Leptogenesis", Revealing the history of the universe with underground particle and nuclear research 2019. 2019.03.07, Tohoku U.

[3] "Flaxion, Axion and Neutron Star", Yonsei university Cosmology and High Energy physics workshop, 2019.02.26, Yonsei University, Seoul, Korea.

[4] "A Limit on Axion from the Cooling Neutron Star in Cassiopeia A", Light Dark World 2018, 2018.12.18, KAIST, Daejeon, Korea.

[5] "Neutrinoless double beta decay, leptogenesis, and gauged $U(1)_{\mu-\tau}$ models", Double beta decay and underground science (DBD18) / Fifth Joint Meeting of the Nuclear Physics Divisions of the APS and the JPS. 2018.10.21-23, Hawaii, USA.

[6] "A Limit on Axion from the Cooling Neutron Star in Cassiopeia A", PACIFIC 2018.9, 2018.09.02, French Polynesia.

[7] "Flaxion - a minimal extension to solve puzzles in the standard model", 53rd Rencontres de Moriond, ELECTROWEAK INTERACTIONS AND UNIFIED THEORIES 2018, 2018.03.13, La Thuile, Italy.

[8] "Flaxion - a minimal extension to solve puzzles in the standard model", PACIFIC 2018, 2018.02.15, Hokkaido, Japan.

[9] "Flaxion - a minimal extension to solve puzzles in the standard model", IBS Conference on Dark World, 2017.11.01, IBS, Daejeon, Korea.

[10] "BSM vs LHC", ATLAS CERN-Tokyo U. workshop, 2017.03.24, the University of Tokyo.

[11] "Flaxon - a minimal extension to solve puzzles in the standard model", KEK Theory Meeting on Particle Physics Phenomenology (KEK-PH2017), 2017.02.16, KEK, Japan.

[12] "Supersymmetry after Higgs discovery", 新粒會, 2016.11.10, Sogang University, Seoul, Korea.

[13] "Beyond the Standard Model", The 22nd Vietnam School of Physics (VSOP-22), 2016.09.10 - 2016.09.12, Quy Nhon, Vietnam.

[14] "Probing the origin of the 750 GeV diphoton excess with the precision measurements at the ILC", The European Linear Collider Workshop 2016 (ECFALC2016), 2016.06.01, Santander, Spain.

[15] "Diphoton Excess and Running Couplings", BSM in Okinawa 2016, 2016.03.02, OIST, Japan.

[16] "Neutrinoless Double Beta Decay and Leptogenesis", IBS-PNU Joint Workshop on Particle Physics, String Theory, and Cosmology, 2015.12.03, Busan, Korea.

[17] "Neutrinoless double beta decay and Leptogenesis", Particle Cosmology and Beyond 2015, 2015.11.17, Kanazawa, Japan.

[18] "Higgs and Beyond the Standard Model," (Lectures), The Second Asia-Europe-Pacific School of High-Energy Physics (AEPSHEP), November 4-17, 2014, Puri, India.

[19] "Supersymmetry after Higgs discovery," Higgs Modes in Condensed Matter and Quantum Gases, June 23-25, 2014, YITP Kyoto.

[20] "Supersymmetry after Higgs discovery," Higgs and Beyond, June 6, 2013, Tohoku U., Sendai.

[21] "Supersymmetry after Higgs discovery," ECFA Linear Collider Workshop 2013, May 29, 2013, DESY, Hamburg, Germany.

[22] "Leptogenesis," Fundamental Physics Using Atoms (FPUA) 2012, September 29, 2012, Tohoku University.

[23] "Boltzmann equation for non-equilibrium particles and its application to non-thermal dark matter production," Toyama mini workshop, February 20, 2012, Toyama University.

8 Teaching Accomplishment

"Particle Physics Medal: Young Scientist Award in Theoretical Particle Physics 2017," given to Dr. Kyohei Mukaida (Ph.D. in 2015) and Dr. Takahiro Terada (Ph.D. in 2015).

9 Contribution to Academic Community

9.1 Editorial Activities

9.2 Organization of Professional Societies

9.3 Organization and Advisory of Conferences

- Organizer Chair, YITP workshop, Progress in Particle Physics 2012-2013
  Organizer, YITP workshop, Progress in Particle Physics 2014
  `http://www2.yukawa.kyoto-u.ac.jp/~ppp.ws/PPP2019/info.html`
- Organizer (2007-present), Summer Institute (Phenomenology of Elementary Particles and Cosmology).
  `https://indico.cern.ch/event/752582/`
- Parallel Session "Physics" Convener (2016), The European Linear Collider Workshop 2016 (ECFALC2016).
  `https://agenda.linearcollider.org/event/7014/`
- Organizer (2015-present), New Physics Forum.
  `http://newphysicsforum.kek.jp`
- Local Organizer, Revealing the history of the universe with underground particle and nuclear research 2016, 2016 May 11-13.
  `http://www.lowbg.org/ugnd/workshop/sympo_all/201605_Tokyo/`

10 Outreach

- 2019 Nov. 9,「宇宙誕生最初の 1 秒の謎と、素粒子の標準模型を超える物理」自然科学カフェ.
- 2013 Jan. 9,「宇宙誕生はじめの 1 秒間の謎に迫る素粒子の世界」三省堂サイエンスカフェ
- 2012 July 21, ヒックス粒子発見に関する一般向け解説会/座談会 (ニコニコ動画にて生放送) に参加、大阪大学
- 2012 Jan. 4,「素粒子の謎、宇宙誕生はじめの 1 秒間の謎 」朝日カルチャーセンター

11 Committee Service

11.1 External Committees

- 日本物理学会若手奨励賞 素粒子論領域 選考委員（2019-2020）
- KEK 理論センター 研究推進委員会委員（2016-2018）
- 素粒子論会委員（2015〜2017。うち 2016〜2017 は幹事。）
- KEK 素粒子原子核研究所 研究計画委員会（2014〜2015）
- 日本物理学会若手奨励賞 素粒子論領域 選考委員（2014〜2016）

11.2 University Committees

理学部 教務委員 (2019-)
理学部 GSC ファカルティ委員 (2019-)
高大接続研究開発センター運営委員会委員 (2019-)

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	3	Malaysia, Taiwan×2
Doctor Course	3	Malaysia, Germany, Taiwan
Foreign researchers hosted	2	Korea, China
Students sent abroad	4	Korea, USA, Germany
Researchers sent abroad	4	Korea, China, Germany
Foreign visitors	23	Germany, Korea, USA, Spain, UK, France, Israel.

Yutaka Matsuo、松尾 泰

1 Education and Professional Experiences

Education

1983	B.S. (Physics)	The University of Tokyo
1985	MSc. (Physics)	The University of Tokyo
1988	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1992−1994	Assistant Professor	The University of Tokyo
1994−1997	Associate Professor	Kyoto University
1997−2018	Associate Professor	The University of Tokyo
2018−	Professor	The University of Tokyo

2 Research Highlights

In string theory and two-dimensional conformal field theory, an infinite-dimensional symmetry – Virasoro algebra- plays an essential role. It is an analog of gauge groups such as SU(3) in the Standard Model of elementary particles. We need in-depth knowledge of the symmetry in many aspects of string theory, starting from the formulation to applications such as the compactification issue. On the other hand, peoples shifted their focus to the dualities in string theory after a seminal work by Seiberg-Witten during the mid-90s. Seiberg and Witten used the knowledge of Riemann surface to explore the structure of the supersymmetric gauge theories. Still, we do not understand the explicit relation between the Virasoro symmetry and 4-dimensional gauge theory.

The situation changed after the Alday-Gaiotto-Tachikawa conjecture about ten years ago. They showed that there is an explicit relation between the instanton partition function of 4-dimensional gauge theory and 2-dimensional conformal field theory by the expansion by the instanton number. My study in the last ten years was devoted to the detailed study of such correspondence to explore the intimate relationship between the Virasoro symmetry and the duality.

To rewrite the instanton correction of the gauge theory in the form of the correlation function of the two-dimensional conformal field theory was not clear at all in the beginning since the Virasoro algebra has a relatively complicated structure. It needs a more universal structure that contains the Virasoro algebra and the duality inside, as clarified by mathematicians Schiffmann and Vasserot (SV). At about the same time, we found a similar algebraic structure by examining the recursion formula of the instanton partition function (Kanno-Matsuo-Zhang 2012). SV proved the AGT conjecture for the pure super-Yang-Mills, and we immediately generalized their proof to the gauge theory with bi-fundamental and fundamental matter multiplets (Matsuo-Rim-Zhang 2014).

This enlarged algebraic framework was generalized to the q-deformed version and was referred to as "Quantum Toroidal Algebra (QTA)." As the name suggests, it has the algebraic structure on a torus, instead of the Virasoro and other symmetries in string theory is defined on a circle, and it has the structure of the duality SL(2,Z), which is the modular group of the torus. This duality structure is analogous to the string theory, and it suggests a deep relation between them. Mathematicians mainly studied QTA from the 90s, and we managed to it to Physics.

Except for the proof of the AGT conjecture for some set-up, mentioned above, I would like to explain the derivation of the quantum Seiberg-Witten curve from the algebra as an important contribution. Until our work, it was not so clear why and how two-dimensional surface played such a profound role in understanding the four-dimensional gauge theory. We showed that a second quantized version of the Seiberg-Witten curve appears as the Ward-Takahashi identity for the coherent state in the QTA. Our result turns out to be an explicit realization of the qq-character conjecture by Nekrasov. Our work provided a good example that connects the geometric set-up in the algebraic framework.

3 Selected Papers

- S. Kanno, Y. Matsuo and H. Zhang, JHEP 1308 (2013) 028
  It presented a proof of Alday-Gaiotto-Tachikawa conjecture for the quiver gauge theories with bifundamental matter field (citation 51).
- J. E. Bourgine, Y. Matuo and H. Zhang, JHEP1604 (2016) 167.
  It showed that a quantum version of Seiberg-Witten curve (so called qq-character of Nekrasov) can be derived from an algebra which extend Virasoro algebra (citation 48)
- I. Kostov and Y. Matsuo JHEP 1210 (2012) 168
  It proved a formula which was essential to compute higher point function in N=4 super Yang Mills (citation 38)
- J. E. Bourgine, M. Fukuda, Y. Matsuo, H. Zhang R.-D. Zhu, PTEP 2016 (2016) no.12, 123B05
  We derive the quantum version of Seiberg-Witten curve for 5D super Yang-Mills. (citation 35)
- Y. Matsuo, C. Rim and H. Zhang, JHEP 1409 (2014) 028
  It presented a proof of AGT conjecture for the quiver gauge theory with fundamental matter through the construction of Gaiotto state (citation 23)

4 Honors, Awards and Professional Society Memberships

5 Research Plan

In the last 20 years, the primary source of inspiration in string theory came from branes, such as D-brane, M-brane, and so on. Since they mostly have the geometrical information so far, we need to introduce an algebraic framework to produce more detailed predictions. The quantum toroidal algebra (QTA), which I have studied the last ten years, fits with this purpose well. As explained in my research highlight, we have managed to derive the quantized version of the

Seiberg-Witten curve. We hope that the quantum toroidal algebra should apply to the issue of string compactification. We note that the topological string (vertex) is the universal building block to describe both of them, and it has a clear interpretation in terms of the QTA.

There are many technical but fundamental details to be explored. One of them is how to introduce the orientifold plane, which describes mirror identification in the space-time. While we have a geometrical interpretation, we do not have the corresponding description in the quantum toroidal algebra. Another one is how to describe T(N) theory, which is a strong coupling 4-dimensional system with $U(N) \times U(N) \times U(N)$. It is an essential building block to construct many other theories. While it is supposed to exist, but nobody knows how to describe it, for instance, we do not have a Langrangian description. In the QTA framework, it is possible to write down the corresponding topological string vertex. At this moment, we have some algebraic description, which might be interpretable as a definition of the theory. There are similar examples in two-dimensional quantum field theory. For instance, the Liouville theory is a quantum field theory with a Langrangian description. At the same time, it has an infinite-dimensional Virasoro symmetry. We note that the latter algebraic frame is sufficient to give the many details of the system. The Virasoro algebra has a quantum deformed version, q-Virasoro algebra. We can define the q-Liouville theory through the q-Virasoro algebra, but it does not have any Lagrangian formulation.

The string compactification is an essential step to understanding the connection between string theory and elementary particle physics. Currently, we have too many consistent Calabi-Yau spaces, which are consistent in string theory but do not fit to describe nature. Once we establish to introduce the second viewpoint (algebraic description), which contains the duality structure in it, there may be other options to limit the candidate of the vacua. The different directions to be explored are to define quantum geometry. Since string theory is a candidate for quantum gravity, we have to answer how to redefine the notion of geometry itself. We hope that the second quantized version of the Seiberg-Witten curve in terms of the QTA serves as a candidate. It will pioneer a gigantic revolution in noncommutative geometry.

The QTA has a deep connection with the integrable models – this was the motivation for the mathematicians to invent it. Even for the application to N=2 super Yang-Mills, we cannot escape from skipping this aspect, and we have been working on this aspect in the last ten years. One thing which was not clarified yet was the proper description of the R-matrix. At this moment, nobody is successful in proving the Yang-Baxter relation, which is essential to establish the integrability. After an appropriate definition of R-matrix, it will be possible how to define the conserved quantities, the scattering matrices, and so on. The study of the integrability is impressive by itself but applicable to other fields. For instance, in the recent work of higher dimensional conformal field theories, Dunkl operator of the QTA helps evaluate the correlation function.

The more ambitious direction is to find the connection with N=4 super Yang-Mills, which is another branch of string theory where the integrability is playing a significant role. While N=2 integrability shows up through the Seiberg-Witten curve, the N=4 case comes from AdS/CFT correspondence. So far, while the techniques used in both theories are similar, there is no direct relation between them. We note that each field has its strong points. For instance, in the N=4 case, we have a description of the black hole, and the relation with the quantum information theory is more manifest. In the N=2 case, as we described, it has a well-established mathematical framework. I think that N=4 integrability is at the transition period, from a two-point function to the multi-point correlation. To find the direct relationship between the two fields will be helpful to understand the role of the integrability in string theory.

6 Publications and Patents

< Refereed Original Papers >

[1] K. Harada and Y. Matsuo, "Plane partition realization of (web of) $\mathcal{W}$ -algebra minimal models," JHEP **1902**, 050 (2019) [arXiv:1810.08512 [hep-th]].

[2] J. E. Bourgine, M. Fukuda, Y. Matsuo and R. D. Zhu, "Reflection states in Ding-Iohara-Miki algebra and brane-web for D-type quiver," arXiv:1709.01954 [hep-th].

[3] M. Fukuda, K. Harada, Y. Matsuo and R. D. Zhu, "Maulik-Okounkov's R-matrix from Ding-Iohara-Miki algebra," PTEP **2017**, no. 9, 093A01 (2017) doi:10.1093/ptep/ptx123 [arXiv:1705.02941 [hep-th]].

[4] J. E. Bourgine, M. Fukuda, K. Harada, Y. Matsuo and R. D. Zhu, "(p,q)-webs of DIM representations, 5d N=1 instanton partition functions and qq-characters," arXiv:1703.10759 [hep-th]. accepted for publication in JHEP.

[5] J. E. Bourgine, M. Fukuda, Y. Matsuo, H. Zhang and R. D. Zhu, "Coherent states in quantum $\mathcal{W}_{1+\infty}$ algebra and qq-character for 5d Super Yang-Mills," PTEP **2016**, no. 12, 123B05 (2016) [arXiv:1606.08020 [hep-th]].

[6] P. M. Ho and Y. Matsuo, "The Nambu bracket and M-theory," PTEP **2016**, no. 6, 06A104 (2016) [arXiv:1603.09534 [hep-th]].

[7] J. E. Bourgine, Y. Matsuo and H. Zhang, "Holomorphic field realization of SH^c and quantum geometry of quiver gauge theories," JHEP **1604**, 167 (2016) [arXiv:1512.02492 [hep-th]].

[8] M. Fukuda, S. Nakamura, Y. Matsuo and R. D. Zhu, "SH^c realization of minimal model CFT: triality, poset and Burge condition," JHEP **1511**, 168 (2015) [arXiv:1509.01000 [hep-th]].

[9] R. D. Zhu and Y. Matsuo, "Yangian associated with 2D $N = 1$ SCFT," PTEP **2015**, no. 9, 093A01 (2015) [arXiv:1504.04150 [hep-th]].

[10] S. Nakamura, F. Okazawa and Y. Matsuo, "Recursive method for the Nekrasov partition function for classical Lie groups," PTEP, no. 3, 033B01 (2015) [arXiv:1411.4222 [hep-th]].

[11] P. M. Ho and Y. Matsuo, "Aspects of Effective Theory for Multiple M5-Branes Compactified On Circle," JHEP **1412**, 154 (2014) [arXiv:1409.4060 [hep-th]].

[12] Y. Matsuo, C. Rim and H. Zhang, "Construction of Gaiotto states with fundamental multiplets through Degenerate DAHA," JHEP **1409**, 028 (2014) [arXiv:1405.3141 [hep-th]].

[13] W. M. Chen, P. M. Ho, H. c. Kao, F. S. Khoo and Y. Matsuo, "Partition function of a chiral boson on a 2-torus from the Floreanini-Jackiw Lagrangian," PTEP **2014**, no. 3, 033B02 (2014) [arXiv:1307.2172 [hep-th]].

[14] S. Kanno, Y. Matsuo and H. Zhang, "Extended Conformal Symmetry and Recursion Formulae for Nekrasov Partition Function," JHEP **1308**, 028 (2013) [arXiv:1306.1523 [hep-th]].

[15] S. Kanno, Y. Matsuo and H. Zhang, "Virasoro constraint for Nekrasov instanton partition function," JHEP **1210**, 097 (2012) [arXiv:1207.5658 [hep-th]].

[16] I. Kostov and Y. Matsuo, "Inner products of Bethe states as partial domain wall partition functions," JHEP **1210**, 168 (2012) [arXiv:1207.2562 [hep-th]].

[17] P. -M. Ho and Y. Matsuo, "Note on non-Abelian two-form gauge fields," JHEP **1209**, 075 (2012) [arXiv:1206.5643 [hep-th]].

< Conference Proceedings >

< Review Papers >

< Books >

< Patent Applications >

7 Invited Presentations at International Conferences

[1] Yutaka Matsuo, "Extended conformal symmetry and recursion formulae for Nekrasov partition function", Todai/Riken joint workshop on Super Yang-Mills, solvable systems and related subjects, The University of Tokyo, October 23-24, 2013.

[2] Yutaka Matsuo, "Extended conformal symmetry and recursion formulae for Nekrasov partition function", PASCOS2013, Taipei, November 20-26, 2013.

[3] Yutaka Matsuo, "Dunkl operator and degenerate double affine Hecke algebra in supersymmetric gauge theories", Workshop 'New Topics on Stochastic and Quantum Interacting Particle Systems', The University of Tokyo, 10 December 2013.

[4] Yutaka Matsuo, "Extended conformal symmetry and recursion formulae for Nekrasov partition function", IV International Conference in the memory of Alexei Zamolodchikov, CFT and Integrability, Sogan University, Seoul, December 16-20, 2013.

[5] Yutaka Matsuo, "Instanton partition function, DDAHA and recursion formula", "Progress in the synthesis of integrabilities arising from gauge-string duality" JSPS/RFBR collaboration, Ootsu, Japan, March 4-7, 2014.

[6] Yutaka Matsuo, "Quantum deformation of W(∞) and quantum geometry of quiver gauge theories", workshop "Classical and quantum integrable systems and supersymmetry", Tajin, 19-24 September, 2016

[7] Yutaka Matsuo, "Toroidal symmetry and duality in string theory", in a workshop "String and M-theory in Okinawa", March 6-9, 2016, OIST.

[8] Yutaka Matsuo, "Brane web and DIM algebra–Description of duality and qq-character", in a workshop "Progress in Quantum Field Theory and String Theory II", March 27-31,2016, Osaka City University

[9] Yutaka Matsuo "Description of (p,q)-brane web from q-deformed toroidal symmetry, 25th International Conference on Integrable Systems and Quantum symmetries, Prague, June 6-10, 2017.

[10] Yutaka Matsuo, "Quantum toroidal symmetry and SL(2,Z) covariant description of AGT and qq-character, INTEGRABILITY IN LOW-DIMENSIONAL QUANTUM SYSTEMS, 26 June 2017 - 21 July 2017, Creswick, Australia.

[11] Yutaka Matsuo, "Web of W algebras and their minimal models", workshop "Topological Field Theories, String theory and Matrix Models - 2018", Moscow, August 20-August 25, 2018.

[12] Yutaka Matsuo, "Plane Partition Realization of (Web of) W-algebra Minimal Models", workshop "International Symposium in Honor of Professor Nambu for the 10th Anniversary of his Nobel Prize in Physics", Osaka City University December 12-14, 2018.

[13] Yutaka Matsuo, "Plane Partition Realization of (Web of) W-algebra Minimal Models", workshop "NCTS Annual Theory Meeting 2018", December 17-20, 2018, Hsinchu Taiwan.

8 Teaching Accomplishment

9 Contribution to Academic Community

9.1 Editorial Activities

- 日本物理学会誌編集委員 2014 年 – 2016 年

9.2 Organization of Professional Societies

9.3 Organization and Advisory of Conferences

- "Workshop New Trends in Integrable Systems 2019", 9-20 September 2019 (Osaka City University): Organizer

10 Outreach

- ホームページ：`http://www-hep.phys.s.u-tokyo.ac.jp/~matsuo/`

11 Committee Service

11.1 External Committees

11.2 University Committees

理学系研究科教務委員会 委員　2015 年 –2018 年

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	1	China
Doctor Course	2	China
Foreign researchers hosted	0	
Students sent abroad	4	France, Russia, Taiwan
Researchers sent abroad	0	
Foreign visitors	3	France, Taiwan

Takeo Moroi、諸井 健夫

1 Education and Professional Experiences

Education

1990	B.S. (Physics)	Tohoku University
1992	MSc. (Physics)	Tohoku University
1995	Ph.D. (Physics)	Tohoku University

Professional Appointments

1995−1995	JSPS fellow	KEK
1995−1998	Research fellow	Laurence Berkeley National Laboratory
1998−2000	Research fellow	Institute of Advanced Study, Princeton
2000−2010	Associate Proffewor	Tohoku University
2010−	Proffesor	The University of Tokyo

2 Research Highlights

I have been working on theoretical particle physics and cosmology, paying particular attention to the physics beyond the standard model (BSM) and its implication to the evalution of the universe. I have published 49 papers on refereed journals after 2012. The followings are the summary of results I obtained during this period. In particular, the works about the stability of the electroweak vacuum and constraints on unstable particles from the big-bang nucleosynthesis are important.

Stability of electroweak (EW) vacuum: In [37, 38], I developed a procedure to calculate the decay rate of the false vacuum in gauge theories at the one-loop level. Our procedure gives manifestly gauge invariant result. Then, in [40, 44], I applied the procedure to the calculation of the decay rate of the EW vacuum. Although it was known that the EW vacuum is unstable if the standard model is valid up to the Planck scale, nobody could perform the full one loop calculation of the decay rate; this is because of the lack of the knowledge about the gauge invariant calculation of the decay rate. I completed the full one loop calculation of the decay rate of EW vacuum. The result is now the most precise calculation of the decay rate of the EW vacuum, and is introduced in Particle Data Book.

Constaints on unstable particles from the BBN: In [41], I studied the effects of long-lived particles on BBN. The effects of unstable particles on BBN were discussed in my old paper. I updated the calculation with using the most recent understandings of the nuclear reaction processes relevant for the BBN as well as the most recent observations of the light element abundances. I also applied the results to supersymmetric model with unstable gravitino (which is the superpartner of graviton). Using the fact that the number of graivitinos produced after inflation is proportional to the reheating temperature and that the light element abundances are too much affected to be consistent with observations if the primordial abundance of the gravitino is too large, upper bound on the reheating temperature is obtained. The constraints are now widely used by people in the field of particle physics and cosmology.

Other research highlights: Other achievements of my research include the followings.

- I proposed a scenario to produce ultra high energy cosmic-ray neutrinos by the early decay of heavy particles, which can explain the origin of PeV neutrionos observed by IceCube experiment [16, 21, 33].
- I proposed "flaxion" scenario, in which the Peccei-Quinn symmetry to solve the strong CP problem is simply embedded into flavor symmetry [34, 42].
- I pointed out that, even if the superparticls are too heavy to be descovered by collider experiments, the effects of superparticles on CP- and flavor-violating quantities (like ϵ_K parameter, electron electric dipole moment, and so on) can be large enough to be observed [9, 13].

3 Selected Papers

- M. Kawasaki, K. Kohri, T. Moroi and Y. Takaesu, Phys. Rev. D **97** (2018) no.2, 023502.
  Selected as Editors Suggestion in Phys. Rev. D., cited 56 times.
- S. Chigusa, T. Moroi and Y. Shoji, Phys. Rev. Lett. **119** (2017) no.21, 211801.
  Selected as Editors Suggestion in Phys. Rev. Lett., cited 36 times.
- Y. Ema, K. Hamaguchi, T. Moroi and K. Nakayama, JHEP **1701** (2017) 096.
  Cited 54 times.
- Y. Ema, R. Jinno and T. Moroi, Phys. Lett. B **733** (2014) 120.
  Cited 62 times.
- T. Moroi and M. Nagai, Phys. Lett. B **723** (2013) 107.
  Cited 58 times.

4 Honors, Awards and Professional Society Memberships

Yukawa-Kimura Prize (2014), "For their research on supergravity and nucleosynthesis."

5 Research Plan

As I mentioned in the section of Research Highlights, I have been working on theoretical particle physics and cosmology. I will persue this direction in the next decade. Currently, the standard model of particle physics is thoght to be successful because most of the results of high energy experiments are well consistent with the predictions of the standard model. However, I believe that the standard model is not the ultimate theory and that the cut-off scale of the standard model is much lower than the Planck scale. This is because there are many issues which cannot be explained by the standard model. From particle physics point of view, we should understand (i) the origin of the neutrino mass, (ii) the origin of the electroweak scale much below the Planck scale, (iii) the reason of the charge quantization (which may indicate the grand unified theory), and so on. In addition, in order to understand the history of the universe, knowledges about the followings are needed: (iv) the particle-physics understanding of dark matter, (v) the mechanism of inflation, (vi) the origin of the asymmetry between the matter and anti-matter densities in the present universe, and so on. My research area will include the study of these issues.

I will attack the questions (i) – (vi) from the following three directions; I would like to propose

- New particle-physics models to solve questions in the standard model.
- New cosmological scenarios based on new physics models, which can explain unsolved mysteries in the thermal history of the universe.
- New ideas to experimentally or observationally confirm/exclude new physics models.

In addition, in the near future, it is expected that new results will be announced from currently going experiments and observations, like the Run-2 LHC, FermiLab muon $g-2$ experiment, flavor experiments, direct dark matter detection experiments, CMB experiments to look for B-mode polarization, and so on. Once new results will come out, I will to study their implications to BSM models. In particular, for the case that there will show up some anomaly which cannot be explained in the standard model, I will be prepared to propose new physics models which may explain the anomaly. In addition, as well as persuing new directions, I will proceed projects which are currently going on. To be more specific, I am planning to complete the following projects in the next few years:

- I will apply the gauge invariant formalism of the decay rate of false vacuum to various BSM models which has false vacuum. The longevity of the electroweak vacuum in BSM models give important constrants. For example, in supersymmetric model, there show up color and/or charge breaking vacua at which scalars with color or electric charge acquire vacuum expectation values; study of the decay rate of the electroweak vacuum is expected to constrain supersymmetric model.
- I will extend the study of BBN constraints. Many BSM models have long-lived particles which may have lifetime longer than ~ 1 sec. If produced in the early universe, they may affect the light element abundances produced by the BBN reactions. Studies of the BBN constraints may give us information about models which may not be acquired by other methods.
- I am planning to consider new ideas to probe BSM models. There are various up-coming experiments and observations, as I mentioned above. I will consider how we can utilize these facilities in searches and studies of BSM models. In particular, as a start-up, I will consider the potentials of future colliders.

6 Publications and Patents

< Refereed Original Papers >

[1] M. Asano, T. Moroi, R. Sato and T. T. Yanagida, "Focus Point Assisted by Right-Handed Neutrinos," Phys. Lett. B **708** (2012) 107.

[2] M. Asano, T. Ito, S. Matsumoto and T. Moroi, "Exploring Supersymmetric Model with Very Light Gravitino at the LHC," JHEP **1203** (2012) 011.

[3] K. Hamaguchi, T. Moroi and K. Mukaida, "Boltzmann equation for non-equilibrium particles and its application to non-thermal dark matter production," JHEP **1201** (2012) 083.

[4] R. Jinno, T. Moroi and K. Nakayama, "Imprints of Cosmic Phase Transition in Inflationary Gravitational Waves," Phys. Lett. B **713** (2012) 129.

[5] T. Moroi, R. Sato and T. T. Yanagida, "Extra Matters Decree the Relatively Heavy Higgs of Mass about 125 GeV in the Supersymmetric Model," Phys. Lett. B **709** (2012) 218.

[6] T. Moroi and K. Nakayama, "Wino LSP detection in the light of recent Higgs searches at the LHC," Phys. Lett. B **710** (2012) 159.

[7] T. Moroi and M. Takimoto, "Thermal Effects on Saxion in Supersymmetric Model with Peccei-Quinn Symmetry," Phys. Lett. B **718** (2012) 105.

[8] R. Jinno, T. Moroi and K. Nakayama, "Probing dark radiation with inflationary gravitational waves," Phys. Rev. D **86** (2012) 123502.

[9] T. Moroi and M. Nagai, "Probing Supersymmetric Model with Heavy Sfermions Using Leptonic Flavor and CP Violations," Phys. Lett. B **723** (2013) 107.

[10] T. Moroi, M. Nagai and M. Takimoto, "Non-Thermal Production of Wino Dark Matter via the Decay of Long-Lived Particles," JHEP **1307** (2013) 066.

[11] M. Ibe, S. Iwamoto, S. Matsumoto, T. Moroi and N. Yokozaki, "Recent Result of the AMS-02 Experiment and Decaying Gravitino Dark Matter in Gauge Mediation," JHEP **1308** (2013) 029.

[12] T. Moroi, K. Mukaida, K. Nakayama and M. Takimoto, "Scalar Trapping and Saxion Cosmology," JHEP **1306** (2013) 040.

[13] T. Moroi, M. Nagai and T. T. Yanagida, "Lepton Flavor Violations in High-Scale SUSY with Right-Handed Neutrinos," Phys. Lett. B **728** (2014) 342.

[14] R. Jinno, T. Moroi and K. Nakayama, "Inflationary Gravitational Waves and the Evolution of the Early Universe," JCAP **1401** (2014) 040.

[15] M. Endo, K. Hamaguchi, S. Iwamoto, T. Kitahara and T. Moroi, "Reconstructing Supersymmetric Contribution to Muon Anomalous Magnetic Dipole Moment at ILC," Phys. Lett. B **728** (2014) 274.

[16] Y. Ema, R. Jinno and T. Moroi, "Cosmic-Ray Neutrinos from the Decay of Long-Lived Particle and the Recent IceCube Result," Phys. Lett. B **733** (2014) 120.

[17] K. Hamaguchi, S. P. Liew, T. Moroi and Y. Yamamoto, "Isospin-Violating Dark Matter with Colored Mediators," JHEP **1405** (2014) 086.

[18] K. Hamaguchi, T. Moroi and T. Terada, "Complexified Starobinsky Inflation in Supergravity in the Light of Recent BICEP2 Result," Phys. Lett. B **733** (2014) 305.

[19] R. Jinno, T. Moroi and T. Takahashi, "Studying Inflation with Future Space-Based Gravitational Wave Detectors," JCAP **1412** (2014) 006.

[20] T. Moroi, K. Mukaida, K. Nakayama and M. Takimoto, "Axion Models with High Scale Inflation," JHEP **1411** (2014) 151.

[21] Y. Ema, R. Jinno and T. Moroi, "Cosmological Implications of High-Energy Neutrino Emission from the Decay of Long-Lived Particle," JHEP **1410** (2014) 150.

[22] M. Endo, T. Moroi and M. M. Nojiri, “Footprints of Supersymmetry on Higgs Decay,” JHEP **1504** (2015) 176.

[23] K. Hamaguchi, T. Moroi and K. Nakayama, “AMS-02 Antiprotons from Annihilating or Decaying Dark Matter,” Phys. Lett. B **747** (2015) 523.

[24] S. Kanemura, T. Moroi and T. Tanabe, “Beam dump experiment at future electronpositron colliders,” Phys. Lett. B **751** (2015) 25.

[25] M. Kawasaki, K. Kohri, T. Moroi and Y. Takaesu, “Revisiting Big-Bang Nucleosynthesis Constraints on Dark-Matter Annihilation,” Phys. Lett. B **751** (2015) 246.

[26] M. Endo, T. Moroi, M. M. Nojiri and Y. Shoji, “Renormalization-Scale Uncertainty in the Decay Rate of False Vacuum,” JHEP **1601** (2016) 031.

[27] H. Ito, T. Moroi and Y. Takaesu, “Studying 750 GeV di-photon resonance at photonphoton collider,” Phys. Lett. B **756** (2016) 147.

[28] H. Ito, T. Moroi and Y. Takaesu, “Di-Higgs decay of stoponium at a future photon-photon collider,” Phys. Rev. D **93** (2016) no.9, 095027.

[29] S. Chigusa and T. Moroi, “Bottom-tau unification in a supersymmetric model with anomaly-mediation,” Phys. Rev. D **94** (2016) no.3, 035016.

[30] H. Ito and T. Moroi, “Production and Decay of Di-photon Resonance at Future e^+e^- Colliders,” Phys. Rev. D **94** (2016) no.1, 015021.

[31] K. J. Bae, K. Hamaguchi, T. Moroi and K. Yanagi, “Probing the origin of 750 GeV diphoton excess with the precision measurements at the ILC,” Phys. Lett. B **759** (2016) 575.

[32] T. Moroi, T. T. Yanagida and N. Yokozaki, “Upper Bound on the Gluino Mass in Supersymmetric Models with Extra Matters,” Phys. Lett. B **760** (2016) 681.

[33] Y. Ema and T. Moroi, “Early decay of PecceiQuinn fermion and the IceCube neutrino events,” Phys. Lett. B **762** (2016) 353.

[34] Y. Ema, K. Hamaguchi, T. Moroi and K. Nakayama, “Flaxion: a minimal extension to solve puzzles in the standard model,” JHEP **1701** (2017) 096.

[35] S. Chigusa and T. Moroi, “Bottom-Tau Unification in Supersymmetric SU(5) Models with Extra Matters,” PTEP **2017** (2017) no.6, 063B05.

[36] H. Ito, O. Jinnouchi, T. Moroi, N. Nagata and H. Otono, “Extending the LHC Reach for New Physics with Sub-Millimeter Displaced Vertices,” Phys. Lett. B **771** (2017) 568.

[37] M. Endo, T. Moroi, M. M. Nojiri and Y. Shoji, “On the Gauge Invariance of the Decay Rate of False Vacuum,” Phys. Lett. B **771** (2017) 281.

[38] M. Endo, T. Moroi, M. M. Nojiri and Y. Shoji, “False Vacuum Decay in Gauge Theory,” JHEP **1711** (2017) 074.

[39] K. Kohri, T. Moroi and K. Nakayama, “Can decaying particle explain cosmic infrared background excess?,” Phys. Lett. B **772** (2017) 628.

[40] S. Chigusa, T. Moroi and Y. Shoji, “State-of-the-Art Calculation of the Decay Rate of Electroweak Vacuum in the Standard Model,” Phys. Rev. Lett. **119** (2017) no.21, 211801.

[41] M. Kawasaki, K. Kohri, T. Moroi and Y. Takaesu, “Revisiting Big-Bang Nucleosynthesis Constraints on Long-Lived Decaying Particles,” Phys. Rev. D **97** (2018) no.2, 023502.

[42] Y. Ema, D. Hagihara, K. Hamaguchi, T. Moroi and K. Nakayama, “Supersymmetric Flaxion,” JHEP **1804** (2018) 094.

[43] H. Ito, O. Jinnouchi, T. Moroi, N. Nagata and H. Otono, “Searching for Metastable Particles with Sub-Millimeter Displaced Vertices at Hadron Colliders,” JHEP **1806** (2018) 112.

[44] S. Chigusa, T. Moroi and Y. Shoji, "Decay Rate of Electroweak Vacuum in the Standard Model and Beyond," Phys. Rev. D **97** (2018) no.11, 116012.

[45] T. Moroi, K. Nakayama and Y. Tang, "Axion-photon conversion and effects on 21 cm observation," Phys. Lett. B **783** (2018) 301.

[46] K. Hamaguchi, M. Ibe and T. Moroi, "The swampland conjecture and the Higgs expectation value," JHEP **1812** (2018) 023.

[47] S. Chigusa, Y. Ema and T. Moroi, "Probing electroweakly interacting massive particles with DrellYan process at 100 TeV hadron colliders," Phys. Lett. B **789** (2019) 106.

[48] S. Asai *et al.*, "Studying gaugino masses in supersymmetric model at future 100 TeV pp collider," JHEP **1905** (2019) 179.

[49] T. Abe, S. Chigusa, Y. Ema and T. Moroi, "Indirect studies of electroweakly interacting particles at 100 TeV hadron colliders," Phys. Rev. D **100** (2019) no.5, 055018.

< **Conference Proceedings** >

[50] R. Jinno, T. Moroi and T. Takahashi, "Studying the Reheating Temperature after Inflation with Inflationary Gravitational Waves," Nucl. Part. Phys. Proc. **263-264** (2015) 97.

< **Review Papers** >

N/A

< **Books** >

N/A

< **Patent Applications** >

N/A

7 Invited Presentations at International Conferences

[1] "Enhancement of the Higgs mass in SUSY model with extra matters," PLANCK2012 (May 28 – June 1, 2012), Warsaw, Poland.

[2] "Supersymmetry, Peccei-Quinn symmetry, and cosmology," SUSY2012 (August 13 – August 18, 2012), Beijin, China.

[3] "Non-WIMP Dark Matters in SUSY Models," Cosmic Frontier (March 6 – March 8, 2013), Palo Alto, CA, U.S.A.

[4] "Probing Beyond-the-Standard-Model Physics with Inflationary Gravitational Waves," PLANCK 2013 (May 20 – 24, 2013), Bonn, Germany.

[5] "Flavor and CP Violations as Probes of BSM Physics," The 3rd KIAS Phenomenology Workshop (November 11 – 15, 2013), Seoul, Korea.

[6] "Studying Early Universe with Inflationary Gravitational Waves," Capri 2014: 5th Workshop on Theory, Phenomenology, and Experiments in Flavor Physics (May 25 – 27, 2014), AnaCapri, Italy.

[7] "Cosmic-Ray Neutrinos from the Decay of Long-Lived Particle and Implications to IceCube Results," IBS-MultiDark Joint Focus Program: WIMPs and Axions (October 10 – 21, 2014), Daejeon, Korea.

[8] "Footprints of Supersymmetry on Higgs Decay," PPC 2015 (June 29 – July 3, 2015), Deadwood, SD, U.S.A.

[9] “Looking for New Physics at the ILC,” International Workshop on Particle Physics and Cosmology (September 14, 2015 – 18, 2015), Sendai, Japan.

[10] “Beam-Dump Experiment at the ILC,” Particle Cosmology and beyond 2015 (November 16 – 19, 2015), Kanazawa, Japan.

[11] “Renormalization-Scale Uncertainty in the Decay Rate of False Vacuum,” IBS-PNU Joint Workshop on Particle Physics, String Theory and Cosmology, (December 2 – 5, 2015), Busan, Korea.

[12] “Wino dark matter and supersymmetric model with heavy sfermions,” Dark Matter from aeV to ZeV, (November 21 – 25, 2016), Durham, United Kingdom.

[13] “PeV Neutrinos from Heavy Relic Decays in Early Universe,” PAHEN (September 25 – 26, 2017), Naples, Italy.

[14] “Stability of electroweak vacuum in the standard model and beyond,” NCTS Annual Theory Meeting 2017 (December 5 – 8, 2017), Hsinchu, Taiwan.

[15] “Stability of electroweak vacuum in the standard model and beyond,” PACIFIC2018 (February 13 – 19, 2018), Hokkaido, Japan.

[16] “Stability of electroweak vacuum in the standard model,” Sugawara Workshop (February 26 – March 3, 2018), Okinawa, Japan.

[17] “State-of-the-art calculation of the decay rate of the electroweak vacuum in the standard model,” KPS meeting (April 25 – 27, 2018), Daejon, Korea.

[18] “Stability of electroweak vacuum in the standard model and beyond,” Cosmological probes of BSM – from the Big Bang to the LHC (May 6 – 12, 2018), Benasque, Spain.

[19] “Conversion of dark radiation to photon in early universe and 21cm signal,” COSMO2018 (August 28 – 31, 2018), Daejeon, Korea.

[20] “Conversion of axion to photon in early universe and 21cm signal,” PACIFIC 2018.09 (August 31 – September 4, 2018), Moorea, French Polynesia.

[21] “Beam-Dump Experiment at the ILC,” Workshop on Long lived particle searches in various energy scales (September 18, 2018), Tokyo, Japan.

[22] “Impact of 100 TeV Collider on Supersymmetry,” Kavli IPMU - ICEPP Joint Workshop (January 7, 2019), Tokyo, Japan.

[23] “Studying Anomaly-Mediated SUSY Model at Future 100 TeV *pp* Collider,” IAS Program on High Energy Physics 2019 (Janurary 7 – 25, 2019), Hong Kong, China.

[24] “Studying Gauginos at Future 100TeV *pp* Collider,” Yonsei university Cosmology and High Energy physics workshop (February 25 – 27, 2019), Seoul, Korea.

[25] “Physics Prospects: High Energy Physics in the Future,” The 40th Anniversary Symposium of the US-Japan Science and Technology Cooperation Program in High Energy Physics (April 15 – 16, 2019), Hawaii, U.S.A.

[26] “Lifetime of Our Universe,” ICCMSE 2019 (May 1 – 5, 2019), Rhodes Island, Greece.

8 Teaching Accomplishment

9 Contribution to Academic Community

9.1 Editorial Activities

- Editor of PTEP 2012 –
- Editor of JPSJ 2019 –

9.2 Organization of Professional Societies

N/A

9.3 Organization and Advisory of Conferences

- Organizer (co-chair) of "New Directions in Cosmology," to be held in the University of Tokyo, March, 2020.

10 Outreach

N/A

11 Committee Service

11.1 External Committees

External committee services are listed above (see Contribution to Academic Community).

11.2 University Committees

Chief of Department of Physics (2017).

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	0	
Doctor Course	0	
Foreign researchers hosted	3	
Students sent abroad	15	USA, Europe, Korea, etc.
Researchers sent abroad	10	USA, Europe, Korea, etc.
Foreign visitors	23	Italy, USA

Hiroaki Aihara、相原 博昭

1 Education and Professional Experiences

Education

1978	B.S. (Physics)	The University of Tokyo
1980	MSc. (Physics)	The University of Tokyo
1984	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1984−1988	Assistant Professor	Department of Physics, The University of Tokyo
1988−1995	Postdoctoral Fellow/Staff Scientist	Lawrence Berkeley National Laboratory
1995−2003	Associate Professor	Department of Physics, The University of Tokyo
2003−	Professor	Department of Physics, The University of Tokyo
2007−	Principal Investigator Deputy Director	Kavli Institute for the Physics and Mathematics of the Universe
2009−2012	Associate Dean	School of Science, The University of Tokyo
2010−	Professor	Center for High Energy Geophysics Research, Earthquake Research Institute, The University of Tokyo
2012−2014	Dean	School of Science, The University of Tokyo
2014	Executive Vice President	The University of Tokyo
2015-	Executive Director, Vice President	The University of Tokyo

2 Research Highlights

My fields of research are high energy particle physics and observational cosmology. Past research activities include experiments at PEP electron-positron collider at SLAC (Stanford Linear Accelerator Center), Tevatron proton-antiproton collider at Fermilab, B factory at KEK and J-PARC accelerator. Major research achievements are significant contributions to 1995 discovery of the top quark at DØ experiment, 2001 observation of CP violation in the B meson system at Belle experiment, and 2014 observation of electron neutrino appearance in a muon neutrino beam at T2K experiment. I am currently involved in a dark energy survey with the Subaru Hyper Suprime Cam and Belle II experiment at Super KEKB accelerator.

The focus of my research has been precision measurement of CP violation and search for new physics in the B meson and τ lepton systems with the Belle detector at the KEK B-factory (KEKB). I was a group leader of the Belle collaboration from 2000 through 2006 and have continued to be an active member. Achievements of the experiment, since 2012, include the investigation of lepton flavor violation in $B \to D^*\ell\nu$ where ℓ can be a τ, μ or e. There is some "tension" in data, which might eventually indicate the lepton flavor violation in the B meson decays. It is one of the main physics goals for the luminosity-upgraded Experiment BelleII, which started data taking in 2019. Our recent measurements of the τ leptons include new measurements of Michel parameters of the τ decays and branching fractions of extremely rare decays $\tau \to \pi\ell^+\ell^-\nu_\tau(\ell = e, \mu)$, which are sensitive to physics beyond the standard model of particle physics such as light sterile neutrinos. These measurements are most precise to date.

The T2K long baseline neutrino oscillation experiment started in April 2009. We searched for muon neutrino to electron neutrino oscillation and reported the first observation of electron neutrino appearance in a muon neutrino beam in 2014, yet another monument in neutrino physics. We continue to improve the precision of the measurement of neutrino oscillation parameters including CP violation parameter δ.

I have been a co-PI of Hyper Suprime Cam (HSC) Dark Energy Survey at Subaru Observatory and lead a project to build a wide field corrector lens system for HSC, which is mounted on the prime focus of the Subaru telescope. With HSC we have conducted extensive wide-field deep survey to investigate Dark Energy through a 3D map of matter distribution detected based on a technique of gravitational weak lensing. In 2019 we published the first cosmological result based on the analysis of weak lensing effects in galaxy imaging data. We continue to increase the galaxy image data with HSC survey.

The current h-index (by ResearcherID) of my refereed papers is 93.

3 Selected 10 papers after January 2012

(Citation statistics is based on ResearcherID)

- "Study of $e^+e^- \to \pi^+\pi^- J/\psi$ and Observation of a Charged Charmoniumlike State at Belle," Authors: Liu, Z. Q.; Shen, C. P.; Yuan, C. Z.; et al., Phys. Rev. Lett. **110** Issue: 25 Published: JUN 17 2013 Times Cited: 422

- "Observation of Two Charged Bottomoniumlike Resonances in $\Upsilon(5S)$ Decays," Authors: Choi, S. -K.; Olsen, S. L.; Adachi, et al., Published: 2012, in Phys. Rev. Lett. Times Cited: 328

- "Observation of Electron Neutrino Appearance in a Muon Neutrino Beam," Authors: K. Abe; J. Adam; H. Aihara, et al., 2014 in Phys. Rev. Lett. Times Cited: 323

- "Measurement of the branching ratio of $\bar{B} \to D^{(*)}\tau^-\bar{\nu}_\tau$ relative to $\bar{B} \to D^{(*)}\ell^-\bar{\nu}_\ell$ decays with hadronic tagging at Belle," Authors: M. Huschle; T. Kuhr; M. Heck, et al., Published: 2015 in Phys. Rev. D Times Cited: 292

- "Measurements of neutrino oscillation in appearance and disappearance channels by the T2K experiment with 6.6×10^{20} protons on target," Authors: Abe, K.; Adam, J.; Aihara, H., et al., Published: 2015 in Physs. Rev. D Times Cited: 192

- "The Physics of the B Factories," Authors: Bevan, A. J.; Golob, B.; Mannel, Th., et al, Published: 2014 in THE EUROPEAN PHYSICAL JOURNAL C Times Cited: 171

- "Extragalactic science, cosmology, and Galactic archaeology with the Subaru Prime Focus Spectrograph," Authors: Takada, Masahiro; Ellis, Richard S.; Chiba, Masashi, et al., Published: 2014 in PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF JAPAN Times Cited: 169

- "Hyper Suprime-Cam," Authors: Satoshi Miyazaki; Yutaka Komiyama; Hidehiko Nakaya, et al., Published: 2012 in PROCEEDINGS OF SPIE - THE INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERIN Times Cited: 162
- "Precise Measurement of the Neutrino Mixing Parameter θ_{23} from Muon Neutrino Disappearance in an Off-Axis Beam," Published: 2014 in Phys. Rev. Lett., Times Cited: 149
- "Measurement of the τ Lepton Polarization and $R(D^*)$ in the Decay $\bar{B} \to D^*\tau^-\bar{\nu}_\tau$," Authors: S. Hirose; T. Iijima; I. Adachi, et al., Published: 2017 in Phys. Rev. Lett. Times Cited: 147

4 Honors, Awards and Professional Society Memberships

2012	Le Prix La Recherche 2012 (Physique) (as T2K collaboration)
2016	The Breakthrough Prize in Fundamental Physics (as T2K collaboration)
2006−	Member, Science Council of Japan
2011−2017	Council member, Science Council of Japan
2019	High Energy and Particle Physics Prize of the European Physical Society (as DØ collboration)

5 Research Plan

I retire in march 2021. I would like to focus on high precision study of CP violation in the B meson system based on the unprecedentedly high-statistics data to be available from BelleII experiment at the Super KEKB factory. It is the mainstream of flavor physics in search for physics beyond the standard model. Another focus is the cosmological analysis of the weak lensing data taken by Hyper Suprime Cam at Subaru Observatory. We investigate the nature of dark energy, a mysterious component that is responsible for accelerating the expansion of the universe, based on weak lensing measurement of 100 million galaxies. This data provides 3D mass mapping of the universe, which in turn yields the information of the equation of the state of Dark Energy.

In addition, I continue to support the Hyper Kamiokande and International Linear Collider projects, which are two top-priorities in high energy physics community in Japan.

6 Publications

[1] "First measurement of the CKM angle ϕ_3 with $B^\pm \to D(K^0_S\pi^+\pi^-\pi^0)K^\pm$ decays", P. K. Resmi *et al.* [Belle Collaboration].

[2] "Observation of $\tau^- \to \pi^-\nu_\tau e^+e^-$ and search for $\tau^- \to \pi^-\nu_\tau\mu^+\mu^-$", Y. Jin *et al.* [Belle Collaboration]. Phys. Rev. D **100**, no. 7, 071101 (2019).

[3] "Operational experience and commissioning of the Belle II vertex detector", B. Schwenker *et al.* [Belle II DEPFET, PXD, SVD Collaboration]. ,PoS VERTEX **2018**, 006 (2019).

[4] "The Belle II silicon vertex detector: Assembly and initial results", R. Thalmeier *et al.* [Belle-II SVD Collaboration]. Nucl. Instrum. Meth. A **936**, 712 (2019).

[5] "The Belle II vertex detector integration", P. Kody *et al.* [Belle-II DEPFET, PXD, SVD Collaboration]. Nucl. Instrum. Meth. A **936**, 616 (2019).

[6] "Search for $\Omega(2012) \to K\Xi(1530) \to K\pi\Xi$ at Belle", S. Jia *et al.* [Belle Collaboration]. Phys. Rev. D **100**, no. 3, 032006 (2019).

[7] "Charm Reflects Poorly on Anticharm", H. Aihara. APS Physics **12**, 52 (2019).

[8] "Search for $B^0 \to X(3872)\gamma$", P.-C. Chou *et al.* [Belle Collaboration]. Phys. Rev. D **100**, no. 1, 012002 (2019).

[9] "Machine learning: hit time finding with a neural network", R. Thalmeier *et al.* [Belle II SVD Collaboration]. PoS TWEPP **2018**, 065 (2019).

[10] "First measurements of absolute branching ractions of the Ξ_c^+ baryon at Belle", Y. B. Li *et al.* [Belle Collaboration]. Phys. Rev. D **100**, no. 3, 031101 (2019).

[11] "Search for $X(3872)$ and $X(3915)$ decay into $\chi_{c1}\pi^0$ in B decays at Belle", V. Bhardwaj *et al.* [Belle Collaboration]. Phys. Rev. D **99**, no. 11, 111101 (2019).

[12] "Measurement of branching fraction and final-state asymmetry for the $\bar{B}^0 \to K_S^0 K^\mp \pi^\pm$ decay", Y. T. Lai *et al.* [Belle Collaboration]. Phys. Rev. D **100**, no. 1, 011101 (2019).

[13] "Evidence for the decay $B^0 \to p\bar{p}\pi^0$", B. Pal *et al.* [Belle Collaboration]. Phys. Rev. D **99**, no. 9, 091104 (2019).

[14] "Studies of radioactive background in SOI pixel detector for solar axion search experiment", Y. Onuki *et al.*. Nucl. Instrum. Meth. A **924**, 448 (2019).

[15] "Latest Belle results on Tau decays", Y. Jin, D. Epifanov and H. Aihara. SciPost Phys. Proc. **1**, 002 (2019).

[16] "Performance Studies of the Belle II Silicon Vertex Detector", K. Lalwani *et al.* [Belle II SVD Group]. PoS VERTEX **2018**, 052 (2019).

[17] "Spatial Resolution of the Belle II Silicon Vertex Detector", S. Halder *et al.* [Belle II SVD Group]. PoS VERTEX **2018**, 054 (2019).

[18] "The Silicon Vertex Detector of the Belle II Experiment", H. Aihara *et al.* [Belle II SVD Collaboration]. PoS VERTEX **2018**, 024 (2019).

[19] "Transverse momentum dependent production cross sections of charged pions, kaons and protons produced in inclusive e^+e^- annihilation at $\sqrt{s} = 10.58$ GeV", R. Seidl *et al.* [Belle Collaboration]. Phys. Rev. D **99**, no. 11, 112006 (2019).

[20] "Construction and quality assurance of the Belle II Silicon Vertex Detector", P. K. Resmi *et al.* [Belle II SVD Collaboration]. PoS VERTEX **2018**, 051 (2019).

[21] "Search for the $B \to Y(4260)K,\ Y(4260) \to J/\psi\pi^+\pi^-$ decays", R. Garg *et al.* [Belle Collaboration]. Phys. Rev. D **99**, no. 7, 071102 (2019).

[22] "Measurements of branching fraction and direct CP asymmetry in $B^\pm \to K_S^0 K_S^0 K^\pm$ and a search for $B^\pm \to K_S^0 K_S^0 \pi^\pm$", A. B. Kaliyar *et al.* [Belle Collaboration]. Phys. Rev. D **99**, no. 3, 031102 (2019).

[23] "First Measurements of Absolute Branching Fractions of the Ξ_c^0 Baryon at Belle", Y. B. Li *et al.* [Belle Collaboration]. Phys. Rev. Lett. **122**, no. 8, 082001 (2019).

[24] "Measurement of the of $\tau^- \to \pi^-\nu_\tau e^+e^-$ branching fraction by Belle", Y. Jin *et al.* [Belle Collaboration]. PoS ICHEP **2018**, 915 (2019).

[25] "Search for the rare decay of $B^+ \to \ell^+\nu_\ell\gamma$ with improved hadronic tagging", M. Gelb *et al.* [Belle Collaboration]. Phys. Rev. D **98**, no. 11, 112016 (2018).

[26] “Observation of $e^+e^- \to \gamma\chi_{c1}$ and search for $e^+e^- \to \gamma\chi_{c0}, \gamma\chi_{c2}$, and $\gamma\eta_c$ at $\sqrt{s}$ near 10.6 GeV at Belle”, S. Jia *et al.* [Belle Collaboration]. Phys. Rev. D **98**, no. 9, 092015 (2018).

[27] “Search for CP violation with kinematic asymmetries in the $D^0 \to K^+K^-\pi^+\pi^-$ decay”, J. B. Kim *et al.* [Belle Collaboration]. Phys. Rev. D **99**, no. 1, 011104 (2019).

[28] “Observation of $\Xi(1620)^0$ and evidence for $\Xi(1690)^0$ in $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ decays”, M. Sumihama *et al.* [Belle Collaboration]. Phys. Rev. Lett. **122**, no. 7, 072501 (2019).

[29] “Measurement of time-dependent CP violation in $B^0 \to K_S^0\pi^0\pi^0$ decays”, Y. Yusa *et al.* [Belle Collaboration]. Phys. Rev. D **99**, no. 1, 011102 (2019).

[30] “Measurement of the branching fraction and time-dependent CP asymmetry for $B^0 \to J/\psi\pi^0$ decays”, B. Pal *et al.* [Belle Collaboration]. Phys. Rev. D **98**, no. 11, 112008 (2018).

[31] “Cosmology from cosmic shear power spectra with Subaru Hyper Suprime-Cam first-year data”, C. Hikage *et al.* [HSC Collaboration]. , Publ. Astron. Soc. Jap. **71**, no. 2, Publications of the Astronomical Society of Japan, Volume 71, Issue 2, April 2019, 43, https://doi.org/10.1093/pasj/psz010 (2019).

[32] “Search for a light CP-odd Higgs boson and low-mass dark matter at the Belle experiment”, I. S. Seong *et al.* [Belle Collaboration]. Phys. Rev. Lett. **122**, no. 1, 011801 (2019).

[33] “Measurement of the CKM matrix element $|V_{cb}|$ from $B^0 \to D^{*-}\ell^+\nu_\ell$ at Belle”, E. Waheed *et al.* [Belle Collaboration]. Phys. Rev. D **100**, no. 5, 052007 (2019).

[34] “Belle II Silicon Vertex Detector (SVD)”, S. Bahinipati *et al.*. , Springer Proc. Phys. **213**, 414 (2018).

[35] “Observation of Transverse $\Lambda/\bar{\Lambda}$ Hyperon Polarization in e^+e^- Annihilation at Belle”, Y. Guan *et al.* [Belle Collaboration]. Phys. Rev. Lett. **122**, no. 4, 042001 (2019).

[36] “Observation of $B^+ \to p\bar{\Lambda}K^+K^-$ and $B^+ \to \bar{p}\Lambda K^+K^+$”, P.-C. Lu *et al.* [Belle Collaboration]. Phys. Rev. D **99**, no. 3, 032003 (2019).

[37] “Measurements of isospin asymmetry and difference of direct CP asymmetries in inclusive $B \to X_s\gamma$ decays”, S. Watanuki *et al.* [Belle Collaboration]. Phys. Rev. D **99**, no. 3, 032012 (2019).

[38] “Search for the lepton-flavor-violating decay $B^0 \to K^{*0}\mu^\pm e^\mp$” , S. Sandilya *et al.* [Belle Collaboration]. Phys. Rev. D **98**, no. 7, 071101 (2018).

[39] “Observation of $\Upsilon(2S) \to \gamma\eta_b(1S)$ decay” , B. G. Fulsom *et al.* [Belle Collaboration]. Phys. Rev. Lett. **121**, no. 23, 232001 (2018).

[40] “Evidence of a structure in $\bar{K}^0\Lambda_c^+$ consistent with a charged $\Xi_c(2930)^+$, and updated measurement of $\bar{B}^0 \to \bar{K}^0\Lambda_c^+\bar{\Lambda}_c^-$ at Belle” , Y. B. Li *et al.* [Belle Collaboration]. , Eur. Phys. J. C **78**, no. 11, 928 (2018).

[41] “Observation of $e^+e^- \to \pi^+\pi^-\pi^0\chi_{b1,2}(1P)$ and search for $e^+e^- \to \phi\chi_{b1,2}(1P)$ at $\sqrt{s} =$ 10.96-11.05 GeV” , J. H. Yin *et al.* [Belle Collaboration]. Phys. Rev. D **98**, no. 9, 091102 (2018).

[42] “Observation of an Excited Ω^- Baryon”, J. Yelton *et al.* [Belle Collaboration]. Phys. Rev. Lett. **121**, no. 5, 052003 (2018).

[43] “Measurement of $\eta_c(1S)$, $\eta_c(2S)$ and non-resonant $\eta'\pi^+\pi^-$ production via two-photon collisions”, Q. N. Xu *et al.* [Belle Collaboration]. Phys. Rev. D **98**, no. 7, 072001 (2018).

[44] “Search for $\Upsilon(1S,2S) \to Z_c^+Z_c^{(\prime)-}$ and $e^+e^- \to Z_c^+Z_c^{(\prime)-}$ at $\sqrt{s} =$ 10.52, 10.58, and 10.867 GeV”, S. Jia *et al.* [Belle Collaboration]. Phys. Rev. D **97**, no. 11, 112004 (2018).

[45] “Measurement of $\cos 2\beta$ in $B^0 \to D^{(*)}h^0$ with $D \to K_S^0\pi^+\pi^-$ decays by a combined time-dependent Dalitz plot analysis of BaBar and Belle data”, I. Adachi *et al.* [BaBar and Belle Collaborations]. Phys. Rev. D **98**, no. 11, 112012 (2018).

[46] "First evidence for $\cos 2\beta > 0$ and resolution of the CKM Unitarity Triangle ambiguity by a time-dependent Dalitz plot analysis of $B^0 \to D^{(*)}h^0$ with $D \to K_S^0\pi^+\pi^-$ decays", I. Adachi *et al.* [BaBar and Belle Collaborations]. Phys. Rev. Lett. **121**, no. 26, 261801 (2018).

[47] "Observation of $\Upsilon(4S) \to \eta'\Upsilon(1S)$", E. Guido *et al.* [Belle Collaboration]. Phys. Rev. Lett. **121**, no. 6, 062001 (2018).

[48] "Measurement of time-dependent CP asymmetries in $B^0 \to K_S^0\eta\gamma$ decays", H. Nakano *et al.* [Belle Collaboration]. Phys. Rev. D **97**, no. 9, 092003 (2018).

[49] "Measurement of the branching fraction of $B \to D^{(*)}\pi\ell\nu$ at Belle using hadronic tagging in fully reconstructed events", A. Vossen *et al.* [Belle Collaboration]. Phys. Rev. D **98**, no. 1, 012005 (2018).

[50] "Inclusive study of bottomonium production in association with an η meson in e^+e^- annihilations near $\Upsilon(5S)$", U. Tamponi *et al.* [Belle Collaboration]. , Eur. Phys. J. C **78**, no. 8, 633 (2018).

[51] "Measurement of the Decays $\Lambda_c \to \Sigma\pi\pi$ at Belle", M. Berger *et al.* [Belle Collaboration]. Phys. Rev. D **98**, no. 11, 112006 (2018).

[52] "Electronics and Firmware of the Belle II Silicon Vertex Detector Readout System", R. Thalmeier *et al.* [Belle-II SVD Collaboration]. PoS TWEPP **-17**, 109 (2017).

[53] "Search for $B^- \to \mu^-\bar{\nu}_\mu$ Decays at the Belle Experiment", A. Sibidanov *et al.* [Belle Collaboration]. Phys. Rev. Lett. **121**, no. 3, 031801 (2018).

[54] "Observation of $\Xi_c(2930)^0$ and updated measurement of $B^- \to K^-\Lambda_c^+\bar{\Lambda}_c^-$ at Belle", Y. B. Li *et al.* [Belle Collaboration]. , Eur. Phys. J. C **78**, no. 3, 252 (2018).

[55] "Study of K_S^0 pair production in single-tag two-photon collisions", M. Masuda *et al.* [Belle Collaboration]. Phys. Rev. D **97**, no. 5, 052003 (2018).

[56] "Measurement of branching fractions of hadronic decays of the Ω_c^0 baryon", J. Yelton *et al.* [Belle Collaboration]. Phys. Rev. D **97**, no. 3, 032001 (2018).

[57] "Observation of Excited Ω_c Charmed Baryons in e^+e^- Collisions", J. Yelton *et al.* [Belle Collaboration]. Phys. Rev. D **97**, no. 5, 051102 (2018).

[58] "Search for light tetraquark states in $\Upsilon(1S)$ and $\Upsilon(2S)$ decays", S. Jia *et al.* [Belle Collaboration]. Phys. Rev. D **96**, no. 11, 112002 (2017).

[59] "Measurement of the tau Michel parameters $\bar{\eta}$ and $\xi\kappa$ in the radiative leptonic decay $\tau^- \to \ell^-\nu_\tau\bar{\nu}_\ell\gamma$", N. Shimizu *et al.* [Belle Collaboration]. , PTEP **2018**, no. 2, 023C01 (2018).

[60] "Measurements of the absolute branching fractions of $B^+ \to X_{c\bar{c}}K^+$ and $B^+ \to \bar{D}^{(*)0}\pi^+$ at Belle", Y. Kato *et al.* [Belle Collaboration]. Phys. Rev. D **97**, no. 1, 012005 (2018).

[61] "Measurement of the τ lepton polarization and $R(D^*)$ in the decay $\bar{B} \to D^*\tau^-\bar{\nu}_\tau$ with one-prong hadronic τ decays at Belle", S. Hirose *et al.* [Belle Collaboration]. Phys. Rev. D **97**, no. 1, 012004 (2018).

[62] "Angular analysis of the $e^+e^- \to D^{(*)\pm}D^{*\mp}$ process near the open charm threshold using initial-state radiation", V. Zhukova *et al.* [Belle Collaboration]. Phys. Rev. D **97**, no. 1, 012002 (2018).

[63] "Study of η and dipion transitions in $\Upsilon(4S)$ decays to lower bottomonia", E. Guido *et al.* [Belle Collaboration]. Phys. Rev. D **96**, no. 5, 052005 (2017).

[64] "Evidence for Isospin Violation and Measurement of CP Asymmetries in $B \to K^*(892)\gamma$", T. Horiguchi *et al.* [Belle Collaboration]. Phys. Rev. Lett. **119**, no. 19, 191802 (2017).

[65] "Search for $\Lambda_c^+ \to \phi p\pi^0$ and branching fraction measurement of $\Lambda_c^+ \to K^-\pi^+p\pi^0$", B. Pal *et al.* [Belle Collaboration]. Phys. Rev. D **96**, no. 5, 051102 (2017).

[66] "Invariant-mass and fractional-energy dependence of inclusive production of di-hadrons in e^+e^- annihilation at $\sqrt{s} = 10.58$ GeV" , R. Seidl *et al.* [Belle Collaboration]. Phys. Rev. D **96**, no. 3, 032005 (2017).

[67] "The Belle II SVD detector", K. R. Nakamura *et al.* [Belle-II SVD Collaboration]. PoS Vertex **2016**, 012 (2017).

[68] "Production cross sections of hyperons and charmed baryons from e^+e^- annihilation near $\sqrt{s}$ = 10.52 GeV", M. Niiyama *et al.* [Belle Collaboration]. Phys. Rev. D **97**, no. 7, 072005 (2018).

[69] "Search for CP Violation and Measurement of the Branching Fraction in the Decay $D^0 \to K^0_S K^0_S$", N. Dash *et al.*. Phys. Rev. Lett. **119**, no. 17, 171801 (2017).

[70] "Measurement of branching fraction and direct CP asymmetry in charmless $B^+ \to K^+K^-\pi^+$ decays at Belle", C.-L. Hsu *et al.* [Belle Collaboration]. Phys. Rev. D **96**, no. 3, 031101 (2017).

[71] "Measurement of the branching fraction and CP asymmetry in $B^0 \to \pi^0\pi^0$ decays, and an improved constraint on ϕ_2" , T. Julius *et al.* [Belle Collaboration]. Phys. Rev. D **96**, no. 3, 032007 (2017).

[72] "The Hyper Suprime-Cam SSP Survey: Overview and Survey Design", H. Aihara *et al.*. , Publ. Astron. Soc. Jap. **70**, S4 (2018).

[73] "Observation of an alternative $\chi_{c0}(2P)$ candidate in $e^+e^- \to J/\psi D\bar{D}$" , K. Chilikin *et al.* [Belle Collaboration]. Phys. Rev. D **95**, 112003 (2017).

[74] "Measurement of the decays $B \to \eta\ell\nu_\ell$ and $B \to \eta'\ell\nu_\ell$ in fully reconstructed events at Belle", C. Bele?o *et al.* [Belle Collaboration]. Phys. Rev. D **96**, no. 9, 091102 (2017).

[75] "First measurement of T-odd moments in $D^0 \to K^0_S\pi^+\pi^-\pi^0$ decays", K. Prasanth *et al.* [Belle Collaboration]. Phys. Rev. D **95**, no. 9, 091101 (2017).

[76] "Performance studies of the Belle II Silicon Vertex Detector with data taken at the DESY test beam in April 2016", T. Lück *et al.* [Belle-II SVD Collaboration]. PoS Vertex **2016**, 057 (2017).

[77] "First Data Release of the Hyper Suprime-Cam Subaru Strategic Program", H. Aihara *et al.*. , Publ. Astron. Soc. Jap. **70**, S8 (2018).

[78] "Belle II Silicon Vertex Detector", D. Dutta *et al.*. , JINST **12**, no. 02, C02074 (2017).

[79] "The Belle II silicon vertex detector assembly and mechanics", K. Adamczyk *et al.* [Belle-II SVD Collaboration]. Nucl. Instrum. Meth. A **845**, 38 (2017).

[80] "The Belle II SVD data readout system", R. Thalmeier *et al.*. Nucl. Instrum. Meth. A **845**, 633 (2017).

[81] "Search for $B \to h\nu\bar{\nu}$ decays with semileptonic tagging at Belle", J. Grygier *et al.* [Belle Collaboration]. Phys. Rev. D **96**, no. 9, 091101 (2017), Addendum: [Phys. Rev. D **97**, no. 9, 099902 (2018)].

[82] "Precise determination of the CKM matrix element $|V_{cb}|$ with $\bar{B}^0 \to D^{*\,+}\,\ell^-\,\bar{\nu}_\ell$ decays with hadronic tagging at Belle", A. Abdesselam *et al.* [Belle Collaboration].

[83] "The Monitoring System of the Belle II Vertex Detector", L. Vitale *et al.* [Belle-II SVD Collaboration]. PoS Vertex **2016**, 051 (2017).

[84] "The Software Framework of the Belle II Silicon Vertex Detector and its Development for the 2016 Test-Beam at DESY", G. Caria *et al.* [Belle-II SVD Collaboration]. PoS Vertex **2016**, 060 (2017).

[85] "Lepton-Flavor-Dependent Angular Analysis of $B \to K^*\ell^+\ell^-$", S. Wehle *et al.* [Belle Collaboration]. Phys. Rev. Lett. **118**, no. 11, 111801 (2017).

[86] "Measurement of the τ lepton polarization and $R(D^*)$ in the decay $\bar{B} \to D^*\tau^-\bar{\nu}_\tau$", S. Hirose *et al.* [Belle Collaboration]. Phys. Rev. Lett. **118**, no. 21, 211801 (2017).

[87] "Search for D^0 decays to invisible final states at Belle", Y.-T. Lai *et al.* [Belle Collaboration]. Phys. Rev. D **95**, no. 1, 011102 (2017).

[88] "Search for the 0^{--} Glueball in $\Upsilon(1S)$ and $\Upsilon(2S)$ decays", S. Jia *et al.* [Belle Collaboration]. Phys. Rev. D **95**, no. 1, 012001 (2017).

[89] "Physics potentials with the second Hyper-Kamiokande detector in Korea", K. Abe *et al.* [Hyper-Kamiokande Collaboration]. , PTEP **2018**, no. 6, 063C01 (2018)

[90] "The Silicon Vertex Detector of the Belle II Experiment", A. Paladino *et al.* [Belle-II SVD Collaboration]. PoS ICHEP **2016**, 248 (2016).

[91] "A scintillation counter consisting of a pure CsI crystal, WLS and APD for Belle II", H. Aihara, D. Epifanov, Y. Jin and K. Wan. PoS ICHEP **2016**, 703 (2016).

[92] "Study of Two-Body $e^+e^- \to B_s^{(*)}\bar{B}_s^{(*)}$ Production in the Energy Range from 10.77 to 11.02 GeV", A. Abdesselam *et al.*.

[93] "Measurement of Michel Parameters ($\bar{\eta}$, $\xi\kappa$) in the radiative leptonic decay of tau at Belle", A. Abdesselam *et al.* [Belle Collaboration]. Nucl. Part. Phys. Proc. **287-288**, 11 (2017).

[94] "Search for a dark vector gauge boson decaying to $\pi^+\pi^-$ using $\eta \to \pi^+\pi^-\gamma$ decays", E. Won *et al.* [Belle Collaboration]. Phys. Rev. D **94**, no. 9, 092006 (2016).

[95] "A bonding study toward the quality assurance of Belle-II silicon vertex detector modules", K. H. Kang *et al.* [Belle-II SVD Collaboration]. Nucl. Instrum. Meth. A **831**, 213 (2016).

[96] "Measurement of the branching ratio of $\bar{B}^0 \to D^{*+}\tau^-\bar{\nu}_\tau$ relative to $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell$ decays with a semileptonic tagging method", Y. Sato *et al.* [Belle Collaboration]. Phys. Rev. D **94**, no. 7, 072007 (2016).

[97] "Study of Excited Ξ_c States Decaying into Ξ_c^0 and Ξ_c^+ Baryons", J. Yelton *et al.* [Belle Collaboration]. Phys. Rev. D **94**, no. 5, 052011 (2016).

[98] "Measurement of the CKM angle φ_1 in $B^0 \to \bar{D}^{(*)0}h^0$, $\bar{D}^0 \to K_S^0\pi^+\pi^-$ decays with time-dependent binned Dalitz plot analysis" , V. Vorobyev *et al.* [Belle Collaboration]. Phys. Rev. D **94**, no. 5, 052004 (2016).

[99] "Studies of charmed strange baryons in the ΛD final state at Belle" , Y. Kato *et al.* [Belle Collaboration]. Phys. Rev. D **94**, no. 3, 032002 (2016).

[100] "Search for a massive invisible particle X^0 in $B^+ \to e^+X^0$ and $B^+ \to \mu^+X^0$ decays", C. S. Park *et al.* [Belle Collaboration]. Phys. Rev. D **94**, no. 1, 012003 (2016).

[101] "Monte Carlo study of the measurement of the Michel parameters in the radiative decay of the τ at Belle", N. Shimizu, H. Aihara and D. Epifanov. Nucl. Instrum. Meth. A **824**, 237 (2016).

[102] "Belle II SVD ladder assembly procedure and electrical qualification", K. Adamczyk *et al.* [Belle-IISVD Collaboration]. Nucl. Instrum. Meth. A **824**, 381 (2016).

[103] "Belle-II VXD radiation monitoring and beam abort with sCVD diamond sensors" , K. Adamczyk *et al.*. Nucl. Instrum. Meth. A **824**, 480 (2016).

[104] "Study of a pure CsI crystal readout by APD for Belle II end cap ECL upgrade", Y. Jin, H. Aihara, O. V. Borshchev, D. A. Epifanov, S. A. Ponomarenko and N. M. Surin. Nucl. Instrum. Meth. A **824**, 691 (2016).

[105] "The silicon vertex detector of the Belle II experiment" , K. Adamczyk *et al.* [Belle-IISVD Collaboration]. Nucl. Instrum. Meth. A **824**, 406 (2016).

[106] "Search for XYZ states in $\Upsilon(1S)$ inclusive decays", C. P. Shen *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 11, 112013 (2016).

[107] "First observation of $\gamma\gamma \to p\bar{p}K^+K^-$ and search for exotic baryons in pK systems", C. P. Shen *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 11, 112017 (2016).

[108] "Search for the decay $B^0 \to \phi\gamma$", Z. King *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 11, 111101 (2016).

[109] "Observation of $D^0 \to \rho^0\gamma$ and search for CP violation in radiative charm decays", A. Abdesselam *et al.* [Belle Collaboration]. Phys. Rev. Lett. **118**, no. 5, 051801 (2017)

[110] "Construction and test of the first Belle II SVD ladder implementing the origami chip-on-sensor design", C. Irmler *et al.*. , JINST **11**, no. 01, C01087 (2016).

[111] "EMC studies for the vertex detector of the Belle II experiment", R. Thalmeier *et al.*. , JINST **11**, no. 01, C01044 (2016).

[112] "Observation of Zb(10610) and Zb(10650) Decaying to B Mesons", A. Garmash *et al.* [Belle Collaboration]. Phys. Rev. Lett. **116**, no. 21, 212001 (2016).

[113] "First Observation of Doubly Cabibbo-Suppressed Decay of a Charmed Baryon: $\Lambda_c^+ \to pK^+\pi^-$", S. B. Yang *et al.* [Belle Collaboration]. Phys. Rev. Lett. **117**, no. 1, 011801 (2016)

[114] "First observation of the decay $\mathrm{B}^0 \to \psi(2\mathrm{S})\pi^0$", V. Chobanova *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 3, 031101 (2016).

[115] "Study of scintillation counter consisting of a pure CsI crystal and avalanche photodiodes", H. Aihara, O. Borshchev, D. Epifanov, Y. Jin, S. A. Ponomarenko and N. M. Surin. PoS PhotoDet **2015**, 052 (2016).

[116] "Search for the rare decay $D^0 \to \gamma\gamma$ at Belle", N. K. Nisar *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 5, 051102 (2016).

[117] "Inclusive and exclusive measurements of B decays to χ_{c1} and χ_{c2} at Belle", V. Bhardwaj *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 5, 052016 (2016).

[118] "Observation of the decay $B_s^0 \to K^0\overline{K}^0$", B. Pal *et al.* [Belle Collaboration]. Phys. Rev. Lett. **116**, no. 16, 161801 (2016).

[119] "Temperature Dependence Measurement of a Hybrid Photo-Detector for Hyper-Kamiokande", M. Jiang *et al.* [Hyper-Kamiokande Working Group]. , JPS Conf. Proc. **8**, 023006 (2015).

[120] "Measurement of the decay $B \to D\ell\nu_\ell$ in fully reconstructed events and determination of the Cabibbo-Kobayashi-Maskawa matrix element $|V_{cb}|$", R. Glattauer *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 3, 032006 (2016).

[121] "Study of $\mathbf{B^0} \to \rho^+\rho^-$ decays and implications for the CKM angle $\boldsymbol{\phi_2}$", P. Vanhoefer *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 3, 032010 (2016), Addendum: [Phys. Rev. D **94**, no. 9, 099903 (2016)].

[122] "Measurement of $D^0\bar{D}^0$ mixing and search for CP violation in $D^0 \to K^+K^-, \pi^+ + \pi^-$ decays with the full Belle data set", M. Stari *et al.* [Belle Collaboration]. Phys. Lett. B **753**, 412 (2016).

[123] "Search for $B^0 \to \pi^-\tau^+\nu_\tau$ with hadronic tagging at Belle", P. Hamer *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 3, 032007 (2016).

[124] "Observation of $B^0 \to p\bar{\Lambda}D^{(*)-}$", Y. Y. Chang *et al.* [Belle Collaboration]. Phys. Rev. Lett. **115**, no. 22, 221803 (2015).

[125] "First model-independent Dalitz analysis of $B^0 \to DK^{*0}$, $D \to K_S^0\pi^+\pi^-$ decay", K. Negishi *et al.* [Belle Collaboration]. , PTEP **2016**, no. 4, 043C01 (2016).

[126] "Inclusive cross sections for pairs of identified light charged hadrons and for single protons in e^+e^- at $\sqrt{s} = 10.58$ GeV", R. Seidl *et al.* [Belle Collaboration]. Phys. Rev. D **92**, no. 9, 092007 (2015).

[127] "Study of π^0 pair production in single-tag two-photon collisions", M. Masuda *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 3, 032003 (2016).

[128] "Energy scan of the $e^+e^- \to h_b(nP)\pi^+\pi^-$ $(n = 1, 2)$ cross sections and evidence for $\Upsilon(11020)$ decays into charged bottomonium-like states", A. Abdesselam *et al.* [Belle Collaboration]. Phys. Rev. Lett. **117**, no. 14, 142001 (2016).

[129] "Measurement of the branching ratio of $\bar{B} \to D^{(*)}\tau^-\bar{\nu}_\tau$ relative to $\bar{B} \to D^{(*)}\ell^-\bar{\nu}_\ell$ decays with hadronic tagging at Belle", M. Huschle *et al.* [Belle Collaboration]. Phys. Rev. D **92**, no. 7, 072014 (2015).

[130] "First observation of the hadronic transition $\Upsilon(4S) \to \eta h_b(1P)$ and new measurement of the $h_b(1P)$ and $\eta_b(1S)$ parameters", U. Tamponi *et al.* [Belle Collaboration]. Phys. Rev. Lett. **115**, no. 14, 142001 (2015).

[131] "Measurement of $e^+e^- \to \gamma\chi_{cJ}$ via initial state radiation at Belle", Y. L. Han *et al.* [Belle Collaboration]. Phys. Rev. D **92**, no. 1, 012011 (2015).

[132] "First Observation of CP Violation in $\overline{B}^0 \to D^{(*)}_{\rm CP}h^0$ Decays by a Combined Time-Dependent Analysis of BABAR and Belle Data" , A. Abdesselam *et al.* [BaBar and Belle Collaborations]. Phys. Rev. Lett. **115**, no. 12, 121604 (2015).

[133] "Study of D^{**} production and light hadronic states in the $\bar{B}^0 \to D^{*+}\omega\pi^-$ decay", D. Matvienko *et al.* [Belle Collaboration]. Phys. Rev. D **92**, no. 1, 012013 (2015).

[134] "Properties of Weak Lensing Clusters Detected on Hyper Suprime-Cam's 2.3 deg^2 Field", S. Miyazaki *et al.*. , Astrophys. J. **807**, no. 1, 22 (2015).

[135] "Search for $B^+ \to \ell^+\nu_\ell\gamma$ decays with hadronic tagging using the full Belle data sample", A. Heller *et al.* [Belle Collaboration]. Phys. Rev. D **91**, no. 11, 112009 (2015).

[136] "Measurements of $B \to \bar{D}D^{*+}_{s0}(2317)$ decay rates and a search for isospin partners of the $D^{*+}_{s0}(2317)$", S.-K. Choi *et al.* [Belle Collaboration]. Phys. Rev. D **91**, no. 9, 092011 (2015), Addendum: [Phys. Rev. D **92**, no. 3, 039905 (2015)].

[137] "Semi-inclusive studies of semileptonic B_s decays at Belle", C. Oswald *et al.* [Belle Collaboration]. Phys. Rev. D **92**, no. 7, 072013 (2015).

[138] "Evidence for the decay $B^0 \to \eta\pi^0$", B. Pal *et al.* [Belle Collaboration]. Phys. Rev. D **92**, no. 1, 011101 (2015).

[139] "Measurement of the electron neutrino charged-current interaction rate on water with the T2K ND280 π^0 detector", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **91**, 112010 (2015).

[140] "Measurement of the ν_μ charged current quasielastic cross section on carbon with the T2K on-axis neutrino beam", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **91**, no. 11, 112002 (2015).

[141] "Measurement of the branching fraction of $B^+ \to \tau^+\nu_\tau$ decays with the semileptonic tagging method", B. Kronenbitter *et al.* [Belle Collaboration]. Phys. Rev. D **92**, no. 5, 051102 (2015).

[142] "Upper bound on neutrino mass based on T2K neutrino timing measurements", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **93**, no. 1, 012006 (2016).

[143] "Physics potential of a long-baseline neutrino oscillation experiment using a J-PARC neutrino beam and Hyper-Kamiokande", K. Abe *et al.* [Hyper-Kamiokande Proto- Collaboration]. , PTEP **2015**, 053C02 (2015).

[144] "Measurements of neutrino oscillation in appearance and disappearance channels by the T2K experiment with 6.6×10^{20} protons on target", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **91**, no. 7, 072010 (2015).

[145] "Search for the decay $B^+ \to \overline{K}^{*0}K^{*+}$ at Belle", Y. M. Goh *et al.* [Belle Collaboration]. Phys. Rev. D **91**, no. 7, 071101 (2015).

[146] "Observation of X(3872) in $B \to X(3872)K\pi$ decays", A. Bala *et al.* [Belle Collaboration]. Phys. Rev. D **91**, no. 5, 051101 (2015).

[147] "Search for B decays to final states with the η_c meson", A. Vinokurova *et al.* [Belle Collaboration]. , JHEP **1506**, 132 (2015), Erratum: [JHEP **1702**, 088 (2017)].

[148] "Measurement of the direct CP asymmetry in $\bar{B} \to X_{s+d}\gamma$ decays with a lepton tag", L. Pesántez *et al.* [Belle Collaboration]. Phys. Rev. Lett. **114**, no. 15, 151601 (2015).

[149] "Measurements of the $\Upsilon(10860)$ and $\Upsilon(11020)$ resonances via $\sigma(e^+e^- \to \Upsilon(nS)\pi^+\pi^-)$", D. Santel *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 1, 011101 (2016).

[150] "Search for $B^0_s \to \gamma\gamma$ and a measurement of the branching fraction for $B^0_s \to \phi\gamma$", D. Dutta *et al.* [Belle Collaboration]. Phys. Rev. D **91**, no. 1, 011101 (2015).

[151] "Measurement of the $\bar{B} \to X_s\gamma$ Branching Fraction with a Sum of Exclusive Decays", T. Saito *et al.* [Belle Collaboration]. Phys. Rev. D **91**, no. 5, 052004 (2015).

[152] "Measurement of the ν_μ charged-current quasielastic cross section on carbon with the ND280 detector at T2K", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **92**, no. 11, 112003 (2015).

[153] "New large aperture, hybrid photo-detector and photo multiplier tube for a gigantic water Cherenkov ring imaging detector" , S. Hirota *et al.* [Hyper-Kamiokande Working Group]. Nucl. Instrum. Meth. A **766**, 152 (2014).

[154] "Measurement of $B^0 \to D_s^- K_S^0 \pi^+$ and $B^+ \to D_s^- K^+ K^+$ branching fractions", J. Wiechczynski *et al.* [Belle Collaboration]. Phys. Rev. D **91**, no. 3, 032008 (2015).

[155] "Search for short baseline ν_e disappearance with the T2K near detector", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **91**, 051102 (2015).

[156] "Measurement of $e^+e^- \to \pi^+\pi^-\psi(2S)$ via Initial State Radiation at Belle", X. L. Wang *et al.* [Belle Collaboration]. Phys. Rev. D **91**, 112007 (2015).

[157] "Evidence of $\Upsilon(1S) \to J/\psi + \chi_{c1}$ and search for double-charmonium production in $\Upsilon(1S)$ and $\Upsilon(2S)$ decays", S. D. Yang *et al.* [Belle Collaboration]. Phys. Rev. D **90**, no. 11, 112008 (2014).

[158] "Neutrino oscillation physics potential of the T2K experiment", K. Abe *et al.* [T2K Collaboration]. , PTEP **2015**, no. 4, 043C01 (2015).

[159] "Observation of a new charged charmoniumlike state in $\bar{B}^0 \to J/\psi K^-\pi^+$ decays", K. Chilikin *et al.* [Belle Collaboration]. Phys. Rev. D **90**, no. 11, 112009 (2014).

[160] "Observation of the decay $B^0 \to \eta' K^*(892)^0$", S. Sato *et al.* [Belle Collaboration]. Phys. Rev. D **90**, no. 7, 072009 (2014).

[161] "Measurement of Time-Dependent CP Violation in $B^0 \to \eta' K^0$ Decays", L. ?antelj *et al.* [Belle Collaboration]. , JHEP **1410**, 165 (2014)

[162] "Observation of $e^+e^- \to \pi^+\pi^-\pi^0\chi_{bJ}$ and Search for $X_b \to \omega\Upsilon(1S)$ at $\sqrt{s} = 10.867$ GeV", X. H. He *et al.* [Belle Collaboration]. Phys. Rev. Lett. **113**, no. 14, 142001 (2014).

[163] "Measurement of the Inclusive Electron Neutrino Charged Current Cross Section on Carbon with the T2K Near Detector", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. Lett. **113**, no. 24, 241803 (2014).

[164] "Measurement of the inclusive ν_μ charged current cross section on iron and hydrocarbon in the T2K on-axis neutrino beam", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **90**, no. 5, 052010 (2014).

[165] "The Physics of the B Factories", A. J. Bevan *et al.* [BaBar and Belle Collaborations]. , Eur. Phys. J. C **74**, 3026 (2014).

[166] "Measurements of the masses and widths of the $\Sigma_c(2455)^{0/++}$ and $\Sigma_c(2520)^{0/++}$ baryons", S. H. Lee *et al.* [Belle Collaboration]. Phys. Rev. D **89**, no. 9, 091102 (2014).

[167] "Measurement of $D^0 - \bar{D}^0$ mixing and search for indirect CP violation using $D^0 \to K_S^0\pi^+\pi^-$ decays", T. Peng *et al.* [Belle Collaboration]. Phys. Rev. D **89**, no. 9, 091103 (2014)

[168] "Search for CP violation in $D^0 \to \pi^0\pi^0$ decays", N. K. Nisar *et al.* [Belle Collaboration]. Phys. Rev. Lett. **112**, 211601 (2014).

[169] "Measurement of the neutrino-oxygen neutral-current interaction cross section by observing nuclear deexcitation γ rays", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **90**, no. 7, 072012 (2014).

[170] "Measurement of the intrinsic electron neutrino component in the T2K neutrino beam with the ND280 detector", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **89**, 092003 (2014), [Phys. Rev. D **89**, 099902 (2014)].

[171] "Precise Measurement of the Neutrino Mixing Parameter θ_{23} from Muon Neutrino Disappearance in an Off-Axis Beam", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. Lett. **112**, no. 18, 181801 (2014).

[172] "Amplitude analysis of $e^+e^- \to \Upsilon(nS)\pi^+\pi^-$ at $\sqrt{s} = 10.865$ GeV", A. Garmash *et al.* [Belle Collaboration]. Phys. Rev. D **91**, no. 7, 072003 (2015).

[173] "Measurement of the lepton forward-backward asymmetry in $B \to X_s\ell^+\ell^-$ decays with a sum of exclusive modes", Y. Sato *et al.* [Belle Collaboration]. Phys. Rev. D **93**, no. 3, 032008 (2016), Addendum: [Phys. Rev. D **93**, no. 5, 059901 (2016)].

[174] "Updated cross section measurement of $e^+e^- \to K^+K^-J/\psi$ and $K^0_SK^0_SJ/\psi$ via initial state radiation at Belle", C. P. Shen *et al.* [Belle Collaboration]. Phys. Rev. D **89**, no. 7, 072015 (2014).

[175] "Measurements of Branching Fractions of τ Lepton Decays with one or more K^0_S", S. Ryu *et al.* [Belle Collaboration]. Phys. Rev. D **89**, no. 7, 072009 (2014).

[176] "Recent Results from the T2K Experiment", K. Abe *et al.*. Nucl. Phys. Proc. Suppl. **246-247**, 23 (2014).

[177] "Observation of $D^0 - \bar{D}^0$ Mixing in e^+e^- Collisions", B. R. Ko *et al.* [Belle Collaboration]. Phys. Rev. Lett. **112**, no. 11, 111801 (2014), Addendum: [Phys. Rev. Lett. **112**, no. 13, 139903 (2014)].

[178] "Developement of Hybrid Photo-detectors for the Hyper-Kamiokande Experiment", S. Hirota *et al.*. Nucl. Phys. Proc. Suppl. **253-255**, 208 (2014).

[179] "Measurement of the Branching Fraction $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$", A. Zupanc *et al.* [Belle Collaboration]. Phys. Rev. Lett. **113**, no. 4, 042002 (2014).

[180] "Search for $B^0 \to p\overline{\Lambda}\pi^-\gamma$ at Belle", Y. T. Lai *et al.* [Belle Collaboration]. Phys. Rev. D **89**, no. 5, 051103 (2014).

[181] "The development of a hybrid photo-detector (HPD) for the Hyper-Kamiokande project", S. Hirota *et al.*. Nucl. Instrum. Meth. A **732**, 303 (2013).

[182] "The Belle II Silicon Vertex Detector", M. Friedl *et al.*. Nucl. Instrum. Meth. A **732**, 83 (2013).

[183] "Search for doubly charmed baryons and study of charmed strange baryons at Belle", Y. Kato *et al.* [Belle Collaboration]. Phys. Rev. D **89**, no. 5, 052003 (2014).

[184] "Measurement of branching fractions and CP violation parameters in $B \to \omega K$ decays with first evidence of CP violation in $B^0 \to \omega K^0_S$", V. Chobanova *et al.* [Belle Collaboration]. Phys. Rev. D **90**, no. 1, 012002 (2014).

[185] "Search for the process $e^+e^- \to J/\psi X(1835)$ at $\sqrt{s} \approx 10.6$ GeV", X. H. He *et al.* [Belle Collaboration]. Phys. Rev. D **89**, no. 3, 032003 (2014).

[186] "Observation of Electron Neutrino Appearance in a Muon Neutrino Beam", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. Lett. **112**, 061802 (2014).

[187] "Measurement of the τ-lepton lifetime at Belle", K. Belous *et al.* [Belle Collaboration]. Phys. Rev. Lett. **112**, no. 3, 031801 (2014).

[188] "Measurement of branching fractions for $B \to J/\psi\eta$ K decays and search for a narrow resonance in the $J/\psi\eta$ final state", T. Iwashita *et al.* [Belle Collaboration]. , PTEP **2014**, no. 4, 043C01 (2014).

[189] "Evidence for the suppressed decay $B^- \to DK^-, D \to K^+\pi^+\pi^0$", M. Nayak *et al.* [Belle Collaboration]. Phys. Rev. D **88**, no. 9, 091104 (2013).

[190] "Measurement of the decays $B^0_s \to J/\psi\phi(1020), B^0_s \to J/\psi f_2'(1525)$ and $B^0_s \to J/\psi K^+K^-$ at Belle", F. Thorne *et al.* [Belle Collaboration]. Phys. Rev. D **88**, no. 11, 114006 (2013).

[191] "Measurement of $e^+e^- \to \omega\pi^0$, $K^*(892)\bar{K}$ and $K_2^*(1430)\bar{K}$ at $\sqrt{s}$ near 10.6 GeV", C. P. Shen *et al.* [Belle Collaboration]. Phys. Rev. D **88**, no. 5, 052019 (2013).

[192] "First observation of the $Z^0_b(10610)$ in a Dalitz analysis of $\Upsilon(10860) \to \Upsilon(\mathrm{nS})\pi^0\pi^0$", P. Krokovny *et al.* [Belle Collaboration]. Phys. Rev. D **88**, no. 5, 052016 (2013).

[193] "Angular analysis of $B^0 \to \phi K^*$ decays and search for CP violation at Belle", M. Prim *et al.* [Belle Collaboration]. Phys. Rev. D **88**, no. 7, 072004 (2013).

[194] “Measurement of Neutrino Oscillation Parameters from Muon Neutrino Disappearance with an Off-axis Beam”, K. Abe *et al.* [T2K Collaboration]. Phys. Rev. Lett. **111**, no. 21, 211803 (2013).

[195] “High-statistics study of K_S^0 pair production in two-photon collisions”, S. Uehara *et al.* [Belle Collaboration]. , PTEP **2013**, no. 12, 123C01 (2013).

[196] “Measurements of branching fractions of leptonic and hadronic D_s^+ meson decays and extraction of the D_s^+ meson decay constant”, A. Zupanc *et al.* [Belle Collaboration]. , JHEP **1309**, 139 (2013).

[197] “Measurement of the wrong-sign decay $D^0 \to K^+\pi^-\pi^+\pi^-$”, E. White *et al.* [Belle Collaboration]. Phys. Rev. D **88**, no. 5, 051101 (2013).

[198] “Search for Bottomonium States in Exclusive Radiative $\Upsilon(2S)$ Decays”, S. Sandilya *et al.* [Belle Collaboration]. Phys. Rev. Lett. **111**, no. 11, 112001 (2013).

[199] “First observation of Cabibbo-suppressed Ξ_c^0 decays”, R. Chistov *et al.* [Belle Collaboration]. Phys. Rev. D **88**, no. 7, 071103 (2013).

[200] “Experimental constraints on the spin and parity of the $Z(4430)^+$”, K. Chilikin *et al.* [Belle Collaboration]. Phys. Rev. D **88**, no. 7, 074026 (2013).

[201] “Evidence for semileptonic $B^- \to p\bar{p}l^-\bar{\nu}_l$ decays”, K.-J. Tien *et al.* [Belle Collaboration]. Phys. Rev. D **89**, no. 1, 011101 (2014).

[202] “Study of Exclusive $B \to X_u\ell\nu$ Decays and Extraction of $\|V_{ub}\|$ using Full Reconstruction Tagging at the Belle Experiment”, A. Sibidanov *et al.* [Belle Collaboration]. Phys. Rev. D **88**, no. 3, 032005 (2013).

[203] “Measurement of exclusive $\Upsilon(1S)$ and $\Upsilon(2S)$ decays into Vector-Pseudoscalar final states”, C. P. Shen *et al.* [Belle Collaboration]. Phys. Rev. D **88**, no. 1, 011102 (2013).

[204] “Evidence for the decay $B^0 \to K^+K^-\pi^0$”, V. Gaur *et al.* [Belle Collaboration]. Phys. Rev. D **87**, no. 9, 091101 (2013).

[205] “Evidence of a new narrow resonance decaying to $\chi_{c1}\gamma$ in $B \to \chi_{c1}\gamma K$”, V. Bhardwaj *et al.* [Belle Collaboration]. Phys. Rev. Lett. **111**, no. 3, 032001 (2013). , BP2013-7

[206] “Evidence of Electron Neutrino Appearance in a Muon Neutrino Beam”, K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **88**, no. 3, 032002 (2013).

[207] “Study of $e^+e^- \to \pi^+\pi^- J/\psi$ and Observation of a Charged Charmoniumlike State at Belle”, Z. Q. Liu *et al.* [Belle Collaboration]. Phys. Rev. Lett. **110**, 252002 (2013).

[208] “Search for $B \to h^{(*)}\nu\bar{\nu}$ with the full Belle $\Upsilon(4S)$ data sample”, O. Lutz *et al.* [Belle Collaboration]. Phys. Rev. D **87**, no. 11, 111103 (2013).

[209] “Measurement of the inclusive ν_μ charged current cross section on carbon in the near detector of the T2K experiment”, K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **87**, no. 9, 092003 (2013).

[210] “Search for an H-dibaryon with mass near $2m_\Lambda$ in $\Upsilon(1S)$ and $\Upsilon(2S)$ decays”, B. H. Kim *et al.* [Belle Collaboration]. Phys. Rev. Lett. **110**, no. 22, 222002 (2013).

[211] “Measurement of the CP violation parameters in $B^0 \to \pi^+\pi^-$ decays”, I. Adachi *et al.* [Belle Collaboration]. Phys. Rev. D **88**, no. 9, 092003 (2013).

[212] “Precision Measurement of Charged Pion and Kaon Differential Cross Sections in e^+e^- Annihilation at $\sqrt{s} = 10.52$ GeV”, M. Leitgab *et al.* [Belle Collaboration]. Phys. Rev. Lett. **111**, 062002 (2013).

[213] “Search for heavy neutrinos at Belle”, D. Liventsev *et al.* [Belle Collaboration]. Phys. Rev. D **87**, no. 7, 071102 (2013), Erratum: [Phys. Rev. D **95**, no. 9, 099903 (2017)].

[214] “Measurement of the inclusive semileptonic branching fraction $\mathcal{B}(B_s^0 \to X^-\ell^+\nu_\ell)$ at Belle”, C. Oswald *et al.* [Belle Collaboration]. Phys. Rev. D **87**, no. 7, 072008 (2013), Erratum: [Phys. Rev. D **90**, no. 11, 119901 (2014)].

[215] "Search for CP Violation in the Decay $D^+ \to K_S^0 K^+$", B. R. Ko *et al.* [Belle Collaboration]. , JHEP **1302**, 098 (2013).

[216] "Study of $B^0 \to \rho^0\rho^0$ decays, implications for the CKM angle ϕ_2 and search for other B0 decay modes with a four-pion final state", I. Adachi *et al.* [Belle Collaboration]. Phys. Rev. D **89**, no. 7, 072008 (2014), Addendum: [Phys. Rev. D **89**, no. 11, 119903 (2014)].

[217] "T2K neutrino flux prediction", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **87**, no. 1, 012001 (2013), Addendum: [Phys. Rev. D **87**, no. 1, 019902 (2013)].

[218] "Study of the hadronic transitions $\Upsilon(2S) \to (\eta, \pi^0)\Upsilon(1S)$ at Belle", U. Tamponi *et al.* [Belle Collaboration]. Phys. Rev. D **87**, no. 1, 011104 (2013).

[219] "Measurements of branching fractions and direct CP asymmetries for $B \to K\pi, B \to \pi\pi$ and $B \to KK$ decays", Y.-T. Duh *et al.* [Belle Collaboration]. Phys. Rev. D **87**, no. 3, 031103 (2013).

[220] "Subaru weak-lensing measurement of a z = 0.81 cluster discovered by the Atacama Cosmology Telescope Survey", H. Miyatake *et al.*. , Mon. Not. Roy. Astron. Soc. **429**, 3627 (2013).

[221] "Evidence for $B^- \to \tau^-\bar{\nu}_\tau$ with a Hadronic Tagging Method Using the Full Data Sample of Belle", I. Adachi *et al.* [Belle Collaboration]. Phys. Rev. Lett. **110**, no. 13, 131801 (2013).

[222] "Precise measurement of the branching fractions for $B_s \to D_s^{(*)+} D_s^{(*)-}$ and first measurement of the $D_s^{*+} D_s^{*-}$ polarization using e^+e^- collisions", S. Esen *et al.* [Belle Collaboration]. Phys. Rev. D **87**, no. 3, 031101 (2013).

[223] "Evidence for $B^- \to D_s^+ K^- \ell^- \bar{\nu}_\ell$ and search for $B^- \to D_s^{*+} K^- \ell^- \bar{\nu}_\ell$", J. Stypula *et al.* [Belle Collaboration]. Phys. Rev. D **86**, 072007 (2012).

[224] "First observation of CP violation and improved measurement of the branching fraction and polarization of $B^0 \to D^{*+} D^{*-}$ decays", B. Kronenbitter *et al.* [Belle Collaboration]. Phys. Rev. D **86**, 071103 (2012).

[225] "Search for B^0 decays to invisible final states", C. L. Hsu *et al.* [Belle Collaboration]. Phys. Rev. D **86**, 032002 (2012).

[226] "Search for Lepton-Flavor-Violating and Lepton-Number-Violating $\tau \to \ell h h'$ Decay Modes", Y. Miyazaki *et al.* [Belle Collaboration]. Phys. Lett. B **719**, 346 (2013).

[227] "First study of η_c, $\eta(1760)$ and $X(1835)$ production via $\eta'\pi^+\pi^-$ final states in two-photon collisions", C. C. Zhang *et al.* [Belle Collaboration]. Phys. Rev. D **86**, 052002 (2012).

[228] "Search for $B \to \phi\pi$ decays", J. H. Kim *et al.* [Belle Collaboration]. Phys. Rev. D **86**, 031101 (2012).

[229] "Extragalactic science, cosmology, and Galactic archaeology with the Subaru Prime Focus Spectrograph", R. Ellis *et al.* [PFS Team]. , Publ. Astron. Soc. Jap. **66**, no. 1, R1 (2014).

[230] "Evidence for the $\eta_b(2S)$ and observation of $h_b(1P) \to \eta_b(1S)\gamma$ and $h_b(2P) \to \eta_b(1S)\gamma$", R. Mizuk *et al.* [Belle Collaboration]. Phys. Rev. Lett. **109**, 232002 (2012).

[231] "Measurement of Branching Fraction and First Evidence of CP Violation in $B^0 \to a_1^\pm(1260)\pi^\mp$ Decays", J. Dalseno *et al.* [Belle Collaboration]. Phys. Rev. D **86**, 092012 (2012).

[232] "Measurement of $\gamma\gamma^* \to \pi^0$ transition form factor at Belle", S. Uehara *et al.* [Belle Collaboration]. Phys. Rev. D **86**, 092007 (2012).

[233] "First observation of exclusive $\Upsilon(1S)$ and $\Upsilon(2S)$ decays into light hadrons", C. P. Shen *et al.* [Belle Collaboration]. Phys. Rev. D **86**, 031102 (2012).

[234] "Search for the decay $B^0 \to DK^{*0}$ followed by $D \to K^-\pi^+$", K. Negishi *et al.* [Belle Collaboration]. Phys. Rev. D **86**, 011101 (2012).

[235] "First Measurement of ϕ_3 with a Model-independent Dalitz Plot Analysis of $B^\pm \to DK^\pm$, $D \to K_S^0\pi^+\pi^-$ Decay", H. Aihara *et al.* [Belle Collaboration]. Phys. Rev. D **85**, 112014 (2012).

[236] "Measurements of Branching Fractions and Time-dependent CP Violating Asymmetries in $B^0 \to D^{(*)\pm}D^{\mp}$ Decays", M. Rohrken *et al.* [Belle Collaboration]. Phys. Rev. D **85**, 091106 (2012).

[237] "Evidence for CP Violation in the Decay $D^+ \to K^0_S\pi^{+}$", B. R. Ko *et al.* [Belle Collaboration]. Phys. Rev. Lett. **109**, 021601 (2012), Erratum: [Phys. Rev. Lett. **109**, 119903 (2012)].

[238] "Readout Electronics for Hyper Suprime-Cam", H. Miyatake, H. Aihara, H. Fujimori, S. Mineo, S. Miyazaki, H. Nakaya and T. Uchida. Phys. Procedia **37**, 1413 (2012).

[239] "Measurement of $B^0 \to J/\psi\eta^{(\prime)}$ and Constraint on the $\eta - \eta'$ Mixing Angle", M. C. Chang *et al.*. Phys. Rev. D **85**, 091102 (2012).

[240] "Search for Time-Dependent CPT Violation in Hadronic and Semileptonic B Decays", T. Higuchi *et al.*. Phys. Rev. D **85**, 071105 (2012).

[241] "Observation of new resonant structures in $\gamma\gamma \to \omega\phi$, $\phi\phi$ and $\omega\omega$", Z. Q. Liu *et al.* [Belle Collaboration]. Phys. Rev. Lett. **108**, 232001 (2012).

[242] "First observation of $B^0_s \to J/\psi\eta$ and $B^0_s \to J/\psi\eta'$", J. Li *et al.* [Belle Collaboration]. Phys. Rev. Lett. **108**, 181808 (2012).

[243] "Precise measurement of the CP violation parameter $\sin 2\phi_1$ in B^0 of $B^0 \to (c\bar{c})K^0$ decays", I. Adachi *et al.*. Phys. Rev. Lett. **108**, 171802 (2012).

[244] "Measurement of the CP-violation Parameter sin2ϕ_1 with a New Tagging Method at the $\Upsilon(5S)$ Resonance", Y. Sato *et al.* [Belle Collaboration]. Phys. Rev. Lett. **108**, 171801 (2012).

[245] "First Muon-Neutrino Disappearance Study with an Off-Axis Beam", K. Abe *et al.* [T2K Collaboration]. Phys. Rev. D **85**, 031103 (2012).

[246] "Measurement of Azimuthal Asymmetries in Inclusive Production of Hadron Pairs in e^+e^- Annihilation at $\sqrt{s} = 10.58$ GeV", R. Seidl *et al.* [Belle Collaboration]. Phys. Rev. D **78**, 032011 (2008), Erratum: [Phys. Rev. D **86**, 039905 (2012)].

7 Invited Presentations at International Conferences

[1] "Exploring the Energy Frontier with Lepton Colliders," SLAC Summer Institute, July 10, 2013.

[2] "Large particle accelerators in Japan – Tools for discoveries and innovation –," Hard and Earth Sciences Workshop (UTkyo Forum), Sao Paulo, Brazil, November 12, 2013.

[3] "HEPAP P5 Report," 5th open meeting for the Hyper-Kamiokande Project, University of British Columbia, July 20, 2014.

[4] "ILC250, Higgs Factory in Japan," ARC Center of Excellence for Particle Physics at the Terascale, Adelaide, Australia, February 23, 2015.

[5] "Japanese HEP community discussion on the 250 GeV ILC," American Workshop on Linear Colliders 2017, June 28, 2017, SLAC

[6] "Funding outlook in Japan," European Neutrino Town Meeting, October 23, 2018, CERN

8 Teaching Accomplishment

9 Contribution to Academic Community

9.1 Editorial Activities

- 2019−2022 Associate Editor, Reviews of Modern Physics, American Physical Society

9.2 Organization of Professional Societies

- 2011−2014 Chair of Commission 11 (Particles and Fields) International Union of Physics and Applied Physics (IUPAP)
- 2014−2017 Chair of Section III (Physical Sciences and Engineering)
  Science Council of Japan

10 Committee Service

10.1 External Committees

- 2012−2014 Advisory Committee for Institute of Particle and Nuclear Studies, KEK
- 2012−2014 Advisory Committee for Accelerator and Applied Research Laboratories, KEK
- 2013−2014 US DOE HEPAP Particle Physics Project Prioritization Panel (P5)
- 2015−2019 Japan Association of High Energy Physicists Executive Committee, Chair
- 2016 US DOE Office of Science, HEP Committee of visitors
- 2019− CERN Scientific Policy Committee
- 2019−2012 Scientific Committee for the Latin American Strategy for Research Infrastructures
- 2019−2022 Department Academic Advisor for the College of Scienec, City University of Hong Kong

11 Internationalization

International students supervised

Undergraduates	8
Master's degree	12
Ph.D.	13

International researchers hosted	8

Shoji Asai、浅井 祥仁

1 Education and Professional Experiences

Education

1990	B.S. (Physics)	The University of Tokyo
1992	MSc. (Physics)	The University of Tokyo
1995	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1995−2003	Assistant Professor	The University of Tokyo, ICEPP
2003−2007	Associate Professor	The University of Tokyo, ICEPP
2007−2013	Associate Professor	The University of Tokyo, Department of Physics
2013−	Professor	The University of Tokyo, Department of Physics
2017−	Director	International Center for the Particle Physics (U.Tokyo)

2 Research Highlights

There are two active fields in my Research. First is hunting of Higgs and Supersymmetry using the energy-frontier accelerator, LHC. Second topics is non-accelerator experiments, especially high-precision test of the bound-state QED using positronium, and searches for Axion-like particles using high power lasers.

- Discovery of the Higgs boson at LHC.
  Research on the Higgs boson at ATLAS/LHC has been promoted from the early stage of preparation. I established VBF analysis using forward jets, and the discovery potential of the Higgs boson has been enhanced by factor 3. I organize the young researchers and students of University of Tokyo and other Universities in Japan to discover Higgs Boson, especially light Higgs boson. Three channels are promising for a light Higgs boson, $H \to \gamma\gamma$,W^+W^- and $\tau^+\tau^-$. I focus into these three channels, and developed new methods to enhance sensitivities or to estimate background using real data. These studies contribute significantly the brilliant discovery of the Higgs Boson. (Selected papers 1 and 2) Figure 1(a) shows distribution of the invariant mass of two photons, and a clear peak is observed at 125 GeV. After the discovery of the Higgs boson, our group focus to measure couplings between the Higgs boson and the various particles. As shown in Fig.1(b), Higgs couplings are found to be proportional to their masses. Although the accuracies are still 5–20 % level, the discovered Higgs boson is the origin of mass, and makes the difference of family.

- Search for Supersymmetric particles and set tight limits on them at ATLAS/LHC.
  I was a group leader of the SUSY working group at the ATLAS group, and made basic ideas (Background estimations and selection criteria) of many studies of the SUSY hunting at ATLAS. (Selected papers 3) Topological informations are introduced to reduce the background and the tight limit on gluino mass about 2.2TeV is obtained.

- Dark matter hunting at LHC
  The lightest neutralino is the good candidate of the dark matter of our Universe, and the mass difference between the dark matter(Neutralino) and Chargino becomes very small in this case. We proposed such a signal(disappearing track) can be detected at LHC Dark(selected paper 4).

- Solve HFS discrepancy for positronium;
  There was serious discrepancy in positronium HFS (Hyper Fine Spliting) between measured values and the calculated value. We(I and my staff Akira Ishida) pointed out there was serious problem due to un-thermalized positronium in all the previous experiments. We propose entirely new method, in which thermalization processes are taken into account. Our new results are consistent with the QED calculation and exclude the old experimental results. (Selected Paper 5)

- First observation of direct transition o-Ps $\rightarrow$ p-Ps using THz light:

- Search for the Photon-Photon collision using XFEL. Photon-photon scatter is the ultimate goal of the QED, and many experimental trials have been performed at visible laser. We have proposed and performed using XFEL and the stringent limits are obtained.

- Search for the Vacuum magnetic birefringence using high magnetic field;

- positronium Bose-Einstein condensation;
  We propose the laser cooling method to make positronium Bose-Einstein condensation. High intensity positron beam is developed with KEK and AIST. And new optical source is developed with Gonokami-Yumoto-Yoshioka Lab.

3 Selected Papers

- The ATLAS collaboration, Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC, Phys.Lett. B716 1-26 (2012)
  The paper has been cited **9931** times and is the memorial paper for the Higgs boson.

- The ATLAS collaboration, Evidence for the spin-0 nature of the Higgs boson using ATLAS data, Phys.Lett. B726 120-144 (2013)
  The paper has been cited **684** times and is the memorial paper that the discovered new boson is identified as Higgs Boson.

- The ATLAS collaboration, Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in sqrt(s) = 7 TeV proton-proton collisions. Phys.Lett. B710 67-85(2012)
  The paper has been cited 363 times. This is the first results of SUSY search at LHC. Analyses format has been established.

- The ATLAS collaboration, Search for charginos nearly mass degenerate with the lightest neutralino based on a disappearing-track signature in pp collisions at root(s)=8 TeV with the ATLAS detector Phys.Rev.D B88 112006, (2013)
  The paper has been cited 185 times. This is the first and epoch making paper to search for degenerate particles.
- A.Ishida and S.Asai et al., New Precision Measurement of Hyperfine Splitting of Positronium Phys. Lett. B734 338-344 The paper has been cited 41 times. Long standing discrepancy between QED prediction and measurements on HFS of Positronium has been solved.

4 Honors, Awards and Professional Society Memberships

- 2012 第 9 回日本学術振興会賞 (for Discovery of Higgs Boson)
- 2013 Nishina Memorial Prize 仁科賞 (for Discovery of Higgs Boson)
- 2013 Yomiuri Gold Medal 読売ゴールドメダル (for Discovery of Higgs Boson)
- 2013 第 5 回 折戸周治賞 (平成基礎財団) (for Discovery of Higgs Boson)
- 2014 第 36 回（2014 年）応用物理学会論文賞, 浅井祥仁, “ヒッグス粒子発見とその意味”.

5 Research Plan

- Precise measurement of coupling between the Higgs boson and the other particles;
  We performed to measure Higgs coupling to various particles precisely (about 5%-20% accuracy), and elucidate the origin of mass and the Higgs potential. Next step is to search for the discrepancy between the measured couplings and the SM predictions.
- Searches for new physics , especially for supersymmetric particles, with ATLAS/LHC;
  Center of mass energy of LHC (14TeV) will increase in 2020, and luminosity is also increased significantly. Next we focus on the electroweak Gauginos, based on the dark matter scenario.
- Quantum computer and deep learning will be used for LHC/analyses.
  We have started collaborations with companies and US/CERN for this business.
- First observation of the Vacuum magnetic birefringence using high magnetic fiedl;
  Current sensitivity is above the QED prediction by the factor 100. Magnetic filed will be increased upto 15T, and noise level will be suppressed by factor 10.
- Positronium Bose-Einstein condensation;
- Small size experiments relating to gravity will be lunched.
  Current small size experiments are focused on the new light particles hidden in our vacuum. This goal is still kept, but small size experiments will be lunched for topics of particles and gravity .

6 Publications and Patents

< Refereed Original Papers >

(Non-Accelerator Physics)

[1] Direct Measurement of Positronium HyperFine Structure: - A New Horizon of Precision Spectroscopy Using Gyrotrons -, S.Asai et.al J Infrared Milli Terahz Waves 33, 766-776 (2012)

[2] Direct Observation of the Hyperfine Transition of the Ground State Positronium. T. Yamazaki, A. Miyazaki, T. Suehara, T. Namba, S. Asai, T. Kobayashi, H. Saito, I. Ogawa, T. Idehara S. Sabchevski. Phys. Rev. Lett. 108, 253401 (2012)

[3] T. Inada, T. Namba, S. Asai, T. Kobayashi, Y. Tanaka, K. Tamasaku, K. Sawada, and T. Ishikawa, "Results of a Search for Paraphotons with Intense X-ray Beams at SPring-8", Phys. Lett. B 722, 301 (2013).

[4] A. Miyazaki, T. Yamazaki, T. Suehara, T. Namba, S. Asai, T. Kobayashi, H. Saito, T. Idehara, I. Ogawa, and Y. Tatematsu, "The Direct Spectroscopy of Positronium Hyperfine Structure Using a Sub-THz Gyrotron", J. Inf. Milli. Terahertz Waves, 35, 1, 91 (2014).

[5] T. Inada, T. Yamaji, S. Adachi, T. Namba, S. Asai, T. Kobayashi, K. Tamasaku, Y. Inubushi, K. Sawada, M. Yabashi, and T. Ishikawa, "Search for Photon-Photon Elastic Scattering in the X-ray Region", Phys. Lett. B 732, 356 (2014).

[6] A.Ishida, T.Namba, S.Asai, T.Kobayashi, H.Saito, M. Yoshida, K. Tanaka, A. Yamamoto, "New precision measurement of hyperfine splitting of positronium", Phys. Lett. B 734, 338 (2014).

[7] A. Miyazaki, T. Yamazaki, T. Suehara, T. Namba, S. Asai, T. Kobayashi, H. Saito, Y. Tatematsu, I. Ogawa and T. Idehara, "First millimeter-wave spectroscopy of ground-state positronium", Prog. Theor. Exp. Phys. 011C01 (2015).

[8] K. Shu, X. Fan, T. Yamazaki, T. Namba, S. Asai, K. Yoshioka and M. Kuwata-Gonokami, "Study on Cooling of Positronium for Bose-Einstein Condensation", J. Phys. B49 104001 (2016)

[9] The ALPHA Collaboration, "An improved limit on the charge of antihydrogen from stochastic acceleration", Nature 529, 373 (2016).

[10] A. Ishida, T. Namba and S. Asai, "Measurement of positronium thermalization in isobutane gas for precision measurement of ground-state hyperfine splitting", J. Phys. B 49, 064008 (2016).

[11] T. Yamaji, T. Inada, T. Yamazaki, T. Namba, S. Asai,i *et al.* "An experiment of X-ray photon-photon elastic scattering with a Laue-case beam collider", Phys. Lett. B 763, 454 (2016).

[12] T. Inada, T. Yamazaki, T. Namba, S. Asai, T. Kobayashi *et al.* "Search for Two-Photon Interaction with Axionlike Particles Using High-Repetition Pulsed Magnets and Synchrotron X Rays", Phys. Rev. Lett. 118, 071803 (2017).

[13] T. Yamazaki, T. Inada, T. Namba, S. Asai, T. Kobayashi *et al.* "Repeating pulsed magnet system for axion-like particle searches and vacuum birefringence experiments", Nucl. Instrum. Methods Phys. Res. A 833, 122 (2016).

[14] The ALPHA Collaboration, "Observation of the 1S-2S transition in trapped antihydrogen", Nature 541, 506 (2017).

[15] T. Inada, T. Yamazaki, T. Yamaji, Y. Seino, X. Fan, S. Kamioka, T. Namba and S. Asai, "Probing Physics in Vacuum Using an X-ray Free-Electron Laser, a High-Power Laser, and a High-Field Magnet", Appl. Sci. **7**(2017)671.

[16] X. Fan, S. Kamioka, K. Yamashita, S. Asai and A. Sugamoto, "Vacuum Magnetic Birefringence Experiment as a probe of Dark Sector", arXiv:1707.03609 (2017).

[17] The ALPHA Collaboration, "Observation of the hyperfine spectrum of antihydrogen", Nature **548**(2017)66.

[18] The ALPHA Collaboration, "Antihydrogen accumulation for fundamental symmetry tests", Nat. Commun. **8**(2017)681.

[19] X. Fan, S. Kamioka, T. Inada, T. Yamazaki, T. Namba, S. Asai *et al.*, "The OVAL experiment: a new experiment to measure vacuum magnetic birefringence using high repetition pulsed magnets", Eur. Phys. J. D **71**(2017)308.

[20] T. Yamaji, T. Yamazaki, K. Tamasaku and T. Namba, "Theoretical calculation of coherent Laue-case conversion between x-rays and ALPs for an x-ray light-shining-through-a-wall experiment", Phys. Rev. D **96**(2017)115001.

[21] K. Yamashita, X. Fan, S. Kamioka, S. Asai and A. Sugamoto, "Generalized Heisenberg-Euler formula in Abelian gauge theory with parity violation", Prog. Theor. Exp. Phys. **2017**(2017)123B03.

[22] T. Yamaji, K. Tamasaku, T. Namba, T. Yamazaki and Y. Seino, "Search for Axion like particles using Laue-case conversion in a single crystal", Phys. Lett. B **782**(2018)523.

[23] X. Fan, S. Kamioka, K. Yamashita, S. Asai and A. Sugamoto, "Vacuum magnetic birefringence experiment as a probe of the dark sector", Prog. Theor. Exp. Phys. **2018**(2018)063B06.

[24] S. Knirck, T. Yamazaki, Y. Okesaku, S. Asai, T. Idehara and T. Inada, "First results from a hidden photon dark matter search in the meV sector using a plane-parabolic mirror system", JCAP **11**(2018)031.

(Accelerator Physics) More than 700 published papers for 2012-2018 (ATLAS papers: Only papers(47 papers) I and my group have contributed significantly are listed)

[25] Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC, The ATLAS Collaboration, accepted by Phys. Lett. B (2012)

[26] Combined search for the Standard Model Higgs boson in pp collisions at 7 TeV with the ATLAS detector, The ATLAS Collaboration, Phys. Rev. D 86, 032003 (2012)

[27] Search for the Standard Model Higgs boson in the H to $\tau^+\tau^-$decay mode in 7 TeV pp collisions with ATLAS, The ATLAS Collaboration, accepted by JHEP (2012)

[28] Search for the Standard Model Higgs boson in the $H \to WW^* \to \ell\nu\ell\nu$ decay mode with 4.7 fb^{-1} of ATLAS data at 7 TeV, The ATLAS Collaboration, accepted by Phys. Lett. B (2012)

[29] Search for Scalar Top Quark Pair Production in Natural Gauge Mediated Supersymmetry Models with the ATLAS Detector in pp Collisions at 7 TeV, The ATLAS Collaboration, Phys. Lett. B 715 44-60 (2012)

[30] Search for supersymmetry in pp collisions at 7 TeV in final states with missing transverse momentum and b-jets with the ATLAS detector, The ATLAS Collaboration, Phys. Rev. D 85, 112006 (2012)

[31] Search for anomaly-mediated supersymmetry breaking with the ATLAS detector based on a disappearing-track signature in pp collisions at 7 TeV, The ATLAS Collaboration, Eur. Phys. J. C72 1993 (2012)

[32] Search for the Standard Model Higgs boson in the diphoton decay channel with 4.9 fb^{-1} of pp collisions at 7 TeV with ATLAS, The ATLAS Collaboration, Phys. Rev. Lett. 108, 111803 (2012)

[33] Combined search for the Standard Model Higgs boson using up to 4.9 fb-1 of pp collision data at 7 TeV with the ATLAS detector at the LHC, The ATLAS Collaboration, Phys.Lett. B710 49-66 (2012)

[34] Search for scalar bottom pair production with the ATLAS detector in pp collisions at 7 TeV , The ATLAS Collaboration, Phys. Rev. Lett. 108, 181802 (2012)

[35] Search for the Higgs boson in the $H \to WW^* \to \ell\nu\ell\nu$ decay channel in pp collisions at 7 TeV with the ATLAS detector, The ATLAS Collaboration, Phys. Rev. Lett. 108, 111802 (2012)

[36] Search for supersymmetry in final states with jets, missing transverse momentum and one isolated lepton in 7 TeV pp collisions using $1 fb^{-1}$ of ATLAS data, The ATLAS Collaboration, Phys.Rev. D85 012006 (2012)

[37] Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in 7 TeV proton-proton collisions, The ATLAS Collaboration, Phys. Lett. B710 67-85 (2012)

[38] Search for the Higgs boson in the two photon decay channel with the ATLAS detector at the LHC, The ATLAS Collaboration, Phys.Lett. B705 452-470 (2011)

[39] Performance of missing transverse momentum reconstruction in proton-proton collisions at 7 TeV with ATLAS, The ATLAS Collaboration, Eur.Phys.J. C72 1844 (2012)

[40] Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in 7 TeV proton-proton collisions, Phys. Lett. B701(2013) 189

[41] Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC , Phys. Lett. B726(2013) 88

[42] Evidence for the spin-0 nature of the Higgs boson using ATLAS data, Phys. Lett. B726(2013) 120

[43] Search for charginos nearly mass degenerate with the lightest neutralino based on a disappearing-track signature in pp collisions at √ s=8TeV with the ATLAS detector, Phys. Rev. D 88(2013) 112006

[44] Search for direct top-squark pair production in final states with two leptons in pp collisions at 8TeV with the ATLAS detector, JHEP 1406(2014) 124

[45] Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum using 8TeV proton–proton collision data, JHEP 1409(2014) 176

[46] Search for direct pair production of the top squark in all-hadronic final states in proton-proton collisions at 8TeV with the ATLAS detector, JHEP 1409(2014) 015

[47] Measurement of the Higgs boson mass from the $H \to \gamma\gamma$ and $H \to ZZ^* \to 4\ell$ channels with the ATLAS detector using 25 fb^{-1} of pp collision data , Phys. Rev. D 90 (2014) 052004

[48] Search for neutral Higgs bosons of the minimal supersymmetric standard model in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector, JHEP 1411(2014) 056

[49] Observation and measurement of Higgs boson decays to WW* with the ATLAS detector, Phys. Rev. D92 (2015) 012006

[50] Search for squarks and gluinos in events with isolated leptons, jets and missing transverse momentum at $\sqrt{s} = 8$ TeV with the ATLAS detector, JHEP1504(2015) 116

[51] Evidence for the Higgs-boson Yukawa coupling to tau leptons with the ATLAS detector, 1504(2015) 117

[52] ATLAS Run 1 searches for direct pair production of third-generation squarks at the Large Hadron Collider ” , Eur.Phys. J. C 75(2015) 510 (2015)

[53] Summary of the searches for squarks and gluinos using $\sqrt{s} = 8$ TeV pp collisions with the ATLAS experiment at the LHC, JHEP 1510(2015) 054

[54] Search for an additional, heavy Higgs boson in the H→ ZZ decay channel at ECM = 8 TeV in pp collision data with the ATLAS detector, Eur. Phys. J. C 76, 45 (2016)

[55] Search for a high-mass Higgs boson decaying to a W boson pair in pp collisions at ECM= 8 TeV with the ATLAS detector, JHEP 01, 032 (2016)

[56] Search for direct scalar top pair production in final states with two tau leptons in PP collisions at ECM=8 TeV with the ATLAS detector, Eur. Phys. J. C 76, 81 (2016)

[57] Search for the electroweak production of supersymmetric particles in ECM=8 TeV pp collisions with the ATLAS detector, Phys. Rev. D 93, 052002 (2016)

[58] Combination of searches for WW, WZ, and ZZ resonances in pp collisions at ECM = 8 TeV with the ATLAS detector, Phys. Lett. B 755, 285 (2016)

[59] A search for top squarks with R-parity-violating decays to all-hadronic final states with the ATLAS detector in ECM = 8 TeV proton–proton collisions, JHEP 06, 067 (2016)

[60] Search for squarks and gluinos in final states with jets and missing transverse momentum at ECM= 13 TeV with the ATLAS detector, Eur. Phys. J. C 76, 392 (2016)

[61] Search for gluinos in events with an isolated lepton, jets and missing transverse momentum at ECM=13 TeV with the ATLAS detector, Eur. Phys. J. C 76, 565 (2016).

[62] Search for top squarks in final states with one isolated lepton, jets, and missing transverse momentum in ECM =13 TeV pp collisions with the ATLAS detector, Phys. Rev. D 94, 052009 (2016)

[63] Search for direct top squark pair production in final states with two leptons in ECM = 13 TeV pp collisions with the ATLAS detector, Eur. Phys. J. C77 (2017) 898

[64] Search for squarks and gluinos in events with an isolated lepton, jets and missing transverse momentum at ECM = 13 TeV with the ATLAS detector', Phys. Rev. D 96 (2017) 112010

[65] Search for a scalar partner of the top quark in the jets plus missing transverse momentum final state at ECM =13 TeV with the ATLAS detector, JHEP 12 (2017) 085

[66] Search for Higgs boson decays to beyond-the-Standard-Model light bosons in four-lepton, JHEP 1806 (2018) 166

[67] Search for squarks and gluinos in final states with jets and missing transverse momentum using 36fb^{-1} of13TeV of pp collision data with the ATLAS detector, Phys.Rev. D97 (2018) 112001

[68] Search for top-squark pair production in final states with one lepton, jets, and missing transverse momentum using 36of 13TeV pp collision data with the ATLAS detector " JHEP 1806 (2018) 108

[69] FCC Collaboration, FCC Physics Opportunities : Future Circular Collider Conceptual Design Report Volume 1, Eur.Phys.J. C79 (2019) no.6, 474

[70] FCC Collaboration, FCC-hh: The Hadron Collider : Future Circular Collider Conceptual Design Report Volume 3, Eur.Phys.J.ST 228 (2019) no.4, 755-1107

[71] Searches for third-generation scalar leptoquarks 13 TeV pp collisions with the ATLAS detector JHEP 1906 (2019) 144

< Conference Proceedings >

[72] T. Suehara, K. Owada, A. Miyazaki, T. Yamazaki, S. Asai, and T. Kobayashi, "Hidden particle search using Sub-THz gyrotron", Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), 2012 37th International Conference on, 1 (2012).

[73] T. Yamazaki, A. Miyazaki, T. Suehara, T. Namba, S. Asai, T. Kobayashi, H. Saito, Y. Tatematsu, I. Ogawa, and T. Idehara, "Direct measurement of the hyperfine structure of the ground state positronium using high power sub-THz radiation", Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), 2012 37th International Conference on, 1 (2012).

[74] A. Miyazaki, T. Yamazaki, T. Suehara, T. Namba, S. Asai, T. Kobayashi, H. Saito, Y. Tatematsu, I. Ogawa, and T. Idehara, "The sub-THz direct spectroscopy of positronium hyperfine splitting", Journal of Physics:

[75] ew Precise Measurement of the Hyperfine Splitting of Positronium", J. Phys. Chem. Ref. Data 44, 031212 (2015).

[76] K. Shu, T. Murayoshi, X. Fan, A. Ishida, T. Yamazaki, T. Namba, S. Asai, K. Yoshioka, M. Kuwata-Gonokami *et al.*"Study on Bose-Einstein condensation of positronium", J. Phys.: Conf. Ser. 791, 012007 (2017).

[77] A. Ishida, "New Precision Measurement of Hyperfine Splitting of Positronium", Def. Diff. Forum 373, 75 (2017).

[78] . Shu, T. Murayoshi, X. Fan, A. Ishida, T. Yamazaki, T. Namba, S. Asai, K. Yoshioka, M. Kuwata-Gonokami *et al.*"Study on Bose-Einstein condensation of positronium", J. Phys.: Conf. Ser. 791, 012007 (2017)

[79] . Ishida, "New Precision Measurement of Hyperfine Splitting of Positronium", Def. Diff. Forum 373, 75 (2017).

[80] A. Ishida, K. Shu, T. Murayoshi, X. Fan, T. Namba, S. Asai, K. Yoshioka, M. Kuwata-Gonokami, N. Oshima, B. E. O'Rourke and R. Suzuki, "Study on positronium Bose-Einstein condensation", JJAP Conf. Proc. **7**(2018)011001.

＜ **Review Papers** ＞

[81] 浅井祥仁．新粒子発見，ヒッグス粒子か? パリティー 2012 年 12 月号

[82] 浅井祥仁, ヒッグス粒子に迫る、日本物理学会誌 67 (2012) 367

[83] 浅井祥仁 , ヒッグス粒子発見とその意味, 応用物理学会誌 2013 年 8 月号 643-648

[84] 浅井祥仁, ヒッグス粒子の見つけ方ー発見と性質をさぐるー、数学セミナー 2014 年 5 月　39-47

[85] 浅井祥仁, 統一論・宇宙論から見たヒッグス粒子発見の意味、日本医事新法 2014 年 3 月　68-70

[86] 難波俊雄, 稲田聡明, 浅井祥仁, 高輝度放射光を用いた未知の素粒子探索実験, 日本放射光学会誌 27(2014)204-209.

[87] 浅井祥仁, " ヒッグス粒子発見とその後の展開 ", RA- DIOISOTOPES 66, 43 (2017)

[88] 山崎高幸、清野結大、稲田聡明、難波俊雄、浅井祥仁、"XFEL の高輝度性を利用した真空の探索 "、レーザー研究 (レーザー学会誌 8 月号) 45 (2017) 488

＜ **Books** ＞

[89] 浅井祥仁 (2012), "ヒッグス粒子の謎", 祥伝社新書.

[90] 浅井祥仁「LHC の物理?ヒッグス粒子発見とその後の展開? 」　基本法則から読み解く物理学最前線　第 7 巻　共立出版

＜ **Patent Applications** ＞

7 Invited Presentations at International Conferences

[1] S.Asai Highlight topics of LHC October AEPSHEP2012

[2] S.Asai Higgs Boson, Dawn of Physics to explore the vacuum, CLEO-PR & OECCPS 2013, July 2013 Kyoto

[3] S.Asai Highlight of LHC Physics (Higgs and SUSY), CNS international school, September 2013 Tokyo

[4] S.Asai SUSY Searches AT ATLAS, CMS international school, October 2013 Teheran

[5] S.Asai Discovery of Higgs boson and Beyond, Fundamental Physics Using Atoms 2014, March 2014 Tokyo

[6] S. Asai, Search for photon-photon scattering using the xFEL; Applications to the Particle physics, 6th Ringberg Meeting on Science with FELs, 2015 年 2 月 25 日, 独国 Ringberg 城.

[7] S. Asai, " SUSY Search@LHC ", 27th Rencontres de Blois Particle Physics and Cosmology, June 2015 France

[8] S. Asai, " The Latest results of LHC Run2, New scalar ϕ (750) ??? Where is the Supersymmetry? ", LEAP2016, March 2016, Japan

[9] . Asai, “ Probe into vacuum field using High- intensity X-ray Applications to the Particle Physics ” , International Conference on X-ray Op- tics and Applications 2017 (XOPT’17), April 19, 2017, Pacifico Yokohama

[10] A. Ishida, “New Measurements of the Positronium Hyperfine Splitting”, The XVIII International Workshop on Low-Energy Positron and Positronium Physics (POSMOL2015), July 19, 2015, Lisboa, Portugal.

[11] A. Ishida, “Precision measurement of the hyperfine splitting of positronium”, International Conference on Precision Physics and Fundamental Physical Constants (FFK-2015), October 12, 2015, Budapest, Hungary.

[12] K. Shu, “Toward a Realization of Bose-Einstein Condensation of Positronium”, 2nd Jagiellonian Symposium on Fundamental and Applied Subatomic Physics, June 6, 2017, Krakow, Poland.

[13] A. Ishida, “Study on positronium Bose-Einstein condensation”, The 3rd China-Japan Joint Workshop on Positron Science (JWPS2017), June 9, Hefei, China.

[14] A. Ishida, “Recent progress in positronium experiments for Bose-Einstein condensation”, Low Energy Antiproton Physics Conference 2018 (LEAP 2018), March 15, Paris, France.

[15] A. Ishida, “Precision tests of fundamental physics using positronium”, 3rd Kyoto Workshop on Positron Sciences “Positron Annihilation Spectroscopy: Fundamentals and Applications”, November 6, 2018, Kyoto University, Japan.

[16] S. Asai, “Tabletop experiments using light and atoms”, Visions for table-top dark matter experiments, February 27, 2019, Tokyo, Japan.

8 Teaching Accomplishment

Student Awards;

- 2012 Akira Miyazaki; NEW TALENT AWARD for an original presentation in Experimental Physics and Isidor Rabi DIPLOMA
- 2012 Akira Miyazaki; First Place outstanding student paper, 36th International Conference on Infrared, Millimeter, and Terahertz Waves
- 2012 Yuichi Sasaki; PLHC2012 Poster Awards,
- 2012 石田明,"若手優秀講演賞", 第 49 回アイソトープ・放射線研究発表会, 東京大学, 2012 年 7 月.
- 2013 宮崎彬 , 東京大学大学院理学系研究科 研究奨励賞.
- 2015 宮崎彬 第 9 回 日本物理学会若手奨励賞,
- 2016 周健治、Student prize awarded for outstanding Student Presentation at 14th International Workshop on Slow Positron Beam Techniques Applications,
- 2016 樊星、Best Student award, International School of Subnuclear Physics 2016, 2016 年 6 月
- 2016 樊星、平成 28 年度学生表彰「東京大学総長賞」（学業)、基礎物理のための最先端光技術の開発および応用と、その成果による本学名誉への貢献、2017 年 3 月.
- 周健治,Best Student award, International School of Subnuclear Physics 2017, 2017 年 6 月.
- 周健治, 最優秀賞　若手口頭発表部門、第 60 回放射線化学討論会、2017 年 9 月.
- 石田明, 日本陽電子科学会奨励賞、2017 年 12 月.
- 上岡修星, 理学系研究科研究奨励賞　修士課程、2018 年 3 月
- 上岡修星、Best Experimental New Talent Presentation award, International School of Subnuclear Physics 2018, 2018 年 6 月.
- 周健治、学生奨励賞、2018 年度量子ビームサイエンスフェスタ、2019 年 3 月.

9 Contribution to Academic Community

9.1 Editorial Activities

9.2 Organization of Professional Societies

- 2013−Now LHC-ATLAS Japan Group leader
- 2018−Now LHC-ATLAS executive board member

- 2018−Now 日本学術会議 (SCJ) 連携会員、物理分素核分野　副代表
- Member of European Strategy Group 2019−Now
- Member of European Strategy Group 2012−2013

9.3 External Committees

9.4 Organization and Advisory of Conferences

Sorry that I can not follow up such a activities. Many conferences I have contributed as AC.

10 Outreach

- ヒッグス粒子に迫る、日本物理学会一般講演会、京都産業大学　２０１２年 9 月
- ヒッグス粒子の謎、　東京大学　安田講堂　２０１２年 3 月
- ヒッグス粒子に迫る、　東京大学　安田講堂　２０１２年 9 月
- 最先端宇宙科学、東京大学　小柴ホール　２０１２年 10 月
- ヒッグス粒子発見と日本の貢献、総合学術会議　２０１２年 7 月
- 毎年、高校生むけに実験と講演 を行っています。（素粒子センター　業務で）

11 Committee Service

11.1 University Committees

2014 年度　理学部総長補佐
2014 年、15 年　理学部放射線管理委員
2013,2014,2015 年　素粒子物理国際研究センター　研究協議会議員
2015 年　素粒子物理国際研究センター　運営委員会
2017 年度より　　東京大学　素粒子物理国際研究センター　センター長
　　　　　　　　全国共同利用研究拠点
2018 年度より　　東京大学　宇宙線研究所　協議会委員
2018 年度より　　卓越大学院　フォトンサイエンス　　コーディネーター
2019 年度より　　理学系研究科物理学専攻　副主任

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	2	German, China
Doctor Course	1	Taiwan
Foreign researchers hosted	0	
Students sent abroad	Many	CERN siwzerland
Researchers sent abroad	Many	CERN siwzerland
Foreign visitors	Too Many and No record	Many seminars at my center and Lab.

Hiroyoshi Sakurai、櫻井 博儀

1 Education and Professional Experiences

Education

1987	B.S. (Physics)	The University of Tokyo
1989	MSc. (Physics)	The University of Tokyo
1993	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1993−1995	Assistant Professor	The University of Tokyo
1995−2000	Researcher	RIKEN
2000−2005	Associate Professor	The University of Tokyo
2005−	Chief Scientist	RIKEN
2011−	Professor	The University of Tokyo
2013−	Vice-director	RIKEN Nishina Center

2 Research Highlights

This Laboratory aims at two major scientific goals: 1) to discover new quantum phenomena associated with a large isospin asymmetry through investigating nuclear structure in very neutron-rich nuclei, 2) to elucidate the r-process path in explosive processes of the universe. To access very neutron-rich nuclei, we have developed new experimental techniques based on in-flight fast radioactive isotope (RI) beams available at the world-leading heavy-ion accelerator facility "RI Beam Factory (RIBF)" at RIKEN, Japan. Since 2012, more than 150 papers have been published under international collaborations. Special emphasis is given to highlighted results, as follows.

New Magicity at N=34

Since magicity loss at N=20 and 28 in the light and neutron-rich nuclei were found, a next question is arising; where large shell gaps exist beyond N=28. A shell model calculation including rather strong monopole residual interactions speculated that N=34 might become a new magic number in the neutron-rich Ca-Ti isotopes. The first spectroscopy of ^{54}Ca was conducted via in-beam gamma spectroscopy (Nature 502.7470, 207 (2013)). Three gamma lines were successfully found and one of them was assigned to be de-excitation gamma ray from 2^+ state to the ground state. According to the systematic trend of 2^+ energy along Z=20 as well as N=34, a large shell gap at N=34 was reduced. This work gave an significant impact to the low-energy nuclear physics community. Both a recent mass measurement and a gamma spectroscopy on ^{54}Ca have supported a large gap at N=34, and theoretical discussions have been highly encouraged, too.

Double Magicity of ^{78}Ni

The double magicity of ^{78}Ni is one of important problems to be investigated in the nuclear structure research. The first spectroscopy data of ^{78}Ni was obtained from systematic half-life measurements around ^{78}Ni (Physical Review Letters 133, 032505 (2014)). Sudden changes of half-life between ^{78}Ni and ^{79,80}Ni and also between ^{78}Ni and ^{77}Co were firstly observed. The sudden changes at Z=28 and N=50 may be caused by sudden changes of β-decay Q value, namely, sudden changes of the nuclear stability. Thus, the observation indicated the double magicity of ^{78}Ni.

In addition to decay spectroscopy, in-beam gamma spectroscopy was successfully conducted to observe excited states in ^{78}Ni (Nature 569, 53–58 (2019)). The direct evidence of the double magicity was obtained. In addition, a shape co-existence was found in ^{78}Ni.

Impacts on the r-Process Path

According to developments of astronomical observations and of simulations for supernovae explosion and neutron-star merger, two scenarios are extensively discussed: cold r-process in neutron-star mergers and hot r-process in supernovae explosions. To elucidate the r-process path, nuclear data of the r-process nuclei have been highly desired. The half-life data for neutron-rich nuclei were obtained by three works. The first work was conducted for 38 neutron-rich isotopes in A∼110 region, and the second work covered more neutron-rich nuclei and gave half-lives of 108 neutron-rich isotopes from Rb to Sn. The third one gave half-lives of 94 isotopes from Cs to Ho.

The half-life data obtained are utilized in a network calculation. The second work (Physical Review Letters 114, 192501 (2015)) demonstrates importance of experimental half-life data. The abundance calculation with the new data could reproduce the r-process abundance pattern very well, especially for A∼120 region and A∼140-160 region. Coming data for the neutron-emission probability and mass information should give further impacts of data to the r-process path study.

3 Selected Papers

- D. Steppenbeck *et al.*, Nature 502.7470, 207 (2013).
  The first evidence of new magic number $N = 34$ in ^{54}Ca was obtained via in-beam gamma spectroscopy. The paper has been cited 164 times.

- Z. Y. Xu *et al.*, Physical Review Letters 133, 032505 (2014).
  The double magic nature of ^{78}Ni was discussed for the first time via systematic trends of half-lives obtained at RIBF. This work has been cited 64 times.

- G. Lorusso *et al.*, Physical Review Letters 114, 192501 (2015).
  This work obtained half-lives of about 110 neutron-rich nuclides, and firstly demonstrated importance of the data to understand the r-process abundance. The paper has been cited 86 times.

- T. Nakamura, H. Sakurai and H. Watanabe, Prog. Part. Nucl. Phys. 97, 53 (2017)
  This review article gave an overview of recent results obtained with in-flight radioactive isotope beams.

- R. Taniuchi *et al.*, Nature 569, 53–58 (2019).
  The direct evidence for the double magicity of ^{78}Ni was obtained via in-beam gamma spec-

troscopy, and shape co-existence was observed, too. This work was introduced in News & Views of *Nature* and Recent Highlight of *Nature Physics*.

4 Honors, Awards and Professional Society Memberships

2009 The GSI Exotic Nuclei Community Membership Award, GSI Exotic Nuclei Community
2015 The Nishina Memorial Prize, Nishina Memorial Foundation
2018 The 21st Century Invention Award, Japan Institute of Invention and Innovation

5 Research Plan

Concerning a perspective for trends of nuclear physics, three directions are being considered: higher excitation energy, heavier nuclei, and EOS in asymmetric nuclear matter.

Discussions for the shell evolution are so far limited to the ground state properties. When we move to highly excited states, a variety of collective modes based on a variety of symmetry are predicted to emerge. An interesting topic is how cluster states would be developed in proton-rich or neutron-rich nuclei. To understand fission dynamics, we need to know the shell structure at finite temperature.

In heavy nuclei, a key ingredient is Coulomb force effect to the nuclear structure. The strong Coulomb force might change orders and spacial distributions of the single particle orbits and also change effective strong interactions between protons and neutrons. As the first step, observation of alpha decay might be promising. One alpha separation energy is going to be negative in the heavy mass region. This suggests that cluster formation or cluster-driven collective effects could be studied rather easily.

The gravitation wave observations in this Century give unique opportunities to test EOS made by microscopic interactions and also by many-body force effects. The gravitation waves would connect a tiny object of nuclei and a big object of neutron stars. The EOS study has become very important in terms of the r-process nucleosynthesis, too.

According to these perspectives, we are conducting two programs which are not introduced in "Recent Highlights". One is related to cluster formation in very light nuclei, and the other is neutron correlation in highly excited nuclei populated by muon capture reaction. These results are being published within a year. In addition, a new method to study neutron condensation in light and neutron-rich nuclei is under preparation.

To populate highly excited states and to produce heavy exotic nuclei, we need low energy radioactive beams, and deep-inelastic collision or fusion reaction may be applied to reveal out exotic collective states and new phenomena originating from strong Coulomb effect. At present, an efficient degrading technique of fast radioactive isotope beams made via in-flight method is being developed under a collaboration with Center for Nuclear Study, the University of Tokyo and with RIKEN. These programs need charged particle detectors or recoil mass spectrometer to identify low-energy reaction products. Tracking Ge detector arrays such as GRETINA and/or AGATA are also needed to detect gammas with high detection efficiency under a high gamma-ray multiplicity condition. As the first step, we are planning to utilize a Ge detector array for the nuclear structure study with fast radioactive isotope beams in next year.

6 Publications and Patents

< **Refereed Original Papers** >

[1] J. Xiao *et al.*, "New Measurements for ^{8}He Excited States", Chin. Phys. Lett. 29, 082501 (2012).

[2] K. Tshoo *et al.*, "$N = 16$ Spherical Shell Closure in ^{24}O", Phys. Rev. Lett. 102, 022501 (2012).

[3] S. Takeuchi *et al.*, "Well Developed Deformation in ^{42}Si", Phys. Rev. Lett. 109, 182501 (2012).

[4] M. Takechi *et al.*, "Interaction cross sections for Ne isotopes towards the island of inversion and halo structures of ^{29}Ne and ^{31}Ne", Phys. Lett. B 707, 357 (2012).

[5] L. H. Lv *et al.*, "Knockout reaction induced by ^{6}He at 82.3 MeV/u", J. Phys. (London) G39, 065102 (2012).

[6] K.-A. Li *et al.*, "Inelastic Scattering of ^{32}Mg at 190 MeV/Nucleon from a Thick Proton Target", Chin. Phys. Lett. 29, 102301 (2012).

[7] N. Kobayashi *et al.*, "One- and two-neutron removal reactions from the most neutron-rich carbon isotopes", Phys. Rev. C 86, 054604 (2012).

[8] D. Kameda *et al.*, "Observation of new microsecond isomers among fission products from in-flight fission of 345 MeV/nucleon ^{238}U", Phys. Rev. C 86, 054319 (2012).

[9] Z. X. Cao *et al.*, "Recoil proton tagged knockout reaction for ^{8}He", Phys. Lett. B 707, 46 (2012).

[10] H. Wang *et al.*, "Observation of New Isotope ^{131}Ag via the Two-Step Fragmentation Technique", Chin. Phys. Lett. **30**, 042501 (2013).

[11] D. Verney *et al.*, "Structure of ^{80}Ge revealed by the β decay of isomeric states in ^{80}Ga: Triaxiality in the vicinity of ^{78}Ni", Phys. Rev. C **87**, 054307 (2013).

[12] P.-A. Söderström *et al.*, "Shape evolution in ^{116,118}Ru: Triaxiality and transition between the O(6) and U(5) dynamical symmetries", Phys. Rev. C **88**, 024301 (2013).

[13] H. Suzuki *et al.*, "Collectivity of neutron-rich Ti isotopes", Phys. Rev. C **88**, 024326 (2013).

[14] K. Kolos *et al.*, "Probing nuclear structures in the vicinity of ^{78}Ni with β- and βn-decay spectroscopy of ^{84}Ga", Phys. Rev. C **88**, 047301 (2013).

[15] H. Watanabe *et al.*, "Isomers in ^{128}Pd and ^{126}Pd: Evidence for a Robust Shell Closure at the Neutron Magic Number 82 in Exotic Palladium Isotopes", Phys. Rev. Lett. **111**, 152501 (2013).

[16] D. Steppenbeck *et al.*, "Evidence for a new nuclear magic number from the level structure of ^{54}Ca", Nature 502.7470, 207 (2013).

[17] L. Audirac *et al.*, "Evaporation-cost dependence in heavy-ion fragmentation", Phys. Rev. C **88**, 041602(R) (2013).

[18] M. Cavallaro *et al.*, "Quantitative analysis of two-neutron correlations in the ^{12}C(^{18}O, ^{16}O)^{14}C reaction", Phys. Rev. C **88**, 054601 (2013).

[19] P. Doornenbal *et al.*, "In-Beam *gamma*-Ray Spectroscopy of ^{34,36,38}Mg: Merging the $N = 20$ and $N = 28$ Shell Quenching", Phys. Rev. Lett. **111**, 212502 (2013).

[20] H. Wang *et al.*, "Collectivity evolution in the neutron-rich Pd isotopes toward the $N = 82$ shell closure", Phys. Rev. C **88**, 054318 (2013).

[21] P.-A. Söderström *et al.*, "Installation and commissioning of EURICA — Euroball-RIKEN Cluster Array", Nucl. Instrum. Method **B317**, 649 (2013).

[22] Y. Sato *et al.*, "One-neutron knockout reaction of ^{17}C on a hydrogen target at 70 MeV/nucleon", Phys. Lett. **B728**, 462 (2014).

[23] H. Wang *et al.*, "Structure of ^{136}Sn and the $Z = 50$ magicity", Prog. Theor. Exp. Phys. 2014, 023D02 (2014).

[24] Z. Y. Xu *et al.*, "β-Decay Half-Lives of ^{76,77}Co, ^{79,80}Ni and ^{81}Cu: Experimental Indication of a Doubly Magic ^{78}Ni", Phys. Rev. Lett. **133**, 032505 (2014).

[25] H. Watanabe *et al.*, "Monopole-Driven Shell Evolution below the Doubly Magic Nucleus ^{132}Sn Explored with the Long-Lived Isomer in ^{126}Pd", Phys. Rev. Lett. **133**, 042502 (2014).

[26] T. Tshoo *et al.*, "Neutron occupancy of the $0d_{5/2}$ orbital and the $N = 16$ shell closure in ^{24}O", Phys. Lett. **B739**, 19 (2014).

[27] M. Takechi *et al.*, "Evidence of halo structure in ^{37}Mg observed via reaction cross sections and intruder orbitals beyond the island of inversion", Phys. Rev. C **90**, 061305 (2014).

[28] J. Taprogge *et al.*, "Identification of a millisecond isomeric state in ^{129}Cd$_{81}$ via the detection of internal conversion and Compton electrons", Phys. Lett. **B738**, 223 (2014).

[29] J. Taprogge *et al.*, "$1p_{3/2}$ Proton-Hole State in ^{132}Sn and the Shell Structure Along $N = 82$", Phys. Rev. Lett. **112**, 132501 (2014).

[30] G. S. Simpson *et al.*, "Yrast 6^+ Seniority Isomers of ^{136,138}Sn", Phys. Rev. Lett. **113**, 132502 (2014).

[31] Y. Satou *et al.*, "One-neutron knockout reaction of ^{17}C on a hydrogen target at 70 MeV/nucleon", Phys. Lett. **B728**, 462 (2014).

[32] Z. Patel *et al.*, "Isomer Decay Spectroscopy of ^{164}Sm and ^{166}Gd: Midshell Collectivity Around $N =$ 100", Phys. Rev. Lett. **113**, 262502 (2014).

[33] T. Nakamura *et al.*, "Deformation-Driven p-Wave Halos at the Drip Line: ^{31}Ne", Phys. Rev. Lett. **112**, 142501 (2014).

[34] S. Michimasa *et al.*, "Quadrupole collectivity in island-of-inversion nuclei ^{28,30}Ne and ^{34,36}Mg, Phys. Rev. C **89**, 054307 (2014).

[35] N. Kobayashi *et al.*, "Observation of a p-Wave One-Neutron Halo Configuration in ^{37}Mg", Phys. Rev. Lett. **112**, 242501 (2014).

[36] P. Doornenbal *et al.*, "Intermediate-energy Coulomb excitation of ^{104}Sn: Moderate $E2$ strength decrease approaching ^{100}Sn", Phys. Rev. C **90**, 061302 (2014).

[37] P. Doornenbal *et al.*, "Rotational level structure of sodium isotopes inside the island of inversion", Prog. Theor. Exp. Phys. 2014, 053D01 (2014).

[38] H. L. Crawford *et al.*, "Shell and shape evolution at $N = 28$: The ^{40}Mg ground state", Phys. Rev. C **89**, 041303 (2014).

[39] Y. G. Ma *et al.*, "Different mechanism of two-proton emission from proton-rich nuclei ^{23}Al and ^{22}Mg", Phys. Lett. **B743**, 306 (2015).

[40] A. Corsi *et al.*, "Neutron-driven collectivity in light tin isotopes: Proton inelastic scattering from ^{104}Sn", Phys. Lett. **B743**, 451 (2015).

[41] A. Corsi *et al.*, "Neutron-driven collectivity in light tin isotopes: Proton inelastic scattering from ^{104}Sn", Phys. Lett. B **743**, 451 (2015).

[42] Y. G. Ma *et al.*, "Different mechanism of two-proton emission from proton-rich nuclei ^{23}Al and ^{22}Mg", Phys. Lett. B **743**, 306 (2015).

[43] G. Lorusso *et al.*, β-Decay Half-Lives of 110 Neutron-Rich Nuclei across the $N = 82$ Shell Gap: Implications for the Mechanism and Universality of the Astrophysical r Process", Phys. Rev. Lett. **114**, 192501 (2015).

[44] J. Taprogge *et al.*, "β decay of ^{129}Cd and excited states in ^{129}In", Phys. Rev. C **91**, 054324 (2015).

[45] Zs. Vajta *et al.*, "γ-ray spectroscopy of ^{19}C via the single-neutron knock-out reaction", Phys. Rev. C **91**, 064315 (2015).

[46] D. Steppenbeck *et al.*, "Low-Lying Structure of ^{50}Ar and the $N = 32$ Subshell Closure", Phys. Rev. Lett. **114**, 252501 (2015).

[47] A. Etile *et al.*, "Low-lying intruder and tensor-driven structures in ^{82}As revealed by β decay at a new movable-tape-based experimental setup", Phys. Rev. C **91**, 064317 (2015).

[48] K. Li *et al.*, "Relativistic Coulomb excitation in ^{32}Mg near 200 MeV/nucleon with a thick target", Phys. Rev. C **92**, 014608 (2015).

[49] R. Lozeva *et al.*, "New decay scheme of the $^{136}_{51}$Sb^{85} 6^- isomer", Phys. Rev. C **92**, 024304 (2015).

[50] A. Matta *et al.*, "New findings on structure and production of ^{10}He from ^{11}Li with the (d, ^{3}He) reaction", Phys. Rev. C **92**, 041302 (2015).

[51] P. Lee *et al.*, "β-delayed γ-ray spectroscopy of non-yrast states in ^{138}Te near the neutron drip line", Phys. Rev. C **92**, 044320 (2015).

[52] Y. X. Watanabe *et al.*, "Pathway for the Production of Neutron-Rich Isotopes around the $N = 126$ Shell Closure", Phys. Rev. Lett. **115**, 172503 (2015).

[53] C. Santamaria *et al.*, "Extension of the $N = 40$ Island of Inversion towards $N = 50$: Spectroscopy of ^{66}Cr, ^{70,72}Fe", Phys. Rev. Lett. **115**, 192501 (2015).

[54] P.-A. Soderstrom *et al.*, "Two-hole structure outside ^{78}Ni: Existence of a μs isomer of ^{76}Co and β decay into ^{76}Ni", Phys. Rev. C **92**, 051305 (2015).

[55] F. Browne *et al.*, "Lifetime measurements of the first 2^+ states in ^{104,106}Zr: Evolution of ground-state deformations", Phys. Lett. B **750**, 448 (2015).

[56] P. Morfouace *et al.*, "Evolution of single-particle strength in neutron-rich ^{71}Cu", Phys. Lett. B **751**, 306 (2015).

[57] J. Litzinger *et al.*, "Transition probabilities in neutron-rich ^{84,86}Se", Phys. Rev. C **92**, 064322 (2015).

[58] N. Kobayashi *et al.*, "One-neutron removal from ^{29}Ne : Defining the lower limits of the island of inversion", Phys. Rev. C **93**, 014613 (2016).

[59] R. Lozeva *et al.*, "New isomer found in $^{140}_{51}$Sb^{89}: phericity and shell evolution between $N = 82$ and $N = 90$", Phys. Rev. C **93**, 014316 (2016).

[60] Z. Patel *et al.*, "Decay spectroscopy of ^{160}Sm: The lightest four-quasiparticle K isomer", Phys. Lett. B **753**, 182 (2016).

[61] D. Suzuki *et al.*, "Second 0^+ state of unbound ^{12}O: Scaling of mirror asymmetry", Phys. Rev. C **93**, 024316 (2016).

[62] Y. Shiga *et al.*, "Investigating nuclear shell structure in the vicinity of ^{78}Ni: Low-lying excited states in the neutron-rich isotopes ^{80,82}Zn", Phys. Rev. C **93**, 024320 (2016).

[63] H. Wang *et al.*, "Spallation reaction study for fission products in nuclear waste: Cross section measurements for ^{137}Cs and ^{90}Sr on proton and deuteron", Phys. Lett. B **754**, 104 (2016).

[64] A. I. Morales *et al.*, "Low-lying excitations in ^{72}Ni", Phys. Rev. C **93**, 034328 (2016).

[65] A. Jungclaus *et al.*, "First observation of γ rays emitted from excited states south-east of ^{132}Sn: The $\pi g_{9/2}^{-1}$ (X) $\nu f_{7/2}$ multiplet of ^{132}In$_{83}$", Phys. Rev. C **93**, 041301 (2016).

[66] P. Doornenbal *et al.*, "Mapping the deformation in the "island of inversion": Inelastic scattering of ^{30}Ne and ^{36}Mg at intermediate energies", Phys. Rev. C **93**, 044306 (2016).

[67] I. Celikovic *et al.*, "New Isotopes and Proton Emitters-Crossing the Drip Line in the Vicinity of ^{100}Sn", Phys. Rev. Lett. **116**, 162501 (2016).

[68] H. Otsu *et al.*, "SAMURAI in its operation phase for RIBF users", Nucl. Instrum. Meth **B376**, 175 (2016).

[69] J. Yasuda *et al.*, "Inverse kinematics (p, n) reactions studies using the WINDS slow neutron detector and the SAMURAI spectrometer", Nucl. Instrum. Meth **B376**, 393 (2016).

[70] B. Blank *et al.*, "New neutron-deficient isotopes from ^{78}Kr fragmentation", Phys. Rev. C **93**, 061301 (2016).

[71] A. Jungclaus *et al.*, "β decay of semi-magic ^{130}Cd: Revision and extension of the level scheme of ^{130}In", Phys. Rev. C **94**, 024303 (2016).

[72] H. Watanabe *et al.*, "Long-lived K isomer and enhanced γ vibration in the neutron-rich nucleus ^{172}Dy: Collectivity beyond double midshell", Phys. Lett. **B760**, 641 (2016).

[73] D. Q. Fang *et al.*, "Proton-proton correlations in distinguishing the two-proton emission mechanism of ^{23}Al and ^{22}Mg", Phys. Rev. C **94**, 044621 (2016).

[74] H. Wang *et al.*, "First spectroscopic information from even-even nuclei in the region "southeast" of ^{132}Sn: Neutron-excitation dominance of the 2^+_1 state in ^{132}Cd", Phys. Rev. C **94**, 051301 (2016).

[75] P.-A. Soderstrom *et al.*, "K-mixing in the doubly mid-shell nuclide ^{170}Dy and the role of vibrational degeneracy", Phys. Lett. **B762**, 404 (2016).

[76] J. Taprogge *et al.*, "Proton-hole and core-excited states in the semi-magic nucleus ^{131}In$_{82}$", Eur. Phys. J. **A52**, 347 (2016).

[77] F. Recchia *et al.*, "Neutron single-particle strengths at $N = 40$, 42: Neutron knockout from ^{68,70}Ni ground and isomeric states", Phys. Rev. C **94**, 054324 (2016).

[78] E. Ideguchi *et al.*, "μs isomers of ^{158,160}Nd", Phys. Rev. C **94**, 064322 (2016).

[79] N. Paul *et al.*, "Are There Signatures of Harmonic Oscillator Shells Far from Stability? First Spectroscopy of ^{110}Zr", Phys. Rev. Lett. **118**, 032501 (2017).

[80] A. I. Morales *et al.*, "Type II shell evolution in $A = 70$ isobars from the $N \geq 40$ island of inversion", Phys. Lett. **B765**, 328 (2017).

[81] J. Wu *et al.*, "94 β-Decay Half-Lives of Neutron-Rich ^{55}Cs to ^{67}Ho: Experimental Feedback and Evaluation of the r-Process Rare-Earth Peak Formation", Phys. Rev. Lett. **118**, 0722701 (2017).

[82] N. Nakatsuka *et al.*, "Observation of isoscalar and isovector dipole excitations in neutron-rich ^{20}O", Phys. Lett. **B768**, 387 (2017).

[83] H. N. Liu *et al.*, "Intruder configurations in the ground state of ^{30}Ne", Phys. Lett. **B767**, 58 (2017).

[84] P. Doornenbal *et al.*, "Low-Z shore of the "island of inversion" and the reduced neutron magicity toward ^{28}O", Phys. Rev. C **95**, 041301(R) (2017).

[85] F. Wang *et al.*, "Spectroscopic factor and proton formation probability for the $d_{3/2}$ proton emitter ^{151m}Lu", Phys. Lett. **B770**, 83 (2017).

[86] B. Moon *et al.*, Nuclear structure and β-decay schemes for Te nuclides beyond $N = 82$", Phys. Rev. C **95**, 044322 (2017).

[87] S. Chen *et al.*, "Low-lying structure and shape evolution in neutron-rich Se isotopes", Phys. Rev. C **95**, 041302(R) (2017).

[88] T. Sumikama *et. al.*, "Observation of new neutron-rich Mn, Fe, Co, Ni, and Cu isotopes in the vicinity of ^{78}Ni", Phys. Rev. C **95**, 051601(R) (2017).

[89] V. Vaquero *et. al.*, "Gamma Decay of Unbound Neutron-Hole States in ^{133}Sn", Phys. Rev. Lett. **118**, 202502 (2017).

[90] E. Sahin *et al.*, "Shell Evolution towards ^{78}Ni: Low-Lying States in ^{77}Cu", Phys. Rev. Lett. **118**, 242502 (2017).

[91] F. Flavigny *et al.*, "Shape Evolution in Neutron-Rich Krypton Isotopes Beyond $N = 60$: First Spectroscopy of ^{98,100}Kr", Phys. Rev. Lett. **118**, 242501 (2017).

[92] A. I. Morales *et al.*, "Simultaneous investigation of the $T = 1$ ($J^\pi = 0^+$) and $T = 0$ ($J^\pi = 9^+$) β decays in ^{70}Br", Phys. Rev. C **95**, 064327 (2017).

[93] H. L. Crawford *et al.*, "Unexpected distribution of $\nu 1f_{7/2}$ strength in ^{49}Ca", Phys. Rev. C **95**, 064317 (2017).

[94] M. Lettmann *et al.*, "Triaxiality of neutron-rich ^{84,86,88}Ge from low-energy nuclear spectra", Phys. Rev. C **96**, 011301(R) (2017).

[95] A. Chester et al., "Recoil distance method lifetime measurement of the 2_1^+ state in ^{94}Sr and implications for the structure of neutron-rich Sr isotopes", Phys. Rev. C **96**, 011302(R) (2017).

[96] B. Moon *et al.*, "β-decay scheme of ^{140}Te to ^{140}I: Suppression of Gamow-Teller transitions between the neutron $h_{9/2}$ and proton $h_{11/2}$ partner orbitals", Phys. Rev. C **96**, 014325 (2017).

[97] F. Browne *et al.*, "K selection in the decay of the $(v\frac{5}{2}[532] \otimes \frac{3}{2}[411])4^-)$ isomeric state in ^{102}Zr", Phys. Rev. C **96**, 024309 (2017).

[98] Z. Patel *et al.*, "Isomer-delayed γ-ray spectroscopy of $A = 159$ -? 164 midshell nuclei and the variation of K-forbidden $E1$ transition hindrance factors", Phys. Rev. C **96**, 034305 (2017).

[99] S. Kawase *et al.*, "Study of proton- and deuteron-induced spallation reactions on the long-lived fission product ^{93}Zr at 105 MeV/nucleon in inverse kinematics", Prog. Theo. Exp. Phys. **2017** 093D03 (2017).

[100] S. Momiyama *et. al.*, "In-beam γ-ray spectroscopy of ^{35}Mg via knockout reactions at intermediate energies", Phys. Rev. C **96**, 034328 (2017).

[101] J. Park *et al.*, "Properties of γ-decaying isomers and isomeric ratios in the ^{100}Sn region", Phys. Rev. C **96**, 044311 (2017).

[102] C.M. Shand *et. al.*, "Shell evolution beyond $Z = 28$ and $N = 50$: Spectroscopy of ^{81,82,83,84}Zn", Phys. Lett. **B773**, 492 (2017).

[103] F. Didierjean *et al.*, "Neutron effective single-particle energies above ^{78}Ni: A hint from lifetime measurements in the $N = 51$ isotones ^{85}Se and ^{87}Kr", Phys. Rev. C **96**, 044320 (2017).

[104] B. Elman *et al.*, "Quadrupole collectivity beyond $N = 50$ in neutron-rich Se and Kr isotopes", Phys. Rev. C **96**, 044332 (2017).

[105] L.A. Gurgi *et al.*, "Isomer spectroscopy of neutron-rich ^{168}Tb$_{103}$", Rad. Phys. Chem. **140**, 493 (2017).

[106] L. Olivier *et al.*, "Persistence of the $Z = 28$ Shell Gap Around ^{78}Ni: First Spectroscopy of ^{79}Cu", Phys. Rev. Lett. **119**, 192501 (2017).

[107] H. Suzuki *et. al.*, "Discovery of ^{72}Rb: A Nuclear Sandbank Beyond the Proton Drip Line", Phys. Rev. Lett. **119**, 192503 (2017).

[108] F. Wang *et al.*, "Reinvestigation of the excited states in the proton emitter ^{151}Lu: Particle-hole excitations across the $N = Z = 64$ subshell", Phys. Rev. C 96, 064307 (2017).

[109] D. Steppenbeck *et. al.*, "Structure of ^{55}Sc and development of the $N = 34$ subshell closure", Phys. Rev. C **96**, 064310 (2017).

[110] Y. K. Tanaka *et al.*, "Missing-mass spectroscopy of the ^{12}C(p, d) reaction near the η'-meson production threshold", Phys. Rev. C **97**, 015202 (2018).

[111] T. Nishi *et al.*, "Spectroscopy of pionic atoms in ^{122}Sn$(d,^3$He$)$ reaction and angular dependence of the formation cross sections", Phys. Rev. Lett. **120**, 152505 (2018).

[112] K. Hadynska-Klek *et al.*, "Quadrupole collectivity in ^{42}Ca from low-energy Coulomb excitation with AGATA", Phys. Rev. C 97, 024326 (2018).

[113] M. L. Cortes *et al.*, "Inelastic scattering of neutron-rich Ni and Zn isotopes off a proton target", Phys. Rev. C 97, 044315 (2018).

[114] A. Corsi *et al.*, "Spectroscopy of nuclei around ^{100}Sn populated via two-neutron knockout reactions", Phys. Rev. C 97, 044321 (2018).

[115] J. Litzinger *et al.*, "Transition probabilities in neutron-rich Se-80,Se-82 and the role of the nu g(9/2) orbital", Phys. Rev. C 97, 044323 (2018).

[116] J. Park *et al.*, "Beta decays of the heaviest $N = Z - l$ nuclei and proton instability of ^{97}In", Phys. Rev. C 97, 051301 (2018).

[117] A. I. Morales *et al.*, "Is seniority a partial dynamic symmetry in the first $\nu g_9/2$ shell?", Phys. Lett. B781, 706 (2018).

[118] Z. Vajta *et al.*, "Proton single particle energies next to ^{78}Ni: Spectroscopy of ^{77}Cu via single proton knock-out reaction", Phys. Lett. B782, 99 (2018).

[119] K. Wimmer *et al.*, "Shape coexistence and isospin symmetry in $A = 70$ nuclei: Spectroscopy of the $T_z = -1$ nucleus ^{70}Kr", Phys. Lett. B785, 411 (2018).

[120] X. Y. Liu *et al.*, "Spectroscopy of $^{65,67}_{2}$5Mn: Strong coupling in the $N = 40$ "island of inversion"", Phys. Lett B785, 441 (2018).

[121] O. Wieland *et al.*, "Low-lying dipole response in the unstable ^{70}Ni nucleus", Phys. Rev. C 98, 064313 (2018).

[122] O. B. Tarasov *et al.*, "Discovery of ^{60}Ca and Implications For the Stability of ^{70}Ca", Phys. Rev. Lett. 121, 022501 (2018).

[123] R. Yokoyama *et al.*, "Beta-gamma spectroscopy of the neutron-rich ^{150}Ba", Prog. Theo. Exp. Phys. 2018, 037 (2018).

[124] C. Santamaria *et al.*, "Tracking with the MINOS Time Projection Chamber", Nucl. Instrum. Method A905, 138 (2018).

[125] S. Cruz *et al.*, "Shape coexistence and mixing of low-lying 0^+ states in ^{96}Sr", Phys. Lett. B786, 94 (2018).

[126] T. Isobe *et al.*, "Application of the Generic Electronics for Time Projection Chamber (GET) readout system for heavy Radioactive isotope collision experiments", Nucl. Instrum. Methods 899, 43 (2018).

[127] J. Yasuda *et al.*, "Extraction of the Landau-Migdal Parameter from the Gamow-Teller Giant Resonance in ^{132}Sn", Phys. Rev. Lett. 121, 132501 (2018).

[128] S. Takeuchi *et al.*, "Coulomb breakup reactions of ^{93,94}Zr in inverse kinematics, Prog. Theo. Exp. Phys. 2019, 013D02 (2019).

[129] A. I. Murray *et al.*, "Spectroscopy of strongly deformed ^{32}Ne by proton knockout reactions", Phys. Rev. C 99, 011302 (2019).

[130] Z. Elekes *et al.*, "Nuclear structure of ^{76}Ni from the $(p, 2p)$ reaction", Phys. Rev. C 99, 014312 (2019).

[131] H. L. Crawford *et al.*, "First Spectroscopy of the Near Drip-line Nucleus ^{40}Mg", Phys. Rev. Lett. 122, 052501 (2019).

[132] P. J. Davies *et al.*, "Toward the limit of nuclear binding on the $N = Z$ line: Spectroscopy of ^{96}Cd", Phys. Rev. C 99, 021302 (2019).

[133] H. N. Liu *et al.*, "How Robust is the $N = 34$ Subshell Closure? First Spectroscopy of ^{52}Ar", Phys. Rev. Lett. 122, 072502 (2019).

[134] V. Vaquero *et al.*, "In-geam gamma-ray spectroscopy of ^{136} at relativistic energies", Phys. Rev. C 99, 034306 (2019).

[135] J. Park *et al.*, "New and comprehensive beta- and beta p-decay spectroscopy results in the vicinity of ^{100}Sn", Phys. Rev. C 99, 034313 (2019).

[136] J. Hwang *et al.*, "Angle-tunable wedge degrader for an energy-degrading RI beamline", Prog. Theo. Exp. Phys. 2019, 043D02 (2019)

[137] S. Michimasa *et al.*, "OEDO, the energy-degrading beamline at RI Beam Factory", Prog. Theo. Exp. Phys. 2019, 043D01 (2019)

[138] N. Paul *et al.*, "Prominence of Pairing in Inclusive (p, 2p) and (p, pn) Cross Sections from Neutron-Rich Nuclei", Phys. Rev. Lett. 122, 162503 (2019).

[139] A. Tolosa-Delgado *et al.*, "Commissioning of the BRIKEN detector for the measurement of very exotic beta-delayed neutron emitters", Nucl. Instrum. Methods A 925, 133-147 (2019)

[140] R. Taniuchi *et al.*, "^{78}Ni revealed as a doubly magic stronghold against nuclear deformation", Nature 569, 53–58 (2019).

[141] K. Wimmer *et al.*, "First spectroscopy of ^{61}Ti and the transition to the Island of Inversion at $N = 40$", Phys. Lett. B792, 16–20 (2019).

[142] H. Wataname *et al.*, "New isomers in ^{125,127}Pd: Competing proton and neutron excitations in neutron-rich palladium nuclides towards the $N = 82$ shell closure", Phys. Lett. B792, 263–268 (2019).

[143] Z. Q. Chen *et al.*, "Proton Shell Evolution below ^{132}Sn: First Measurement of Low-lyding beta-Emitting Isomers in $123, 125$Ag", Phys. Rev. Lett. 122, 212502 (2019).

[144] D. Lubos *et al.*, "Improved Value for the Gamow-Teller Strength of the ^{100}Sn Beta Decay", Phys. Rev. Lett. 122, 222502 (2019).

[145] V. Phong *et al.*, "Observation of a mu s isomer in ^{134}In: Proton-neutron coupling "southeast" of ^{132}Sn", Phys. Rev. C 100, 011302 (2019).

[146] K. Wimmer *et al.*, "Discovery of ^{68}Br in secondary reactions of radioactive beams", Phys. Lett. B795, 266–270 (2019).

[147] V. Vaquero *et al.*, "Inclusive cross sections for one- and multi-nucleon removal from Sn, Sb, and Te projectiles beyond the $N = 82$ shell closure", Phys. Lett. B795, 356–361 (2019).

[148] R. Yokoyama *et al.*, "Strong one-neutron emission from two-neutron unbound states in beta decays of the r-process nucli ^{86,87}Ga", Phys. Rev. C 100, 031302 (2019).

[149] S. Chen *et al.*, "Quasifree Neutron Knockout from ^{54}Ca Corroborates Arising $N = 34$ Neutron Magic Number", Phys. Rev. Lett. 123, 142501 (2019).

[150] K. Nakano *et al.*, "Isotope production in proton-, deuteron-, and carbon-induced reactions on ^{93}Nb at 113 MeV/nucleon", Phys. Rev. C 100, 044605 (2019).

[151] L. Sinclair *et al.*, "Half-lives of ^{73}Sr and ^{76}Y and the consequences for the proton dripline", Phys. Rev. C 100, 044311 (2019).

[152] J. Estee *et al.*, "Extending the dynamic range of electronics in a Time Projection Chamber", Nucl. Instrum. Methods A 944, 162509 (2019).

[153] H. Wang *et al.*, "Enhancement of element production by incomplete fusion reaction with weakly bound deuteron", Communications Physics 2, 78 (2019).

$<$ **Conference Proceedings** $>$

[154] V. Lapoux *et al.*, "Spectroscopy of the Unbound States of the Drip-Line Nucleus ^{24}O", Prog. Theor. Phys. (Kyoto), Suppl. 196, 111 (2012).

[155] K. Hadyńska-Klçk *et al.*, "Towards the Determination of Superdeformation in ^{42}Ca", Acta Phys. Pol. B 44, 617 (2013).

[156] D. Steppenbeck *et al.*, "Investigating the strength of the $N = 34$ subshell closure in ^{54}Ca", J. Phys. Conf. Ser. **445** 012012 (2013).

[157] Y. Satou *et al.*, “Invariant Mass Spectroscopy of ^{23}O via the (p,p’) Reaction in Inverse Kinematics”, Few-Body Systems 54, 287, 2013.

[158] K. Tshoo *et al.*, “The $N = 16$ Spherical Shell Closure in ^{24}O”, Few-Body Systems 54, 459, 2013.

[159] R. Chen *et al.*, “Proton Elastic Scattering of F-23,25”, Few-Body Systems, 54, 1405 (2013).

[160] N. Kobayashi *et al.*, “Breakup Reactions of Drip-Line Nuclei Near $N = 20$, 28”, Few-Body Systems, 54, 1441 (2013).

[161] J. W. Hwang *et al.*, “Discovery of the First 2^- State in C-16 via Neutron Knockout Reaction”, Few-Body Systems, 54, 1469 (2013).

[162] N. Kobayashi *et al.*, “Breakup reactions of neutron drip-line nuclei near $N = 20$, 28”, J. Phys. Conf. Ser. 436, 012047 (2013).

[163] Z. Y. Xu *et al.*, “Systematic study of β-decay half-lives in the vicinity of ^{78}Ni”, JPS Conf. Proc. 1, 013035 (2014).

[164] M. Matsushita *et al.*, “In-beam γ-ray spectroscopy of ^{38,40,42}Si”, INPC2013 (IUPAP), EPJ web of Conf. **v.66**, p.02070 (2014).

[165] A. Jungclaus *et al.*, “Isomer and beta decay spectroscopy in the ^{132}Sn region with EURICA”, INPC2013 (IUPAP), EPJ web of Conf. **v.66**, p.02040 (2014).

[166] S. Calinescu *et al.*, “Study of the Neutron-rich Isotope ^{46}Ar Through Intermediate Energy Coulomb Excitation”, Acta Phys. Pol. **B45**, 199 (2014).

[167] F. Browne *et al.*, “Gamma-ray Spectroscopy in the Vicinity of ^{108}Zr”, Acta Phys. Pol. **B46**, 721 (2015).

[168] V. Werner *et al.*, “Collectivity of neutron-rich Cr and Fe toward $N = 50$”, EPJ Web of Conferences **107**, 03007 (2016).

[169] E. Sahin *et al.*, “First Results on the Excited States in ^{77}Cu”, Acta Phys. Pol. **B47**, 889 (2016).

[170] L. A. Gurgi *et al.*, “Isomer Spectroscopy of Neutron-rich ^{165,167}Tb”, Acta Phys. Pol. **B48**, 601 (2017).

[171] L. A. Gurgi *et al.*, “Isomer Spectroscopy of Neutron-rich ^{168}Tb”, Radiation Physics and Chemistry 140, 493–496 (2017).

[172] D. Steppenbeck *et al.*, “Low-lying Structures Of Exotic Sc Isotopes And The Evolution Of The $N = 34$ Subshell Closure”, Proceedings of science (INPC2016), 030 (2017).

[173] H. Wang *et al.*, “Spallation reaction study for the long-lived fission products in nuclear waste: Cross section measurements for ^{137}Cs, ^{90}Sr and ^{107}Pd using inverse kinematics method”, Energy Procedia **131**, 127-132 (2017).

[174] S. Kawase *et al.*, “Cross section measurement of residues produced in proton- and deutron-induced spallation reactions on ^{93}Zr at 105 MeV/u using the inverse kinematics method”, EPJ Web Conf. **146**, 02012 (2017).

[175] H. Wang *et al.*, “Spallation reaction study for fission products in nuclear waste: Cross section measurements for ^{137}Cs, ^{90}Sr and ^{107}Pd on proton and deuteron”, EPJ Web Conf. **146**, 09022 (2017).

[176] K. Nakano *et al.*, “Cross sections for nuclide production in proton- and deuteron-induced reactions on ^{93}Nb measured using the inverse kinematics method”, EPJ Web Conf. **146**, 11046 (2017).

[177] Y. X. Watanabe *et al.*, “Production of $N = 126$ Nuclei and Beyond Using Multinucleon Transfer Reactions”, Fission and Properties of Neutron-rich Nuclei, 227 (2018).

[178] F. Recchia *et al.*, “Neutron knockout from ^{68,70}Ni ground and isomeric states”, J. Phys. Conf. Ser. 966, 012048 (2018).

[179] M. Lettmann *et al.*, “Signatures of triaxiality in low-spin spectra of ^{86}Ge”, J. Phys. Conf. Ser. 1023, 012023 (2018).

[180] T. Goigoux *et al.*, "^{67}Kr TWO-PROTON RADIOACTIVITY: RESULTS AND THEORETICAL INTERPRETATIONS", Acta Phys. Pol. **B50**, 399–404 (2019).

[181] F. Recchia *et al.*, "ISOMER SPECTROSCOPY IN ODD-EVEN Ti ISOTOPES: APPROACHING N=40", Acta Phys. Pol. **B50**, 699–674 (2019).

< Review Papers >

[182] T. Motobayashi and H. Sakurai , "Research with fast radioactive isotope beams at RIKEN", Prog. Theor. Exp. Phys., 03C001 (2012).

[183] T. Nakamura, H. Sakurai and H. Watanabe, "Exotic nuclei explored at in-flight separators", Prog. Part. Nucl. Phys. **97**, 53 (2017).

[184] H. Sakurai, "Nuclear physics with RI Beam Factory", Frontiers of Physics, 13(6), 132111 (2018).

[185] 櫻井博儀, 「2 重に魔法数をもったニッケル-78」, パリティ, 2016 年 12 月号.

[186] 櫻井博儀, 「百年の計」, Isotope News [特別号 No.1], 2017 年 1 月号.

[187] 本林透, 櫻井博儀, 「魔法数の帰趨をめぐって」, 原子核研究第 61 巻 2 号 1, 2017.

[188] 櫻井博儀, "核廃棄物の核変換処理と核反応率", パリティ, 2018 年 1 月.

[189] 櫻井博儀, "不安定核ビームを利用した核構造研究", 原子核研究, 2018 年 1 月.

[190] 新倉潤 他, "負ミューオン捕獲反応による核変換", 中間子科学学会会誌「めそん」 No. 49 (2019).

< Books >

[191] 櫻井博儀 :『元素はどうしてできたのか　誕生・合成から「魔法数」まで』, PHP サイエンス・ワールド新書, PHP 研究所, 2013 年 12 月.

< Patent Applications >

7 Invited Presentations at International Conferences

[1] H. Sakurai, "Leapfrog in nuclear physics with RIBF", Korean Physics Society, Division of Nuclear Physics, Daejeon (Korea), April 2012.

[2] H. Sakurai, "Highlights and future plans at RIBF", The 2nd International Nuclear Physics Conference "Nuclear Structure and Dynamics", Opatija (Croatia), July 2012.

[3] H. Sakurai, "Highlights and future plans at RIBF", Nuclear Structure 2012, Argonne (USA), August 2012.

[4] H. Sakurai, "Few-Body Programs at RIKEN RIBF Facility", 20th International Conference on Few-body Problems in Physics, Fukuoka (Japan), August 2012.

[5] H. Sakurai, "Recent highlights and future plans at RIBF", APCTP Mini-Workshop on Nuclear Structure, Pohang (Korea), September 2012.

[6] H. Sakurai, "Recent results at RIBF", XLI International Workshop on Gross Properties of Nuclei and Nuclear Excitations, Hirschegg (Austria), January 2013.

[7] H. Sakurai, "Nuclear data produced at the RIBF", New Energy Forum 2013, Xi'an (China), September 2013.

[8] H. Sakurai, "Overview of RIBF", 1st RIBF-RISP Joint Workshop, Daejeon (Korea), November 2013.

[9] H. Sakurai, "The RIKEN RI Beam Factory -Its Scientific Programs", 17th International Conference on Accelerators and Beam Utilization (ICABU 2013), Daejeon (Korea), November 2013.

[10] H. Sakurai, "Present Status of RIBF", JUSTIPEN-JUSEIPEN Joint Workshop, Wako (Japan), December 2013.

[11] H. Sakurai, "Nuclear data programs at RIBF for nuclear engineering and transmutation", 16th ASRC International Workshop on "Nuclear Fission and Structure of Exotic Nuclei", Tokai (Japan), March 2014.

[12] H. Sakurai, "Status of RIBF and Strategy of Operation", SAMURAI International Collaboration Workshop, Sendai (Japan), Sepember 2014

[13] H. Sakurai, "Emergence of Exotic Phenomena in Unstable Nuclei — how to observe them", International School of Nuclear Physics in Eriche, Sicily (Italy), Sepember 2014.

[14] H. Sakurai, "Physics of Exotic Nuclei at RIBF", 4^{th} APS/JPS Joint Meeting 2014, Waikoloa, Hawaii (USA), October 2014.

[15] N. Kobayashi, "Using particle-gamma coincidences to study nuclear reactions and structure with fast radioactive ion beams", 4th APS/JPS Joint Meeting 2014, Waikoloa, Hawaii (USA), October 2014.

[16] H. Sakurai, "Physics Programs at RIBF", International Symposium on Physics of Unstable Nuclei 2014, Ho Chi Minh City (Vietnam), November 2014.

[17] H. Sakurai, "New results on the structure of exotic nuclei", APS Spring Meeting, Baltimore (USA), April 2015.

[18] H. Sakurai, "Recent progress on exotic nuclei at RIBF", Mazurian Lakes Conference on Physics Frontiers in Nuclear Physics, Piaski (Poland), September 2015.

[19] H. Sakurai, "Current and future programs at RIBF", 2015 ANPhA Symposium, Gyeongju (Korea), October 2015.

[20] H. Sakurai, "Overview of RIBF", RISP Workshop, Daejeon (Korea), November 2015.

[21] H. Sakurai, "Scientific programs with exotic nuclei at RIBF", 27th ASRC International Workshop "Nuclear Fission and Exotic Nuclei", Tokai (Japan), December 2015.

[22] H. Sakurai, "Overview of physics experiments at RIPS/BigRIPS", International Symposium on Physics with Fragment Separators —25th Anniversary of RIKEN-Projectile Fragment Separator (RIPS25), Hayama (Japan), December 2015.

[23] H. Sakurai, "Nuclear magic numbers", The 71st Fujihara Seminar-Shimoda 2016, Shimoda (Japan), July 2016,

[24] H. Sakurai, "Decay studies of exotic nuclei at RIKEN", The 2016 Zakopane Conference on Nuclear Physics "Extremes of the Nuclear Landscape", Zakopane (Poland), August 2016.

[25] H. Sakurai, "Post RIBF project", RIBF Users Meeting 2016, Wako (Japan), Sepember 2016.

[26] H. Sakurai, "Long-lived Fission Product Transmutation", 21st International Conference on Cyclotrons and their applications, Zurich (Switzerland), Sepember 2016.

[27] H. Sakurai, "Recent highlights and future projects at RIBF", Shapes and Symmetries in Nuclei: from Experiment to Theory, Orsay (France), Nobember 2016.

[28] H. Sakurai, "Recent Activities and Plans at RIBF", IBS-RIKEN Conference on Recent Developments in RI Physics, Daejeon, Korea, November 2016.

[29] H. Sakurai, "The status and future of RIBF", ANPhA2916 Symposium, Sendai (Japan), November 2016.

[30] H. Sakurai, "New Magicity and Magicity Loss in Atomic Nuclei", Joint 13th Asia Pacific Physics Conference and 22nd Australian Institute of Physics Congress, Brisbane (Australia), December 2016.

[31] H. Sakurai, "Recent highlights and future projects for the nuclear structure study at RIBF", 16th International Symposium on Capture Gamma-ray Spectroscopy and Related Topics, Shanghai Jiao Tong University (China), September 2017.

[32] H. Sakurai, "Decay Spectroscopy at RIBF past and future", Collaboration workshop on RI and heavy-ion sciences, Ewha Womans University, Seoul (Korea), October 2017.

[33] S. Koyama, "Study of cluster structure in ^{16}C", Workshop on Nuclear Cluster Physics 2017, Hokkaido University (Japan), October 2017.

[34] M. Niikura, "Gamma-ray spectroscopy in the closest vicinity of ^{78}Ni at RIBF", Fall meeting of the Korean Physics Society, HICO at Gyeongju (Korea), October 2017.

[35] H. Sakurai, "Recent activities and perspectives", 1st Symposium on Intermediate-energy Heavy Ion Collisions (iHIC2018), Beijing, (China), April 2018.

[36] H. Sakurai, "The RIBF Facility and Its Future", 20th Northeastern Asian Symposiu-2018 on Nuclear Physics in the 21st Century, Nagoya (Japan), April 2018.

[37] H. Sakurai, "Recent activities and highlights at the RIBF", International Conference on Simplicity, Symmetry and Beauty of Atomic Nuclei, Shanghai (China), September 2018.

[38] H. Sakurai, "Recent highlights and future programs at RIBF", The 10th China-Japan Joint Nuclear Physics Symposium, Huizhou (China), November 2018.

[39] H. Sakurai, "Facility-upgrade of RIBF for diversity enhancement in nuclear physics", 13th International Conference on Nucleus-Nucleus Collision, Omiya (Japan), December 2018.

[40] H. Sakurai, "In-flight radioactive isotope beam facilities and nulear physics at RIBF", 1st African Nuclear Physics Conference (ANPC2019), Kruger (South Africa), July 2019

8 Teaching Accomplishment

- 2005 Nobuaki IMAI, Award for Outstanding Young Physicists Young Scientist, Nuclear Experimental Physics Forum of Japan
- 2010 Yuichi ICHIKAWA, Award for Outstanding Young Physicists Young Scientist, Nuclear Experimental Physics Forum of Japan
- 2011 Daisuke SUZUKI, 1st Ph.D. Thesis Award, GANIL, France
- 2015 Zhengyu Xu, the RIBF Users Group Thesis Award, Japan
- 2019 Ryo Taniuchi, the RIBF Users Group Thesis Award, Japan

9 Contribution to Academic Community

9.1 Editorial Activities

- 2010-present Board Member of Associated Editors of Nuclear Physics A

9.2 Organization of Professional Societies

- **Nuclear Physics (Experiment) Community in Japan**
  2006-present Member and Secretary, Steering Committee, Nuclear Physics Forum in Japan
  2001-2003 Secretary, Nuclear Physics Forum in Japan
- **Japan Physical Society**
  2014-2016 Executive Member of JPS
  2006-2009 Member of JPS program committee (experimental nuclear physics)
  2000-2003 Member, Editorial Board for the JPS Bulletin
- **Science Council of Japan**
  2006-present Member-at-Large of Science Council of Japan
- **Ministry of Education, Culture, Sports, Science and Technology**
  2001-2003 Scientific Officer, Research Promotion Bureau, MEXT

9.3 Organization and Advisory of Conferences

- Organizer of Tours-2012 Conference, Germany, July, 2012
- Advisory member of International Conference on Nuclear Structure 2012, Argonne, USA, August, 2012
- Advisory member of China-Japan Joint Symposium, Beijing, China, Oct., 2012
- Advisory member of SCRIBE 2012 Conference, India, Nov., 2012

- Chair of International Conference on Electromagnetic Separators and Techniques related to their Applications, Matsue, Japan, Dec., 2012.
- Advisory member of International Conference on Nuclear Physics, Firenze, Italy, June, 2013.
- Advisory member of International Workshop on Nuclear Structure Physics with advanced gamma-detector arrays, Padova, Italy, June, 2013
- Advisory member of the International Nuclear Physics Conference "Nuclear Structure and Dynamics III", Partoroz, Slovenia, June 2015
- Advisory member of China-Japan Joint Symposium, Osaka, Japan, Oct., 2015
- Organizing committee member of the 14th International Symposium on Nuclei in the Cosmos XIV, Niigata, Japan, June, 2016
- Advisory member of the 26th International Nuclear Physics Conference (INPC2016), Adelaide, Australia, Sept., 2016
- Advisory member of the 16th International Symposium on Capture Camma-Ray Spectroscopy and Related Topics (CGS16), Shanghai, China, Sept. 2017
- Advisory member of the International Symposium on Physics of Unstable Nuclei 2017 (ISPUN17), Halong City, Vietnam, Sept. 2017
- Co-chair, China-Japan Joint Symposium, , China, Oct., 2018
- Advisory member of the 5th Joint Meeting of the Nuclear Physics Divisions of the APS and the JPS, Hawaii, USA, Oct., 2018
- Advisory member of the 13th International Conference on Nucleus-Nucleus Collisions (NN2018), Omiya, Japan, Dec., 2018
- Advisory member of the 5th Joint Meeting of the Nuclear Physics Divisions of the APS and the JPS, Hawaii, USA, Oct., 2018
- Advisory member of the 27th International Nuclear Physics Conference (INPC2019), Glasgow, UK, July, 2019

10 Outreach

- **公開シンポジウム**
  学術会議シンポジウム「周期表が拓く科学と技術　-国際周期表年を迎えて」(2019 年 2 月 23 日）の組織運営
  学術会議シンポジウム「基礎科学研究の意義と社会　-物理分野から」(2018 年 12 月 17 日）での講演。「元素の進化、合成と変換」

- 理学部オープンキャンパス
  「ガンマ線をみよう」　2012, 2014, 2016, 2018 年

- 高校教育支援活動
  埼玉県立不動岡高校での SSH プログラムにおいて物理授業「はかる！」を担当。2010 年より毎年
  川口市立高校 1 年生進路指導　講演「自立と自立」　2019 年 2 月

- 市民講座
  2019 年　芦屋市サイエンス講座「元素の進化と変換」
  東京商工会議所荒川支部主催の「“ 親子一緒に ” 先端研究者から科学を学ぼう！」で、荒川区の小中学生向けの講義を実施。2016 年より毎年

11 Committee Service

11.1 External Committees

- **Domestic Institutes**

2012-2016	Member of J-PARC Program Advisory Committee, IPNS, KEK
2012-2014	Member of Steering Committee of IPNS, KEK
2007-2011	Member of Steering Committee, RCNP, Osaka University
2001-2003	Member, Research Plan Committee, IPNS, KEK

- **Oversea Institutes**

2017-present	Member of iThemba LABS Scientific and Technical Advisory Committee iThemba LABS, South Africa
2017-present	Member of the GANIL Scientific Council GANIL, France
2014	Member of International Advisory Committee Institute of Modern Physics, China
2012-present	Member of RISP International Advisory Committee Institute of Basic Science, Korea
2011-present	Member of RCNST Steering Committee Beihang Univ., China
2009-2017	Member of Program Advisory Committee GANIL, France
2009-2014	Member of FRIB Scientific Advisory Committee Michigan State University, USA

11.2 University Committees

2017–	理学系研究科研究科長補佐
	2018– 理学図書館館長、運営委員会委員長
	2017– 国際交流委員会委員長
	2017 理学系図書委員会委員長
2017–	リーディング大学院 ALPS・学務委員会委員
2013–2016	理学系研究科「キャリア支援室運営委員会」委員
2013	全学「国際総合日本学ネットワーク専門部会」委員

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	0	
Doctor Course	1	China
Foreign researchers hosted	0	
Students sent abroad	4	USA, France, UK
Researchers sent abroad	1	France
Foreign visitors	2	France, USA

Masashi Yokoyama、横山 将志

1 Education and Professional Experiences

Education

1997	B.S. (Physics)	The University of Tokyo
1999	MSc. (Physics)	The University of Tokyo
2002	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

2002–2003	Postdoctoral Fellow	The University of Tokyo
2003–2009	Assistant Professor	Kyoto University
2009–	Associate Professor	The University of Tokyo

Visiting, Guest Appointments

2006–2008	Visiting Scientist	Fermil National Accelerator Laboratory

2 Research Highlights

The main focus of my research has been search for new physics in elementary particles using neutrino oscillation as a probe. I have been studying neutrino oscillations with the T2K long baseline neutrino experiment, in which intense neutrino and anti-neutrino beams from the J-PARC accelerator complex are detected with the Super-Kamiokande detector, 295 km away. We have reported several world-leading results in the neutrino oscillation physics. The most notable ones are:

- observation of muon neutrino to electron neutrino ($\nu_\mu \to \nu_e$) oscillation and
- first hint of CP violation in the lepton sector.

In T2K, I led the near neutrino detector group to characterize the properties of the neutrino beam just after production. During 2012–2019, our group led the design, construction, operation, and analysis of additional near detectors to measure the neutrino interaction at the near detector hall. In order to further reduce systematic uncertainties for more precise measurements, I proposed a major upgrade of the near detector to improve its performance. I have been leading a group of ∼100 physicists from 9 countries for this project (CERN-NP07).

As the successor of Super-Kamiokande, we have proposed the Hyper-Kamiokande experiment, a water Cherenkov detector with 190 kt fiducial mass. From 2010 to 2015, I was in charge of the sensitivity studies of long baseline experiment using Hyper-Kamiokande and J-PARC neutrino beam. I was the main author of the proposal to the J-PARC Physics Advisory Committee in 2015 (arXiv:1412.4673) and the journal publication describing the physics sensitivity (PTEP 2015 053C02). Currently, I am leading the project as a member of the Steering Committee and the Technical Coordinator of the Hyper-Kamiokande proto-collaboration, consisting of $\sim$ 340 members from 17 countries.

3 Selected Papers

Number of citations is based on INSPIRES database, as of October 27, 2019.

- K. Abe *et al.* [T2K Collaboration], "Observation of Electron Neutrino Appearance in a Muon Neutrino Beam," Phys. Rev. Lett. **112**, 061802 (2014).
  This paper established the existence of $\nu_\mu \to \nu_e$ oscillation for the first time in the world, with more than 7σ statistical significance. The paper has been cited 530 times.

- K. Abe *et al.* [Hyper-Kamiokande Proto-Collaboration], "Physics potential of a long-baseline neutrino oscillation experiment using a J-PARC neutrino beam and Hyper-Kamiokande," PTEP **2015**, 053C02 (2015).
  This paper describes the physics potential of a long-baseline experiment using the J-PARC accelerator and Hyper-Kamiokande. I am the corresponding author of this paper. The paper has been cited 221 times.

- K. Abe *et al.* [T2K Collaboration], "Combined Analysis of Neutrino and Antineutrino Oscillations at T2K," Phys. Rev. Lett. **118**, no. 15, 151801 (2017)
  This paper reports the first-ever search for the CP violation in the leptonic sector, which resulted in an indication of CP violation with 90% confidence interval. The paper has been cited 168 times.

- K. Abe *et al.* [Super-Kamiokande Collaboration], "Search for proton decay via $p \to e^+\pi^0$ and $p \to \mu^+\pi^0$ in 0.31 megaton·years exposure of the Super-Kamiokande water Cherenkov detector," Phys. Rev. D **95**, no. 1, 012004 (2017)
  This paper reports the latest results from the search for proton decay in Super-Kamiokande. A lower limit on the proton lifetime is set at $\tau/B(p \to e^+\pi^0) > 1.6 \times 10^{34}$ years. The paper has been cited 128 times.

- K. Abe *et al.* [T2K Collaboration], "Search for CP Violation in Neutrino and Antineutrino Oscillations by the T2K Experiment with 2.2×10^{21} Protons on Target," Phys. Rev. Lett. **121**, no. 17, 171802 (2018)
  This paper describes the latest results of CP violation search. CP-conserving values of the phase in mixing matrix, δ_{CP}, are outside of 2σ confidence interval, suggesting a large CP violation in the lepton sector. One of graduate students in my group was main analyzer of this result. The paper has been cited 82 times.

4 Honors, Awards and Professional Society Memberships

- 2012 Le Prix La Recherche (as a member of T2K collaboration)

- 2013, Suwa Prize from Foundation for High Energy Accelerator Science (as J-PARC neutrino beam group)

- 2015, Breakthrough Prize in Fundamental Physics (as a member of K2K/T2K collaboration)

5 Research Plan

I will continue to study particle physics and astrophysics in the ongoing T2K and Super-Kamiokande experiments and future Hyper-Kamiokande experiment.

Study of neutrinos with T2K and Super-Kamiokande It is indispensable to continue the ongoing experiments and maximize their science output in parallel to the construction of Hyper-Kamiokande. In addition to accumulating more data, I will complete the upgrade of the near detector in 2021, when a major upgrade of the J-PARC accelerator is scheduled. With the upgraded beam and detectors, we will be able to bring down the systematic error from current 6-7% to 4% and measure neutrino oscillations with better precision. Because these improvements can be directly applied to the Hyper-Kamiokande, it will be also an important step to maximize the output in the early stage of Hyper-Kamiokande. It is also important as a place to foster young researchers who will be leaders in various fields in the next generation.

Particle physics and astrophysics by Hyper-Kamiokande Hyper-Kamiokande will have significantly enhanced capabilities compared to Super-Kamiokande by using a new type of photosensors in addition to the 8.4 times larger effective mass. We aim to start the experiment in 2027, and expect the world-leading science output in the wide range of particle physics and astrophysics over several decades like Super-Kamiokande. There are three major studies that I would like to pursue with Hyper-Kamiokande.

Search for the nucleon decay The grand unification theory (GUT) of elementary particles unifying electromagnetic, weak and strong interactions predicts decay of protons. For the decay $p \to e^+ + \pi^0$, which is the most general mode predicted in many GUT models, Hyper-Kamiokande will have a potential to observe the decay signal for the lifetime of up to 10^{35} years. There is no other project with this sensitivity planned in near future.

Study of neutrino oscillations The search for the asymmetry between particles and antiparticles (CP symmetry) is a major goal in study of neutrino oscillations. The CP violation in neutrinos is considered be a key to solve the origin of baryon asymmetry of the universe. With Hyper-Kamiokande, a definitive discovery and detailed measurements will be possible.

Neutrino Astrophysics I plan to extend my research area to astrophysics using neutrinos. We can investigate the supernova explosion mechanism in very detail by observing neutrinos from supernovae, that have not been observed since 1987. If a supernova explosion occurs near the center of the Galaxy, 50,000 to 90,000 neutrinos will be observed in Hyper-Kamiokande (in comparison to only 11 events observed in Kamiokande for SN1987A). Combining with other observations using optical telescopes and gravitational waves, we can pursue multi-messenger astronomy including neutrinos. Further, we will study astronomy by observing neutrinos from past supernovae.

Those experiments are carried out by international collaborations with more than 10 participating countries. For example, in the T2K experiment $\sim 75\%$ of collaborators are from outside Japan. Graduate students in our group will be educated in an international environment.

6 Publications and Patents

< Refereed Original Papers >

[1] K. Abe *et al.* [T2K Collaboration], "First Muon-Neutrino Disappearance Study with an Off-Axis Beam," Phys. Rev. D **85**, 031103 (2012)

[2] K. Ueno *et al.* [Super-Kamiokande Collaboration], "Search for GUT monopoles at Super-Kamiokande," Astropart. Phys. **36**, 131 (2012)

[3] H. Nishino *et al.* [Super-Kamiokande Collaboration], "Search for Nucleon Decay into Charged Antilepton plus Meson in Super-Kamiokande I and II," Phys. Rev. D **85**, 112001 (2012)

[4] P. A. Amaudruz *et al.* [T2K ND280 FGD Collaboration], "The T2K Fine-Grained Detectors," Nucl. Instrum. Meth. A **696**, 1 (2012)

[5] C. Regis *et al.* [Super-Kamiokande Collaboration], "Search for Proton Decay via $p \to \mu^+ K^0$ in Super-Kamiokande I, II, and III," Phys. Rev. D **86**, 012006 (2012)

[6] K. Abe *et al.* [Super-Kamiokande Collaboration], "Evidence for the Appearance of Atmospheric Tau Neutrinos in Super-Kamiokande," Phys. Rev. Lett. **110**, no. 18, 181802 (2013)

[7] G. Cheng *et al.* [MiniBooNE and SciBooNE Collaborations], "Dual baseline search for muon antineutrino disappearance at $0.1\text{eV}^2 < \Delta m^2 < 100\text{eV}^2$," Phys. Rev. D **86**, 052009 (2012)

[8] K. Abe *et al.* [T2K Collaboration], "T2K neutrino flux prediction," Phys. Rev. D **87**, no. 1, 012001 (2013) Addendum: [Phys. Rev. D **87**, no. 1, 019902 (2013)]

[9] K. Abe *et al.* [T2K Collaboration], "Measurement of the inclusive ν_μ charged current cross section on carbon in the near detector of the T2K experiment," Phys. Rev. D **87**, no. 9, 092003 (2013)

[10] K. Abe *et al.* [T2K Collaboration], "Evidence of Electron Neutrino Appearance in a Muon Neutrino Beam," Phys. Rev. D **88**, no. 3, 032002 (2013)

[11] K. Abe *et al.* [Super-Kamiokande Collaboration], "Search for Nucleon Decay via $n \to \bar{\nu}\pi^0$ and $p \to \bar{\nu}\pi^+$ in Super-Kamiokande," Phys. Rev. Lett. **113**, no. 12, 121802 (2014)

[12] K. Abe *et al.*, "Calibration of the Super-Kamiokande Detector," Nucl. Instrum. Meth. A **737**, 253 (2014)

[13] K. Abe *et al.* [T2K Collaboration], "Measurement of Neutrino Oscillation Parameters from Muon Neutrino Disappearance with an Off-axis Beam," Phys. Rev. Lett. **111**, no. 21, 211803 (2013)

[14] H. Zhang *et al.* [Super-Kamiokande Collaboration], "Supernova Relic Neutrino Search with Neutron Tagging at Super-Kamiokande-IV," Astropart. Phys. **60**, 41 (2015)

[15] K. Abe *et al.* [T2K Collaboration], "Observation of Electron Neutrino Appearance in a Muon Neutrino Beam," Phys. Rev. Lett. **112**, 061802 (2014)

[16] A. Renshaw *et al.* [Super-Kamiokande Collaboration], "First Indication of Terrestrial Matter Effects on Solar Neutrino Oscillation," Phys. Rev. Lett. **112**, no. 9, 091805 (2014)

[17] K. Abe *et al.* [T2K Collaboration], "Precise Measurement of the Neutrino Mixing Parameter θ_{23} from Muon Neutrino Disappearance in an Off-Axis Beam," Phys. Rev. Lett. **112**, no. 18, 181801 (2014)

[18] K. Abe *et al.* [T2K Collaboration], "Measurement of the intrinsic electron neutrino component in the T2K neutrino beam with the ND280 detector," Phys. Rev. D **89**, 092003 (2014) [Phys. Rev. D **89**, 099902 (2014)]

[19] K. Abe *et al.* [T2K Collaboration], "Measurement of the neutrino-oxygen neutral-current interaction cross section by observing nuclear deexcitation γ rays," Phys. Rev. D **90**, no. 7, 072012 (2014)

[20] A. J. Bevan *et al.* [BaBar and Belle Collaborations], "The Physics of the B Factories," Eur. Phys. J. C **74**, 3026 (2014)

[21] K. Abe *et al.* [T2K Collaboration], "Measurement of the inclusive ν_μ charged current cross section on iron and hydrocarbon in the T2K on-axis neutrino beam," Phys. Rev. D **90**, no. 5, 052010 (2014)

[22] K. Abe *et al.* [T2K Collaboration], "Measurement of the Inclusive Electron Neutrino Charged Current Cross Section on Carbon with the T2K Near Detector," Phys. Rev. Lett. **113**, no. 24, 241803 (2014)

[23] K. Abe *et al.* [Super-Kamiokande Collaboration], "Search for proton decay via $p \to \bar{\nu} K^+$ using 260 kiloton·year data of Super-Kamiokande," Phys. Rev. D **90**, no. 7, 072005 (2014)

[24] V. Takhistov *et al.* [Super-Kamiokande Collaboration], "Search for Trilepton Nucleon Decay via $p \to e^+\nu\nu$ and $p \to \mu^+\nu\nu$ in the Super-Kamiokande Experiment," Phys. Rev. Lett. **113**, no. 10, 101801 (2014)

[25] K. Abe *et al.* [T2K Collaboration], "Neutrino oscillation physics potential of the T2K experiment," PTEP **2015**, no. 4, 043C01 (2015)

[26] K. Abe *et al.* [Super-Kamiokande Collaboration], "Limits on sterile neutrino mixing using atmospheric neutrinos in Super-Kamiokande," Phys. Rev. D **91**, 052019 (2015)

[27] K. Abe *et al.* [Super-Kamiokande Collaboration], "Test of Lorentz invariance with atmospheric neutrinos," Phys. Rev. D **91**, no. 5, 052003 (2015)

[28] K. Abe *et al.* [T2K Collaboration], "Search for short baseline ν_e disappearance with the T2K near detector," Phys. Rev. D **91**, 051102 (2015)

[29] M. Litos *et al.* [Super-Kamiokande Collaboration], "Search for Dinucleon Decay into Kaons in Super-Kamiokande," Phys. Rev. Lett. **112**, no. 13, 131803 (2014).

[30] K. Abe *et al.* [T2K Collaboration], "Measurement of the ν_μ charged-current quasielastic cross section on carbon with the ND280 detector at T2K," Phys. Rev. D **92**, no. 11, 112003 (2015)

[31] K. Suzuki *et al.* [T2K Collaboration], "Measurement of the muon beam direction and muon flux for the T2K neutrino experiment," PTEP **2015**, no. 5, 053C01 (2015)

[32] K. Abe *et al.* [T2K Collaboration], "Measurements of neutrino oscillation in appearance and disappearance channels by the T2K experiment with 6.6×10^{20} protons on target," Phys. Rev. D **91**, no. 7, 072010 (2015)

[33] K. Abe *et al.* [Hyper-Kamiokande Proto-Collaboration], "Physics potential of a long-baseline neutrino oscillation experiment using a J-PARC neutrino beam and Hyper-Kamiokande," PTEP **2015**, 053C02 (2015)

[34] K. Abe *et al.* [T2K Collaboration], "Upper bound on neutrino mass based on T2K neutrino timing measurements," Phys. Rev. D **93**, no. 1, 012006 (2016)

[35] K. Choi *et al.* [Super-Kamiokande Collaboration], "Search for neutrinos from annihilation of captured low-mass dark matter particles in the Sun by Super-Kamiokande," Phys. Rev. Lett. **114**, no. 14, 141301 (2015)

[36] K. Abe *et al.* [T2K Collaboration], "Measurement of the ν_μ charged current quasielastic cross section on carbon with the T2K on-axis neutrino beam," Phys. Rev. D **91**, no. 11, 112002 (2015)

[37] K. Abe *et al.* [T2K Collaboration], "Measurement of the electron neutrino charged-current interaction rate on water with the T2K ND280 π^0 detector," Phys. Rev. D **91**, 112010 (2015)

[38] J. Gustafson *et al.* [Super-Kamiokande Collaboration], "Search for dinucleon decay into pions at Super-Kamiokande," Phys. Rev. D **91**, no. 7, 072009 (2015)

[39] K. Ieki *et al.* [DUET Collaboration], "Measurement of absorption and charge exchange of π^+ on carbon," Phys. Rev. C **92**, 035205 (2015)

[40] V. Takhistov *et al.* [Super-Kamiokande Collaboration], "Search for Nucleon and Dinucleon Decays with an Invisible Particle and a Charged Lepton in the Final State at the Super-Kamiokande Experiment," Phys. Rev. Lett. **115**, no. 12, 121803 (2015)

[41] K. Abe *et al.* [T2K Collaboration], "Measurement of the muon neutrino inclusive charged-current cross section in the energy range of 1–3 GeV with the T2K INGRID detector," Phys. Rev. D **93**, no. 7, 072002 (2016)

[42] Y. Zhang *et al.* [Super-Kamiokande Collaboration], "First measurement of radioactive isotope production through cosmic-ray muon spallation in Super-Kamiokande IV," Phys. Rev. D **93**, no. 1, 012004 (2016)

[43] E. Richard *et al.* [Super-Kamiokande Collaboration], "Measurements of the atmospheric neutrino flux by Super-Kamiokande: energy spectra, geomagnetic effects, and solar modulation," Phys. Rev. D **94**, no. 5, 052001 (2016)

[44] K. Abe *et al.* [T2K Collaboration], "Measurement of Muon Antineutrino Oscillations with an Accelerator-Produced Off-Axis Beam," Phys. Rev. Lett. **116**, no. 18, 181801 (2016)

[45] K. Abe *et al.* [Super-Kamiokande Collaboration], "Real-Time Supernova Neutrino Burst Monitor at Super-Kamiokande," Astropart. Phys. **81**, 39 (2016)

[46] K. Abe *et al.* [T2K Collaboration], "Measurement of double-differential muon neutrino charged-current interactions on C_8H_8 without pions in the final state using the T2K off-axis beam," Phys. Rev. D **93**, no. 11, 112012 (2016)

[47] K. Abe *et al.* [T2K Collaboration], "Measurement of Coherent π^+ Production in Low Energy Neutrino-Carbon Scattering," Phys. Rev. Lett. **117**, no. 19, 192501 (2016)

[48] K. Abe *et al.* [T2K Collaboration], "First measurement of the muon neutrino charged current single pion production cross section on water with the T2K near detector," Phys. Rev. D **95**, no. 1, 012010 (2017)

[49] K. Abe *et al.* [Super-Kamiokande Collaboration], "Solar Neutrino Measurements in Super-Kamiokande-IV," Phys. Rev. D **94**, no. 5, 052010 (2016)

[50] K. Abe *et al.* [Super-Kamiokande Collaboration], "Search for Neutrinos in Super-Kamiokande associated with Gravitational Wave Events GW150914 and GW151226," Astrophys. J. **830**, no. 1, L11 (2016)

[51] K. Abe *et al.* [Super-Kamiokande Collaboration], "Search for proton decay via $p \to e^+\pi^0$ and $p \to \mu^+\pi^0$ in 0.31 megaton·years exposure of the Super-Kamiokande water Cherenkov detector," Phys. Rev. D **95**, no. 1, 012004 (2017)

[52] E. S. Pinzon Guerra *et al.* [DUET Collaboration], "Measurement of σ_{ABS} and σ_{CX} of π^+ on carbon by the Dual Use Experiment at TRIUMF (DUET)," Phys. Rev. C **95**, no. 4, 045203 (2017)

[53] K. Abe *et al.* [Hyper-Kamiokande Collaboration], "Physics potentials with the second Hyper-Kamiokande detector in Korea," PTEP **2018**, no. 6, 063C01 (2018)

[54] K. Abe *et al.* [T2K Collaboration], "Combined Analysis of Neutrino and Antineutrino Oscillations at T2K," Phys. Rev. Lett. **118**, no. 15, 151801 (2017)

[55] K. Abe *et al.* [T2K Collaboration], "Search for Lorentz and CPT violation using sidereal time dependence of neutrino flavor transitions over a short baseline," Phys. Rev. D **95**, no. 11, 111101 (2017)

[56] T. Fukuda *et al.*, "First neutrino event detection with nuclear emulsion at J-PARC neutrino beamline," PTEP **2017**, no. 6, 063C02 (2017)

[57] K. Yamada *et al.*, "First demonstration of an emulsion multi-stage shifter for accelerator neutrino experiments in J-PARC T60," PTEP **2017**, no. 6, 063H02 (2017)

[58] K. Abe *et al.* [T2K Collaboration], "Updated T2K measurements of muon neutrino and antineutrino disappearance using 1.5×10^{21} protons on target," Phys. Rev. D **96**, no. 1, 011102 (2017)

[59] K. Abe *et al.* [T2K Collaboration], "Measurement of the single π^0 production rate in neutral current neutrino interactions on water," Phys. Rev. D **97**, no. 3, 032002 (2018)

[60] K. Abe *et al.* [Super-Kamiokande Collaboration], "Search for nucleon decay into charged antilepton plus meson in 0.316 megaton·years exposure of the Super-Kamiokande water Cherenkov detector," Phys. Rev. D **96**, no. 1, 012003 (2017)

[61] K. Abe *et al.* [T2K Collaboration], "Measurement of $\bar{\nu}_\mu$ and ν_μ charged current inclusive cross sections and their ratio with the T2K off-axis near detector," Phys. Rev. D **96**, no. 5, 052001 (2017)

[62] K. Abe *et al.* [T2K Collaboration], "Measurement of neutrino and antineutrino oscillations by the T2K experiment including a new additional sample of ν_e interactions at the far detector," Phys. Rev. D **96**, no. 9, 092006 (2017) Erratum: [Phys. Rev. D **98**, no. 1, 019902 (2018)]

[63] K. Abe *et al.* [Super-Kamiokande Collaboration], "Search for an excess of events in the Super-Kamiokande detector in the directions of the astrophysical neutrinos reported by the IceCube Collaboration," Astrophys. J. **850**, no. 2, 166 (2017)

[64] K. Abe *et al.* [T2K Collaboration], "First measurement of the ν_μ charged-current cross section on a water target without pions in the final state," Phys. Rev. D **97**, no. 1, 012001 (2018)

[65] K. Abe *et al.* [Super-Kamiokande Collaboration], "Atmospheric neutrino oscillation analysis with external constraints in Super-Kamiokande I-IV," Phys. Rev. D **97**, no. 7, 072001 (2018)

[66] C. Kachulis *et al.* [Super-Kamiokande Collaboration], "Search for Boosted Dark Matter Interacting With Electrons in Super-Kamiokande," Phys. Rev. Lett. **120**, no. 22, 221301 (2018)

[67] Z. Li *et al.* [Super-Kamiokande Collaboration], "Measurement of the tau neutrino cross section in atmospheric neutrino oscillations with Super-Kamiokande," Phys. Rev. D **98**, no. 5, 052006 (2018)

[68] K. Abe *et al.* [T2K Collaboration], "Measurement of inclusive double-differential ν_μ charged-current cross section with improved acceptance in the T2K off-axis near detector," Phys. Rev. D **98**, 012004 (2018)

[69] Y. Hayato *et al.* [Super-Kamiokande Collaboration], "Search for Neutrinos in Super-Kamiokande Associated with the GW170817 Neutron-star Merger," Astrophys. J. **857**, no. 1, L4 (2018)

[70] K. Abe *et al.* [T2K Collaboration], "Characterization of nuclear effects in muon-neutrino scattering on hydrocarbon with a measurement of final-state kinematics and correlations in charged-current pionless interactions at T2K," Phys. Rev. D **98**, no. 3, 032003 (2018)

[71] K. Abe *et al.* [T2K Collaboration], "Search for CP Violation in Neutrino and Antineutrino Oscillations by the T2K Experiment with 2.2×10^{21} Protons on Target," Phys. Rev. Lett. **121**, no. 17, 171802 (2018)

[72] M. Jiang *et al.* [Super-Kamiokande Collaboration], "Atmospheric Neutrino Oscillation Analysis with Improved Event Reconstruction in Super-Kamiokande IV," PTEP **2019**, no. 5, 053F01 (2019)

[73] L. Wan *et al.* [Super-Kamiokande Collaboration], "Measurement of the neutrino-oxygen neutral-current quasielastic cross section using atmospheric neutrinos at Super-Kamiokande," Phys. Rev. D **99**, no. 3, 032005 (2019)

[74] K. Abe *et al.* [T2K Collaboration], "Search for neutral-current induced single photon production at the ND280 near detector in T2K," J. Phys. G **46**, no. 8, 08LT01 (2019)

[75] K. Abe *et al.* [T2K Collaboration], "Search for light sterile neutrinos with the T2K far detector Super-Kamiokande at a baseline of 295 km," Phys. Rev. D **99**, no. 7, 071103 (2019)

[76] K. Abe *et al.* [T2K Collaboration], "Search for heavy neutrinos with the T2K near detector ND280," Phys. Rev. D **100**, no. 5, 052006 (2019)

[77] K. Abe *et al.* [T2K Collaboration], "Measurement of the ν_μ charged-current cross sections on water, hydrocarbon, iron, and their ratios with the T2K on-axis detectors," PTEP **2019**, no. 9, 093C02 (2019).

< Conference Proceedings >

[78] M. Yokoyama, "Future (underground) Water Cherenkov detectors," Nucl. Phys. Proc. Suppl. **235-236**, 183 (2013).

[79] M. Yokoyama, "Hyper-Kamiokande Project," in proceedings of the Sixteenth Lomonosov Conference on Elementary Particle Physics, A. I. Studenikin (*ed.*), World Scientific.

[80] M. Yokoyama [Hyper-Kamiokande Proto Collaboration], "The Hyper-Kamiokande Experiment," in proceedings of Prospects in Neutrino Physics (NuPhys2016), 12–14 Dec 2016, London, United Kingdom. arXiv:1705.00306 [hep-ex].

[81] M. Yokoyama, "Long-baseline neutrino experiments," PoS ICHEP **2018**, 696 (2019).

7 Invited Presentations at International Conferences

[1] Masashi Yokoyama, "Future Water Cherenkov Detectors," The XXV International Conference on Neutrino Physics and Astrophysics (NEUTRINO2012), June 3-9 2012, Kyoto, Japan.

[2] Masashi Yokoyama, "Developments in Asia," Intensity Frontier Neutrino subgroup meeting, Mar. 6–7 2013, SLAC, USA.

[3] Masashi Yokoyama, "Nucleon Deacay Search with Hyper-Kamiokande," Intensity Frontier Workshop, Argonne National Laboratory, IL, USA, Apr. 25–27, 2013.

[4] Masashi Yokoyama, "Long Baseline Experiments in Japan," Colloquium Towards CP violation in neutrino Physics, Prague, Czech Republic, May 23–24, 2013.

[5] Masashi Yokoyama, "Hyper-Kamiokande: Detector Design and Phyiscs Potential," Community Summer Study 2013 (Snowmass on the Mississippi), Minneapolis, MN, USA, Jul. 29–Aug. 6, 2013.

[6] Masashi Yokoyama, "Hyper-Kamiokande Project," 16th Lomonosov Conference, Moscow, Russia, Aug. 22–28, 2013.

[7] Masashi Yokoyama, "Experimental Status of Neutrino Physics," XXIV Workshop on Weak Interactions and Neutrinos (WIN13), Natal, Brazil, Sep. 16–21, 2013.

[8] Masashi Yokoyama, "Status and future prospects of neutrino oscillation experiments," Beyond the Standard Model 2014, KEK, Tsukuba, Japan, Mar. 3–7, 2014

[9] Masashi Yokoyama, "The Hyper-Kamiokande Project," Japan Geoscience Union Meeting 2014, Yokohama, Apr 28 – May 2, 2014.

[10] Masashi Yokoyama, "The future Japanese neutrino program," Strategy Workshop on AstroParticle in Switzerland 2014, Cartigny, Switzerland, 11-13 June 2014.

[11] Masashi Yokoyama, "Future Plans in Japan," 14th International Workshop on Next generation Nucleon Decay and Neutrino Detectors (NNN14), APC Paris, France, Nov 4–6, 2014.

[12] Masashi Yokoyama, "T2K and J-PARC neutrino experiments," XVI International Workshop on Neutrino Telescopes, Venice, Italy, Mar 2–6, 2015.

[13] Masashi Yokoyama, "Study of neutrino oscillations in the T2K experiment and development of new neutrino detectors," 10th anniversary of JSPS-RFBR cooperative program symposium, Moscow, Russia, October 21, 2015.

[14] Masashi Yokoyama, "Hyper-Kamiokande, Near Detectors and Physics Potencials," Korean Physics Society pioneer symposium, October 20, 2016, Gwangju, Korea.

[15] Masashi Yokoyama, "T2K ND280 Upgrade," 11th International Workshop on Neutrino-Nucleus Scattering in the Few-GeV Region (NuINT17), Toronto, Canada, June 25–30, 2017.

[16] Masashi Yokoyama, “Hyper-Kamiokande,” 18th Lomonosov Conference, Moscow State University, August 24–30, 2017.

[17] Masashi Yokoyama, “Long-baseline neutrino experiments,” plenary talk, The 39th International Conference on High Energy Physics (ICHEP2018), 4–11 July, 2018, Seoul, Korea.

[18] Masashi Yokoyama, “Hyper-Kamiokande,” 19th Lomonosov Conference, Moscow State University, August 22–28, 2019.

[19] Masashi Yokoyama, “Status of Hyper-Kamiokande,” Korean Physics Society pioneer symposium, October 24, 2019, Gwangju, Korea.

8 Teaching Accomplishment

6 graduate students from my group got Best Student Award in Spring School of High Energy Physics: Shimizu (2013), Chikuma, Hosomi (2014), Lou (2015), Tamura (2017), and Ogawa (2019).

9 Contribution to Academic Community

9.1 Editorial Activities

- Editor, Progress of Theoretical and Experimental Physics (PTEP)
- Member of Promotion Committee, Progress of Theoretical and Experimental Physics (PTEP)
- Editor, High Energy News (2009–2018)

9.2 Organization of Professional Societies

- Member of High Energy Committee, Japan Association of High Energy Physicists (2013–2015)

9.3 Organization and Advisory of Conferences

Co-chair

- 14th International Workshop on Next generation Nucleon Decay and Neutrino Detectors (NNN2013)
- 5th International Workshop on new photon-detectors (PD18)

Program Advisory Committee

- 4th International Workshop on new photon-detectors (PD15)

Local Organizing Committee

- 25th International Conference on Neutrino Physics and Astrophysics (NEUTRINO2012)
- 8th International Workshop on Ring Imaging Cherenkov Detectors (RICH2013)
- 10th International workshop on neutrino-nucleus interactions in the few-GeV region (NuINT2015)
- HINT2015 international workshop
- Workshop for Neutrino Programs with facilities in Japan (Oct. 2015)
- 21st International Workshop on Next generation Nucleon Decay and Neutrino Detectors (NNN2020)

Working Group Convener

- International Workshop on Neutrino Factories, Super Beams and Beta Beams (NuFact), Neutrino Scattering Physics WG (2011–2013)
- 39th International Conference on High Energy Physics (ICHEP2018), Neutrino Physics Session

10 Outreach

- 「ニュートリノ研究の発展と展望」第 28 回東京大学理学部公開講演会 梶田隆章教授ノーベル賞受賞記念連続講演会「カミオカから宇宙をみる」，2016 年 4 月 24 日
- 「ニュートリノ振動研究の最前線」，東京大学理学部オープンキャンパス，2016 年 8 月 3-4 日
- 「ニュートリノでさぐる素粒子と宇宙の謎」， 平成 28 年度 愛媛県高等学校教育研究会理科部会 全体会講演，松山市，2016 年 12 月 21 日
- 「ニュートリノビームで狙う宇宙の謎」, 東大理学部 高校生のための冬休み講座 2017, 東京大学, 2017 年 12 月 27 日
- 愛媛県立宇和島東高等学校 研修旅行 模擬授業， 2012–2019 各年 1 回

11 Committee Service

11.1 External Committees

- Member of Future Planning Committee, Institute of Particle and Nuclear Study, KEK (2013–2015)
- Member of Advisory Committee, Institute for Cosmic Ray Research, The University of Tokyo (2012–)
- Member of International Advisory Committee, Particle Data Group (2018–)

11.2 University Committees

理学系研究科広報委員会 委員 2014–2018 年度
理学部放射線管理委員会 委員 2019 年度–
フォトンサイエンス・リーディング大学院プログラム コーディネーター補佐 2012 年度–
フォトンサイエンス関連教育プログラム委員会委員 委員 2019 年度–

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	2	Germany, Switzerland
Master Course	0	
Doctor Course	1	
Foreign researchers hosted	2	Spain, Canada
Students sent abroad	6	Canada, France, Switzerland
Researchers sent abroad	1	Switzerland
Foreign visitors	3	France, Brazil

Condensed Matter

Hosho Katsura、桂 法称

1 Education and Professional Experiences

Education

2004	B.S. (Physics)	The University of Tokyo
2006	MSc. (Superconductivity)	The University of Tokyo
2008	Ph.D. (Applied Physics)	The University of Tokyo

Professional Appointments

2008−2009	Special Postdoctoral Researcher	RIKEN
2009−2010	Postdoctoral Fellow for Research abroad	KITP, UC Santa Barbara
2010−2012	Lecturer	Gakushuin University
2012−2014	Associate Professor	Gakushuin University
2014−	Associate Professor	The University of Tokyo

2 Research Highlights

• **Disordered topological insulators and superconductors**

Topological phases of matter have been the focus of much attention in the last decade. In most cases, however, the definition of topological invariants that characterize distinct topological phases heavily relies on translation symmetry, which can be broken by the presence of impurities. In a series of works [29, 15], we have established the notion of topological invariants for disordered free-fermion systems based on noncommutative geometry. This approach is not only mathematically rigorous, but practically very useful as it provides a way to compute the topological invariant numerically. To demonstrate the power of this approach, we compute the $\mathbf{Z}_2$ topological invariants for the Wilson-Dirac Hamiltonian describing three-dimensional topological insulators in class AII [18]. Our group has also developed a method to detect phase transitions in disordered topological insulators/superconductors using artificial neural networks (ANN) [14]. This machine learning-based approach enables us to map out the phase diagram of disordered topological superconductors in class DIII where the conventional approach fails. The results obtained are fully consistent with those obtained by the transfer-matrix method and noncommutative geometry approach, demonstrating the validity of our newly developed approach.

• **Topological magnon systems**

The idea of topological phases of fermions can be carried over to bosons such as magnons, elementary excitations in ordered magnets. In fact, there is a close parallel between them. One such example is the thermal Hall effect of magnons, which was predicted in [H. Katsura, N. Nagaosa, and P. A. Lee, Phys. Rev. Lett. **104**, 066403 (2010)] and later observed experimentally in [Y. Onose *et al.*, Science **329**, 297 (2010)], [42]. Although the thermal Hall conductivity does not exhibit quantization because of the lack of “Fermi sea” of magnons, the mechanism is essentially the same as in integer quantum Hall effect with zero net magnetic field. A natural question to ask is whether there are magnonic counterparts of topological insulators with time-reversal symmetry. The main technical obstacle is the fact that the Kramers theorem does not hold in bosonic systems. To overcome this, we introduced the notion of what we call *pseudo-time-reversal symmetry* that guarantees the Kramers degeneracy even in magnonic systems [2]. This allows us to define a $\mathbf{Z}_2$ topological invariant for magnon spin-Hall systems in two dimensions, which fully characterizes the presence or absence of helical edge states at the system boundary. The use of the $\mathbf{Z}_2$ invariant was illustrated in a magnonic version of the Kane-Mele model. Furthermore, the result has been generalized to three dimensions. In Ref. [1], we define a set of $\mathbf{Z}_2$ topological invariants that characterize distinct topological phases analogous to strong topological, weak topological, and trivial phases of the ordinary three-dimensional topological insulators in class AII. To show how this works, we constructed a magnonic analog of the Fu-Kane-Mele model and compared the values of $\mathbf{Z}_2$ invariants with the spectra of surface magnons.

- **Strongly interacting Majorana fermions**

Whereas the concept of Majorana fermions arose in the context of high-energy physics, they have been the focus of renewed attention in condensed matter physics as they have potential applications in quantum computation. To date, considerable effort has been devoted to the studies of free Majorana fermions. On the other hand, the effects of interactions on Majorana fermions have not been fully explored. In Ref. [31], we studied the Kitaev chain with nearest-neighbor interactions and identified the frustration-free case in which the ground states can be written down exactly. Using these ground states, we demonstrated explicitly that there exists a set of operators each of which maps one of the ground states to the other with opposite fermionic parity. These operators can be thought of as an interacting generalization of Majorana edge zero modes. The results have been generalized to include spatially inhomogeneous cases [10]. We have also studied a model of interacting Majorana fermions with $\mathcal{N} = 1$ supersymmetry (SUSY) [8]. Using a variety of methods, we found that SUSY is broken in one phase, but not in the other. In the SUSY broken phase, the Nambu-Goldstone fermions associated with the SUSY breaking have cubic dispersion at long wavelength. In the SUSY unbroken phase, we identified a super-frustration-free point at which the ground-state energy is exactly zero.

- **Mathematical physics of quantum many-body systems**

We have been interested in mathematical aspects of quantum many-body systems such as the Hubbard model. In Ref. [39], we extended the Nagaoka ferromagnetism to the SU(n) Fermi-Hubbard model in which each fermion carries SU(n)-"spin" degrees of freedom. We also studied strongly correlated spinor bosons and proved basic theorems about the ground-state properties of the spin-1 and 2 Bose-Hubbard models [38, 7]. Another highlight is the answer to the basic question about the ground-state (GS) energies of bosons and fermions with the same form of the Hamiltonian [37, 16]. We compared the GS energies of the spinless fermions and hard-core bosons with the same hopping term and proved that under certain conditions fermions can have a lower GS energy than bosons, providing a counterexample to the naive expectation that bosons always have a lower GS energy than fermions. In addition to the above-mentioned works, we have also studied solvable/integrable models [11, 21, 23, 28, 33] and conformal field theories [17, 44].

3 Selected Papers

- H. Katsura, D. Schuricht, and M. Takahashi, Phys. Rev. B **92**, 115137 (2015)
  This work has been cited 68 times (google scholar).

- H. Kondo, Y. Akagi, and H. Katsura, Phys. Rev. B **100**, 144401 (2019)
  This work was selected as an Editor's suggestion.

- X-L. Qi, H. Katsura, and A. W. W. Ludwig, Physical Review Letters **108**, 196402 (2012)
  The paper has been cited 214 times (google scholar).

- T. Ideue *et al.*, Phys. Rev. B **85**, 134411 (2012)
  The paper was selected as an Editors' Suggestion and cited 96 times (google scholar).

- Hosho Katsura and Tohru Koma, J. Math. Phys. **57**, 021903 (2016); **59**, 031903 (2018).
  This work has established the notion of topological invariants for topological insulators and superconductors with disorder. The results obtained can be thought of as a noncommutative version of the Atiyah-Singer index theorem.

4 Honors, Awards and Professional Society Memberships

- 2015 Young Scientist Award of the Physical Society of Japan (Division 8)

- 2016 Nevill F. Mott Prize (International Conference on Strongly Correlated Electron Systems 2016)

5 Research Plan

We will continue studying various aspects of condensed matter and statistical physics. In particular, we will focus on the following subjects in the coming few years.

• Topological phases in magnets

In our previous work [1, 2], we have constructed several toy models of topological magnon systems in two and three dimensions. Although the models are somewhat artificial, we found recently that a very similar situation is realized in van der Waals magnetic materials such as CrI_3 and $CrBr_3$ [D. R. Klein *et al.*, Nat. Phys. (2019)]. For example, in a bilayer CrI_3, the Cr moments in each layer are ferromagnetically coupled, but the moments are aligned antiferromagnetically between the layers. This is an ideal situation for the two-dimensional version of our models. The question then is whether a significant Dzyaloshinskii-Moriya interaction that drives a system to a $\mathbf{Z}_2$ topological phase exists. To answer this, we will make a comparison between existing experimental data and theoretical calculation based on a phenomenological model. We will also address the implications of the nontrivial $\mathbf{Z}_2$ topological phase in real systems. The situation in three-dimensional models is more challenging, as each lattice site in the model accommodates two spins pointing opposite directions. However, it is likely that this kind of situation happens more naturally in the Schwinger-boson mean-field theory (SBMFT). We thus try to examine various paramagnetic and spin-liquid models using SBMFT, and see if it really happens. Also, we plan to generalize our theory to include magnonic versions of topological crystalline insulators, which would be useful for exploring topological phases in stacked layers of van der Waals materials.

• **Non-ergodic dynamics in quantum many-body systems**

Recent years have seen a growing interest in non-ergodic behavior in quantum many-body systems such as many-body localization and scarred eigenstates. In this context, the PXP model has played a central role as a paradigmatic model exhibiting quantum scarred eigenstates and anomalous dynamics. In addition, this model is a particular case of a more general model realized by an array of Rydberg atoms in one dimension [41], [A. Keesling *et al.*, Nature, **568**, 207 (2019)]. One of the features of the model is a hard-core constraint due to the Rydberg blockade, i.e., a simultaneous excitation of adjacent atoms is forbidden. A natural question is whether this kind of constraint is necessary to achieve quantum scarred states. In order to answer this question, we will try to see if there are models without constraints that exhibit quantum many-body scars or anomalous non-ergodic behavior. Another interesting issue is whether or not systems with scars have anything to do with more conventional non-erdogic systems, i.e., integrable systems. Although we do not think we can address this issue in full generality, we do think that we can construct a class of concrete models that interpolate between integrable and non-integrable models, for which the existence of scarred eigenstates can be proved rigorously. If this is the case, those models will provide clearer examples of non-integrable but non-ergodic systems in proximity to conventional integrable systems.

6 Publications and Patents

< Refereed Original Papers >

[1] Hiroki Kondo, Yutaka Akagi, and Hosho Katsura, Phys. Rev. B **100**, 144401 (2019) [Selected as Editors' suggestion].

[2] Hiroki Kondo, Yutaka Akagi, Hosho Katsura, Phys. Rev. B **99**, 041110(R) (2019)

[3] Naoyuki Shibata, Hosho Katsura, Phys. Rev. B **99**, 224432 (2019).

[4] Nobuyuki Yoshioka, Ryusuke Hamazaki, Phys. Rev. B 99, 214306 (2019) [Selected as Featured in Physics & Editors' Suggestion].

[5] Naoyuki Shibata and Hosho Katsura, Phys. Rev. B **99**, 174303 (2019).

[6] Nobuyuki Yoshioka, Yutaka Akagi, and Hosho Katsura, Phys. Rev. E **99**, 032113 (2019).

[7] Hong Yang and Hosho Katsura, Phys. Rev. Lett. **122**, 053401 (2019).

[8] Noriaki Sannomiya and Hosho Katsura, Phys. Rev. D **99**, 045002 (2019).

[9] Nobuyuki Yoshioka, Yoshiki Imai, and Manfred Sigrist, J. Phys. Soc. Jpn. **87**, 124602 (2018).

[10] Jurriaan Wouters, Hosho Katsura, and Dirk Schuricht, Phys. Rev. B **98**, 155119 (2018).

[11] Eiki Iyoda, Hosho Katsura, and Takahiro Sagawa, Phys. Rev. D **98**, 086020 (2018).

[12] Kohei Kawabata, Yuto Ashida, Hosho Katsura, and Masahito Ueda, Phys. Rev. B **98**, 085116 (2018). [Selected as Editors' Suggestion].

[13] Adrien Bolens, Hosho Katsura, Masao Ogata, and Seiji Miyashita, Phys. Rev. B **97**, 161108(R) (2018).

[14] Nobuyuki Yoshioka, Yutaka Akagi, and Hosho Katsura, Phys. Rev. B **97**, 205110 (2018) [Selected as Editors' Suggestion].

[15] Hosho Katsura and Tohru Koma, J. Math. Phys. **59**, 031903 (2018).

[16] Wenxing Nie, Hosho Katsura, and Masaki Oshikawa, Phys. Rev. B **97**, 125153 (2018).

[17] Shota Tamura and Hosho Katsura, Prog. Theor. Exp. Phys **2017**, 113A01 (2017).

[18] Yutaka Akagi, Hosho Katsura, and Tohru Koma, J. Phys. Soc. Jpn. **86**, 123710 (2017) [Selected as Papers of Editors' Choice].

[19] Yun-Tak Oh, Hosho Katsura, Hyunyong Lee, and Jung Hoon Han, Phys. Rev. B **96**, 165126 (2017).

[20] Adrien Bolens, Hosho Katsura, Masao Ogata, and Seiji Miyashita, Phys. Rev. B **95**, 235115 (2017).

[21] Takuma Udagawa and Hosho Katsura, J. Phys. A: Math. Theor. **50**, 405002 (2017).

[22] Kohei Kawabata, Ryohei Kobayashi, Ning Wu, and Hosho Katsura, Phys. Rev. B. **95**, 195140 (2017).

[23] O. Salberger, T. Udagawa, Z. Zhang, H. Katsura, I. Klich, and V. Korepin, J. Stat. Mech., 063103 (2017)

[24] Hyunyong Lee, Yun-Tak Oh, Jung Hoon Han, and Hosho Katsura, Phys. Rev. B, **95**, 060413(R) (2017).

[25] Noriaki Sannomiya, Hosho Katsura, and Yu Nakayama, Phys. Rev. D **95**, 065001 (2017).

[26] Noriaki Sannomiya, Hosho Katsura, and Yu Nakayama, Phys. Rev. D **94**, 045014 (2016).

[27] Yasuyuki Hatsuda, Hosho Katsura, and Yuji Tachikawa, New J. Phys. **18**, 103023 (2016).

[28] Panjin Kim, Hosho Katsura, Nandini Trivedi, and Jung Hoon Han, Phys. Rev. B **94**, 195110 (2016).

[29] Hosho Katsura and Tohru Koma, J. Math. Phys. **57**, 021903 (2016).

[30] Hiroaki T. Ueda, Yutaka Akagi, and Nic Shannon, Physical Review A **93**, 021606(R) (2016).

[31] Hosho Katsura, Dirk Schuricht, and Masahiro Takahashi, Phys. Rev. B **92**, 115137 (2015).

[32] Kouichi Okunishi and Hosho Katsura, J. Phys. A: Math. Theor. **48**, 445208 (2015).

[33] Hosho Katsura, J. Stat. Mech., P01006 (2015).

[34] Hosho Katsura, Phys. Rev. D **89**, 085019 (2014).

[35] Hosho Katsura, Phys. Rev. A **88**, 065602 (2013).

[36] Shintaro Takayoshi, Hosho Katsura, Noriaki Watanabe, and Hideo Aoki, Phys. Rev. A **88**, 063613 (2013).

[37] Wenxing Nie, Hosho Katsura, Masaki Oshikawa, Phys. Rev. Lett. **111**, 100402 (2013).

[38] Hosho Katsura and Hal Tasaki, Phys. Rev. Lett. **110**, 130405 (2013).

[39] Hosho Katsura and Akinori Tanaka, Phys. Rev. A **87**, 013617 (2013).

[40] Shu Tanaka, Ryo Tamura, and Hosho Katsura, Phys. Rev. A **86**, 032326 (2012).

[41] Igor Lesanovsky and Hosho Katsura, Phys. Rev. A 86, 041601(R) (2012).

[42] T. Ideue, Y. Onose, H. Katsura, Y. Shiomi, S. Ishiwata, N. Nagaosa, and Y. Tokura, Phys. Rev. B **85**, 134411 (2012) [Selected as Editors' Suggestion].

[43] Masahiro Takahashi, Hosho Katsura, Mahito Kohmoto, and Tohru Koma, New J. Phys. **14**, 113012 (2012).

[44] Hosho Katsura, J. Phys. A: Math. Theor. **45**, 115003 (2012) [IOP Select].

[45] Masahiro Sato, Hosho Katsura, and Naoto Nagaosa, Phys. Rev. Lett. **108**, 237401 (2012).

[46] Xiao-Liang Qi, Hosho Katsura, and Andreas W. W. Ludwig, Phys. Rev. Lett. **108**, 196402 (2012).

＜ Conference Proceedings ＞

[47] Shu Tanaka, Ryo Tamura, and Hosho Katsura, "Entanglement Properties of a Quantum Lattice-Gas Model on Square and Triangular Ladders", Kinki University Series on Quantum Computing - Vol. 9, *Physics, Mathematics, and All that Quantum Jazz* (World Scientific, 2014).

＜ Review Papers ＞

[48] 吉岡信行, 赤城 裕, 桂 法称, "ニューラルネットワークによる物理状態の判定から表現まで", 固体物理 54, No. 9, 51 (2019).

[49] 桂 法称, "非線形方程式とトポロジカル励起 (特集 :「数理モデルと普遍性」)", 数理科学, 2016 年 1 月号 No. 631.

[50] 桂 法称, "新著紹介『マルチフェロイクス；物質中の電磁気学の新展開』（有馬孝尚・著）", 日本物理学会誌 70, No. 8, 646 (2015).

[51] 桂 法称，丸山　勲, "フラットバンドの構成法—分子の奏でるハーモニー—", 固体物理 50, No. 5, 41 (2015).

[52] 桂 法称, "量子統計力学と恒等式 (特集 :「発展する統計力学」)", 数理科学, 2013 年 6 月号　No.600.

[53] 引原俊哉，桂 法称，丸山　勲，西野友年, "エネルギー・スケール変調による量子系の境界条件・トポロジーの制御", 日本物理学会誌 67, No. 6, 394 (2012).

＜ Books ＞

＜ Patent Applications ＞

7 Invited Presentations at International Conferences

[1] H. Katsura, "Integrable dissipative spin chains", *Topological phase workshop*, Tohoku University, Sendai, Japan (July 2019).

[2] H. Katsura, "Integrable dissipative spin chains", *Amsterdam Summer Workshop on Low-D Quantum Condensed Matter 2019*, University of Amsterdam, Amsterdam, Netherland (July 2019).

[3] H. Katsura, "Supersymmetry breaking and Nambu-Goldstone fermions in lattice models", *KIAS Workshop on Topology and Correlation in Quantum Materials*, Hotel Shilla Stay at Haeundae, Busan, Korea (May, 2019).

[4] H. Katsura, "Frustration-free Majorana fermion models", *Interacting Majorana Fermions* The University of Britich Columbia, Vancouver, Canada (May 2019).

[5] H. Katsura, "Z2 invariants for disordered topological insulators and superconductors", *Theoretical studies of topological phases of matter*, The University of Tokyo, Tokyo, Japan (Feb. 2019).

[6] . Katsura, "Fradkin, Fredkin, or Fridkin?", *Exactly Solvable Models of Quantum Field Theory and Statistical Mechanics*, Simons Center for Geometry and Physics, Stony Brook, US (Nov. 2018).

[7] Y. Akagi, "Detection of phase transition in quantum spin chains via unsupervised machine learning", *Mini-workshop on "Machine Learning in Physics"*, The University of Tokyo, Tokyo, Japan (Sept. 2018).

[8] H. Katsura, "Z2 invariant for topological magnon insulators", *Quantum Magnetism: Frustration, Low-dimensionality, Topology*, University of Chinese Academy of Sciences, Beijing, China (Sept. 2018).

[9] H. Katsura, "Z2 topological invariants of fermionic and bosonic insulators", Progress in the Mathematics of Topological States of Matter, Tohoku University, Sendai, Japan (August 2018).

[10] H. Katsura, "Sine-square deformation of onedimensional critical systems", *Integrable systems in Condensed Matter / Statistical Physics*, International Centre for Theoretical Sciences, Bangalore, India (Aug. 2018).

[11] H. Katsura, "Fradkin, Fredkin or Fridkin?", *EXACTLY SOLVABLE QUANTUM CHAINS*, International Institute of Physics, Natal, Brazil (June 2018).

[12] H. Katsura, "Majorana excitations in Kitaev spin liquids", *SAMAHANG PISIKA NG PILIPINAS Physics Society of the Philippines*, Puerto Princesa, Philippines, June 2018.

[13] H. Katsura, "Topological order and zero modes in interacting Kitaev/Majorana chains", *Quantum Devices*, International Institute of Physics, Natal, Brazil (Aug. 2017).

[14] H. Katsura, "Tasaki is ubiquitous", *Flatband Networks in Condensed Matter and Photonics*, Institute for Basic Science, Daejon, Korea (Aug. 2017).

[15] H. Katsura, "Disordered topological insulators with time-reversal symmetry: Z2 index", *Topological Materials Science: Intensive-Interactive Meeting*, Keio University, Kanagawa, Japan (Nov. 2016).

[16] H. Katsura, "Supersymmetry breaking and Nambu-Goldstone fermions in lattice models", *Quantum Matter, Spacetime and Information (YKIS2016)*, Kyoto University, Kyoto, Japan (July 2016).

[17] H. Katsura, "Microscopic mechanisms of spin-driven ferroelectricity and the thermal Hall effect in insulating magnets", *International Conference on Strongly Correlated Electron Systems (SCES2016)*, Zhejiang University, Hangzhou, China (May 2016).

[18] H. Katsura, "Topological indices of disordered insulators with time-reversal symmetry", *LMU-UT Cooperation in Physics Workshop*, The University of Tokyo, Tokyo , Japan (Feb. 2016).

[19] Y. Akagi, "Topological defects in quantum spin-nematics", *The 20th International Conference on Magnetism (ICM2015)*, Barcelona (July 2015).

[20] H. Katsura, "Topological order in interacting Kitaev/Majorana chains", *Novel Quantum States in Condensed Matter (NQS2014)*, Kyoto University, Kyoto, Japan (Nov. 2014).

[21] H. Katsura, "Exact ground states of an interacting Kitaev/Majorana chain", *New Horizon of Strongly Correlated Physics (NHSCP2014)*, ISSP, Chiba, Japan (June 2014).

[22] H. Katsura, "Interacting Rydberg atoms as quantum hard squares", *Workshop on Disordered and Topological Systems*, Zhejiang University, Hangzhou, China (Mar. 2013).

[23] H. Katsura, "Inhomogeneous but solvable/integrable models", *Infinite Analysis: Past, Present and Future*, Kyoto University, Kyoto, Japan (Mar. 2013).

[24] H. Katsura, "Sine-square deformation of one-dimensional critical systems", *Novel Development of Statistical Physics*, The University of Tokyo, Tokyo, Japan (Nov. 2012).

[25] H. Katsura, "Entanglement spectra of two-dimensional solvable models", *Entanglement Spectra in Complex Quantum Wavefunctions*, MPIPKS, Dresden, Germany (Nov. 2012).

[26] H. Katsura, "Entanglement spectra of two-dimensional solvable models", *Correlations and Entanglement in Many-body Systems Out of Equilibrium*, Tsing Hua University, Hsinchu, Taiwan (Sept. 2012).

[27] H. Katsura, "Golden chain of strongly interacting Rydberg atoms", *APCTP Focus Program on Quantum Condensation (QC12)*, APCTP, Pohang, Korea (Aug. 2012).

8 Teaching Accomplishment

- A work lead by a Ph.D. student (Nobuyuki Yoshioka) in the group [4] was featured in UTokyo FOCUS. (https://www.u-tokyo.ac.jp/focus/en/articles/z0508_00052.html).
- Nobuyuki Yoshioka won the 14th Young Scientist Award of the Physical Society of Japan for his research on classification and representation of physical states by neural networks.

9 Contribution to Academic Community

9.1 Editorial Activities

9.2 Organization of Professional Societies

9.3 Organization and Advisory of Conferences

9.4 Referee Services

Physical Review Letters, Physical Review B, Physical Review X, Nature Communications, Scientific Reports, Annals of Physics, Journal of Physics A, Journal of Physics: Condensed Matter, Euro Physics Letters, International Journal of Modern Physics A, Journal of Physical Society of Japan, PTEP, New Journal of Physics, Entropy, Modern Physics Letter A, Quantum Information Processing, iScience, Journal of Magnetism and Magnetic Materials, Physica Status Solidi, ...

10 Outreach

- 2015−2019 年　東京大学理学部・オープンキャンパス「多体自由度が織りなす森羅万象」
- 2018−2019 年　生徒研究成果合同発表会 (スーパーサイエンスハイスクール校 [SSH]) 助言指導

11 Committee Service

- 2012−2013 年　日本物理学会 領域 11 領域運営委員 (The Physical Society of Japan, Division 11, committee member)
- 2013−2015 年　日本物理学会 新著紹介小委員会委員

11.1 External Committees

2019− Progress of Theoretical and Experimental Physics 企画委員 (planning committee)

11.2 University Committees

2018 年 – 理学部広報委員会 (School of Science, Public Relations committee) 委員
2018 年 – 理学部ニュース編集委員会 委員

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	4	China, US, India
Master Course	1	China
Doctor Course	1	The Netherlands
Foreign researchers hosted	0	
Students sent abroad	1	Switzerland
Researchers sent abroad	0	
Foreign visitors	10	China, India, US, UK, Luxembourg, Germany, Slovenia

Masao Ogata、小形 正男

1 Education and Professional Experiences

Education

1982	B.S. (Physics)	The University of Tokyo
1984	MSc. (Physics)	The University of Tokyo
1987	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1986−1993	Research Associate	Institute for Solid State Physics, The University of Tokyo
1989−1991	Postdoctoral fellow	Theoretische Physik, ETH-Hönggerberg, and Interdisziplinäres Projektzentrum, Switzerland
1991−1993	Postdoctoral fellow	Joseph Henry Laboratories of Physics, Princeton University
1993−2000	Associate Professor	Institute of Physics (Komaba), The University of Tokyo
2000−2008	Associate Professor	Department of Physics, The University of Tokyo
2008−present	Professor	Department of Physics, The University of Tokyo

2 Research Highlights

1) High-T_{c} superconductivity and Mott insulator ([ ] is a reference in the Publication List)

We have been studying mechanisms of high-temperature superconductivity from a viewpoint of strongly correlated electron systems. In particular, we have been studying t-J model and t-t'-U Hubbard model (t' is the next-nearest-neighbor hopping) in two-dimension. Due to the strong correlation in these models, it is believed that the conventional perturbative approach and mean-field theories will fail. For this reason, we have been using mainly numerical methods for studying these models. High-T_{c} superconductivity occurs when carriers are doped into Mott insulators. Thus the relation between superconductivity and Mott insulator is a very important and interesting problem. We found that the bound-states of doubly occupied sites (doublons) and unoccupied sites (holons) play important roles in the Mott metal-insulator transition. When carriers are doped into such a Mott insulator, similar bound-states occur, but in this case, the Mott transition becomes a crossover at $U = U_{\mathrm{co}}$ between weak- and strong correlation region[10] (Selected Papers no. 1, see below). It is found that for the weak correlation region ($U < U_{\mathrm{co}}$) $d_{x^2-y^2}$-wave superconductivity is a BCS-type, while for the strong correlation region ($U > U_{\mathrm{co}}$) superconductivity becomes a kinetic-energy-driven type as in the t-J model. We showed that the behavior for $U > U_{\mathrm{co}}$ is consistent with experiments.

2) Dirac electrons in solids

We have been studying the novel properties of Dirac electrons in solids, including bismuth (three-dimensional anisotropic Dirac electrons), massless Dirac electrons in organic conductors and in the surface states of topological insulators, Weyl semimetals, and new materials. In the Selected Papers no. 2 [66], we reviewed progress in the theoretical understanding of transport and optical properties of bismuth and bismuth-antimony alloys. We found that there is a fundamental relationship between spin-Hall conductivity and orbital susceptibility even in the insulating state, and the possibility of a fully spin-polarized electric current in magneto-optics [3]. The magnitude of spin-Hall conductivity estimated theoretically turns out to be about 100 times larger than that of Pt [4,17].

As a new material, we found that cubic inverse perovskites, Ca_3PbO and its family have three-dimensional Dirac electrons with a very small mass near the Γ-point exactly at the Fermi energy [2,42]. We proposed a mechanism of the appearance of Dirac electrons as well as some design principles in this series of materials. After this study, Takagi's group started to synthesize and investigate Ca_3PbO and its family to find out the theoretically predicted Dirac electron features. For various Dirac and Weyl electron systems, we have been studying physical properties such as, Nernst effect [11], the effects of tilting and anisotropy on conductivity [14], anomalous Meissner effect [23], NMR relaxation rates [38,57], and magnetoresistance [48,60]. In particular, we discuss with NMR group in Dresden to find a good agreement with the experimental results of $1/T_1$ in Weyl semimetal, TaAs [57].

3) Topological materials

N. Okuma was one of the PhD students in our group and he generalized the concept of the spin-momentum locking to magnonic systems and derived a formula to calculate spin expectation value for one-magnon states of general two-body spin Hamiltonians. He showed that a spin vortex in momentum space generated in a kagome lattice antiferromagnet has the winding number $Q = -2$. He is a very talented student and succeeded to have a single-author PRL [41]. Recently we started to study Dirac nodal line materials [52,62]. Although Z_2 index is usually used to detect a Dirac nodal line, we found that nodal line can exist even in the Z_2-trivial system such as SnSe [52].

4) Orbital magnetic susceptibility

We derived an exact and general formula for orbital magnetic susceptibility in terms of Bloch wave functions in the presence of spin-orbit interaction and inversion symmetry breaking [20,36]. The relationship to the Berry curvature is clarified. It turns out that there are 6 contributions including Landau-Peierls susceptibility. Corrections to the Peierls phase are also found [29], and this new method is applied to excitonic insulator [30].

5) Linear response theory for Seebeck effect

Based on the linear response theory, range of validity of Sommerfeld-Bethe relation and Mott formula was clarified for a general Hamiltonian [58]. The contribution of phonon drag is derived which is valid even under the strong disorder. This method is applied to $FeSb_2$ which shows a huge Seebeck coefficient up to 50 mV/K at low temperatures [59].

We also have several papers collaborating with experimental groups [1, 54, 55, 61], and with other theoretical groups in the Department [46, 53, 56].

3 Selected Papers

- H. Yokoyama, M. Ogata, Y. Tanaka, K. Kobayashi, and H. Tsuchiura: J. Phys. Soc. Jpn. **82**, 014707-1-16 (2013). "Crossover between BCS Superconductor and Doped Mott Insulator of d-wave Pairing State in Two-Dimensional Hubbard Model"

In this work [10], we clarified a crossover between weak- and strong-correlation region as s function of electron mutual interaction in the Hubbard model using variational wave functions. This paper has been cited 68 times.

- Y. Fuseya, M. Ogata, and H. Fukuyama: J. Phys. Soc. Jpn. **84**, 012001-1-22 (2015). "Transport Phenomena and Diamagnetism of Dirac Electrons in Bismuth"
  This is a review paper on bismuth and bismuth-antimony alloys as a typical example of Dirac electron system [66]. For example, a huge spin Hall effect and the possibility of a fully spin-polarized current in magneto-optics are discussed. This paper has been cited 63 times since 2015.

- T. Kariyado and M. Ogata: Phys. Rev. Materials **1**, 061201(R) (2017). "Evolution of Band Topology by Competing Band Overlap and Spin-Orbit Coupling: Twin Dirac Cones in Ba_3SnO as a Prototype"
  In this paper, we showed that cubic inverse perovskites, Ca_3PbO and its family have three-dimensional Dirac electrons exactly at the Fermi energy [42]. We proposed some design principles in this series of materials to control the band overlap and spin-orbit interaction.

- N. Okuma: Phys. Rev. Lett. **119**, 107205-1-6 (2017). "Magnon Spin-Momentum Locking: Various Spin Vortices and Dirac magnons in Noncollinear Antiferromagnets"
  In this work, the concept of the spin-momentum locking to magnonic systems is developed, and a formula to calculate spin expectation value for one-magnon states of general two-body spin Hamiltonians is derived [41].

- M. Ogata: J. Phys. Soc. Jpn. **86**, 044713-1-18 (2017). "Theory of Magnetization in Bloch Electron Systems"
  In this paper, we derived an exact and general formula for orbital magnetic susceptibility in terms of Bloch wave functions for a general case with spin-orbit interaction and inversion-symmetry breaking, clarifying the connection to the Berry curvature [36].

4 Honors, Awards and Professional Society Memberships

- 1999 Yukawa Memorial Prize of Nishinomiya (西宮湯川記念賞) for "Study on One-Dimensional Strongly Correlated Electron Systems"

- 2005 Japan IBM Science Prize (日本 IBM 科学賞) for "Theoretical Studies on Mechanisms of Superconductivity in the Strong Correlation Regime in Novel Superconductors"

- 2013 Highly Cited Article in J. Phys. Soc. Jpn."Recent Topics of Organic Superconductors" by A. Ardavan, S. Brown, S. Kagoshima, K. Kanoda, K. Kuroki, H. Mori, M. Ogata, S. Uji, and J. Wosnitza: J. Phys. Soc. Jpn. **81**, 011004-1-27 (2012).

- 2014 Highly Cited Article in J. Phys. Soc. Jpn."Crossover between BCS Superconductor and Doped Mott Insulator of d-wave Pairing State in Two-Dimensional Hubbard Model" by H. Yokoyama, M. Ogata, Y. Tanaka, K. Kobayashi, and H. Tsuchiura: J. Phys. Soc. Jpn. **82**, 014707-1-16 (2013).

- 2016 Highly Cited Article in J. Phys. Soc. Jpn.“Orbital Magnetism of Bloch Electrons I. General Formula” by M. Ogata and H. Fukuyama: J. Phys. Soc. Jpn. **84**, 124708-1-13 (2015).

- JPSJ Outstanding Referee: Masao Ogata, March 2015.

- JPSJ Papers of Editors' Choice “Effect of Phonon Drag on Seebeck Coefficient Based on Linear Response Theory: Applications to $FeSb_2$” by H. Matsuura, H. Maebashi, M. Ogata and H. Fukuyama: J. Phys. Soc. Jpn. **88**, 074601 (2019).

5 Research Plan

Future research plans are as follows.

• Linear Response Theory and its Extention

Recently we have been studying general orbital- and spin-susceptibility and thermoelectric transport properties using linear response theory. These are rather orthodox methods, but we found that there are many unsolved problems, for example, the Berry curvature contribution to orbital magnetic susceptibility and the violation of Mott formula. Even if we do not include strong correlation, one-body problem in Dirac or Weyl electron systems gives various unexpected phenomena, such as large diamagnetism, spin-Hall effect and magnetoresistance which is linear as a function of magnetic field. Thus we would like to continue the research of exotic phenomena based on the general framework of the linear response theory. This topics include multiferroic responses, contribution from multipole order parameters, spintronics, spin current, etc. We will make collaboration with experimental groups on the topics like excitonic insulator (with Takagi's group), antiferromagnetic spintronics (with Nakatsuji's group), and spin current, spin Hall effects (with Hayashi's group).

• Dirac and Weyl Fermions in Solids:

We have been studying various properties of Dirac and Weyl electron systems, and we will continue to search for exotic states. It has been understood that Dirac fermions appear quite often in various solids including bulk bismuth, two-dimensional graphene, quasi-two-dimensional organic conductors, and surface states of topological insulators. Each field of research is fertile itself. For example, we would like to study occurrence condition and stability condition of Dirac electrons. In some organic materials, there is a phase transition from non-Dirac phase to Dirac phase, and thus it is interesting to study such phase transition. Furthermore, it is worthwhile to study the phenomena induced by strong spin-orbit coupling in Dirac systems, for example, spin current induced by photon, multiferroic, spin Hall effect, relaxation of spin current, etc.

• Strongly Correlated Electron Systems:

We would like to continue the research of strongly correlated electron systems. At present, our group is not so much involved in this problem. But if there are interesting problems, we would like to continue to try new ideas and to pursue new techniques for understanding the deep nature of electron correlations. For example, it is worthwhile to try new states for the pseudo-gap phase observed in high-T_c superconductors.

There is a group of materials of organic conductors in low (one- or two-) dimensions which show superconductivity, magnetism, metal-insulator transition, Dirac electron systems, nodal line states and so on. In these systems, not only the spin degrees of freedom but also the charge degrees of freedom play important roles that lead to new exotic states. Therefore, it will be an interesting problem to study the interplay between strong correlation and Dirac electrons. Furthermore, by starting from the organic conductors, I think we can approach bio-materials in a viewpoint of electron systems.

We would like to continue research on unconventional superconductivity and exotic magnetism, since new materials and new phenomena will be discovered continuously. For example, when there are several interactions competing with each other, frustration occurs in spin or charge degrees of freedom. In such cases, frustration will lead to large quantum fluctuations which eventually may give novel states, including unconventional superconductivity, spin liquid state and so on.

6 Publications and Patents

< Refereed Original Papers >

[1] H. Yang, Z. Wang, D. Fang, T. Kariyado, G. Chen, M. Ogata, T. Das, A. V. Balatsky, and Hai-Hu Wen: Phys. Rev. B **86**, 214512-1-8 (2012). "Unexpected weak spatial variation of local density of states induced by individual Co impurity atoms in $Na(Fe_{1-x}Co_x)As$ crystals revealed by scanning tunneling spectroscopy"

[2] T. Kariyado and M. Ogata: J. Phys. Soc. Jpn. **81**, 064701-1-11 (2012). "Low-Energy Effective Hamiltonian and the Surface States of Ca_3PbO"

[3] Y. Fuseya, M. Ogata and H. Fukuyama: J. Phys. Soc. Jpn. **81**, 013704-1-4 (2012). "Spin-Polarization in Magneto-Optical Conductivity of Dirac Electrons"

[4] Y. Fuseya, M. Ogata and H. Fukuyama: J. Phys. Soc. Jpn. **81**, 093704-1-4 (2012). "Spin-Hall Effect and Diamagnetism of Dirac Electrons"

[5] H. Matsuura, K. Miyake, and H. Fukuyama: J. Phys. Soc. Jpn. **81**, 095001-1-2 (2012). "Antiferromagnetic Exchange Interaction between Electrons on Degenerate LUMOs in Benzene Dianion"

[6] H. Matsuura, M. Ogata, K. Miyake, and H. Fukuyama: J. Phys. Soc. Jpn. **81**, 104705-1-8 (2012). "Theory of Mechanism of π-d interaction in Iron-Phthalocyanine"

[7] H. Matsuura, and K. Miyake: J. Phys. Soc. Jpn. **81**, 113705-1-4 (2012). "Theory of Charge Kondo Effect on Pair Hopping Mechanism" (selected as JPSJ editors' choice)

[8] T. Kanao, H. Matsuura, and M. Ogata: J. Phys. Soc. Jpn. **81**, 063709-1-4 (2012). "Theory of Defect-Induced Kondo Effect in Graphene: Numerical Renormalization Group Study"

[9] N. Arakawa and M. Ogata: Phys. Rev. B **86**, 1251261-1-15 (2012). "Origin of the heavy fermion behavior in $Ca_{2-x}Sr_xRuO_4$: Roles of Coulomb interacion and the rotation of RuO_6 octahedra"

[10] H. Yokoyama, M. Ogata, Y. Tanaka, K. Kobayashi, and H. Tsuchiura: J. Phys. Soc. Jpn. **82**, 014707-1-16 (2013). "Crossover between BCS Superconductor and Doped Mott Insulator of d-wave Pairing State in Two-Dimensional Hubbard Model"

[11] I. Proskurin, and M. Ogata: J. Phys. Soc. Jpn. **82**, 063712-1-4 (2013). "Thermoelectric Transport Coefficients for Massless Dirac Electrons in Quantum Limit"

[12] H. Matsuura and K. Miyake: J. Phys. Soc. Jpn. **82**, 063709-1-4 (2013). "Effect of Spin-Orbit Interaction on $(4d)^3$- and $(5d)^3$-Based Oxides"

[13] N. Arakawa and M. Ogata: Phys. Rev. B **87**, 195110-1-11 (2013). "Competition between spin fluctuations in $Ca_{2-x}Sr_xRuO_4$ around $x = 0.5$"

[14] Y. Suzumura, I. Proskurin, and M. Ogata: J. Phys. Soc. Jpn. **83**, 023701-1-4 (2014). "Effect of Tilting on the In-Plane Conductivity of Dirac Electrons in Organic Conductor"

[15] H. Matsuura and M. Ogata: J. Phys. Soc. Jpn. **83**, 063701-1-4 (2014). "A Poorman's Derivation of of Quantum Compass-Heisenberg Interaction: Superexchange Interaction in J-J Coupling Scheme"

[16] Y. Suzumura, I. Proskurin, and M. Ogata: J. Phys. Soc. Jpn. **83**, 094705-1-9 (2014). "Dynamical Conductivity of Dirac Electrons in Organic Conductors"

[17] Y. Fuseya, M. Ogata, and H. Fukuyama: J. Phys. Soc. Jpn. **83**, 074702-1-11 (2014). "Spin-Hall Effect and Diamagnetism of Anitostopic Dirac Electrons in Solids"

[18] N. Okuma and M. Ogata: J. Phys. Soc. Jpn. **84**, 034710-1-4 (2015). "Long-Range Coulomb Interaction Effects on the Surface Dirac Electron System of a Three-Dimensional Topological Insulator"

[19] Y. Fujimoto, K. Miyake, and H. Matsuura: J. Phys. Soc. Jpn. **84**, 043702-1-5 (2015). "Deformation of the Fermi Surface and Anomalous Mass Renormalization by Critical Spin Fluctuations through Asymmetric Spin-Orbit Interaction"

[20] M. Ogata and H. Fukuyama: J. Phys. Soc. Jpn. **84**, 124708-1-13 (2015). "Orbital Magnetism of Bloch Electrons I. General Formula"

[21] I. Proskurin, M. Ogata, and Y. Suzumura: Phys. Rev. B **91**, 195413-1-14 (2015). "Longitudinal conductivity of massless fermions with tilted Dirac cone in magnetic field"

[22] Y. Fujimoto, K. Miyake, and H. Matsuura: J. Phys. Soc. Jpn. **84**, 043702-1-5 (2015). "Deformation of the Fermi Surface and Anomalous Mass Renormalization by Critical Spin Fluctuations through Asymmetric Spin-Orbit Interaction"

[23] T. Mizoguchi and M. Ogata: J. Phys. Soc. Jpn. **84**, 084704-1-7 (2015). "Meissner Effect of Dirac Electrons in Superconducting State due to Inter-band Effect"

[24] H. Fukuyama and M. Ogata: J. Phys. Soc. Jpn. **85**, 023702-1-3 (2016). "Solitons in the Crossover between Band Insulator and Mott Insulator: Application to TTF-Chloranil under Pressure"

[25] T. Mizoguchi and N. Arakawa: Phys. Rev. B **93**, 041304(R) (2016). "Controlling spin Hall effect by using a band anti crossing and nonmagnetic impurity scattering"

[26] M. Ogata: J. Phys. Soc. Jpn. **85**, 064709-1-11 (2016). "Orbital Magnetism of Bloch Electrons: II. Application to Single-Band Models and Corrections to Landau-Peierls Susceptibility"

[27] M. Ogata: J. Phys. Soc. Jpn. **85**, 104708-1-10 (2016). "Orbital Magnetism of Bloch Electrons: III. Application to Graphene"

[28] H. Yokoyama, S. Tanuma and M. Ogata: J. Phys. Soc. Jpn. **85**, 124707-1-21 (2016). "Staggered Flux State in Two-Dimensional Hubbard Model"

[29] H. Matsuura and M. Ogata: J. Phys. Soc. Jpn. **85**, 074709-1-6 (2016). "Theory of Orbital Susceptibility in the Tight-Binding Model: Corrections to the Peierls Phase"

[30] H. Matsuura and M. Ogata: J. Phys. Soc. Jpn. **85**, 093701-1-4 (2016). "Theory of Orbital Susceptibility on Excitonic Insulator"

[31] T. Mizoguchi, K. Hwang, K.-H. Lee, and Y. B. Kim: Phys. Rev. B **94**, 064416 (2016). "Generic model for the hyperkagome iridate in the local-moment regime"

[32] N. Okuma and M. Ogata: Phys. Rev. B **93**, 140205-1-4 (2016). "Unconventional Spin Hall Effect and Axial Current Generation in a Dirac Semimetal"

[33] N. Yoshioka, H. Matsuura, and M. Ogata: J. Phys. Soc. Jpn. **85**, 064712-1-6 (2016). "Quantum Hall Effect of Massless Dirac Fermions and Free Fermions in Hofstadter's Butterfly"

[34] T. Shibuya, H. Matsuura, and M. Ogata: J. Phys. Soc. Jpn. **85**, 114701-1-4 (2016). "Magnetic Chirality Induced from RKKY Interaction at an Interface of a Ferromagnet/Heavy Metal Heterostructure"

[35] Y. Tanaka and M. Ogata: J. Phys. Soc. Jpn. **85**, 104706-1-6 (2016). "Correlation Effects on Charge Order and Zero-Gap State in the Organic Conductor α-(BEDT-TTF)$_2$I$_3$"

[36] M. Ogata: J. Phys. Soc. Jpn. **86**, 044713-1-18 (2017). "Theory of Magnetization in Bloch Electron Systems"

[37] N. Okuma and K. Nomura: Phys. Rev. B **95**, 115403-1-8 (2017). "Microscopic derivation of magnon spin current in topological insulator/ ferromagnet heterostructure"

[38] T. Hirosawa, H. Maebashi, and M. Ogata: J. Phys. Soc. Jpn. **86**, 063705-1-5 (2017). "Nuclear Spin Relaxation Time Due to the Orbital Currents in Dirac Electron Systems"

[39] H. Maebashi, M. Ogata, and H. Fukuyama: J. Phys. Soc. Jpn. **86**, 083702-1-4 (2017). "Lorentz Covariance of Dirac Electrons in Solids: Dielectric and Diamagnetic Properties"

[40] T. Mizoguchi, L. D. C. Jaubert, and M. Udagawa: Phys. Rev. Lett. **119**, 077207 (2017). "Clustering of Topological Charges in a Kagome Classical Spin Liquid"

[41] N. Okuma: Phys. Rev. Lett. **119**, 107205-1-6 (2017). "Magnon Spin-Momentum Locking: Various Spin Vortices and Dirac magnons in Noncollinear Antiferromagnets"

[42] T. Kariyado and M. Ogata: Phys. Rev. Materials **1**, 061201(R) (2017). "Evolution of Band Topology by Competing Band Overlap and Spin-Orbit Coupling: Twin Dirac Cones in Ba_3SnO as a Prototype"

[43] M. Ogata and H. Fukuyama: J. Phys. Soc. Jpn. **86**, 094703-1-5 (2017). "Theory of Spin Seebeck Effects in a Quantum Wire"

[44] H. Fukuyama, J. Kishine, and M. Ogata: J. Phys. Soc. Jpn. **86**, 123706-1-5 (2017). "Energy Landscape of Charge Excitations in the Boundary Region between Dimer-Mott and Charge Ordered States in Molecular Solids"

[45] K. Tokushuku, J. Kishine and M. Ogata: J. Phys. Soc. Jpn. **86**, 124701-1-6 (2017). "Tunable Spin Dynamics in Chiral Soliton Lattice"

[46] A. Bolens, H. Katsura, M. Ogata, and S. Miyashita: Phys. Rev. B **95**, 235115 (2017). "Synergetic effect of spin-orbit coupling and Zeeman splitting on the optical conductivity in the one-dimensional Hubbard model"

[47] N. Okuma, M. R. Masir and A. H. MacDonald: Phys. Rev. B **95**, 165418 (2017). "Theory of the spin-Seebeck effect at a topological-insulator/ ferromagnetic-insulator interface"

[48] V. Könye and M. Ogata: Phys. Rev. B **98**, 195420 (2018). "Magnetoresistance of a three-dimensional Dirac gas"

[49] Y. Suzumura and M. Ogata: Phys. Rev. B **98**, 161205(R) (2018). "Role of acoustic phonons in exotic conductivity of two-dimensional Dirac electrons"

[50] M. Hosoi, H. Matsuura, M. Ogata: J. Phys. Soc. Jpn. **87**, 075001 (2018). "New Magnetic Phases in the Chiral Magnet $CsCuCl_3$ under High Pressures"

[51] T. Hinokihara: J. Phys. Soc. Jpn. **87**, 074705 (2018). "Slave Boson Analysis of f^2-Configuration Systems with Γ_1 Singlet Crystalline-Electric-Field Ground State under the Cubic Symmetry"

[52] I. Tateishi, H. Matsuura: J. Phys. Soc. Jpn. **87**, 073702 (2018). "Face Centered Cubic SnSe as a Z_2 Trivial Dirac Nodal Line Material"

[53] A. Bolens, H. Katsura, M. Ogata, and S. Miyashita: Phys. Rev. B **97**, 161108(R) (2018). "Mechanism for sub-gap optical conductivity in honeycomb Kitaev materials"

[54] I. Tateishi, N. T. Cuong, C. A. S. Moura, M. Cameau, R. Ishibiki, A. Fujino, S. Okada, A. Yamamoto, M. Araki, S. Ito, S. Yamamoto, M. Niibe, T. Tokushima, D. E. Weibel, T. Kondo, M. Ogata, and I. Matsuda: Phys. Rev. Materials **3**, 024004 (2019). "Semi-metallicity of free-standing hydrogenated monolayer boron from MgB_2"

[55] Y. Togawa, J. Kishine, P. A. Nosov, T. Koyama, G. W. Paterson, S. McVitie, Y. Kousaka, J. Akimitsu, M. Ogata, and A. S. Ovchinnikov: Phys. Rev. Lett. **122**, 017204 (2019). "Anomalous Temperature Behavior of the Chiral Spin Helix in $CrNb_3S_6$ Thin Lamellae"

[56] M. Hosoi, T. Mizoguchi, T. Hinokihara, H. Matsuura, and M. Ogata: arXiv:1804.04874. "Dzyaloshinskii-Moriya Interaction between Multipolar Moments in $5d^1$ Systems"

[57] H. Maebashi, T. Hirosawa, M. Ogata, and H. Fukuyama: J. Phys. Chem. Solids **128**, 138-143 (2019). "Nuclear Magnetic Relaxation and Knight Shift Due to Orbital Interaction in Dirac Electron Systems"

[58] M. Ogata and H. Fukuyama, J. Phys. Soc. Jpn. **88**, 075703 (2019). "Range of Validity of Sommerfeld-Bethe Relation Associated with Seebeck Coefficient and Phonon Drag Contribution"

[59] H. Matsuura, H. Maebashi, M. Ogata, and H. Fukuyama: J. Phys. Soc. Jpn. **88**, 075601 (2019). "Effect of Phonon Drag on Seebeck Coefficient Based on Linear Response Theory: Application to $FeSb_2$"

[60] V. Könye and M. Ogata: Phys. Rev. B **100**, 155430 (2019). "Thermoelectric transport coefficients of a Dirac electron gas in high magnetic fields"

[61] N. T. Cuong, I. Tateishi, M. Cameau, M. Niibe, N. Umezawa, B. Slater, K. Yubata, T. Kondo, M. Ogata, S. Okada, and I. Matsuda: preprint. "Topological Dirac nodal loops in non-symmorphic hydrogenerated monolayer boron"

[62] Y. Suzumura, T. Tsumuraya, R. Kato, H. Matsuura, and M. Ogata, J. Phys. Soc. Jpn. **88**, 124704 (2019). "Role of velocity field and principal axis of tilted Dirac cones in effective Hamiltonian of non-coplanar nodal loop"

＜ **Conference Proceedings** ＞

[63] N. Okuma and M. Ogata: J. Phys.: Conf. Ser. **603**, 012018-1-7 (2015). "Study of spin transport in Dirac systems"

[64] Other 20 papers.

＜ **Review Papers** ＞

[65] M. Ogata: Physica C **481**, 125-131 (2012). "Stripe states in t-t'-J model from a variational viewpoint"

[66] Y. Fuseya, M. Ogata, and H. Fukuyama: (invited review article) J. Phys. Soc. Jpn. **84**, 012001-1-22 (2015). "Transport Phenomena and Diamagnetism of Dirac Electrons in Bismuth"

[67] A. Ardavan, S. Brown, S. Kagoshima, K. Kanoda, K. Kuroki, H. Mori, M. Ogata, S. Uji, and J. Wosnitza: J. Phys. Soc. Jpn. **81**, 011004-1-27 (2012). "Recent Topics of Organic Superconductors"

[68] Y. Fuseya, M. Ogata, and H. Fukuyama, (in Japanese). "Theory of Dirac electrons in Bismuth" 伏屋雄紀、小形正男、福山秀敏：固体物理 **47**, 193-205 (2012). "ビスマスにおけるディラック電子の理論"

[69] H. Matsuura and K. Miyake, (in Japanese). "Kondo effect and superconductivity in the valence-skipping phenomena" 松浦弘泰、三宅和正：固体物理 **48**, no. 8 (2013). "原子価スキッピング現象における近藤効果と超伝導"

[70] H. Watanabe and M. Ogata, (in Japanese) "Searching for a frustrated liquid state with three states without order or gap" 渡部 洋、小形正男： 日本物理学会誌 **69**, 130 (2014). "秩序なし＋ギャップなしのドロドロ三つ巴液体状態を求めて"

[71] H. Matsuura and K. Miyake, (in Japanese). "Cooperation of spin-orbit interaction and many body effects" 松浦弘泰、三宅和正: 固体物理 **51**, No. 2 (2016). "スピン軌道相互作用と多体効果の協奏"

[72] M. Ogata and H. Matsuura, (in Japanese) "Revisit to the magnetism of electrons in solids: a unified theory" 小形正男、松浦弘泰: 固体物理 **52**, No. 10 (2017). "固体中電子の磁性再考：大統一理論"

＜ **Books** ＞

[73] M. Ogata, (in Japanese) "Field Theory and Green's Functions for Condensed-Matter — How do we solve quantum many-body systems? " (2018) 小形正男：『物性物理のための場の理論・グリーン関数 — 量子多体系をどう解くか？』臨時別冊・数理科学 SGC ライブラリ 142 (サイエンス社).

[74] (part of the book in Japanese) "Physics of Molecular Materials — New trend in condensed-matter —" (2015). (共著)『分子性物質の物理 — 物性物理の新潮流 —』（鹿野田一司、宇治進也 編著）朝倉書店

7 Invited Presentations at International Conferences

[1] M. Ogata, Y. Fuseya, and H. Fukuyama: 12th Japanese-German Symposium "Emergent Phenomena in Novel Quantum Phases of Condensed Matter" (Shuzenji, Japan, July 14–17, 2012) "Spin Hall effect and large diamagnetism in bismuth"

[2] M. Ogata and T. Kariyado: Conference of Materials and Mechanisms of Superconductivity 2012 (M2S 2012) (Washington D.C. July 29–August 3, 2012) "Impurity bound-state as a prove of order-parameter symmetry in Iron-Pnictide superconductors"

[3] M. Ogata and H. Yokoyama: "Superconductivity research advanced by new materials and spectroscopies" (Sendai, July 23–25, 2013) "Superconductivity in the Hubbard model near the Mott insulator"

[4] M. Ogata, Y. Fuseya, and H. Fukuyama: Workshop on Quantum Materials (MPI, Stuttgart, December 9–11, 2013) "Spin Hall effect and large diamagnetism in Dirac electrons in Bismuth"

[5] M. Ogata: RIKEN-APW joint workshop "Highlights in condensed matter physics" (RIKEN, Wako, January 23–25, 2014) "Spin Hall effect and large diamagnetism in Dirac electrons in Bismuth"

[6] H. Matsuura: Trends in Theory of Correlated Materials 2013 (EPFL, Lausanne, Swiss, October 2–5, 2013) "Derivation of Dzyloshinskii-Moriya Interaction on Metallic Chiral Magnet $CrNb_3S_6$"

[7] M. Ogata and H. Yokoyama: ISSP international workshop and symposium "New Horizon of Strongly Correlated Physics" (NHSCP2014) (ISSP, June 16–July 4, 2014). "Crossover between BCS superconductor and doped Mott insulator, and possible normal states in the two-dimensional Hubbard model"

[8] M. Ogata, H. Yokoyama, and S. Tamura: International conference on strongly correlated electron systems (SCES 2014) (Grenoble, France, July 7–11 2014). "Crossover between BCS superconductor and doped Mott insulator in the two-dimensional Hubbard model"

[9] M. Ogata, H. Yokoyama, and S. Tamura: International Workshop "Research Frontier of Transition-metal Compounds Opened by Advanced Spectroscopies" (Sendai, Sep.30–Oct.2, 2014). "Superconductivity and flux state in the Hubbard model"

[10] M. Ogata and H. Yokoyama: YITP Long-term Workshop "Novel Quantum States in Condensed Matter" (NQS 2014) (Kyoto, November 4–December 4, 2014). "High-T_c superconductivity from the Hubbard model"

[11] Y. Fuseya: NQS 2014. "Anomalously large spin-magnetic moment and its transport properties of Dirac electrons in bismuth"

[12] H. Matsuura: 1st RIKEN-Sophia Joint Symposium: Recent Progresses on the Muon-Site Estimation (Tokyo, Dec 15–16, 2014). "Effect of Defect on Dirac Electron Systems"

[13] Y. Fuseya: American Physical Society March meeting 2015, (Mar. 5, 2015). "Spin Hall effect and Landau spectrum of Dirac electrons in bismuth"

[14] Y. Fuseya: ISSP workshop "Topological Aspects in Correlated Electron Systems" (ISSP, March 26, 2015). "Spin Hall Effect and Large Anisotropic g-Factor of Bismuth"

[15] M. Ogata and H. Yokoyama: Martin Gutzwiller's Scientific Universe: From Wavefunctions over Periodic Orbits to Sun, Moon and Earth (Dresden, Germany, October 28–31, 2015). "Crossover between BCS Superconductivity and Doped Mott Insulator in Two-Dimensional Hubbard Model"

[16] M. Ogata, Y. Fuseya and H. Fukuyama: Hong Kong Forum of Physics 2015 "Novel Quantum States and Their Manipulations" (Hong Kong, January 10–12, 2016). "Spin Hall effect and large diamagnetism in Dirac electrons in solids"

[17] M. Ogata, Y. Fuseya and H. Fukuyama: Tsinghua-UTokyo Workshop on Recent Topics in Materials Physics, Science and Engineering (Tokyo, March 9–11, 2016). "Spin Hall effect and spin-polarization in magneto-optical conductivity of Dirac electrons"

[18] M. Ogata, H. Maebashi, T. Hirosawa, and H. Fukuyama: Int. Workshop on "Frontiers of Research in Quantum Materials" (Stuttgart, December 18–20, 2017) "Charge dynamics of Dirac electrons: Large permittivity, and NMR $1/T_1T$ due to orbital motion"

[19] H. Matsuura: Trend in Theory of Correlated Materials (TTCM2017) (Tsukuba, September 10–13, 2017). "Theory of Orbital Susceptibility in the Tight Binding model: Correction to the Peierls Phase and Application to Excitonic Insulator"

[20] H. Matsuura: RIKEN Symposium Int. Workshop on Organic Molecule Systems (Malaysia, August 1–3, 2017) "Theory of Orbital Susceptibility in the Tight Binding model: Correction to the Peierls Phase and Application to Excitonic Insulator"

[21] M. Ogata (Plenary): 4th International Conference on Functional Materials Science 2018 (ICFMS2018) in conjunction with 2nd RIKEN Symposium International Workshop on Organic Molecular System (Bali, Indonesia, November 12–15, 2018). "Organic Materials as Low-Dimensional Strongly Correlated Electron Systems"

[22] H. Matsuura: Workshop on Thermal and Charge Transport across Flexible Nano-Interfaces (TCTFN2018) (Tokyo Metropolitan University, Japan, November 11–12, 2018). "Effect of Phonon Drag on Seebeck Coefficient Based on Linear Response Theory"

[23] H. Matsuura: 4th ICFMS 2018 in conjunction with 2nd RIKEN Symposium International Workshop on Organic Molecular System (Bali, Indonesia, November 12–15, 2018). "Theory of Magnetic Phase Diagram in Chiral Magnet $CsCuCl_3$ under High Pressures"

[24] M. Ogata: European Materials Research Society 2019 Spting meeting (eMRS 2019) (Nice, France, May 27–31, 2019). "Effect of Phonon Drag on Seebeck Coefficient Based on Linear Response Theory: Application to $FeSb_2$"

[25] H. Matsuura: Swiss-Japan bilateral workshop, Trends in Theory of Correlated Materials (TTCM2019) (Kyoto, Japan, October 2019). "Effect of Phonon Drag on Seebeck Coefficient Based on Linear Response Theory: Application to $FeSb_2$"

[26] M. Ogata: Materials Research Meeting 2019 (MRM2019), (Yokoyama, December 10–14, 2019). "Effect of Phonon Drag on Seebeck Coefficient Based on Linear Response Theory: Application to $FeSb_2$"

8 Teaching Accomplishment

- N. Okuma received “MERIT award” in recognition of excellent achievement in the MERIT program in FY2017. MERIT (統合物質科学リーダー養成プログラム) is “Materials Education Program for the Future Leaders in Research, Industry, and Technology” which was selected to be a Program for Leading Graduate Schools, an initiative launched in 2011 by the Ministry of Education, Culture, Sports, Science and Technology of Japan.

- K. Tokushuku received Poster presentation award in JSPS Core-to-Core Program “Young Scientist Seminar 2015” (November 1-3, 2015). 広島大学キラル物性研究拠点・キラル物性若手の会・秋の学校

- H. Nakata received Poster presentation award in JSPS Core-to-Core Program “Young Scientist Seminar 2015” (November 1-3, 2015).

- N. Okuma received Best Preview Award (among 99 posters) by “Magnon Spin-Momentum Locking: Possible Realization in kagomelattice antiferromagnet” in “International Conference on Topological Materials Science 2017” (May 9-13, 2017, Tokyo Institute of Technology)

9 Contribution to Academic Community

9.1 Editorial Activities

- Editorial board of Journal of Physical Society of Japan, September 1995-present.

- Head Editor of Journal of Physical Society of Japan, September 2004-present.

9.2 Organization of Professional Societies

- Representative of Field No. 8 (strongly correlation) of Physical Society of Japan, 2013-2014. (日本物理学会・領域 8 代表)

- Director of Physical Society of Japan, 2015-2017. (日本物理学会・理事)

- Vice chair of Gender Equality Promotion Committee in Physical Society of Japan, 2013-2015. (日本物理学会・男女共同参画推進委員会・副委員長 2013-2015 (委員 2012-2015)).

- Advisory Board of Yukawa Institute for Theoretical Physics, Kyoto University, 2015-2017, 2019-present. (京都大学・基礎物理学研究所・運営協議会)

- ISSP Advisory Committee Member in Institute for Solid State Physics, University of Tokyo, 2012-present. (東京大学物性研究所・協議会委員)

- Coordinator of Research Group of Solid State Physics in Japan, 2015-2018 (物性委員会幹事)

- Japanese Committee member of APCTP (Asia Pacific Center for Theoretical Physics), 2017-present. (APCTP 日本委員会)

- Member of Muon Science Proposal Review Committee (MSPRC) of J-PARC/MLF, December 2012-present. (J-PARC ミュオン共同利用実験審査委員会)
- Member of Sub-committee of Neutron Science Proposal Review Committee, 2017-present. (中性子分科)
- Member of Proposal Review Committee of Supercomputer Center of Institute for Solid State Physics, The University of Tokyo, April 2012-present.
- Selection Committee member of Sir Martin Wood Prize for Japan, 2019-

9.3 Organization and Advisory of Conferences

- Organizing Committee member of International Symposium on Materials Science Opened by Molecular Degrees of Freedom (MDF2012), (Miyazaki, Japan, December 1-4, 2012).
- Program Committee member of The 12th Asia Pacific Physics Conference (APPC12), (Makuhari, Chiba, July 14-19, 2013).
- Organizing Committee member of the International Conference on Strongly Correlated Electron Systems (SCES'13), (Tokyo, August 5-9, 2013).
- Organizing Committee member of the International Workshop "Novel Quantum States in Condensed Matter 2014" (NQS2014), (Kyoto, Japan, November 4–December 5, 2014).
- Chair of International Workshop on Dirac Electrons in Solids (Koshiba Hall, Tokyo, January 14-15, 2015)
- Organizer (vice chair) of the 14^{th} Bilateral Japanese-German Symposium "Effects of Parity Mixing in Correlated Electron Systems". (Chateraise Gateaux Kingdom, Sapporo, September 26-29, 2016).
- Organizing Committee member of the 12th International Symposium on Crystalline Organic Metals, Superconductors and Magnets (ISCOM2017), (Zao, Miyagi, September 24-29, 2017).
- Organizing Committee member of the International Workshop "Novel Quantum States in Condensed Matter 2017" (NQS2017), (Kyoto, Japan, October 23–November 24, 2017).
- Organizing Committee member of the International Conference on Strongly Correlated Electron Systems (SCES'19), (Okayama, September 23-28, 2019).
- Organizing Committee member and Program Committee member of 29th International Conference on Low Temperature Physics (LT29), (Sapporo, August 15-22, 2020).

10 Outreach

- 2012 Public lectures in Air University on "Quantum Physics (量子物理)" (放送大学における講義)

11 Committee Service

11.1 External Committees

- 男女共同参画合協会連絡会委員（物理学会代表）2012-2015.
- 日本物理学会・領域委員会委員 2017-2019.
- Editor of "Mathematical Sciences", 2013-present. (数理科学 編集委員)
- Planning Committee member of University of Tokyo Press 2015-present. (東京大学出版会・企画委員)

11.2 University Committees

理学部教務委員会委員　2012 年 –2017 年

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	2	Canada, Switzerland
Master Course	1	Germany
Doctor Course	1	Hungary
Foreign researchers hosted	2	Russia, Iran
Students sent abroad	8	Canada ×3, USA, Switzerland ×2, Germany, France
Researchers sent abroad	2	USA ×2
Foreign visitors	11	Canada, USA, Switzerland, Sweden

Synge Todo、藤堂 眞治

1 Education and Professional Experiences

Education

1991	B.S. (Physics)	The University of Tokyo
1993	MSc. (Physics)	The University of Tokyo
1996	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1996−1996	PostDoc Researcher	Institute for Solid State Physics, The University of Tokyo
1996−2002	Assistant Professor	Institute for Solid State Physics, The University of Tokyo
2000−2002	PostDoc Researcher	Theoretische Physik, ETH Zürich
2002−2011	Lecturer	Department of Applied Physics, The University of Tokyo
2011−2014	Project Professor	Institute for Solid State Physics, The University of Tokyo
2014−2018	Associate Professor	Department of Physics, The University of Tokyo
2014−2018	Associate Professor	Institute for Solid State Physics, The University of Tokyo (joint appointment)
2015−2017	Invited Researcher	National Institute for Materials Science (joint appointment)
2017−	NIMS Special Researcher	National Institute for Materials Science (joint appointment)
2018−	Professor	Department of Physics, The University of Tokyo
2018−	Professor	Institute for Solid State Physics, The University of Tokyo (joint appointment)
2018−	Professor	Mathematics and Informatics Center, The University of Tokyo (joint appointment)

2 Research Highlights

We are exploring novel methods in computational physics based on stochastic method such as the Monte Carlo simulation, path-integral representation of quantum fluctuations, information compression by using the singular value decomposition and the tensor network, statistical machine learning, etc. By making full use of these powerful numerical methods, we aim to elucidate various exotic phases, phase transitions, and dynamics specific to quantum many-body systems, from strongly correlated systems such as the spin systems and the Bose-Hubbard model to real materials. We are also researching parallelization methods for leading-edge supercomputers, and developing and releasing open-source software for next-generation physics simulations.

2.1 Development of simulation algorithms for strongly-correlated many-body systems

Markov-chain Monte Carlo (MCMC) without detailed balance: We have developed a general method for constructing transition probabilities that do not satisfy the detailed balance, and showed that the autocorrelation time is reduced greatly compared to the conventional Metropolis method [29, 34, 36, 38]. Energy gap estimation: We have developed a method to calculate gap and spin wave velocity by MCMC. We have successfully measured the Haldane gap of the $S = 4$ Heisenberg antiferomagnetic chain by combining the gap estimation with the parallel loop algorithm [10, 12, 28, 37]. Topological order: We have developed a method to calculate the local Z_N Berry phase that characterize the topological order in quantum spin systems [4, 26, 40].

2.2 Application of machine learning (ML) technique to materials science

ML for molecular dynamics (MD): Most of the many-body techniques are computationally too costly for MD simulations. We showed that ML can be effective for building fast, linear-scaling MD potentials that capture correlated electron physics [32]. Crystal structure prediction: We propose an efficient theoretical scheme for structure prediction on the basis of the idea of data assimilation, which optimizes the energy by the first-principles calculation and experimental data simultaneously. We demonstrate this method for polymorphs of SiO_2 [21, 30].

2.3 Novel state and critical phenomena in strongly correlated systems

Deconfined criticality: We have examined the J-Q model by using quantum Monte Carlo simulation. We observed a critical exponent indicating a deconfined criticality, but the exponent was systematically shifted as the size increased. From the critical exponent of the finite temperature phase transition, there is no crossover to the first-order transition toward absolute zero, which strongly supports the deconfined criticality scenario [6, 9]. Kitaev materials: We show that the ground state of the quantum Kitaev model can be expressed with high accuracy by the tensor network representation called string gas. We discussed various magnetic ordered states stabilized in the vicinity of Na_2IrO_3 [17]. Field-induced magnetic order: We have revealed that a large quantum fluctuation occurs in the vicinity of half the saturation magnetization in square lattice Heisenberg magnet with frustrated interactions. Furthermore, we found that in the kagomé lattice antiferromagnet, multiple magnetization plateaus were generated in the magnetic field [18, 23, 31]. Long-range interaction: We simulated a two-dimensional square lattice Ising model with algebraically decaying long-range interaction using the order-N cluster algorithm and evaluated the critical exponent, and establish the phase boundary precisely [13]. Strongly anisotropic system: We have developed a new method that combines quantum Monte Carlo with stochastic optimization. Our method automatically adjusts various parameters including the system aspect ratio during simulation. Not only the critical point is automatically determined, but also the critical amplitude and spin wave velocity can be calculated with high accuracy [7, 11, 39].

2.4 Cooperative phenomena in non-equilibrium and non-steady states

Optical bistability in cavity system: We develop an efficient numerical method to solve the quantum master equation of microscopic models with photons and two-level atoms. The photon number distribution function and the relaxation timescale show system-size dependences characteristic of the first-order phase transition in equilibrium systems [24]. Non-ergodicity in harmonic oscillators: We propose a new non-ergodic model, which consists of harmonic oscillators. We reconsider the definition of the ergodicity, and clarify that the non-ergodicity observed in our model is caused by the localized mode [27].

2.5 Development of open-source software for next-generation parallel simulations

ALPS is an open source software for the simulation of strongly correlated quantum lattice models such as quantum magnets, and lattice bosons. The programs enable non-experts to start numerical simulations by Monte Carlo, diagonalization, the density matrix renormalization group, and the dynamical mean field theory [14, 45, 48]. We developed a modern quantum lattice model solver HΦ [15, 49]. Finite temperature properties and excitation spectrum can be calculated by the thermal pure quantum state and the shifted Krylov subspace method. We are also developing a portal site of material science simulation MateriApps with the aim of further disseminating and spreading material science applications together with MateriApps LIVE! and MateriApps Installer for environment where simulation can be started easily [41].

3 Selected Papers

- Synge Todo, Hidemaro Suwa, Geometric Allocation Approaches in Markov Chain Monte Carlo, J. Phys.: Conf. Ser. **473**, 012013 (10pp) (2013).
  This paper proposed novel approach to Markov chain Monte Carlo.

- Kenji Harada, Takafumi Suzuki, Tsuyoshi Okubo, Haruhiko Matsuo, Jie Lou, Hiroshi Watanabe, Synge Todo, Naoki Kawashima, Possibility of Deconfined Criticality in SU(N) Heisenberg Models at Small N, Phys. Rev. B **88**, 220408(R) (4pp) (2013).
  This paper investigated one of the most fundamental problems in statistical physics, so-called the deconfined critical phenomena.

- Alexander Gaenko, Andrey E. Antipov, Gabriele Carcassi, Tianran Chen, Xi Chen, Qiaoyuan Dong, Lukas Gamper, Jan Gukelberger, Ryo Igarashi, Sergey Iskakov, Mario Könz, James P. F. LeBlanc, Ryan Levy, Ping Nang Ma, Joseph E Paki, Hiroshi Shinaoka, Synge Todo, Matthias Troyer, Emanuel Gull, Updated Core Libraries of the ALPS Project, Comp. Phys. Comm **213**, 235–251 (2017).
  This paper is about the development of a newer version of ALPS.

- Gia-Wei Chern, Kipton Barros, Zhentao Wang, Hidemaro Suwa, Cristian D. Batista, Semiclassical dynamics of spin density waves, Phys. Rev. B **97**, 035120 (2018).
  The work has been selected as Editors' Suggestion.

- Synge Todo, Haruhiko Matsuo, Hideyuki Shitara, Parallel loop cluster quantum Monte Carlo simulation of quantum magnets based on global union-find graph algorithm, Comp. Phys.

Comm. **239**, 84–93 (2019).
This paper describes one of the largest parallel quantum Monte Carlo simulation on the K computer.

4 Honors, Awards and Professional Society Memberships

4.1 Awards

- Prizes for Science and Technology, The Commendation for Science and Technology by MEXT Japan (April 2019)

4.2 Professional Society Memberships

- Member of Physical Society of Japan

5 Research Plan

Computational scientific approaches as a method for systematic studies of many-body physics have become increasingly important in recent years. New algorithms, including the quantum Monte Carlo methods, tensor networks, and machine learning (ML), have been developed one after another, and are more and more used in the study of strongly correlated systems, such as the quantum spin systems and electron systems. Making full use of these novel algorithms, experiences of parallelization, performance development of the state-of-the-art high-performance computer, such as Fugaku supercomputer, we aim for the development of new computational physics through fundamental and essential achievements that can rewrite textbooks of physics. Not limited to statistical physics and condensed-matter physics, we will actively promote joint research with researchers in various fields of physics, information engineering, and computer science.

Future researches will include new axes such as "physics of quantum computation and quantum communication" in addition to "development of simulation algorithms for strongly-correlated many-body systems", "application of machine learning technique to materials science", "novel state and critical phenomena in strongly correlated systems", "cooperative phenomena in non-equilibrium and non-steady states", and "development of open-source software for next-generation parallel simulations".

5.1 Novel state and critical phenomena in strongly correlated systems

As is clear from the 2016 Nobel Prize in Physics by D. Thouless, D. Haldane, and M. Kosterlitz, topological order and topological excitation are very important in exotic phase transitions and nontrivial quantum states. Various topological order parameters, such as "string order parameter", "plaquette order parameter", and "twisted order parameter", have been proposed for one-dimensional topological states. However, in more than two dimensions, there remain many unsolved problems: existence of "symmetry-protected topological phases", vortices deconfinement in the quantum XY model, quantitative measurements of entanglement spectrum and geometric measure of entanglement. We will develop the basic theory of quantum information from the viewpoint of computational science aiming to elucidate the physical mechanism behind them.

5.2 Development of simulation algorithms for strongly-correlated many-body systems

We will review and deepen the Markov chain Monte Carlo (MCMC) method from the basic principle. We will find the basic principles common to recently proposed MCMC methods, such as the rejection-free MCMC, MCMC without detailed balance, event-chain MCMC, etc, and build a new universal framework that can be applied to a wider range of problems. We develop various new algorithms that take advantage of the characteristics of stochastic processes: perfect annealing and rejection-free Hamiltonian MC, etc. In addition, to solve the “negative sign problem”, which is the largest difficulty in the quantum MC method, we will conduct research on various methods based on unitary transformation, hybrid methods with tensor networks, etc. Regarding the tensor network algorithms, based on the ATRG (Anisotropic Tensor Renormalization Group) method we recently proposed, we will work on the development of methods for finite-temperature, high-dimensional frustrated quantum spin systems and fermion systems, and for dynamic structure factors.

5.3 Application of machine learning technique to materials science

In parallel with application research such as material exploration by machine learning, crystal/surface/interface structure prediction, coupling constant estimation, etc., we study extraction of physical principles from deep learning results, distributed processing in deep learning, optimization based on physics, machine learning using tensor networks, etc. In addition, by collaborating with researchers in the field of information science, we promote large-scale parallelization of data-scientific methods, such as singular value decomposition, wavelet basis, sparse modeling, and semi-definite programming have come to be used in computational physics simulations, and apply them to wider fields.

5.4 Cooperative phenomena in non-equilibrium and non-steady states

The generalized Langevin equation incorporating the memory effect has attracted much attention, and its application to polymer systems and quantum open systems has been discussed. In experiments and simulations of molecular dynamics, the power-law autocorrelation of random forces is universally observed. However, there is not enough understanding about what causes this universality. By using the long-term simulation of particle systems and spin systems, we discuss the classification of dynamics into universality classes and violation of ergodicity. We also study the relaxation of classical integrable systems and the effects of perturbation from the viewpoint of prethermalization. In addition, we will improve the method of quantum master equation for dissipative quantum systems and aim to understand the dynamics of resonator systems from a microscopic degrees of freedom.

5.5 Physics of quantum computation and quantum communication

We will develop simulation methods of quantum gates including the effects of dissipation and decoherence based on the quantum master equation to establish a quantum computer evaluation method. In addition, we will work on the possibility of quantum memory using composite qubits composed of the diamond NV center and the surrounding carbon isotopes, their operability, and machine learning of coupling constants and the initial state. In addition, with the application of quantum simulation to strongly correlated electron systems in mind, we develop fundamental algorithms for quantum gate design and quantum circuit optimization, and evaluate them on classical computers as well as on real quantum computers.

6 Publications and Patents

< Refereed Original Papers >

[1] T. Nakada, T. Mori, S. Miyashita, M. Nishino, S. Todo, W. Nicolazzi, P. A. Rikvold, Critical temperature and correlation length of an elastic interaction model for spin-crossover materials, Phys. Rev. B **85**, 054408 (8pp) (2012).

[2] J. Nasu, S. Todo, S. Ishihara, Ordering and Excitation in Orbital Compass Model on a Checkerboard Lattice, Phys. Rev. B **85**, 205141 (12pp) (2012).

[3] J. S. M. Anderson, M. Nakata, R. Igarashi, K. Fujisawa, M. Yamashita, The second-order reduced density matrix method and the two-dimensional Hubbard model, Computational and Theoretical Chemistry **1003**, 22–27 (2013).

[4] Yuichi Motoyama, Synge Todo, Path-integral Monte Carlo method for the local Z_2 Berry phase, Phys. Rev. E **87**, 021301(R) (5pp) (2013).

[5] H. Nakano S. Todo, T. Sakai, Long-Range Order of the Three-Sublattice Structure in the $S = 1$ Heisenberg Antiferromagnet on the Spatially Anisotropic Triangular Lattice, J. Phys. Soc. Jpn. **82**, 043715 (5pp) (2013).

[6] Kenji Harada, Takafumi Suzuki, Tsuyoshi Okubo, Haruhiko Matsuo, Jie Lou, Hiroshi Watanabe, Synge Todo, Naoki Kawashima, Possibility of Deconfined Criticality in SU(N) Heisenberg Models at Small N, Phys. Rev. B **88**, 220408(R) (4pp) (2013).

[7] Shinya Yasuda, Synge Todo, Monte Carlo simulation with aspect ratio optimization: Anomalous anisotropic scaling in dimerized antiferromagnet, Phys. Rev. E **88**, 061301(R) (5pp) (2013).

[8] Akiko Masaki, Takafumi Suzuki, Kenji Harada, Synge Todo, Naoki Kawashima, Parallelized Quantum Monte Carlo Algorithm with Nonlocal Worm Updates, Phys. Rev. Lett. **112**, 140603 (5pp) (2014).

[9] Takafumi Suzuki, Kenji Harada, Haruhiko Matsuo, Synge Todo, Naoki Kawashima, Thermal Phase Transition of Generalized Heisenberg Models for SU(N) Spins on Square and Honeycomb Lattices, Phys. Rev. B **91**, 094414 (7pp) (2015).

[10] Hidemaro Suwa, Synge Todo, Generalized Moment Method for Gap Estimation and Quantum Monte Carlo Level Spectroscopy, Phys. Rev. Lett. **115**, 080601 (5pp) (2015).

[11] Shinya Yasuda, Hidemaro Suwa, Synge Todo, Stochastic approximation of dynamical exponent at quantum critical point, Phys. Rev. B **92**, 104411 (10pp) (2015).

[12] Arnab Sen, Hidemaro Suwa, Anders W. Sandvik, Velocity of excitations in ordered, disordered, and critical antiferromagnets, Phys. Rev. B **92**, 195145 (2015).

[13] Toshiki Horita, Hidemaro Suwa, Synge Todo, Upper and lower critical decay exponents of Ising ferromagnet with long-range interaction, Phys. Rev. E **95**, 012143 (11pp) (2017).

[14] Alexander Gaenko, Andrey E. Antipov, Gabriele Carcassi, Tianran Chen, Xi Chen, Qiaoyuan Dong, Lukas Gamper, Jan Gukelberger, Ryo Igarashi, Sergey Iskakov, Mario Könz, James P. F. LeBlanc, Ryan Levy, Ping Nang Ma, Joseph E Paki, Hiroshi Shinaoka, Synge Todo, Matthias Troyer, Emanuel Gull, Updated Core Libraries of the ALPS Project, Comp. Phys. Comm **213**, 235–251 (2017).

[15] Mitsuaki Kawamura, Kazuyoshi Yoshimi, Takahiro Misawa, Youhei Yamaji, Synge Todo, Naoki Kawashima, Quantum Lattice Model Solver $\mathcal{H}\Phi$, Comp. Phys. Comm **217**, 180–192 (2017).

[16] Yu-Chin Tzeng, Hiroaki Onishi, Tsuyoshi Okubo, Ying-Jer Kao, Quantum phase transitions driven by rhombic-type single-ion anisotropy in the S = 1 Haldane chain, Phys. Rev. B **96**, 060404(R) (2017).

[17] Tsuyoshi Okubo, Kazuya Shinjo, Youhei Yamaji, Naoki Kawashima, Shigetoshi Sota, Takami Tohyama, Masatoshi Imada, Ground-state properties of Na2IrO3 determined from an ab initio Hamiltonian and its extensions containing Kitaev and extended Heisenberg interactions, Phys. Rev. B **96**, 054434 (2017).

[18] Kazuya Nomura, Yasuhiro H. Matsuda, Yasuo Narumi, Koichi Kindo, Shojiro Takeyama,Yuko Hosokoshi, Toshio Ono, Naoya Hasegawa, Hidemaro Suwa, Synge Todo, Magnetization process of the S = 1/2 two-leg organic spin-ladder compound BIP-BNO, J. Phys. Soc. Jpn. **86**, 104713 (3pp) (2017).

[19] Gia-Wei Chern, Kipton Barros, Zhentao Wang, Hidemaro Suwa, Cristian D. Batista, Semiclassical dynamics of spin density waves, Phys. Rev. B **97**, 035120 (2018).

[20] Shohei Hayashida, Hajime Ishikawa, Yoshihiko Okamoto, Tsuyoshi Okubo, Zenji Hiroi, Maxim Avdeev, Pascal Manuel, Masato Hagihala, Minoru Soda, Takatsugu Masuda, Magnetic state selected by magnetic dipole interaction in the kagome antiferromagnet NaBa2Mn3F11, Phys. Rev. B **97**, 054411 (2018).

[21] Naoto Tsujimoto, Daiki Adachi, Ryosuke Akashi, Synge Todo, Shinji Tsuneyuki, Crystal structure prediction supported by incomplete experimental data, Phys. Rev. Materials **2**, 053801 (7pp) (2018).

[22] Lin Hao, D. Meyers, Hidemaro Suwa, Junyi Yang, Clayton Frederick, Tamene R. Dasa, Gilberto Fabbris, Lukas Horak, Dominik Kriegner, Yongseong Choi, Jong-Woo Kim, Daniel Haskel, Philip J. Ryan, Haixuan Xu, Cristian D. Batista, M. P. M. Dean, Jian Liu, Giant magnetic response of a two-dimensional antiferromagnet, Nat. Phys. **14**, 806–810 (2018).

[23] H. Yamaguchi, Y. Sasaki, T. Okubo, M. Yoshida, T. Kida, M. Hagiwara, Y. Kono, S. Kittaka, T. Sakakibara, M. Takigawa, Y. Iwasaki, Y. Hosokoshi, Field-enhanced quantum fluctuation in an $S = 1/2$ frustrated square lattice, Phys. Rev. B **98**, 094402 (6pp) (2018).

[24] Tatsuhiko Shirai, Takashi Mori, Seiji Miyashita, FloquetGibbs state in open quantum systems, Eur. Phys. J. Special Topics **227**, 323–333 (2018).

[25] Tatsuhiko Shirai, Synge Todo, Hans de Raedt, Seiji Miyashita, Optical bistability in a low-photon-density regime, Phys. Rev. A **98**, 043802 (13pp) (2018).

[26] Yuichi Motoyama, Synge Todo, Z_N Berry phase and symmetry protected topological phases of SU(N) antiferromagnetic Heisenberg chain, Phys. Rev. B **98**, 195127 (6pp) (2018).

[27] Fumihiro Ishikawa, Synge Todo, Localized mode and nonergodicity of a harmonic oscillator chain, Phys. Rev. E **98**, 062140 (8pp) (2018).

[28] Synge Todo, Haruhiko Matsuo, Hideyuki Shitara, Parallel loop cluster quantum Monte Carlo simulation of quantum magnets based on global union-find graph algorithm, Comp. Phys. Comm. **239**, 84–93 (2019).

[29] Hiroshi Watanabe, Satoshi Morita, Synge Todo, Naoki Kawashima, Fast algorithm for generating random bit strings and multispin coding for directed percolation, J. Phys. Soc. Jpn. **88**, 024004 (8pp) (2019).

[30] Daiki Adachi, Naoto Tsujimoto, Ryosuke Akashi, Synge Todo, Shinji Tsuneyuki, Search for Common Minima in Joint Optimization of Multiple Cost Functions, Comp. Phys. Comm. **241**, 92–97 (2019).

[31] R. Okuma, D. Nakamura, T. Okubo, A. Miyake, A. Matsuo, K. Kindo, M. Tokunaga, N. Kawashima, S. Takeyama, Z. Hiroi, A series of magnon crystals appearing under ultrahigh magnetic fields in a kagom antiferromagnet, Nat. Comm. **10**, 1229 (7pp) (2019).

[32] Hidemaro Suwa, Justin S. Smith, Nicholas Lubbers, Cristian D. Batista, Gia-Wei Chern, Kipton Barros, Machine learning for molecular dynamics with strongly correlated electrons, Phys. Rev. B **99**, 161107 (5pp) (2019).

＜ **Conference Proceedings** ＞

[33] 片桐孝洋, 大島聡史, 中島研吾, 米村崇, 熊洞宏樹, 樋口清隆, 橋本昌人, 高山恒一, 藤堂眞治, 岩田潤一, 内田和之, 佐藤正樹, 羽角博康, 黒木聖夫, レイテンシコアの高度化・高効率化による将来の HPCI システムに関する調査研究のためのアプリケーションと性能評価, 情報処理学会研究報告 **HPC-137(2)**, 1–12 (2012).

[34] Hidemaro Suwa, Synge Todo, Geometric allocation approach for transition kernel of Markov chain, in Monte Carlo Methods and Applications (proceedings of Eighth IMACS Seminar on Monte Carlo Methods), ed. K. K. Sabelfeld, I. Dimov, pp. 213–222 (De Gruyter, Berlin, 2012).

[35] 片桐孝洋, 大島聡史, 中島研吾, 米村崇, 熊洞宏樹, 樋口清隆, 橋本昌人, 高山 恒一, 藤堂眞治, 岩田潤一, 内田和之, 佐藤正樹, 羽角博康, 黒木聖夫, レイテンシコアの高度化・高効率化による将来の HPCI システムに関する調査研究のためのアプリケーション最適化と異機種計算機環境での性能評価, 情報処理学会研究報告 **HPC-139(4)**, 1–9 (2013).

[36] 諏訪秀麿, 藤堂眞治, 詳細つりあいを満たさないマルコフ連鎖モンテカルロ法とその一般化, 数理解析研究所 講究録 **1848**, 93–107 (2013).

[37] Synge Todo, Haruhiko Matsuo, Hideyuki Shitara, Loop Cluster Monte Carlo Simulation of Quantum Magnets Based on Global Union-Find Algorithm, in Proceedings of the International Conference on High Performance Computing, Networking, Storage and Analysis 2013 (SC13) (Denver, USA, Nov. 2013).

[38] Synge Todo, Hidemaro Suwa, Geometric Allocation Approaches in Markov Chain Monte Carlo, J. Phys.: Conf. Ser. **473**, 012013 (10pp) (2013).

[39] Shinya Yasuda, Synge Todo, Numerical Analysis of Quantum Phase Transitions with Dynamic Control of Anisotropy, JPS Conf. Proc. **1**, 012127 (5pp) (2014).

[40] Yuichi Motoyama, Synge Todo, Path-Integral Monte Carlo for the Gauge-Fixed Berry Connection and the Local Z_2 Berry Phase, JPS Conf. Proc. **1**, 012130 (5pp) (2014).

[41] Yusuke Konishi, Ryo Igarashi, Shusuke Kasamatsu, Takeo Kato, Naoki Kawashima, Tsutomu Kawatsu, Hikaru Kouta, Masashi Noda, Shoichi Sasaki, Yayoi Terada, Synge Todo, Shigehiro Tsuchida, Kazuyoshi Yoshimi, Kanako Yoshizawa, MateriApps — a Portal Site of Materials Science Simulation, JPS Conf. Proc. **5**, 011007 (5pp) (2015).

[42] Hiroshi Watanabe, Satoshi Morita, Hajime Inaoka, Haruhiko Matsuo, Synge Todo, Nobuyasu Ito, Scalable and Highly SIMD-vectorized Molecular Dynamics Simulation Involving Multiple Bubble Nuclei, in Proceedings of the International Conference on High Performance Computing, Networking, Storage and Analysis 2015 (SC15) (Austin, USA, Nov. 2015).

[43] Ken Nakanishi, Shin-ichi Maeda, Takeru Miyato, Daisuke Okanohara, Neural Multi-scale Image Compression, in Computer Vision ACCV 2018. ACCV 2018. Lecture Notes in Computer Science, vol 11366, pp. 718–732 (Springer, Cham, 2018).

＜Review Papers＞

[44] 藤堂眞治, 量子モンテカルロ法による新しい量子相・量子臨界現象の探求, 計算工学 **17**, 2841–2844 (2012).

[45] 藤堂眞治, “実験技術” としての量子多体系シミュレーションソフトウェア ALPS, 日本物理学会誌 **70**, 275–282 (2015).

[46] 渡辺宙志, 藤堂眞治, 特集「『京』が拓いた物性物理」について, 分子シミュレーション研究会会誌 アンサンブル **18**, 5–6 (2016).

[47] 西野友年, 大久保 毅, テンソルネットワーク形式の進展と応用, 日本物理学会誌 **72**, 702 (2017).

[48] 山地洋平, 三澤貴宏, 吉見一慶, 河村光晶, 藤堂眞治, 川島直輝, 量子格子模型の汎用数値対角化パッケージ $\mathcal{H}\Phi$ -スピン液体近傍の熱・スピン励起への適用-, 固体物理 **52**, 539–550 (2017).

[49] 本山裕一, 三澤貴宏, 加藤岳生, 藤堂眞治, 物質科学シミュレーションのポータルサイト MateriApps, 固体物理 **52**, 743–755 (2017).

[50] 藤堂眞治, 「1968 年のモンテカルロシミュレーション」50 周年に寄せて, to appear in 日本物理学会誌.

＜Books＞

[51] Synge Todo, Loop Algorithm in Strongly Correlated Systems: Numerical Methods (Springer Series in Solid-State Sciences), ed. A. Avella, F. Mancini, pp. 153–184 (Springer-Verlag, Berlin, 2013).

[52] 藤堂眞治 (編), ケイサンブッシツカガク 計算物質科学イニシアティブ (学研プラス, 2016).

7 Invited Presentations at International Conferences

[1] Synge Todo, "Quantum Monte Carlo level spectroscopy," Swiss-Japan Workshop 2012 Current Topics in Theory of Correlated Materials, September 2012, Wako.

[2] Synge Todo, "The ALPS project: Open source software for strongly correlated systems," CCP2012: Conference on Computational Physics, October 2012, Kobe.

[3] Synge Todo, "Quantum Monte Carlo level spectroscopy," CQDC'12 International Workshop on Cooperative Quantum Dynamics and Its Control, October 2012, Julich.

[4] Synge Todo, "Next-generation quantum Monte Carlo simulation of strongly correlated materials on peta-scale supercomputer," IEEE CPMT Symposium Japan 2012, December 2012, Kyoto.

[5] Synge Todo, "Large-scale Monte Carlo Study for Exotic Phase Transitions of Strongly Correlated Quantum Magnets," Collaborative Conference on Materials Research 2013, June 2013, Jeju.

[6] Synge Todo, "Geometric Allocation Approaches in Markov Chain Monte Carlo," ICSG2013 International Meeting on Inference, Computation, and Spin Glasses, July 2013, Sapporo.

[7] Synge Todo, "Quantum Phase Transition and Universality of Quantum Spin Models with Strong Spatial Anisotropy," Tappei Tensor Network Workshop 2013, December 2013, Taipei.

[8] Hidemaro Suwa, "Quantum Monte Carlo Analysis with Geometric Allocation Approach for Spin-boson Systems," Trends in Theory of Correlated Materials (TTCM2014), October 2014, Aoyama.

[9] Hidemaro Suwa, "Worldline Quantum Monte Carlo Analysis of Critical Phenomena in Spin-Boson Systems," 1st Meeting of Condensed Matter Physics, July 2015, Tsinghua University.

[10] Hidemaro Suwa, "Geometric Allocation Approach to Irreversible Markov Chain," Break and Beyond Detailed Balance Condition -expanding to machine learning-, December 2015, Kyoto.

[11] Hidemaro Suwa, "Phase-Transition Study of Spin-Phonon Systems by Worldline Quantum Monte Carlo Breaking Detailed Balance," Institute Seminar, January 2016, S.N. Bose National Centre for Basic Sciences, Kolkata, India,.

[12] Hidemaro Suwa, "Irreversible Quantum Monte Carlo Algorithm and Unbiased Spectral Gap Estimation," Workshop: Topics in Advanced Monte Carlo Methods, March 2016, Kyoto.

[13] Hidemaro Suwa, "Dynamical exponent at superfluid–Bose-glass transition of hard-core Bose-Hubbard model," Extraordinary series on quantum phase transition in magnetic systems: II, April 2016, Beijing.

[14] Synge Todo, "Critical Decay Exponent of Ising Ferromagnet with Long-range Interaction," 2nd Conference on Condensed Matter Physics, July 2016, Nanjing.

[15] Hidemaro Suwa, "Multiple Gapless-Excitation Modes at Neel to Valence-Bond-Solid Transition," 2nd Conference on Condensed Matter Physics, July 2016, Nanjing.

[16] Hidemaro Suwa, "Quantum Monte Carlo Analysis of Linearly Dispersing Spinons at Deconfined Quantum-Critical Poin," Riken Seminar, August 2016, Wako.

[17] Hidemaro Suwa, "Quantum Monte Carlo Analysis of Linearly Dispersing Spinons at Deconfined Quantum-Critical Point," CNLS Seminar, August 2016, Los Alamos.

[18] Tsuyoshi Okubo, "Multiple-q States and Skyrmion Lattice in Frustrated Spin Systems," Skyrmionics: Materials, Phenomena and Applications, August 2017, Santa Fe.

[19] Synge Todo, "Recent progress in Markov Chain Monte Carlo Method (plenary talk)," 36th JSST Annual International Conference on Simulation Technology, October 2017, Tokyo.

[20] Tsuyoshi Okubo, "Tensor network study on Kitaev materials," Novel Quantum States in Condensed Matter 2017, November 2017, YITP.

[21] Tsuyoshi Okubo, "Tensor network study on Kitaev materials," International Conference on Magnetism, July 2018, San Francisco.

[22] Synge Todo, "Crystal structure prediction by assimilating experimental data and simulation," PCoMS Seminar, August 2018, Akiu.

[23] Synge Todo, "Data assimilation in materials science crystal structure prediction supported by incomplete experimental data," RECS: 3rd International Symposium on Research and Education of Computational Science, September 2018, Tokyo.

[24] Synge Todo, "Algorithms and Libraries in Computational Condensed Matter Physics," The 2nd Innovation Camp for Computational Materials Science, October 2018, Yonago.

[25] Tsuyoshi Okubo, "Information compression by tensor networks and its application to condensed matter physics," The 2nd Innovation Camp for Computational Materials Science, October 2018, Yonago.

[26] Tsuyoshi Okubo, "Tensor network quantum states and their application to quantum spin systems," Interdisciplinary Workshop on Tensor Network, October 2018, Wako.

[27] Tsuyoshi Okubo, "Tensor network study on Kitaev materials: Search for Kitaev spin liquid," The 2nd Asia Pacific Workshop on Quantum Magnetism, December 2018, Bengaluru.

[28] Synge Todo, "Optical bistability in a quantum low photon-density regime," International Conference on Frontiers of Correlated Electron Sciences, May 2019, Tokyo.

[29] Synge Todo, "Markov-chain Monte Carlo without detailed balance," X Brazilian Meeting on Simulational Physics, July 2019, Ouro Preto.

[30] Synge Todo, "Optical bistability in a quantum low photon-density regime," Computational Approaches to Quantum Many-body Problems, July 2019, Kashiwa.

8 Teaching Accomplishment

- H. Suwa, Springer Theses (March 2012)
- K. Nakanishi, The School of Science Encouragement Award (Master program) (March 2019)

9 Contribution to Academic Community

9.1 Editorial Activities

N.A.

9.2 Organization of Professional Societies

N.A.

9.3 Organization and Advisory of Conferences

- 情報処理学会 HPCS2012 アドバイザリ委員 2012
- Chair of Organization Committee of CMSI Kobe International Workshop 2013: Recent Progress in Tensor Network Algorithms 2013
- 情報処理学会 HPCS2013 アドバイザリ委員 2013
- Member of Organization Committee of CMSI Kobe International Workshop 2014: Tensor Network Algorithms in Materials Science 2014
- 高度情報科学技術研究機構 成果報告会プログラム委員 2014−2015
- Member of Organization Committee of 1st International Symposium on Research and Education of Computational Science (RECS) 2016
- Member of Organization Committee of International Workshop on Tensor Networks and Quantum Many-Body Problems (TNQMP2016) 2016
- Member of Organization Committee of 2nd International Symposium on Research and Education of Computational Science (RECS) 2017
- Member of Organization Committee of 3rd International Symposium on Research and Education of Computational Science (RECS) 2018
- Member of Organization Committee of International Workshop on Computational Approaches to Quantum Many-body Problems (CAQMP2019) 2019
- Member of Organization Committee of 4th International Symposium on Research and Education of Computational Science (RECS) 2019

- Member of Organization Committee of International Conference of Frontiers of Correlated Electron Scinces (FCES19) 2019
- Member of Organization Committee of International Conference of Frontiers of Statitstical Physics (FSP2019) 2019

10 Outreach

- 藤堂眞治, ALPS 講習会, 2013 年 3 月, 神戸.
- 藤堂眞治, 「計算物質科学広報の現状と課題」, 計算物質科学 “見える化” シンポジウム, 2013 年 3 月, 秋葉原.
- 藤堂眞治, 「続 計算物質科学広報の現状と課題」, 第 2 回 TUT-CMSI 見える化シンポジウム, 2014 年 3 月, 秋葉原.
- 藤堂眞治, 第 5 回 CMSI 神戸ハンズオン: ALPS チュートリアル, 2013 年 6 月, 神戸.
- 藤堂眞治, 第 7 回 CMSI 神戸ハンズオン: バージョン管理システムチュートリアル, 2013 年 8 月, 神戸.
- 藤堂眞治, 第 9 回 CMSI 神戸ハンズオン: ALPS チュートリアル, 2013 年 11 月, 神戸.
- 藤堂眞治, 第 13 回 CMSI 神戸ハンズオン: ALPS チュートリアル, 2014 年 2 月, 神戸.
- 藤堂眞治, 第 4 回 CCMS(柏) ハンズオン: Rokko チュートリアル, 2014 年 3 月, 柏.
- 藤堂眞治, 第 16 回 CMSI 神戸ハンズオン: ALPS チュートリアル, 2014 年 6 月, 神戸.
- 藤堂眞治, 第 18 回 CMSI 神戸ハンズオン: Rokko チュートリアル, 2014 年 9 月, 神戸.
- 藤堂眞治, 第 6 回 CCMS(柏) ハンズオン: ALPS チュートリアル, 2014 年 10 月, 柏.
- 藤堂眞治, 「見える化に向けた CMSI のアクティビティ」, 第 3 回 TUT-CMSI 計算物質科学見える化シンポジウム, 2015 年 2 月, 東京.
- 藤堂眞治, 第 25 回 CMSI 神戸ハンズオン: Rokko チュートリアル, 2015 年 7 月, 神戸.
- 藤堂眞治, 第 9 回 CCMS(秋葉 UDX) ハンズオン: 物質科学計算パッケージソフト MateriApps LIVE!, 2015 年 9 月, 秋葉原.
- 藤堂眞治, 第 26 回 CMSI 神戸ハンズオン: バージョン管理システムチュートリアル, 2015 年 9 月, 神戸.
- 藤堂眞治, 第 12 回 CMSI 産官学連続研究会 「物質科学計算環境 MateriApps LIVE! 講習会」, 2016 年 1 月, 東京.
- 藤堂眞治, 「ここまで来た、計算物質科学の見える化活動」, 第 4 回 TUT-CMSI 見える化シンポジウム, 2016 年 3 月, 秋葉原.

- 藤堂眞治, 「ケイサン ブッシツ カガク」, 見える化シンポジウム 2017 ～シミュレーションの価値～, 2017 年 3 月, 東京.
- 藤堂眞治, CCMS ハンズオン: ALPS 講習会, 2017 年 7 月, 柏.
- 藤堂眞治, CCMS ハンズオン: MateriApps LIVE!講習会, 2017 年 10 月, 柏.
- 藤堂眞治, 「ぜんぶ方程式のせいだ～That's all because of equation」, 理化学研究所計算科学研究機構一般公開, 2017 年 10 月, 理研 AICS.
- 藤堂眞治, 「計算科学の見える化：方程式～アルゴリズム～データ」, 見える化シンポジウム 2018～シミュレーション可視化の未来, 2018 年 2 月, 日本橋.
- 藤堂眞治, CCMS ハンズオン: MateriApps LIVE!講習会, 2018 年 3 月, 柏.
- 藤堂眞治, CCMS ハンズオン: MateriApps LIVE!講習会, 2018 年 8 月, 柏.
- 藤堂眞治, 「ぜんぶ方程式のせいだ～That's all because of equation」, 理化学研究所計算科学研究センター一般公開, 2018 年 11 月, 神戸.
- 藤堂眞治, 「進歩したか、物質科学の見える化」, 見える化シンポジウム 2019 バーチャルでリアルを超えろ ～難解サイエンスを映像で感覚的につたえる～, 2019 年 3 月, 秋葉原.
- Synge Todo, MateriApps LIVE! Tutorial, 2019 年 7 月, Ouro Preto, Brazil.
- 藤堂眞治, 解析・線形代数入門 ～データサイエンスのための～ (東京大学数理・データサイエンスコンソーシアム 社会人向け講座), 2019 年 10 月, 東京.
- 藤堂眞治, CCMS ハンズオン: MateriApps LIVE!講習会, 2019 年 11 月, 柏.

11 Committee Service

11.1 External Committees

- 日本学術振興会特別研究員等審査会専門委員及び国際事業委員会書面審査員 2012–2014
- 理化学研究所スーパーコンピュータ「京」運用懇談会 利用者側委員 2013–2014
- 日本学術振興会 国際事業委員会書面評価委員 2014–2015
- 理化学研究所計算科学研究機構研究業績評価委員会委員 2015–2016
- 日本物理学会領域 3 若手奨励賞審査委員 2016–2018
- 高度情報科学技術研究機構 利用研究課題審査委員会委員 2016–
- 九州大学 情報基盤研究開発センター公募型プロジェクト審査委員会委員 2017–
- 日本学術振興会 特別研究員等審査会専門委員会、卓越研究員候補者選考委員会書面審査委員及び国際事業委員会書面審査員・書面評価員 2017–

11.2 University Committees

物性研究所附属計算物質科学研究センター 運営委員会 委員 2012–

物性研究所スーパーコンピュ-タ共同利用運営委員会 委員 2012–

物性研究所スーパーコンピュ-タ共同利用課題審査委員会 委員 2012–

物性研究所 次世代スーパーコンピュータ戦略プログラム分野 2 計算物質科学イニシアティブ運営委員会 委員 2012–2016

物性研究所 次世代スーパーコンピュータ戦略プログラム分野 2 計算物質科学イニシアティブ企画室 委員 2012–2016

物性研究所 次世代スーパーコンピュータ戦略プログラム分野 2 計算物質科学イニシアティブ広報小委員会 委員長 2012–2016

計算科学アライアンス運営委員会 委員 2016–

物性研究所 ポスト「京」重点課題 (7)「次世代の産業を支える新機能デバイス・高性能材料の創成」運営委員会 委員 2016–

理学系研究科ネットワーク委員会 委員 2017–

数理・情報教育研究センター運営委員会 委員 2017–

数理・情報教育研究センター数学基礎教育部門運営委員会 委員 2017–

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	3	USA, USA, UK
Master Course	2	China, China
Doctor Course	1	Austria
Foreign researchers hosted	0	
Students sent abroad	3	France, Switzerland, Germany
Researchers sent abroad	1	USA
Foreign visitors	4	Germany, Austraria, Switzerland, USA

Shinji Tsuneyuki、常行 真司

1 Education and Professional Experiences

Education

1984	B.S. (Physics)	The University of Tokyo
1986	M.Sc. (Physics)	The University of Tokyo
1990	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1987−1992	Research Associate	Dept. of Physics, The University of Tokyo
1992−2002	Associate Professor	ISSP, The University of Tokyo
2002−2007	Associate Professor	Dept. of Physics, The University of Tokyo
2007−	Professor	Dept. of Physics, The University of Tokyo

2 Research Highlights

Computer simulations from first principles enable us to investigate properties and behavior of materials beyond the limits of experiments. Our main subject is to develop and apply such methods to explain the physics of materials, to predict material properties, and to create new materials. Highlights of my research from 2012 are summarized as follows.

(i) Development of the transcorrelated method for condensed matter

The transcorrelated (TC) method, initially proposed by S. F. Boys and N. C. Handy more than 40 years ago but forgotten until recently, is a wave function theory for first-principles electronic structure calculation with explicitly correlated wave functions. We noticed its conceptual and practical importance and have been trying to establish the method for an alternative of the density functional theory for years. In 2006, we reported the first application of the TC method to the band structure calculation, but there was a severe problem of the computational cost. After 2012, we developed new algorithms to speed up the calculation drastically[2, 21] and realized its application to various materials and extended the method for the calculation of electronic excitation spectra also [12]. We showed that the electronic band structure of ZnO is reproduced best among the first-principles methods reported so far [27].

(ii) Development of the first-principles simulation of the thermal properties of crystals.

For the simulation of the thermal properties of crystals, a precise calculation of the anharmonic phonon effect is necessary. A problem there is that the spatiotemporal scale of phonon properties is diverse. So it is not easy to simulate them by the simple application of the first-principles simulation. We developed a method to combine first-principles molecular dynamics with so-called sparse modeling, and established reliable calculation of the thermal conductivity of crystals [8]. We also introduced the self-consistent phonon approach to calculate soft phonon modes of high-temperature/high-symmetry phases realized by the thermal fluctuation of atoms with a modest computational cost [16, 36]. We applied these methods to clarify the mechanism of extremely low thermal conductivity in a clathrate[14, 37]. Our code is open for the public and used by researchers in the academy and also in industry.

(iii) Development of the Superconducting DFT code and its application to hydrogen sulfide at high pressure

In 2015, hydrogen sulfide made a record of the superconducting transition temperature (Tc) at high pressure. The surprisingly high Tc above 200K is explained by the phonon mechanism, on which we have contributed by the world's first calculation of the accurate Tc with the superconducting density functional theory (SCDFT) [17, 22]. In this study, we used an in-house SCDFT code we developed in collaboration with Prof. R. Arita, for which we had made an efficient method for the Brillouin-zone integration to improve the convergence of the calculation [11].

(iv) Development of the data assimilation method to predict crystal structures Theoretical prediction of crystal structures from its chemical composition and physical conditions has been a long-standing problem of physical sciences. Although there have been so many successful researches on the structural search algorithms, the number of atoms in the unit cell reachable with these algorithms is limited. We made a method to assimilate powder diffraction data in the structure simulation [42, 51]. We showed the search of complicated crystal structures are highly accelerated even if the diffraction data is incomplete due to the experimental constraints or the problem of the quality of the sample. The method will support structure determination in, for example, high-pressure experiments or materials development.

(v) Non-thermal laser ablation of metals by a femtosecond laser

Femtosecond laser irradiation on a metal surface changes the electron subsystem and causes ablation without apparent thermal damage to the surrounding area. We often call this phenomenon a non-thermal ablation, but its physical mechanism is unclear. Based on the first-principles calculation of an electronically high-temperature system, we proposed the electronic entropy-driven mechanism for the ‘non-thermal’ ablation. We developed a simple simulation model for ablation and succeeded in the reproduction of the ablation depth of Copper as a function of the laser-fluence [38].

3 Selected Papers

- M. Ochi, et al., Correlated Band Structure of a Transition Metal Oxide ZnO Obtained from a Many-Body Wave Function Theory, Phys. Rev. Lett. 118, 026402 (2017).
  This work is the first successful application of wave function theory to the band calculation of a transition metal oxide. The result was best among the first-principles methods reported so far.

- T. Tadano, et al., Anharmonic force constants extracted from first-principles molecular dynamics: applications to heat transfer simulations, J. Phys.: Condens. Matter 26, 225402 (2014).
  The paper has been cited 114 times (Google Scholar).
- T. Tadano, et al., Impact of Rattlers on Thermal Conductivity of a Thermoelectric Clathrate: A First-Principles Study, Phys. Rev. Lett. **114**, 095501 (2015).
  The paper has been cited 107 times (Google Scholar).
- R. Akashi et al., First-principles study of the pressure and crystal-structure dependences of the superconducting transition temperature in compressed sulfur hydrides, Phys. Rev. B 91, 224513 (2015).
  This was the first application of SCDFT to hydrogen sulfide and strongly supported the phonon mechanism of its superconductivity. The paper has been cited 114 times (Google Scholar).
- Y. Tanaka and S. Tsuneyuki, Possible electronic entropy-driven mechanism for non-thermal ablation of metals, Appl. Phys. Express 11, 046701 (2018).
  This paper was selected as Spotlights 2018.

4 Honors, Awards and Professional Society Memberships

5 Research Plan

(i) Further development of the Transcorrelated (TC) method

Most of the first-principles calculation of condensed matter is based on density functional theory (DFT), although DFT sometimes gives wrong results, especially for so-called strongly correlated electronic systems. A serious problem of DFT is that the reliability depends on the exchange-correlation energy functional, of which neither the exact form nor the systematic way of improvement is not known. The TC method, on the other hand, is a wave function theory and systematically improvable if we ignore the computational cost. We are planning to extend the TC method further to treat strongly correlated electronic systems, including Mott insulators. The final goal is to establish the TC method as a better alternative for DFT.

(ii) Applications and extension of the data assimilation method

We have developed the data-assimilation method for crystal structure prediction by utilizing the X-ray diffraction data. It is useful when the information of the diffraction data is not enough for structure determination. One of such examples is the matter containing hydrogen atoms which hardly scatter X-ray. We started collaborative researches with experimental groups to clarify the structure and electronic effect of hydrogen atoms in various materials.

The idea of our data-assimilation method comes from the Bayes ' theorem. It is so general that we can consider various extensions of the method by using different types of experimental data. As another example, we are planning to use STM images to determine reconstructed surface structures.

(iii) First-principles calculation of the superconducting transition temperature

Application of the present SCDFT is limited to the phonon-mediated superconductors except for the inclusion of the plasmon effect. Now we are trying to include the spin-fluctuation effect in the formalism. We also plan to develop a method appropriate for strong electron-phonon coupling to treat bi-polaron superconductivity.

(iv) Non-thermal laser ablation of metals by a femtosecond laser

We have proposed the entropy-driven mechanism for non-thermal laser ablation and developed a simple continuum model for the simulation applicable to relatively low laser fluence. To study the laser ablation in a wide range of laser fluence, we have to take into account the thermal motion of atoms explicitly. Thus we are planning to develop and validate a multiscale simulation method for laser ablation taking account of the electronic entropy. For the validation, we are collaborating with experimental groups at the University of Tokyo, including Prof. Yumoto's group in our department.

(v) Applications of the first-principles calculation

We will apply the first-principles calculation for various materials in collaboration with experimental groups. Some projects are underway, such as materials for photochromism (Tokyo Institute of Technology) and materials for secondary ion batteries (Tohoku University, Kyoto University).

6 Publications and Patents

< Refereed Original Papers >

[1] Y. Gohda and S. Tsuneyuki, "Structural phase transition of graphene caused by GaN epitaxy", Appl. Phys. Lett. **100**, 053111 (2012).

[2] M. Ochi, K. Sodeyama, R. Sakuma, and S. Tsuneyuki, "Efficient algorithm of the transcorrelated method for periodic systems", J. Chem. Phys. **136**, 094108 (2012).

[3] Y. Ando, Y. Gohda, and S. Tsuneyuki, "Dependence of the Schottky barrier on the work function at metal/SiON/SiC(0001) interfaces identified by first-principles calculations", Surf. Sci. **606** 1501 (2012).

[4] Yoshiki Iwazaki, Toshimasa Suzuki, Youichi Mizuno, and Shinji Tsuneyuki, Doping-induced phase transitions in ferroelectric $BaTiO_3$ from ?rst-principles calculations, Phys. Rev. B **86**, 214103 (2012).

[5] Y. Gohda and S. Tsuneyuki, "Optical conductivity of highly mismatched GaP alloys", Appl. Phys. Lett., **102**, 023901 (2013).

[6] Y. Ando, Y. Gohda, and S. Tsuneyuki, "*Ab initio* molecular dynamics study of the Helmholtz layer formed on solid-liquid interfaces and its capacitance", Chem. Phys. Lett. **556**, 9 (2013).

[7] T. Kobori, K. Sodeyama, T. Otsuka, Y. Tateyama and S. Tsuneyuki, "Trimer effects in fragment molecular orbital-linear combination of molecular orbitals calculation of one-electron orbitals for biomolecules", J. Chem. Phys. 139, 094113 (2013).

[8] T. Tadano, Y. Gohda, and S. Tsuneyuki, Anharmonic force constants extracted from first-principles molecular dynamics: applications to heat transfer simulations, J. Phys.: Condens. Matter 26, 225402 (2014).

[9] Y. Iwazaki, Y. Gohda and S. Tsuneyuki, Diversity of hydrogen configuration and its roles in $SrTiO_3$, APL Materials, 2, (2014) 012103.

[10] M. Ochi, K. Sodeyama and S. Tsuneyuki, "Optimization of the Jastrow factor using the random-phase approximation and a similarity-transformed Hamiltonian: Application to band-structure calculation for some semiconductors and insulators", J. Chem. Phys. 140, 074112 (2014).

[11] M. Kawamura, Y. Gohda, and S. Tsuneyuki, "Improved tetrahedron method for the Brillouin-zone integration applicable to response functions", Phys. Rev. B, 89, 094515 (2014).

[12] M. Ochi and S. Tsuneyuki, Optical Absorption Spectra Calculated from a First-Principles Wave Function Theory for Solids: Transcorrelated Method Combined with Configuration Interaction Singles, J. Chem. Theory Comput. **10**, 4098 (2014).

[13] Z. Torbatian, T. Ozaki, S. Tsuneyuki, and Y. Gohda, "Strain effects on the magnetic anisotropy of $Y_2Fe_{14}B$ examined by first-principles calculations", Appl. Phys. Lett. **104**, 242403 (2014).

[14] T. Tadano, Y. Gohda and S. Tsuneyuki, Impact of Rattlers on Thermal Conductivity of a Thermoelectric Clathrate: A First-Principles Study, Phys. Rev. Lett. **114**, 095501 (2015).

[15] M. Ochi and S. Tsuneyuki, Second-order Møller-Plesset perturbation theory for the transcorrelated Hamiltonian applied to solid-state calculations, Chem. Phys. Lett. **621**, 177 (2015) (selected as Editor's Choice).

[16] T. Tadano and S. Tsuneyuki, Self-consistent phonon calculations of lattice dynamical properties in cubic $SrTiO_3$ with first-principles anharmonic force constants, Phys. Rev. B 92, 054301 (2015).

[17] R. Akashi, M. Kawamura, S. Tsuneyuki, Y. Nomura, and R. Arita First-principles study of the pressure and crystal-structure dependences of the superconducting transition temperature in compressed sulfur hydrides Phys. Rev. B 91, 224513 (2015)

[18] R. Akashi, M. Ochi, S. Bordacs, R. Suzuki, Y. Tokura, Y. Iwasa, and R. Arita Two-dimensional valley electrons and excitons in noncentrosymmetric 3R-MoS2 Phys. Rev. Applied 4, 014002 (2015)

[19] J. Y. Xue, T. Izumi, A. Yoshii, K. Ikemoto, T. Koretsune, R. Akashi, R. Arita, H. Taka, H. Kita, S. Sato, H. Isobe Aromatic hydrocarbon macrocycles for highly efficient organic light-emitting devices with single-layer architectures Chem. Sci. 7, 896 (2016)

[20] W. Sano, T. Koretsune, T. Tadano, R. Akashi, and R. Arita, Effect of Van Hove singularities on high-T_c superconductivity in H_3S, Phys. Rev. B 93, 094525 (2016).

[21] M. Ochi, Y. Yamamoto, R. Arita, and S. Tsuneyuki, "Iterative diagonalization of the non-Hermitian transcorrelated Hamiltonian using a plane-wave basis set: Application to *sp*-electron systems with deep core states", J. Chem. Phys. 144, 104109 (2016).

[22] R. Akashi, W. Sano, R. Arita, S. Tsuneyuki Possible "Magneli" phases and self-alloying in superconducting sulfur hydride Phys. Rev. Lett. 117, 075503 (2016).

[23] M. Ochi, R. Akashi, and K. Kuroki: Strong Bilayer Coupling Induced by the Symmetry Breaking in the Monoclinic Phase of BiS2-Based Superconductors J. Phys. Soc. Jpn. 85, 094705(2016).

[24] N. Sato and S. Tsuneyuki, Perovskite-type oxyhydride with a two-dimensional electron system: First-principles prediction of $KTiO_2H$, Appl. Phys. Lett. 109, 172903 (2016).

[25] T. Miyamachi, S. Nakashima, S. Kim, N. Kawamura, Y. Tatetsu, Y. Gohda, S. Tsuneyuki, and F. Komori: Epitaxially stabilized iron thin films via effective strain relief from steps, Phys. Rev. B 94, 045439 (2016).

[26] Y. Tatetsu, Y. Gohda, and S. Tsuneyuki: First-Principles Study of the Role of Cu in Improving the Coercivity of Nd-Fe-B Permanent Magnets, Phys. Rev. Appl. 6, 064029 (2016)

[27] M. Ochi, R. Arita, and S. Tsuneyuki, Correlated Band Structure of a Transition Metal Oxide ZnO Obtained from a Many-Body Wave Function Theory, Phys. Rev. Lett. 118, 026402 (2017).

[28] S. Yamada, F. Shimojo, R. Akashi, and S. Tsuneyuki, Efficient method for calculating spatially extended electronic states of large systems with a divide-and-conquer approach, Phys. Rev. B 95, 045106 (2017).

[29] R. Arita, T. Koretsune, S. Sakai, R. Akashi, Y. Nomura, and W. Sano, Nonempirical Calculation of Superconducting Transition Temperatures in Light-Element Superconductors, Adv. Mater. 1602421 (2017)

[30] M. Kawamura, R. Akashi, and S. Tsuneyuki, Anisotropic superconducting gaps in YNi_2B_2C: A first-principles investigation, Phys. Rev. B 95, 054506 (2017).

[31] H. Katow, J. Usukura, R. Akashi, K. Varga, and S. Tsuneyuki, Numerical investigation of triexciton stabilization in diamond with multiple valleys and bands, Phys. Rev. B 95, 125205 (2017).

[32] N. Sato, R. Akashi, and S. Tsuneyuki, Universal two-dimensional characteristics in perovskite-type oxyhydrides $ATiO_2H$ (A = Li, Na, K, Rb, Cs), J. Chem. Phys. 147,034507 (2017).

[33] C. Morice, R. Akashi, T. Koretsune, S. S. Saxena, and R. Arita, Weak phonon-mediated pairing in BiS_2 superconductor from first-principles, Phys. Rev. B 95, 180505(R) (2017).

[34] R. Akashi, Y. Iida, K. Yamamoto, and K. Yoshizawa, Interference of the Bloch phase in layered materials with stacking shifts, Phys. Rev. B 95, 245401 (2017).

[35] I. Kruglov, R. Akashi, S. Yoshikawa, A. R. Oganov, and M. M. D. Esfahani, Refined phase diagram of the HS system with high-Tc superconductivity Phys. Rev. B 96, 220101(R) (2017).

[36] T. Tadano and S. Tsuneyuki, First-Principles Lattice Dynamics Method for Strongly Anharmonic Crystals, J. Phys. Soc. Japan 87, 041015 (2018).

[37] T. Tadano and S. Tsuneyuki, Quartic Anharmonicity of Rattlers and its Effect on Lattice Thermal Conductivity of Clathrates from First Principles, Phys. Rev. Lett. 120, 105901 (2018).

[38] Y. Tanaka and S. Tsuneyuki, Possible electronic entropy-driven mechanism for non-thermal ablation of metals, Appl. Phys. Express 11, 046701 (2018).

[39] Y. Gohda, Y. Tatetsu, and S. Tsuneyuki: Electron theory on grain-boundary structures and local magnetic properties of neodymium magnets, Mater. Trans., 59, 332 (2018).

[40] Tomoya Naito, Ryosuke Akashi and Haozhao Liang, Application of a Coulomb energy density functional for atomic nuclei: Case studies of local density approximation and generalized gradient approximation, Phys. Rev. C97, 044319 (2018).

[41] R. Akashi and Y. S. Nagornov "Stochastic Formalism for Thermally Driven Distribution Frontier: A Nonempirical Approach to the Potential Escape Problem" J. Phys. Soc. Jpn. 87, 063801 (2018).

[42] N. Tsujimoto, D. Adachi, R. Akashi, S. Todo and S. Tsuneyuki, Crystal structure prediction supported by Insufficient experimental data, Phys. Rev. Materials 2, 053801 (2018).

[43] R. Nagai, R. Akashi, S. Sasaki, and S. Tsuneyuki "Neural-network Kohn-Sham exchange-correlation potential and its out-of-training transferability" J. Chem. Phys. 148, 241737 (2018).

[44] Yasutomi Tatetsu, Shinji Tsuneyuki, and Yoshihiro Gohda: First-principles study on substitution effects in $Nd_2(Fe, X)_{14}B$, Materialia, 4, 388 (2018).

[45] Y. K. Wakabayashi, Y. Krockenberger, N. Tsujimoto, T. Boykin, S. Tsuneyuki, Y. Taniyasu and H. Yamamoto, Ferromagnetism above 1000 K in a highly cation-ordered double-perovskite insulator Sr_3OsO_6, Nature Communications 1, 535 (2019).

[46] Tomoya Naito, Xavier Roca-Maza, Gianluca Colò, and Haozhao Liang, Coulomb exchange functional with generalized gradient approximation for self-consistent Skyrme Hartree-Fock calculations, Phys. Rev. C99, 024309 (2019).

[47] Takeru Yokota and Tomoya Naito, Functional-renormalization-group aided density functional analysis for the correlation energy of the two-dimensional homogeneous electron gas, Phys. Rev. B99, 115106 (2019).

[48] Yusuke Oba, Terumasa Tadano, Ryosuke Akashi and Shinji Tsuneyuki, First-principles study of phonon anharmonicity and negative thermal expansion in ScF_3, Phys. Rev. Materials 3, 033601 (2019).

[49] T. Pal, S. Doi, H. Maeda, K. Wada, C. M. Tan, N. Fukui, R. Sakamoto, S. Tsuneyuki, S. Sasaki and H. Nishihara, Interfacial transmetallation synthesis of a platinadithiolene nanosheet as a potential 2D topological insulator, Chem. Sci. 10, 5218-5225 (2019).

[50] Y. S. Nagornov and R. Akashi, Non-empirical weighted Langevin mechanics for the potential escape problem: parallel algorithm and application to the Argon clusters, Physica A: Stat. Mech. Appl. 528, 121481 (2019).

[51] D. Adachi, N. Tsujimoto, R. Akashi, S. Todo, S. Tsuneyuki, Search for common minima in joint optimization of multiple cost functions, Comput. Phys. Commun. 241, 92-97 (2019).

＜ Conference Proceedings ＞

[52] M. Ochi and S. Tsuneyuki, "Optimization of the Jastrow factor in the correlated wave function of electrons using the first-principles transcorrelated method for solid-state calculations", J. Phys. Conf. Ser. 454, 012020 (2013).

[53] T. Tadano and S. Tsuneyuki, First-principles analysis of anharmonic nuclear motion and thermal transport in thermoelectric materials, AIP Conf. Proc. 1702, 090063 (2015).

＜ Review Papers ＞

[54] 常行真司「スパコンで未来社会への競争力を築くー計算物質科学イニシアティブ (CMSI) について」, 工業材料 vol.60, No.4, 18-22 (2012).

[55] 常行真司「京コンピュータが拓く高圧力の物質科学」, 高圧力の科学と技術 Vol. 23, No.2, 88 (2013).

[56] 河村光晶, 常行真司「最適化テトラヘドロン法を用いた高精度ブリルアン領域積分」, 固体物理 vol.51(1), 25 (2016).

[57] 明石遼介、是常隆、有田亮太郎、常行真司「高圧下で硫化水素が示す高温超伝導：これまでのまとめ」, 固体物理 vol.51, 729 (2016).

[58] 合田義弘, 立津慶幸, 常行真司「ネオジム磁石の粒界構造と局所磁性の電子論」, 日本金属学会誌 vol.81(1), 26 (2017).

[59] 常行真司，杉野修，有田亮太郎,「第一原理シミュレーション概観」, 固体物理 vol.52(11), 575 (2017).

[60] 只野央将， 常行真司,「第一原理からの非調和フォノンと格子熱伝導」, 固体物理 vol.52(11), 637 (2017).

[61] 越智正之，有田亮太郎，常行真司,「固体のための波動関数理論：トランスコリレイティッド法の発展」, 固体物理 vol.52(11), 715 (2017).

＜ **Patent Applications** ＞

7 Invited Presentations at International Conferences

[1] S. Tsuneyuki, 'Atomistic Modeling of Materials Based on First-Principles Calculation', The Seventh General Meeting of ACCMS-VO, Nov. 23-25, 2012 (Sendai, Japan).

[2] S. Tsuneyuki, 'Transcorrelated method: a feasible and self-consistent wave function theory for solids', Asian Workshop on First-Principles Electronic Structure Calculations (Asian-15), Nov. 5-7, 2012 (Taipei, Taiwan).

[3] S. Tsuneyuki, "Software Development in the Computational Materials Science Initiative for Innovative Materials", The 7th International Conference on the Science and Technology for Advanced Ceramics (STAC-7) (Mielparque, Yokohama), Jun. 20, 2013.

[4] S. Tsuneyuki, "Computer Experiments for Materials Science", The international symposium on Recent Trend of Interdisciplinary Research of Physics, Earth and Space Science (Osaka), Dec. 17-18, 2013.

[5] S. Tsuneyuki, Computer Experiments for Materials Science, International HPC Summer School on HPC Challenges in Computational Sciences (Budapest,June 1-6, 2014).

[6] S. Tsuneyuki, Atomistic Modeling of Materials Based on First-Principles Calculation, The 10th NOBUGS conference (NOBUGS2014) (New Opportunities for Better User Group Software) （KEK, Sept. 24-26, 2014）(Plenary).

[7] S. Tsuneyuki, Toward Accurate Calculation of Electronic and Structural Properties of Materials from First Principles, The 9th General meeting of ACCMS-VO (OIST, Okinawa, 12.20-22, 2014).

[8] S. Tsuneyuki, Recent Progress in the Transcorrelated Method for Condensed Matter, ICQC2015 Satellite Symposium in Kobe: Novel Computational Methods for Qnatitative Electronic Structure Calculations, Kobe University, Kobe, Jun. 16-18, 2015.

[9] S. Tsuneyuki，Atomistic Modeling of Materials from First Principles, AIMR International Symposium (AMIS2016), Tohoku Univ., Sendai, Feb. 21-24, 2016 (plenary).

[10] S. Tsuneyuki: First-principles modeling of the thermal properties of materials, The 14th International Nanotech Symposium & Nano-Convergence Expo, NANO KOREA 2016, KINTEX, Korea, Jul. 16, 2016.

[11] S. Tsuneyuki: First-principles theoretical study of exotic high-pressure phases, The17th International Conference on High Pressure in Semiconductor Physics (HPSP-17) & The Workshop on High pressure Study on Superconducting, (WHS), Sanjo-Kaikan, The University of Tokyo, Tokyo, Aug. 8, 2016 (Plenary).

[12] S. Tsuneyuki: First-Principles Calculation and Modelling of Thermal Transport in Heavily Anharmonic Crystals, Japan-France-Spain Joint-Symposium on Theoretical and Computational Science of Complex Systems, Fukui Institute for Fundamental Chemistry, Kyoto University, Kyoto, Oct. 28, 2016.

[13] S. Tsuneyuki, Transcorrelated Method for Condensed Matter, CECAM Workshop: Theoretical Chemistry for Extended Systems: systematically improvable electronic structure method, CECAM-FR-GSO (Toulouse), May 22-24, 2017.

[14] S. Tsuneyuki, "MI2I", Paris Meeting – Computational Materials: Challenges and Future Opportunities (Paris), May 31-Jun. 2, 2017.

[15] Shinji Tsuneyuki, "Crystal structure prediction by assimilating incomplete powder diffraction data", Symposium at Spetses, Spetses, Greece, Jun. 11-15, 2018.

[16] S. Tsuneyuki, "Transcorrelated method: the idea and its applications", International Conference on Frontiers of Correlated Electron Sciences, The University of Tokyo, Tokyo, May 29, 2019.

[17] S. Tsuneyuki, "Crystal Structure Prediction by Assimilating Incomplete Powder Diffraction Data", The 18th International Conference on Density Functional Theory and its Applications (DFT2019), Allicante, Spain, July 21-27, 2019.

[18] S. Tsuneyuki, "First-principles material simulation and beyond", Materials Research Meeting 2019 (MRM2019), Yokoyama, Dec. 10-14, 2019 (Plenary).

8 Teaching Accomplishment

N. Tsujimoto, Best Poster Award, The 10th International Conference on the Science and Technology for Advanced Ceramics (STAC-10), Aug. 1-3, 2017, Yokohama.

9 Contribution to Academic Community

9.1 Editorial Activities

- 雑誌「固体物理」編集委員（1993～現在）

9.2 Organization of Professional Societies

- Representative Director of Computational Materials Science Initiative (CMSI) （HPCI 戦略機関「計算物質科学イニシアティブ」統括責任者）(2010.9-2016.3)
- Leader of CDMSI, Issue 7 of the Post-K Computer application development project. （ポスト「京」重点課題７「次世代の産業を支える新機能デバイス・高性能材料の創成（CDMSI）」課題責任者, 2016.4-2020.3）
- Vice Chairman of the HPCI (High-Performance Computing Infrastructure) Consortium, （HPCI コンソーシアム副理事長）(2014.5-2016.4, 2018.5-)
- JST さきがけ「理論・実験・計算科学とデータ科学が連携・融合した先進的マテリアルズインフォマティクスのための基盤技術の構築」研究総括 (2015.7-)
- ハイドロジェノミクス研究会（旧：水素量子アトミクス研究会）世話人 (2004–現在)

9.3 Organization and Advisory of Conferences

- MAterial Simulation in Petaflops era (MASP2012), Workshop: June 25th -July 1st and July 3rd-11th, Symposium: July 2nd, 12th, and 13th, 2012 (Organizing Committee)
- International Symposium on Computics: Quantum Simulation and Design (ISC-QSD), 11-13 Oct. 2012 (Organizing Committee).
- JSAP-MRS Joint Symposium, Sep. 16-20, 2013, Doshisha University, Kyoto (Organizing Committee)
- The 1st International Symposium on Research and Education of Computational Science (RECS2016), Nov. 29-30, 2016, The University of Tokyo, Tokyo (Organizing Committee)
- Car-Parrinello Molecular Dynamics 2017 (CPMD2017), Oct 18-20, 2017, Epochal Tsukuba, Tsukuba (Organizing Committee)
- The 3rd International Symposium on Research and Education of Computational Science (RECS2018), Sep. 20-21, 2018, The University of Tokyo, Tokyo (Organizing Committee)

- PRESTO International Symposium on Materials Informatics, Feb. 9-11, 2019, The University of Tokyo, Tokyo (Symposium Chair)
- The 4th International Symposium on Research and Education of Computational Science (RECS2019), Oct. 2, 2019, The University of Tokyo, Tokyo (Organizing Committee)
- Materials Research Meeting (MRM2019), Dec. 10-14, 2019, Yokohama (Symposium Organizer).

10 Outreach

- 日本物理学会市民向け講演会 (2012).
- 東大理学部 高校生のための夏休み講座 2012「コンピュータ上に物質をつくる」(2012)

11 Committee Service

11.1 External Committees

- Adjunct Member of Science Council of Japan, 2015– (日本学術会議 連携会員)
- 文部科学省 科学技術・学術審議会専門委員 (2013.5–) [数学イノベーション委員会委員 (–2017) ナノテクノロジー・材料技術委員会 (2013–)]
- 社団法人 HPCI コンソーシアム　幹事（2016–2017）副理事長 (2018–)、HPCI システムの今後の運営の在り方に関する調査検討ワーキンググループ委員長 (2018–)
- 筑波大学計算科学研究センター運営協議会委員 (2011.4–) 一般財団法人総合科学研究機構東海事業センター（CROSS) 選定委員会（2015.4–)
- 産総研機能材料コンピュテーショナルデザイン研究センター アドバイザー (2016–)
- J-PARC サイエンスプロモーションボード (2017–)
- JST CREST「ナノスケール・サーマルマネージメント基盤技術の創出」 領域アドバイザー (2017–)
- NEDO 超先端材料超高速開発基盤技術プロジェクトアドバイザリーボードメンバー (2017–)
- 東北大学金属材料研究所 国際外部評価委員（2018）
- 理化学研究所計算科学研究センター 国際外部評価委員 (2019)
- 凝縮系科学賞選考委員（2013–）
- ミレニアムサイエンスフォーラム　サー・マーティン・ウッド賞選考委員（2017–）

11.2 University Committees

理学系研究科 副研究科長（2018.4–）
（理学系研究科・理学部技術部長、理学系研究科・理学部環境安全管理室長、TAO 運営諮問員会委員、理学系教育会議委員ほか）
東京大学教育研究評議会 評議員 (2019.4–)
物性研究所・計算物質科学研究センター・センター長（2011.4–）
物性研究所・スーパーコンピュータ共同利用委員会委員，同 課題審査委員
情報基盤センター・スーパーコンピューティング専門委員会委員（2013.4.1–）
数理情報教育研究センター運営委員（2017–）
東京大学 計算科学アライアンス 運営委員（2016–）、副代表（2019–）

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	1	Korea
Master Course	2	Sweden, Romania
Doctor Course	2	Romania, Iran
Foreign researchers hosted	2	UK, Russia
Students sent abroad	2	USA
Researchers sent abroad	1	Russia
Foreign visitors	20	USA, UK, Germany, Italy, Switzerland, PR China

Shuji Hasegawa、長谷川 修司

1 Education and Professional Experiences

Education

1983	B.S. (Physics)	Department of Physics, The University of Tokyo
1985	MSc. (Physics)	Department of Physics, The University of Tokyo

Professional Appointments

1985−1990	Researcher	Advanced Research Laboratory, Hitachi, Ltd. (Research on electron holography with Dr. Akira Tonomura)
1990−1994	Assistant Professor	Department of Physics, The University of Tokyo (Research on surface physics with Prof. Shozo Ino)
1992−1994	Guest Researcher (concurrently)	Japan Science and Technology Agency (Sakigake Project)
1994−2010	Associate Professor	Department of Physics, The University of Tokyo
2010−Present	Professor	Department of Physics, The University of Tokyo

2 Research Highlights

The main interest of my group is electronic/spin transport at crystal surfaces, especially through " surface electronic states " (electronic bands characteristic of surface atomic layers). The surface electronic states at crystal surfaces are intrinsically two-dimensional and space-inversion-symmetry-broken systems with one or two atomic-layer thickness, which should be different from traditional two-dimensional electronic systems so that they can be a new class of playground for transport physics. For measuring the surface-state transport, we have developed ultrahigh vacuum (UHV) systems in which we can perform both of four-point-probe resistance measurements at low temperature (down to 0.8 K) under strong magnetic field in UHV and molecular-beam-epitaxy (MBE) growth of atomic layers without exposing samples to air. As described below, recent results from my group in 2012-present are about atomic-layer superconductivity and topological surface electronic states. I have published more than 200 original/review papers and gotten about 7,500 citations in total (by Scopus). I published 39 papers and got 3,031 citations in 2012-2018. I have delivered more than 60 invited talks/lectures at international/domestic conferences/symposia in 2012-2018.

(1) Atomic-layer (surface-state) superconductivity

We have found various kinds of atomic-layer superconductors on Silicon and Germanium crystal surfaces covered with one or two atomic layers of metals with the critical temperature 0.8-4 K. They are interesting not only by large fluctuation due to low dimensionality, but also by the space-inversion-symmetry (SIS) breaking. We have found some signatures of non-BCS superconductivity in one-atomic-layer alloy of Thallium and Lead on a Silicon crystal surface where the surface electronic states are spin-split due to Rashba effect originating from the SIS breaking and strong spin-orbit coupling. It can have spin-triplet Cooper pairs due to parity mixing effect (Phys. Rev. Lett. **115**, 147003 (2015), Phys. Rev. B **98**, 134505 (2018)).

We have found that superconductor-to-insulator transition in Thallium double atomic layers on a Silicon crystal surface (2D Materials **4**, 025020 (2017)) and one-unit layer of $NbSe_2$ (Phys. Rev. B **99**, 220501(R) (2019)) induced by applying magnetic field is mediated by a so-called Bose metal in which Cooper pairs are incoherent due to phase fluctuation, showing finite resistance even though there are Cooper pairs.

We are the first to show superconductivity at graphene. This is due to Ca atoms intercalation between the graphene layers to dope high-density carriers (ACS Nano **10**, 2761 (2016)).We have also clarified the stacking structure of the superconducting Ca-intercalated bilayer graphene by positron diffraction experiments (Carbon, accepted (2019)).

Since these atomic-layer superconductors are easily oxidized and deteriorated in air, we need to measure the transport properties in UHV just after the atomic layers are grown in UHV. For this purpose, we have developed a world-first ultrahigh vacuum system in which four-point-probe magnetoresistance measurements are possible in UHV, down to 0.8 K under magnetic field of 7 T (e-Journal of Surface Science and Nanotechnology **10**, 400 (2012)).

(2) Topological surface states

We have succeeded in opening a non-trivial energy gap at Dirac point in a topological surface state due to time-reversal-symmetry breaking, by forming a high-quality heterojunction between a ferromagnetic layer and a topological insulator (Nano Letters **17**, 3493 (2017)). This will lead to a realization of quantum anomalous Hall effect in which a dissipation-less chiral edge state is created. Actually we have recently measured the Hall resistance of MnTe/BiSbTe heterojunction showing nearly quantized Hall resistance.

3 Selected Papers

- S. Ichinokura, K. Sugawara, A. Takayama, T. Takahashi, and S. Hasegawa: “*Superconducting Calcium-Intercalated Bilayer Graphene*”, ACS Nano **10**, 2761-2765 (2016)

  This paper has obtained 124 citations. This is the first paper to report superconductivity at graphene. With this paper, we have received The Best Paper Prize 2018 at Division of Thin Films and Surface Physics in The Japan Society of Applied Physics (応用物理学会薄膜・表面物理分科会 第2回論文賞). Satoru Ichinokura, the 1st author received the Best Doctoral Thesis Prize 2015 (平成27年度 東京大学大学院理学系研究科 研究奨励賞).

- A.V. Matetskiy, S. Ichinokura, L.V. Bondarenko, A.Y. Tupchaya, D.V. Gruznev, A.V. Zotov, A.A. Saranin, R. Hobara, A. Takayama, and S. Hasegawa: “*Two-dimensional superconductor with giant Rashba effect: One-atomic-layer Tl-Pb compound on Si(111)*”, Phys. Rev. Lett. **115**, 147003 (2015).

This paper has obtained 67 citations. This reports superconductivity in spin-splitting surface electronic states due to Rashba effect. This can host unconventional (non-BCS) superconductivity in which spin-triplet Coopers exist. We have already obtained some signatures for it (Phys. Rev. B **98**, 134505 (2018)).

- T. Kambe, R. Sakamoto, T. Kusamoto, T. Pal, N. Fukui, K. Hoshiki, T. Shimojima, Z. Wang, T. Hirahara, K. Ishizaka, S. Hasegawa, F. Liu, and H. Nishihara: "*Redox control and high conductivity of nickel bis(dithiolene) complex pi-nanosheet, a candidate of the first organic topological insulator*", Journal of The American Chemical Society **136** (41), 14357-14360 (2014)

  This paper has obtained 180 citations. This reports fabrication of a single-molecular sheet, Nickel Bis(dithiolene) Complex π-nanosheet, a possible two-dimensional topological insulator. It shows high electrical conductivity which can be changed by redox control.

- M. Yamada, T. Hirahara, and S. Hasegawa: "*Magnetotransport measurements of a superconducting surface state of In- and Pb-induced structures on Si(111)*", Phys. Rev. Lett. **110**, 237001 (2013).

  This paper has obtained 112 citations. This reports the first measurements of magnetoresistance of atomic-layer superconductors, clarifying the nature of two-dimensional superconductivity.

- P. De Padova, P. Vogt, A. Resta, J. Avila, I. Razado-Colambo, C. Quaresima, C. Ottaviani, B. Olivieri, T. Bruhn, T. Hirahara, T. Shirai, S. Hasagawa, M. C. Asensio, and G. Le Lay: "*Evidence of Dirac Fermions in Multilayer Silicene*", Appl. Phys. Lett. **102**, 163106 (2013).

  This paper has obtained 169 citations. We have found Dirac-cone type bands of multi-layer Silicene, two-dimensional Graphene-like sheet made of Silicon atoms. Surprisingly, Silicon atoms deposited on a Silver crystal surface grow in a Silicene-by-Silicene structure, not in a diamond structure.

4 Honors, Awards and Professional Society Memberships

【Honors and Awards】

- 2018 The Best Paper Prize, Division of Thin Films and Surface Physics, The Japan Society of Applied Physics (応用物理学会薄膜・表面物理分科会 第 2 回論文賞), with Satoru Ichinokura, Katsuaki Sugawara, Akari Takayama, and Takashi Takahashi, "*Superconducting Calcium-Intercalated Bilayer Graphene*" (ACS Nano **10**, 2761-2765 (2016)).
- 2016 APEX/JJAP Editorial Contribution Award, The Japan Society of Applied Physics.
- 2014 Surface Science Highly Valued Reviewer, Elsevier.

【Society Memberships】

- The Physical Society of Japan
- The Japanese Society of Applied Physics
- The Japanese Society of Microscopy
- The Japan Society of Vacuum and Surface Science

5 Research Plan

By utilizing our original techniques of experiments, *in-situ* four-point probes for transport measurements in ultrahigh vacuum combined with molecular beam epitaxy for surface atomic-layer structure control, I will expand and deepen physics on charge/spin transport at surface electronic states on crystals and atomic layers. As mentioned already, I am the first to detect unambiguously surface-state electrical conduction, and have expanded the study to surface-state superconductivity and Rashba/topological surface states. In the next six years before my retirement, I plan the following research projects.

(1) Non-reciprocal charge/spin transport at surfaces

Due to break down of space-inversion symmetry at crystal surfaces, we can expect non-reciprocal transport in which currents of charge and spin in right and left directions are different, much like in a diode. But the mechanism for such novel non-reciprocal transport is spin-related; so-called spin-momentum locking effect (Edelstein effect), spin-Hall effect, and chiral edge states emerge on surfaces of strong spin-orbit coupling materials. These leads to non-dissipation transport, which is quite different in diodes with energy dissipation. We have already shown a preliminary result by using circularly polarized light to inject spins into topological insulators, resulting in photocurrent flowing in one direction without *pn* junctions (D. Fan *et al.*, arxiv:1809.08063). In a magnetic topological surface state (T. Hirahara, *et al.*, Nano Letters **17**, 3493 (2017)), a chiral edge state is created and dissipation-less current flows in one direction. We plant to directly detect these in the nearest future.

(2) Surface-state superconductivity Superconductivity at surface electronic states on crystal surfaces of strong spin-orbit coupling materials such topological insulators and Rashba systems, should be different from conventional BCS superconductivity, because of the spin-splitting in the states and resulting mixing of spin-singlet and spin-triplet Cooper pairs. We have already obtained some signatures for the non-BSC superconductivity by scanning tunneling microscopy measurements (T. Nakamura, *et al.*, Phys. Rev. B **98**, 134505 (2018)). We can expect spin-polarized supercurrent and Majorana Fermions on such symmetry broken superconductors. Our experimental techniques of low-temperature micro-four-point probes are good to detect them.

6 Publications and Patents

< Refereed Original Papers >

[1] T. Hirahara, N. Fukui, T. Shirasawa, M. Yamada, M. Aitani, H. Miyazaki, M. Matsunami, S. Kimura, T. Takahashi, S. Hasegawa, and K. Kobayashi, *Atomic and Electronic Structure of Ultrathin Bi(111) Films Grown on Bi_2Te_3(111) Substrates: Evidence for a Strain-Induced Topological Phase Transition*, Phys. Rev. Lett. **109**, 227401 (Nov, 2012).

[2] T. Uetake, T. Hirahara, Y. Ueda, N. Nagamura, R. Hobara, and S. Hasegawa, *Anisotropic conductivity of the Si(111)4×1-In surface: Transport mechanism determined by the temperature dependence*, Phys. Rev. B **86**, 035325 (Jul, 2012).

[3] Y. Fukaya, K. Kubo, T. Hirahara, S. Yamazaki, W. H. Choi, H. W. Yeom, A. Kawasuso, S. Hasegawa, and I. Matsuda, *Atomic and Electronic Structures of Si(111)-$\sqrt{21} \times \sqrt{21}$ Superstructure*, e-Journal of Surface Science and Nanotechnology **10**, 310 (Jul, 2012).

[4] M. Yamada, T. Hirahara, S. Hasegawa, H. Mizuno, Y. Miyatake, and T. Nagamura, *Surface Electrical Conductivity Measurement System with Micro-Four-Point Probes at Sub-Kelvin Temperature under High Magnetic Field in Ultrahigh Vacuum*, e-Journal of Surface Science and Nanotechnology **10**, 400 (Jul, 2012).

[5] P. De Padova, P. Vogt, A. Resta, J. Avila, I. Razado-Colambo, C. Quaresima, C. Ottaviani, B. Olivieri, T. Bruhn, T. Hirahara, T. Shirai, S. Hasagawa, M. C. Asensio, and G. Le Lay, *Evidence of Dirac Fermions in Multilayer Silicene*, Appl. Phys. Lett, **102**, 163106 (Apr, 2013).

[6] M. Yamada, T. Hirahara, and S. Hasegawa, *Magnetotransport measurements of a superconducting surface state of In- and Pb-induced structures on Si(111)*, Phys. Rev. Lett. **110**, 237001 (Jun, 2013).

[7] T. Tono, T. Hirahara, and S. Hasegawa, *In situ transport measurements on ultrathin Bi(111) films using a magnetic tip: Possible detection of current-induced spin polarization in the surface states*, New J. Phys. **15**, 105018 (Oct 2013).

[8] M. Aitani, Y. Sakamoto, T. Hirahara, M. Yamada, H. Miyazaki, M. Matsunami, S. Kimura, and S. Hasegawa, *Fermi level tuning of topological insulator thin films*, Jpn. J. Appl. Phys. **52**, 110112 (Oct, 2013).

[9] N. Nagamura, R. Hobara, T. Uetake, T. Hirahara, M. Ogawa, T. Okuda, K. He, P. Moras, P. M. Sheverdyaeva, C. Carbone, K. Kobayashi, I. Matsuda, and S. Hasegawa, *Anisotropic Electronic Conduction in Metal Nanofilms Grown on a One-Dimensional Surface Superstructure*, Phys. Rev. B **89**, 125415 (Mar, 2014).

[10] M. Aitani, T. Hirahara, S. Ichinokura, M. Hanaduka, D. Y. Shin, S. Hasegawa:*In situ Magnetotransport Measurements of Ultrathin Bi films: Evidence for a Surface-Bulk Coherent Transport*, Phys. Rev. Lett. **113**, 206802 (Nov, 2014).

[11] T. Shirasawa, M. Sugiki, T. Hirahara, M. Aitani, T. Shirai, S. Hasegawa, and T. Takahashi: *Structure and transport properties of Cu doped Bi_2Se_3 films*, Phys. Rev. B **89**, 195311 (May, 2014).

[12] T. Shirai, T. Shirasawa, T. Hirahara, N. Fukui, T. Takahashi, and S. Hasegawa: *Structure Determination of Multilayer Silicene Grown on Ag(111) films by Electron Diffraction: Evidence for Ag Segregation at the Surface*, Phys. Rev. B **89**, 241403(R) (Jun, 2014).

[13] N. Fukui, R. Hobara, T. Hirahara, Y. Miyatake, H. Mizuno, T. Sasaki, T. Nagamura, and S. Hasegawa: *In-situ Micro-fabrication and Measurements of Bi_2Se_3 Ultrathin Films in a Multi-chamber System having Focus Ion Beam, Molecular Beam Epitaxy, and Four-Tip Scanning Tunneling Microscope*, e-J. Surf. Sci. Nanotech. **12**, 423 (Oct, 2014).

[14] R. Sakamoto, T. Kambe, T. Kusamoto, T. Pal, N. Fukui, T. Shimojima, Z. Wang, T. Hirahara, K. Ishizaka, S. Hasegawa, F. Liu, and H. Nishihara: *Redox control and high conductivity of nickel bis(dithiolene) complex π-nanosheet, a candidate of the first organic topological insulator*, J. Am. Chem. Soc. **136** (41), 14357 (Sep, 2014).

[15] S. Ichinokura , T. Hirahara, S. Hasegawa, O. Sakai and T.T. Suzuki: *Electron-spin dependent $^4He^+$ ion scattering on Bi surfaces*, Radiation Effects and Defects in Solids **169** (12), 1003 (Nov, 2014).

[16] T.T. Suzuki, O. Sakai, S. Ichinokura , T. Hirahara, and S. Hasegawa: *Target element dependent spin-orbit coupling in polarized $^4He^+$ ion scattering*, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms **354**, 163 (July, 2015).

[17] T. Hirahara, T. Shirai, T. Hajiri, M. Matsunami, K. Tanaka, S. Kimura, S. Hasegawa, and K. Kobayashi:*Role of Quantum and Surface-State Effects in the Bulk Fermi Level Position of Ultrathin Bi films*, Phys. Rev. Lett.**115**, 106803 (Sep, 2015).

[18] A.V. Matetskiy, S. Ichinokura, L.V. Bondarenko, A.Y. Tupchaya, D.V. Gruznev, A.V. Zotov, A.A. Saranin, R. Hobara, A. Takayama, and S. Hasegawa: *Two-dimensional superconductor with giant Rashba effect: One-atomic-layer Tl-Pb compound on Si(111)*, Phys. Rev. Lett. **115**, 147003 (Oct, 2015).

[19] A.V. Matetskiy, I. A. Kibirev, T. Hirahara, S. Hasegawa, A.V. Zotov, and A.A. Saranin: *Direct observation of a gap opening in topological interface states of $MnSe/Bi_2Se_3$ heterostructure*, Appl. Phys. Lett. **107**, 091604 (Sep, 2015).

[20] S. Ichinokura, K. Sugawara, A. Takayama, T. Takahashi, and S. Hasegawa:*Superconducting Calcium-Intercalated Bilayer Graphene*, ACS Nano **10**, 2761 (Jan, 2016)).

[21] R. Akiyama, K. Fujisawa, T. Yamaguchi, R. Ishikawa and S. Kuroda: *Two-dimensional quantum transport of multivalley (111) surface state in topological crystalline insulator SnTe thin films*, Nano Research **9**, 490 (Feb, 2016).

[22] T. Nakamura, R. Yoshino, R. Hobara,S. Hasegawa, and T. Hirahara: *Development of a convenient in situ UHV scanning tunneling potentiometry system using a tip holder equipped with current-injection probes*, e-J. Surf. Sci. Nanotech. **14**, 216-224 (2016).

[23] S. Ito, B. Feng, M. Arita, A. Takayama, R.-Y. Liu, T. Someya, W.-C. Chen, T. Iimori, H. Namatame, M. Taniguchi, C.-M. Cheng, S.-J. Tang, F. Komori, K. Kobayashi, T.-C. Chiang, and I. Matsuda: *Proving Nontrivial Topology of Pure Bismuth by Quantum Confinement*, Phys. Rev. Lett. **117**, 236402 (2016).

[24] R. Ishikawa, T. Yamaguchi, Y. Ohtaki, R. Akiyama, S. Kuroda, *Thin film growth of a topological crystal insulator SnTe on the CdTe (111) surface by molecular beam epitaxy*, Journal of Crystal Growth **453**, 124-129 (2016).

[25] S. Ichinokura, L. Bondarenko, A. Tupchaya, D. Gruznev, A. Zotov, A. Saranin, and S. Hasegawa: *Superconductivity in thallium double atomic layer and transition into an insulating phase intermediated by a quantum metal state*, 2D Materials **4**, 025020 (2017).

[26] Y. K. Wakabayashi, R. Akiyama, Y. Takeda, M. Horio, G. Shibata, S. Sakamoto, Y. Ban, Y. Saitoh, H. Yamagami, A. Fujimori, M. Tanaka, and S. Ohya, *Origin of the large positive magnetoresistance of $Ge_{1-x}Mn_x$ granular thin films*, Phys. Rev. B **95**, 014417 (2017).

[27] T. Hirahara, S. V. Eremeev, T. Shirasawa, Y. Okuyama, T. Kubo, R. Nakanishi, R. Akiyama, A. Takayama, T. Hajiri, S. Ideta, M. Matsunami, K. Sumida, K. Miyamoto, Y. Takagi, K. Tanaka, T. Okuda, T.Yokoyama, S. Kimura, S. Hasegawa, and E. V. Chulkov: *A large-gap magnetic topological heterostructure formed by subsurface incorporation of a ferromagnetic layer*, Nano Letters **17**, 3493-3500 (May, 2017)

[28] R. Akiyama, Y. Takano, Y. Endo, S. Ichinokura, R. Nakanishi, K. Nomura, and S. Hasegawa: *Berry phase shift from 2π to π in Bilayer graphene by Li-intercalation and sequential desorption*, Appl. Phys. Lett. **110**, 233106 (4pp) (Jun, 2017).

[29] P. Chen, Woei Wu Pai, Y.-H. Chan, A. Takayama, C.-Z. Xu, A. Karn, S. Hasegawa, M. Y. Chou, S.-K. Mo, A.-V. Fedorov, and T.-C. Chiang: *Emergence of charge density waves and a pseudogap in single-layer $TiTe_2$*, Nature Communications **8**, 516-521 (Sep, 2017).

[30] S. Ohya, A. Yamamoto, T. Yamaguchi, R. Ishikawa, R. Akiyama, L. D. Anh, S. Goel, Y. K. Wakabayashi, S. Kuroda, M. Tanaka, *Observation of the inverse spin Hall effect in the topological crystalline insulator SnTe using spin pumping*, Physical Review B **96**, 094424 (Sep, 2017).

[31] Y. Nakata, K. Sugawara, S. Ichinokura, Y. Okada, T. Hitosugi, T. Koretsune, S. Hasegawa, T. Sato, and T. Takahashi: *Observation of Anisotropic Band Splitting in Monolayer $NbSe_2$: Implications for Superconductivity and Charge Density Wave*, npj 2D Materials and Applications **2**, 12 (May, 2018).

[32] Y. Nakata, K. Sugawara, S. Ichinokura, Y. Okada, T. Hitosugi, T. Koretsune, S. Hasegawa, T. Sato, and T. Takahashi: *Observation of Anisotropic Band Splitting in Monolayer $NbSe_2$: Implications for Superconductivity and Charge Density Wave*, npj 2D Materials and Applications **2**, 12 (6pp) (May, 2018).

[33] T. Hirahara and S. Hasegawa: *Comment on " Quantum transport in the surface states of epitaxial Bi(111) thin films "*, Phys. Rev. B **97**, 207401 (3pp) (May, 2018).

[34] R. Akiyama, K. Sumida, S. Ichinokura, A. Kimura, K. Kokh, O. Tereshchenko, and S. Hasegawa: *Shbunikov-de Haas oscillations of p and n-type topological insulator $(Bi_xSb_{1-x})_2Te_3$*, J. Phys.: Cond. Matt. **30**, 265001 (8pp) (Jun, 2018).

[35] Y. Endo, S. Ichinokura, R. Akiyama, A. Takayama, K. Sugawara, T. Takahashi, K. Nomura, and S. Hasegawa: *Weak localization in bilayer graphene with Li-intercalation/desorption*, J. Phys.: Cond. Matt., **30**, 305701 (7pp) (Jul, 2018).

[36] Y. Shiomi, K. T. Yamamoto, R. Nakanishi, T. Nakamura, S. Ichinokura, R. Akiyama, S. Hasegawa, and E. Saitoh: *Efficient Edelstein effects in one-atom-layer Tl-Pb compound*, Appl. Phys. Lett. **113**, 052401 (4pp) (Aug, 2018).

[37] T. Nakamura, H. Kim, S. Ichinokura, A. Takayama, A.V. Zotov, A.A. Saranin, Y. Hasegawa, and S. Hasegawa:*Unconventional Superconductivity in the single-atom-layer alloy Si(111)-$\sqrt{3} \times \sqrt{3}$-(Tl, Pb)*, Phys. Rev. B **98**, 134505 (6pp) (Oct, 2018) (Editors ' suggestion).

[38] H. Toyama, H. Huang, T. Nakamura, L. V. Bondarenko, A. Y. Tupchaya, D. V. Gruznev, A. Takayama, A. V. Zotov, A. A. Saranin, and S. Hasegawa: *Thickness dependence of surface structure and superconductivity in Pb atomic layers*, J. Phys. Soc. Japan **87**, 113601 (5pp)(Oct, 2018).

[39] H. Toyama, H. Huang, T. Nakamura, L. V. Bondarenko, A. Y. Tupchaya, D. V. Gruznev, A. Takayama, A. V. Zotov, A. A. Saranin, and S. Hasegawa:*Superconductivity of Pb Ultrathin Film on Ge(111) Surface*, Defect and Diffusion Forum **386**, 80-85 (Sep, 2018)

[40] T. Nakamura, A. Takayama, R. Hobara, D.V. Gruznev, A.V. Zotov, A.A. Saranin, S. Hasegawa:*Superconducting single-atomic-layer Tl-Pb compounds on Ge(111) and Si(111) surfaces*, Applied Surface Science **479**, 679-684 (Feb, 2019),

[41] S. Ichinokura, Y. Nakata, K. Sugawara, Y. Endo, A. Takayama, T. Takahashi, and S. Hasegawa:*Vortex-induced quantum metallicity in mono-unit-layer superconductor $NbSe_2$* , Phys. Rev. B **99**, 220501(R) (Jun, 2019).

[42] N. V. Denisov, A. V. Matetskiy, A. N. Mihalyuk, S. V. Eremeev, S. Hasegawa, A. V. Zotov, and A. A. Saranin:*Superconductor-insulator transition in an anisotropic two-dimensional electron gas assisted by one-dimensional Friedel oscillations: (Tl,Au)/Si(100)-c(2×2)*, Phys. Rev. B **100**, 155412 (Oct, 2019).

[43] Y. Endo, Y. Fukaya, I. Mochizuki, A. Takayama, T. Hyodo, S. Hasegawa: *Structure of Superconducting Ca-intercalated Bilayer Graphene/SiC studied using Total-Reflection High-Energy Positron Diffraction*, Carbon, in press (2019).

< Conference Proceedings >

None.

< Review Papers >

[44] 長谷川修司, 究極のナノマテリアル—表面超構造—, 自動車技術　**67** (11), 102 (Nov, 2013).

[45] 長谷川修司：表面での電子・スピン輸送研究の最近の展開, 表面科学 **36**, 112 (Mar, 2015).

[46] 一ノ倉聖, 平原徹, 酒井治, 長谷川修司, 鈴木拓：ビスマス表面におけるスピン依存イオン散乱, 表面科学 **36**, 408 (Aug, 2015).

[47] 長谷川修司：物理科学、この *30* 年：表面物理学, パリティ **30**, 14 (Apr, 2015).

[48] 一ノ倉聖, 保原麗, 高山あかり, 長谷川修司, Andrey V. Matetskiy, Leonid V. Bondarenko, Alexandra Y. Tupchaya, Dimitry V. Gruznev, Andrey V. Zotov, Alexander A. Saranin： *In situ* 電気伝導測定による *Rashba* 型表面構造（*Tl, Pb)/Si(111)* の超伝導の観測, 表面科学 **37** (8), 363-368（2016).

[49] 高橋隆、菅原克明、一ノ倉聖、高山あかり、長谷川修司: ２層グラフェン層間化合物の２次元超伝導, 表面科学 **38**, 460-465 (Sep, 2017).

[50] 長谷川修司:表面電子状態 —タム・ショックレー状態からトポロジカル状態—, 固体物理 **53**(11), 565-574（Nov, 2018）.

[51] S. Hasegawa:*Charge and Spin Transport on Surfaces and Atomic Layers Measured by Multi-Probe Techniques*, J. Phys.: Cond. Matt. **31**, 223001 (12pp) (Mar, 2019) (Topical Review),

＜**Books**＞

[52] S. Hasegawa, T. Hirahara, Y. Kitaoka, S. Yoshimoto, T. Tono, and T. Ohta, *Nanometer-Scale Four-Point Probe Resistance Measurements of Individual Nanowires by Four-Tip STM*, pp. 153-165, in Atomic Scale Interconnection Machines, ed. Christian Joachim (Springer 2012).

[53] S. Hasegawa（分担執筆）: *Reflection High-Energy Electron Diffraction*, pp. 1925-1938, in Characterization of Materials, ed. Elton N. Kaufmann (Wiley 2012).

[54] 長谷川修司（分担執筆）: 電子的・電気的特性 （第３章）in 表面物性の基礎（現代表面科学シリーズ） 日本表面科学会編集 (共立, Oct 2012).

[55] S. Hasegawa:*"The Image is My Life."*, in “In Memory of Akira Tonomura: Physicist and Electron Microscopist”(World Scientific, 2013), pp. 156-163.

[56] 長谷川修司, 問題 *4.30* 「良い論文を書くには？」, in 問題と解説で学ぶ表面科学（現代表面科学シリーズ６）(共立, Nov 2013). p.177

[57] S. Hasegawa:*"The Image is My Life."*, in “In Memory of Akira Tonomura: Physicist and Electron Microscopist” Eds. K. Fujikawa and Y. A. Ono (World Scientific, 2014), pp. 156-163.

[58] 長谷川修司：研究者としてうまくやっていくには, (講談社ブルーバックス, Dec, 2015).

[59] 長谷川修司, 他分担執筆, パリティ編集委員会編：先生、物理っておもしろいんですか？, (丸善, May, 2015).

[60] 長谷川修司: 物理学を例にとって考える“研究する意味”, in 科学の技法—東京大学「初年次ゼミナール理科」テキスト—、東京大学教養教育高度化機構初年次教育部門 増田建・坂口菊恵 編 （2017　東京大学出版会）pp. 214-221.

[61] 長谷川修司: Part II, 第５章 多探針計測法, in 分子アーキテクトにクス —単分子技術が拓く新たな機能—, 日本化学会編、化学同人（Dec, 2018） PP. 83-89.

[62] S. Ichinokura and S. Hasegawa: *Chapter 6: Transport Measurement; Carrier Transport*, in Monatomic Two-Dimensional Layers, ed. I. Matsuda, (Elsevier, Jan, 2019) pp.159-197.

7 Invited Presentations at International Conferences

[1] S. Hasegawa:*Surface nanomaterials: Low-dimensional, spin-split, and superconducting*, The 2nd International School on Surface Science: Technologies and Measurements on Atomic Scale, 2012 年 10 月 6 日 (Sochi, Russia).

[2] S. Hasegawa:*Topological and superconducting surface states*, Workshop of DFG- and NOW- Research Units FOR 1700, FOR 1162 and FOM on Physics at the borderline between 1D and 2D, 2013 年 2 月 14 日 (Bad Honnef, Germany).

[3] S. Hasegawa, *Surface Nanomaterials for Electronics and Spintronics*, Nanomeeting 2013 (Belarusian State University of Informatics and Radioelectronic), 2013 年 5 月 28 日 (Minsk, Belarus).

[4] S. Hasegawa, *Charge and Spin Transport Topological at Surfaces with Strong Electron-Phonon and Spin-Orbit Couplings*, International Workshop and Final Conference on "Energy Dissipation at Surfaces", 2013 年 6 月 6 日 (Bad Honnef, Germany).

[5] S. Hasegawa, *Surface Nanomaterials for Sustainable Growth - Superconducting and Spin-split Surface States* -, The Second Asian School-Conference on Physics and Technology of Nanostructured Materials (ASCO-NANOMAT 2013, Far Eastern Federal University), 2013 年 8 月 21 日 (Vladivostok, Russia).

[6] S. Hasegawa, *Spin Splitting and Spin Transport at Surface States of Non-Magnetic Materials with Strong Spin-Orbit Coupling*, 2013 NSFC-JSPS seminar on magnetic surface and films (Fudan University), 2013 年 10 月 22 日 (Shanghai, China).

[7] S. Hasegawa, *Spin at Crystal Surfaces*, Workshop on Quantum Materials (Max Planck Institute), 2013 年 12 月 9 日 (Stuttgart, Germany).

[8] S. Hasegawa, *Spins Transport at Crystal Surfaces*, The 2nd International Symposium on the Functionality of Organized Nanostructures (FON '14), 2014 年 11 月 28 日, National Museum of Emerging Science and Innovation (Miraikan), Tokyo.

[9] S. Hasegawa, *Spins at Crystal Surfaces*, LMU-Todai Cooperation in Physics Workshop, 2014 年 10 月 27 日, Ludwig-Maximilians-Universitat Munchen (Germany).

[10] S. Hasegawa, *Spin-split surface states and electronic/spin transport therein*, The 11th Surface Nanoscience Workshop, 2015 年 2 月 14 日, PyeongChang (Republic of Korea).

[11] S. Hasegawa, *Charge/spin transport and superconductivity at Rashba spin-split surface states*, The 23rd International Colloquium on Scanning Probe Microscopy (ICSPM23), 2015 年 12 月 11 日, ニセコ, 北海道.

[12] S. Hasegawa,*Surface Transport of Topological and Non-topological Materials*, The 10th International Symposium on Atomic Level Characterizations for New Materials and Devices (ALC'15), 2015 年 10 月 26 日, 松江, 島根.

[13] S. Hasegawa,*Charge/Spin Transport at Surfaces*, The 7th International Conference on Scanning Probe Spectroscopy and Related Methods (SPS'15), 2015 年 6 月 22-24 日, Poznan (Poland).

[14] S. Hasegawa,*Surface transport below 1 K*, International Workshop on LEED and Related Techniques, 2015 年 5 月 28 日, Hannover (Germany).

[15] S. Hasegawa, *Atomic-Layer Superconductors*, International Symposium on Two-Dimensional Layered Materials and Art: Two Worlds Meet, 2016 年 3 月 24 日, IMeRA, Marseille (France).

[16] S. Hasegawa, *Atomic-Layer Superconductors*, Cooperation in Physics Workshop of LMU-UTokyo, 2016 年 3 月 1 日, 小柴ホール、東京大学.

[17] S. Hasegawa, *Atomic-Layer Superconductors*, The 16th Japan-Korea-Taiwan Workshop on Strongly Correlated Electron Systems, 2016 年 2 月 19 日, 小柴ホール、東京大学.

[18] S. Hasegawa: *Low-Dimensionality, Symmetry Breaking, and Topology on Surfaces*, 2016 IBS Conference -Surface Atomic Wires-, 2016 年 8 月 17 日, Pohang, Korea.

[19] S. Hasegawa: *Atomic-Layer Superconductors*, The 20th International Vacuum Congress, 2016 年 8 月 26 日, Busan, Korea.

[20] S. Hasegawa: *Symmetry-Broken Monolayer Superconductors The 10th International Workshop on LEEM/PEEM*, 2016 年 9 月 14 日, Monterey, California, USA.

[21] S. Hasegawa: *Superconductivity and Spin Current at Surface States*, Workshop at the Research Center Julich on Charge transport at surfaces and nanostructures with multi-probe techniques, 2016 年 9 月 21 日, Julich, Germany.

[22] S. Hasegawa: *Parity-Broken Monatomic-Layer Superconductors*, Workshop of ENS-UTokyo, 2016 年 11 月 17 日, Ecole Normale Superieure, Paris (France).

[23] S. Hasegawa: *Parity-Broken Atomic-Layer Superconductors*, MPI-UBC-UTokyo Workshop, 2016 年 12 月 5 日, 東京大学.

[24] S. Hasegawa: *Parity-Brokn Monatomic-Layer Superconductors*, APCTP-Quantum Materials Symposium 2017, 2017 年 2 月 22 日, YongPyong Resort, Korea.

[25] S. Hasegawa: *Parity-Brokn Monatomic-Layer Superconductors*, 2017 中華民国物理年会 Taiwan-AVS Symposium on Frontiers of 2D Materials, 2017 年 1 月 17 日, 淡江大学、新台北、台湾.

[26] S. Hasegawa: *Atomic-Layer Superconductors*, The 11th International Symposium on Atomic Level Characterizations for New Materials and Devices '17, 2017 年 12 月 8 日, Hawai (USA).

[27] S. Hasegawa: *Graphene Intercalation*, The 5th Workshop on Physics between Ecole Normale Superiure and University of Tokyo, 2017 年 11 月 16 日, University of Tokyo.

[28] S. Hasegawa: *Atomic-Layer Superconductors*, The 16th International Conference on the Formation of Semiconductor Interfaces, 2017 年 7 月 3 日, Hannover (Germany).

[29] S. Hasegawa: *Monatomic-Layer Superconductors*, The 13th International Conference on Diffusion in Solids and Liquids - DSL2017, 2017 年 6 月 27 日, Wien (Austria).

[30] S. Hasegawa: *Atomic-Layer Superconductors*, Graphene EU Flagship-Japan Second Workshop, 2017 年 5 月 6 日, Barcelona (Spain).

[31] S. Hasegawa: *Multi-probe Techniques for Surfaces and 2D Materials –Superconductivity and Spin Current at Surfaces–*, Surface Physics and LEEM workshop 2017, 2017 年 4 月 17 日, 重慶大学 (中国).

[32] S. Hasegawa: *Dissipationless currents at atomic layers*, 2018 International Conference on Nanoscience + Technology (ICN+T 2018), 2018 年 7 月 26 日, Brno (Czech).

[33] S. Hasegawa: *Atomic-Layer Superconductors and Topological Superconductors*, The 3rd Asia-Pacific Symposium on Solid Surfaces (APSSS-3), 2018 年 8 月 21 日, Pohang (Korea).

[34] S. Hasegawa: *Dissipationless currents at atomic layers*, The 3rd International Workshop on Charge transport with multi-tip STM Techniques, 2018 年 9 月 19 日, Julich, Germany.

[35] S. Hasegawa: *Dissipationless currents at atomic layers*, 2018 Workshop of Max Planck-UBC-UTokyo Centre of Quantum Materials, 2018 年 12 月 11 日, 東京大学（本郷）.

[36] S. Hasegawa: *Towards high-temperature quantum anomalous Hall effect*, IBS Conference on Surface Atomic Wires 2019, 2019 年 8 月 27 日, Pohang (Korea).

8 Teaching Accomplishment

(MS: Master Course Student, DS: Doctor Course Student)

- 白井皓寅 (MS)：表面科学技術者資格認定 （公益社団法人日本表面科学会、2012 年 7 月）

- 一ノ倉聖 (DS)、申東潤 (MS)、中村友謙 (MS)：表面科学技術者資格認定（公益社団法人日本表面科学会、2013 年 7 月）

- 一ノ倉聖 (DS)：Travel Award at The 7th International Symposium on Surface Science (ISSS-7)(公益社団法人日本表面科学会, 2014 年 11 月).

- 一ノ倉聖 (DS)：平成 26 年度講演奨励賞（スチューデント部門）(公益社団法人日本表面科学会, 2014 年 11 月).

- 一ノ倉聖 (DS)：平成 27 年度 理学系研究科研究奨励賞（博士課程）（東京大学大学院理学系研究科, 2016 年 3 月).

- 遠藤由大 (MS)：第 36 回表面科学学術講演会 講演奨励賞（スチューデント部門）「SiC 結晶上２層グラフェンの輸送特性および Li インターカレートによる影響」（2017 年 3 月 10 日）.

- 遠藤由大 (MS)：日本表面科学会 第 4 回関東支部セミナーポスター賞（日本表面科学会）「SiC 上 2 層グラフェンにおける量子輸送特性」(2016 年 10 月 18 日).

- 一ノ倉聖 (DS)：Springer Thesis Award, (2016 年 5 月 20 日)

- 一ノ倉聖 (DS)：平成 28 年日本学術振興会リンダウ・ノーベル賞受賞者会議派遣事業　採用・派遣 (2016 年 6 月 26 日-7 月 1 日).

- 一ノ倉聖 (DS)：表面科学会 第 1 回関東支部講演大会 講演奨励賞（日本表面科学会）「その場４端子電気伝導測定による SiC 上２層グラフェンの輸送特性」(2016 年 4 月).

- 遠藤由大 (MS)：表面科学会 第 1 回関東支部講演大会 学生講演奨励賞（日本表面科学会）「カルシウムをインターカレートした２層グラフェンにおける超伝導」(2016 年 4 月).

- 武内康範 (MS)：The Best Poster Award at The 8th International Symposium on Surface Science (公益社団法人日本表面科学会), *Two-dimensional conducting layer on* $SrTiO_3$ *surface induced by hydrogenation*, 2017 年 10 月.

- 一ノ倉 聖 (DS)、菅原 克明、高山 あかり、高橋 隆、長谷川修司：応用物理学会薄膜・表面物理分科会 第 2 回論文賞 (公益社団法人応用物理学会), 2018 年 3 月, 受賞論文：“*Superconducting Calcium-Intercalated Bilayer Graphene* (ACS Nano, **10**, 2761-2765 (2016))”.

- 遠藤 由大 (DS)：日本物理学会領域 9　第 3 回学生賞 (日本物理学会第 73 回年次大会), 2018 年 3 月, 受賞発表：“全反射高速陽電子回折法による 2 層グラフェン層間化合物の構造解析”

- 中西 亮介 (MS)：理学系研究科研究奨励賞 (修士課程), 2018 年 3 月, 受賞修士論文：“トポロジカル (結晶) 絶縁体の薄膜作製と特性評価”.

- 遠山晴子 (MS)：“*Superconductivity of Pb ultrathin film on Ge(111) surface*”, The Young Scientist Award at The 4th Asian School-Conference on Physics and Technology of Nanostructured Materials, Vladivostok, Russia, 2018 年 9 月.

- 一ノ倉 聖 (DS)：“分子線エピタキシーとその場での電子輸送測定を用いた 2 次元超伝導の開拓”, 第 13 回日本物理学会若手奨励賞 (領域 9), 2019 年 3 月.

- 鄭 帝洪 (MS) : 日本物理学会領域 9 第 6 回学生賞 (日本物理学会 2019 秋季大会), 2018 年 9 月, 受賞発表 :“ Yb 蒸着されたグラフェン/SiC における強磁性の発現”

9 Contribution to Academic Community

9.1 Editorial Activities

- Associate Editor of *e-Journal of Surface Science and Nanotechnology* (The Japan Society of Vacuum and Surface Science), 2003-present.
- Editor-in-Chief of *Bulletin of The Physical Society of Japan*, 2017-2018, Associate Editor of the Bulletin, 2015-2016.

9.2 Organization of Professional Societies

- Executive Board Member of The Japan Society of Vacuum and Surface Science (former The Surface Science Society of Japan), 2000-present.
- Chair of The Surface/Interface Division (Division 9) of The Physical Society of Japan, 2013-2014.

9.3 Organization and Advisory of Conferences

- Member of Organizing Committee of Asian-Pacific Symposium on Solid Surfaces (APSSS), 2014-present (biennially).
- Co-Chairmen of Symposium on Surface and Nano Sciences (The Surface/Thin Films Division of The Japan Society of Applied Physics), 2010-present (annual).
- Member of Organizing Committee of International Symposium on Surface Science and Nanotechnology (ISSS), organized by The Japan Society of Vacuum and Surface Science, 2005-present (every three years).

10 Outreach

- Mock lectures and open lab for high-school students, for Utsunomiya High School, Maebashi High School, Shonan High School, and Tsuchiura-Dai-Ichi High School, and others upon request, 2009-present (annually).
- Trainer for the (candidates of) Japan delegates (high school students) for International Physics Olympiad, 2005-present (annually).
- Many introductory talks at high schools about Physics Olympiad as the Chair of The Japan Committee of Physics Olympiad.

11 Committee Service

11.1 External Committees

- Executive Board Member of The Japan Society of Vacuum and Surface Science (former The Surface Science Society of Japan), 2000-present; Vice-president, 2019-present
- Executive Board Member of The Physical Society of Japan (Editor-in Chief of the Bulletin),2017-2018.
- Associate Editor of e-Journal of Surface Science and Nanotechnology (The Japan Society of Vacuum and Surface Science), 2003-present.
- Executive Board Member of The Committee of Japan Physics Olympiad (NPO-JPhO), 2002-present; Chair, 2018-present.
- Editorial Board Member for Textbook of Junior-High-School Science (Dainippon Tosho Co., Ltd.) 2009-present.

11.2 University Committees

- Chair of Department of Physics, and a member related committees in School of Science, 2017-2018
- A member of the steering committee of Cryogenics Center, 2019-present

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	5	USA, Tunisia, India, Russia, China
Master Course	10	China, Russia, USA, Netherlands, Germany, Korea
Doctor Course	2	China
Foreign researchers hosted	1	Russia
Students sent abroad	8	Russia, USA, Germany, France
Researchers sent abroad	3	USA, Russia, France
Foreign visitors	27	Russia, France, Switzerland, China, Korea, Germany, Austria

Masamitsu Hayashi、林 将光

1 Education and Professional Experiences

Education

2000	B.S. (Applied Physics)	Tohoku University
2002	M.S. (Applied Physics)	Tohoku University
2007	Ph.D (Materials Science and Engineering)	Stanford University

Professional Appointments

2007−2008	Post-doctoral fellow	IBM Alamden Research Center
2008−2019	Senior research scientist	National Institute for Materials Science
2016−	Associate Professor	The University of Tokyo

2 Research Highlights

We have been working on the physics of transport, magnetism and optical response in thin film heterostructures, particularly putting focus on the effects of spin orbit interaction. The following are representative achievements of our work since 2012.

With regard to spin transport in thin film heterostructures, we have established means to study current induced torque that develop due to the strong spin orbit interaction of the materials under study[40]. Studies of Ta/CoFeB/MgO heterostructrures reveal that the torque exhibits a significant dependence on the Ta and CoFeB layer thicknesses[44]. Surprisingly, a 1nm thickness variation of the Ta layer can change the magnitude of the current induce torque by nearly two orders of magnitude. These results illustrate that the presence of atomically thin metals can profoundly change the landscape for controlling magnetic moments in such heterostructures electrically. The vector measurements we developed is now being used as a standard for evaluating current induced torque in thin film heterostructures.

We have revealed the relationship between the structure and the spin Hall angle of the early $5d$ transition metals[30]. The structure of the metals influences the spin Hall angle via changes in its resistivity. We find that the spin Hall effect of the amorphous-like transition metals depends on the number of $5d$ electrons, suggesting that the element dependent spin orbit coupling and the electron Berry curvature play an important role in defining the efficiency of spin current generation.

The spin Hall magnetoresistance (SMR), first reported in 2013, is a magnetoresistance that arise in bilayers made of ferromagnetic layer and non-magnetic layer that exhibits sizable spin Hall effect. The magnitude of the SMR scales with the square of the spin Hall angle of the non-magnetic layer. Originally, SMR was studied in non-magnetic metal/ferromagnetic insulator bilayers. We have studied the SMR in bilayers where the ferromagnetic insulator is replaced by a ferromagnetic metal and found that the spin dependent transport properties of the ferromagnetic metal layer causes a unique temperature dependence of the SMR[28].

These studies have shown that the SMR can be used to evaluate the spin Hall angle in technologically relevant metallic bilayers. However, we have also found that certain materials (e.g. textured Co) can cause SMR-like magnetoresistance and may contaminate the measurements[12].

Using the concept of spin Hall magnetoresistance, we have demonstrated for the first time (independently with a group from Germany) that a heat current can be converted to spin current[15]. The effect, referred to as the spin Nernst effect, was theoretically proposed for nearly a decade ago. We find that the conversion efficiency of the spin Nernst effect is similar in magnitude with that of the spin Hall effect (conversion of current to spin current), but the sign is different. Later on, it was found from band structure calculations that the origin of the spin Nernst effect is directly related to the energy dependence of the spin Hall conductivity near the Fermi level.

On the front of magnetism, we find the Dzyaloshinskii-Moriya interaction (DMI) emerges at interfaces of a heavy metal layer and a ferromagnetic metal layer. The size and sign of the DMI strongly depends on the material used for the heavy metal layer[37]. These results show that chiral magnetism can be designed by combining materials with different spin orbit coupling. Using the interface DMI, we have revealed the unique inertia of chiral domain walls[23] and the strong repulsive force that acts on neighboring domain walls. These findings led to the demonstration of more than ten multiple chiral domain walls moving in sync with current pulses[19]. More recently, we have shown that the interfacial DMI can be modulated with current: the DMI increases with increasing current with a rate that agrees with what is predicted by the model based on the spin Doppler effect[2]. The results imply that the interfacial DMI may partly originate from equilibrium spin current which can be modulated externally.

Recently, we have started working on the coupling of electron spin with phonons. We find a large planar-Hall like transverse voltage develops in magnetic thin film when surface acoustic waves (SAW) are excited in ferromagnetic thin films[3]. The size of the voltage is more than an order of magnitude larger than its electronic counterpart (i.e. planar Hall effect). We consider acoustic current can generate magneto-galvanic effects similar to the electric and thermo-electric currents but the effect can be significantly larger.

We have also initiated research on the interaction between electron spin and light. Our recent results show that irradiation of circularly polarized light in the visible range generates a helicity dependent photocurrent in Cu/Bi bilayers[7]. The effect can arise from a spin momentum locked band at the Cu/Bi interface. The interaction of electron spin and light in materials with strong spin orbit coupling may form as a new platform for studying the coupling between the two degree of freedom.

3 Selected Papers

- N. Kato, M. Kawaguchi, Y. C. Lau, T. Kikuchi, Y. Nakatani, M. Hayashi, Current-Induced Modulation of the Interfacial Dzyaloshinskii-Moriya Interaction. Phys. Rev. Lett. 122, 257205 (2019).

  This is the first paper to report on the observation of the spin Doppler effect, i.e., modulation of the interfacial Dzyaloshinskii-Moriya interaction using current.

- Hirose, N. Ito, M. Kawaguchi, Y. C. Lau, M. Hayashi, Circular photogalvanic effect in Cu/Bi bilayers, Appl. Phys. Lett. 113, 222404 (2018).
  This work was selected as one of the Highlights in APL.

- P. Sheng, Y. Sakuraba, Y.-C. Lau, S. Takahashi, S. Mitani, M. Hayashi, The spin Nernst effect in tungsten, Science Advances 3, e1701503 (2017).
  This is one of the first papers to report on the observation of the spin Nernst effect, an effect that converts heat current to spin current.

- J. Torrejon *et al.* Interface Control of the Magnetic Chirality in CoFeB—MgO Heterosctructures with Heavy Metal Underlayers. Nature Comm. 5, 4655 (2014).
  Experimental demonstration of the Dzyaloshinskii-Moriya interaction that develops at the interface and depends on the combination of materials. Citation: 260 (Google scholar)

- J. Kim *et al.* Layer thickness dependence of the current induced effective field vector in Ta—CoFeB—MgO. Nature Mater. 12, 240 (2013).
  First report on the vector measurements of the spin orbit torque in thin film heterostructures. Citation: 560 (Google scholar)

4 Honors, Awards and Professional Society Memberships

- The Young Scientists' Prize, The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, 2016

- IUPAP Young Scientist Medals in the field of Magnetism, IUPAP Commission on Magnetism, 2015

- President prize, National Institute for Materials Science, 2015

- Sir Martin Wood Prize, Millennium Science Forum, 2014

- Funai Foundation Achievement Award, Funai Foundation, 2014

5 Research Plan

Currently, we are working on the physics of spin orbit materials. Our studies cover transport, magnetism, thermal and optical response of thin film heterostructures with strong spin orbit coupling. We put a particular focus on the physics of strong correlations between spin, photon, phonon and magnon and look for systems that can applied to quantum technologies.

The spin orbit interaction couples the electron spin with its orbital motion, giving rise to unique electronic structures and physical properties. Majority of the topological insulators and Weyl/Dirac semimetals are formed from elements with strong spin orbit interaction. As classification of the topological materials is mostly completed, the interest now is to construct exotic materials with unconventional functionalities. We aim to design and build topological materials using thin film heterostructures. With the state of art thin film deposition tools, one may form atomically thin films layer by layer on demand to create artificial structures that do not exist in nature. The electronic structure of such thin film heterostructure is influenced by the symmetry of the lattice as well as the atomic orbitals, interfacial electronic states and periodicity of any repeated structure. We will work on forming atomically thin artificial heterostructures to engineer the electronic structure and develop topological/quantum materials that can be used to couple the electron spin to other degrees of freedom.

The ultimate goal of our research is to develop systems that enable room temperature quantum technology. The strong coupling of electron spins with other degrees of freedom, e.g. photons, phonons, magnons to list a few, may open new pathways toward establishing robust quantum states that can be sustained at room temperature. The coupling will enable transfer of quantum information from one state to the other. We have started working on the interaction of electron spin with photons and phonons. Even with conventional materials that exist in nature, there are many fascinating physics that are yet uncovered and may have diverse implication both scientifically and technologically. As the degree of coupling can be tuned by materials engineering, we will use atomically thin artificial heterostructures as the building blocks to engineer systems with robust quantum states.

6 Publications and Patents

< **Refereed Original Papers** >

[1] Y. C. Lau, Z. Chi, T. Taniguchi, M. Kawaguchi, G. Shibata, N. Kawamura, M. Suzuki, S. Fukami, A. Fujimori, H. Ohno, M. Hayashi, “Giant perpendicular magnetic anisotropy in Ir/Co/Pt multilayers”. Phys. Rev. Mater. 3, 104419 (2019).

[2] N. Kato, M. Kawaguchi, Y. C. Lau, T. Kikuchi, Y. Nakatani, M. Hayashi, “Current-Induced Modulation of the Interfacial Dzyaloshinskii-Moriya Interaction”. Phys. Rev. Lett. 122, 257205 (2019).

[3] T. Kawada, M. Kawaguchi, M. Hayashi, “Unidirectional planar Hall voltages induced by surface acoustic waves in ferromagnetic thin films”. Phys. Rev. B 99, 184435 (2019).

[4] Y. Ishikuro, M. Kawaguchi, N. Kato, Y. C. Lau, M. Hayashi, ”Dzyaloshinskii-Moriya interaction and spin-orbit torque at the Ir/Co interface”, Phys. Rev. B 99, 134421 (2019).

[5] Y.-C. Lau, H. Lee, G. Qu, K. Nakamura, M. Hayashi, ”Spin Hall effect from hybridized orbitals”, Phys. Rev. B 99, 064410 (2019).

[6] S. Isogami, J. Uzuhashi, T. Ohkubo, M. Hayashi, ”Crystalline-structure-dependent magnetoresistance in ferromagnetic metal/conducting amorphous oxide heterostructures”, Phys. Rev. Mater. 3, 024408 (2018).

[7] Hirose, N. Ito, M. Kawaguchi, Y. C. Lau, M. Hayashi,” Circular photogalvanic effect in Cu/Bi bilayers”, Appl. Phys. Lett. 113, 222404 (2018).

[8] S. Sumi, H. Awano, and M. Hayashi, ”Interference Induced Enhancement of Magneto-Optical Effect in Pt/TbCo Hetero-Structured Films”, Crystal 8, 377 (2018).

[9] Y. Marui, M. Kawaguchi, and M. Hayashi, ”Optical Detection of Spin-Orbit Torque and Current-Induced Heating”, Appl. Phys. Express 11, 5 093001 (2018).

[10] R. Iguchi, A. Yagmur, Y. C. Lau, S. Daimon, E. Saitoh, M. Hayashi, and K. Uchida, ”Thermographic Measurements of Spin-Current-Induced Temperature Modulation in Metallic Bilayers”, Phys. Rev. B 98 014402 (2018).

[11] Y. Ishikuro, M. Kawaguchi, Y. C. Lau, Y. Nakatani, and M. Hayashi, ”Domain-Wall Resistance in CoFeB-Based Heterostructures with Interface Dzyaloshinskii-Moriya Interaction”, Appl. Phys. Express 11, 073001 (2018).

[12] M Kawaguchi, D Towa, YC Lau, S Takahashi, M Hayashi, ”Anomalous spin Hall magnetoresistance in Pt/Co bilayers”, Appl. Phys. Lett. 112, 202405 (2018)

[13] C Abert, H Sepehri-Amin, F Bruckner, C Vogler, M Hayashi, D Suess, ”Back-Hopping in Spin-Transfer-Torque Devices: Possible Origin and Countermeasures”, Phys. Rev. Appl. 9, 054010 (2018).

[14] S. Sumi, H. Awano, and M. Hayashi, ”Interference Induced Enhancement of Magneto-Optical Kerr Effect in Ultrathin Magnetic Films”, Scientific Reports 8, 776 (2018).

[15] P. Sheng, Y. Sakuraba, Y.-C. Lau, S. Takahashi, S. Mitani, M. Hayashi, ”The spin Nernst effect in tungsten”, Science Advances 3, e1701503 (2017).

[16] Y.-C. Lau, M. Hayashi, ”Spin torque efficiency of Ta, W, and Pt in metallic bilayers evaluated by harmonic Hall and spin Hall magnetoresistance measurements”, Jpn. J. Appl. Phys. 56, 0802B5 (2017).

[17] C. Abert, H. Sepehri-Amin, F. Bruckner, C. Vogler, M. Hayashi, D. Suess, ”Fieldlike and Dampinglike Spin-Transfer Torque in Magnetic Multilayers”, Phys. Rev. Appl. 7, 054007 (2017).

[18] S. Bosu, H. Sepehri-Amin, Y. Sakuraba, S. Kasai, M. Hayashi, K. Hono, ”High frequency out-of-plane oscillation with large cone angle in mag-flip spin torque oscillators for microwave assisted magnetic recording”, Appl. Phys. Lett. 110, 142403 (2017).

[19] R. P. del Real, V. Raposo, E. Martinez, and M. Hayashi, "Current-Induced Generation and Synchronous Motion of Highly Packed Coupled Chiral Domain Walls", Nano Lett. 17, 1814 (2017).

[20] Y.-C. Lau, P. Sheng, S. Mitani, D. Chiba, and M. Hayashi, "Electric Field Modulation of the Non-Linear Areal Magnetic Anisotropy Energy", Appl. Phys. Lett. 110 022405 (2017).

[21] Y. Nakatani, M. Hayashi, S. Kanai, S. Fukami, and H. Ohno, "Electric field control of Skyrmions in magnetic nanodisks", Appl. Phys. Lett. 108, 152403 (2016).

[22] J. H. Kwon, J. Yoon, P. Deorani, J. M. Lee, J. Sinha, K.-J. Lee, M. Hayashi, and H. Yang, "Giant nonreciprocal emission of spin waves in Ta/Py bilayers", Sci. Adv. 2 (2016).

[23] J. Torrejon, E. Martinez, and M. Hayashi, "Tunable inertia of chiral magnetic domain walls", Nature Comm. 7, 13533 (2016).

[24] J. Torrejon, J. Kim, J. Sinha, and M. Hayashi, "Spin-Orbit Effects in CoFeB/MgO Heterostructures with Heavy Metal Underlayers", SPIN 06, 1640002 (2016).

[25] R. Soucaille, M. Belmeguenai, J. Torrejon, J. V. Kim, T. Devolder, Y. Roussigne, S. M. Cherif, A. A. Stashkevich, M. Hayashi, and J. P. Adam, Probing the Dzyaloshinskii-Moriya interaction in CoFeB ultrathin films using domain wall creep and Brillouin light spectroscopy", Phys. Rev. B 94, 104431 (2016).

[26] I. Gross, L. J. Martinez, J. P. Tetienne, T. Hingant, J. F. Roch, K. Garcia, R. Soucaille, J. P. Adam, J. V. Kim, S. Rohart, A. Thiaville, J. Torrejon, M. Hayashi, and V. Jacques, "Direct measurement of interfacial Dzyaloshinskii-Moriya interaction in X—CoFeB—MgO heterostructures with a scanning NV magnetometer (X=Ta, TaN, and W)", Phys. Rev. B 94, 064413 (2016).

[27] T. Ueno, N. Inami, R. Sagayama, Z. Wen, M. Hayashi, S. Mitani, R. Kumai, and K. Ono, Relation between electronic structure and magnetic anisotropy in amorphous TbCo films probed by x-ray magnetic circular dichroism", J. Phys. D-Appl. Phys. 49, 205001 (2016).

[28] J. Kim, P. Sheng, S. Takahashi, S. Mitani, and M. Hayashi, Spin Hall Magnetoresistance in Metallic Bilayers. Phys. Rev. Lett. 116, 097201 (2016).

[29] S. Bosu, H. Sepehri-Amin, Y. Sakuraba, M. Hayashi, C. Abert, D. Suess, T. Schrefl, and K. Hono, Reduction of critical current density for out-of-plane mode oscillation in a mag-flip spin torque oscillator using highly spin-polarized Co2Fe(Ga0.5Ge0.5) spin injection layer", Appl. Phys. Lett. 108, 072403 (2016).

[30] J. Liu, T. Ohkubo, S. Mitani, K. Hono, and M. Hayashi, Correlation between the spin Hall angle and the structural phases of early 5d transition metals", Appl. Phys. Lett. 107, 232408 (2015).

[31] T. Ueno, J. Sinha, N. Inami, Y. Takeichi, S. Mitani, K. Ono, and M. Hayashi, Enhanced orbital magnetic moments in magnetic heterostructures with interface perpendicular magnetic anisotropy", Scientific Reports 5, 14858 (2015).

[32] J. H. Kwon, P. Deorani, J. Yoon, M. Hayashi, and H. Yang. Influence of tantalum underlayer on magnetization dynamics in Ni81Fe19 films", Appl. Phys. Lett. 107, 022401 (2015).

[33] J. Sinha, C. Banerjee, A. K. Chaurasiya, M. Hayashi, and A. Barman, Improved magnetic damping in CoFeB vertical bar MgO with an N-doped Ta underlayer investigated using the Brillouin light scattering technique", RSC Advances 5, 57815 (2015).

[34] T. Taniguchi., S. Mitani. and M. Hayashi. Critical current destabilizing perpendicular magnetization by the spin Hall effect", Phys. Rev. B 92, 024428 (2015).

[35] J. Torrejon, F. Garcia-Sanchez, T. Taniguchi, J. Sinha, S. Mitani, J.-V. Kim, and M. Hayashi, Current-driven asymmetric magnetization switching in perpendicularly magnetized CoFeB/MgO heterostructures, Phys. Rev. B 91, 214434 (2015).

[36] J. Sinha, M. Grube, M. Kodzuka, T. Ohkubo, S. Mitani, K. Hono, and M. Hayashi. "Influence of Boron Diffusion on the Perpendicular Magnetic Anisotropy in Ta—CoFeB—MgO Ultrathin Films. J. Appl. Phys. 117, 043913 (2015).

[37] J. Torrejon, J. Kim, J. Sinha, S. Mitani, M. Hayashi, M. Yamanouchi, and H. Ohno. "Interface Control of the Magnetic Chirality in CoFeB—MgO Heterosctructures with Heavy Metal Underlayers", Nature Comm. 5, 4655 (2014).

[38] J. Sinha and M. Hayashi. "Linewidth Variation of the Higher Harmonics in Spin-Torque Vortex Oscillators", IEEE Magn. Lett. 5, 3000204 (2014).

[39] J. Kim, J. Sinha, S. Mitani, M. Hayashi, S. Takahashi, S. Maekawa, M. Yamanouchi, and H. Ohno, "Anomalous temperature dependence of current-induced torques in CoFeB/MgO heterostructures with Ta-based underlayers", Phys. Rev. B 89, 174424 (2014).

[40] M. Hayashi, J. Kim, M. Yamanouchi, and H. Ohno, "Quantitative characterization of the spin-orbit torque using harmonic Hall voltage measurements", Phys. Rev. B 89, 144425 (2014).

[41] F. Sanches, V. Tiberkevich, K. Y. Guslienko, J. Sinha, M. Hayashi, O. Prokopenko, and A. N. Slavin. "Current-Driven Gyrotropic Mode of a Magnetic Vortex as a Nonisochronous Auto-Oscillator", Phys. Rev. B 89, 140410 (2014).

[42] J. Sinha, M. Hayashi, A. J. Kellock, S. Fukami, M. Yamanouchi, M. Sato, S. Ikeda, S. Mitani, S. H. Yang, S. S. P. Parkin and H. Ohno, "Enhanced interface perpendicular magnetic anisotropy in Ta—CoFeB—MgO using nitrogen doped Ta underlayers", Appl. Phys. Lett. 102, 242405 (2013).

[43] M. Yamanouchi, L. Chen, J. Kim, M. Hayashi, H. Sato, S. Fukami, S. Ikeda, F. Matsukura and H. Ohno, "Three terminal magnetic tunnel junction utilizing the spin Hall effect of iridium-doped copper", Appl. Phys. Lett. 102, 212408 (2013).

[44] J. Kim, J. Sinha, M. Hayashi, M. Yamanouchi, S. Fukami, T. Suzuki, S. Mitani, and H. Ohno. "Layer thickness dependence of the current induced effective field vector in Ta—CoFeB—MgO", Nature Mater. 12, 240 (2013).

[45] J. H. Kwon, S. S. Mukherjee, P. Deorani, M. Hayashi and H. Yang, "Characterization of Magnetostatic Surface Spin Waves in Magnetic Thin Films: Evaluation for Microelectronic Applications", Appl. Phys. A. 111, 369 (2013).

[46] H. Sepehri-Amin, D. Prabhu, M. Hayashi, T. Ohkubo, K. Hioki, A. Hattori, and K. Hono. "Coercivity enhancement of rapidly solidified Nd-Fe-B magnet powders", Scripta Mater. 68, 167 (2013).

[47] M. Hayashi, Y. K. Takahashi, and S. Mitani, "Microwave assisted resonant domain wall nucleation in permalloy nanowires", Appl. Phys. Lett., 101, 172406 (2012).

[48] L. Thomas, M. Hayashi, R. Moriya, C. Rettner, and S. S. P. Parkin, "Topological repulsion between domain walls in magnetic nanowires leading to the formation of bound states", Nat. Commun. 3, 810 (2012).

[49] M. Hayashi, M. Yamanouchi, S. Fukami, J. Sinha, S. Mitani, and H. Ohno, "Spatial control of magnetic anisotropy for current induced domain wall injection in perpendicularly magnetized CoFeB—MgO nanostructures", Appl. Phys. Lett. 100, 192411 (2012).

[50] M. Hayashi, J. i. Ieda, Y. Yamane, J.-i. Ohe, Y. K. Takahashi, S. Mitani, and S. Maekawa, "Time-Domain Observation of the Spinmotive Force in Permalloy Nanowires", Phys. Rev. Lett. 108, 147202 (2012).

[51] B. Varaprasad, A. Srinivasan, Y. K. Takahashi, M. Hayashi, A. Rajanikanth, and K. Hono. "Spin polarization and Gilbert damping of Co2Fe(GaxGe1-x) Heusler alloys", Acta Mater. 60, 6257 (2012).

[52] S. S. Mukherjee, J. H. Kwon, M. Jamali, M. Hayashi, and H. Yang. "Interference-mediated modulation of spin waves. Phys. Rev. B 85, 224408 (2012).

[53] Z. C. Wen, H. Sukegawa, S. Kasai, M. Hayashi, S. Mitani, and K. Inomata. "Magnetic Tunnel Junctions with Perpendicular Anisotropy Using a Co2FeAl Full-Heusler Alloy. Appl. Phys. Exp. 5, 063003 (2012).

[54] M. Hayashi, Y. Nakatani, S. Fukami, M. Yamanouchi, S. Mitani, and H. Ohno, ”Domain wall dynamics driven by spin transfer torque and the spin-orbit field. J. Phys.-Condes. Matter 24, 024221 (2012).

＜**Conference Proceedings**＞

[55] T. Taniguchi, S. Mitani, and M. Hayashi, ”Current-Induced Instability of a Perpendicular Ferromagnet in Spin Hall Geometr”y”, IEEE Trans. Magn. 52, 1400204 (2016).

[56] Z. Wen, J. Kim, H. Sukegawa, M. Hayashi, and S. Mitani, ”Spin-orbit torque in Cr/CoFeAl/MgO and Ru/CoFeAl/MgO epitaxial magnetic heterostructures”, AIP Advances 6, 056307 (2016).

[57] T. Suzuki, H. Tanigawa, Y. Kobayashi, K. Mori, Y. Ito, Y. Ozaki, K. Suemitsu, T. Kitamura, K. Nagahara, E. Kariyada, N. Ohshima, S. Fukami, M. Yamanouchi, S. Ikeda, M. Hayashi, M. Sakao, and H. Ohno, Low-current domain wall motion MRAM with perpendicularly magnetized CoFeB/MgO magnetic tunnel junction and underlying hard magnets”, 2013 Symposium on VLSI Technology, T138, (2013).

＜**Review Papers**＞

[58] 林　将光, ”界面ジャロシンスキー・守谷相互作用と旋回性磁区構造の発現機構-スピンホールトルク駆動磁壁移動素子への展開”- 日本磁気学会誌「まぐね」　, vol.10, no.4, pp. 186-191 (2015).

[59] J. Torrejon and M. Hayashi, ”Spin Hall torque driven chiral domain walls in magnetic heterostructures”, ”Magnetic Nano- and Microwires: Design, synthesis, properties and applications”, Woodhead publishing, Elsevier, (2015).

[60] 林　将光, ”電流による磁区の一斉移動 -スピン軌道相互作用を利用した磁化制御技術の新展開-”, 応用物理学会誌「応用物理」vol. 83, no. 7, 547 (2014).

[61] S. Parkin, M. Hayashi, L. Thomas, X. Jiang, R. Moriya and W. Gallagher, ”Emerging Spintronic Memories”, Handbook of Spin Transport and, Taylor and Francis (2011).

[62] M. Hayashi, L. Thomas, R. Moriya, C. Rettner and S. S. P. Parkin, ”Development of current controlled domain wall devices”, 日本磁気学会誌「まぐね」, vol.4, no.8, pp. 396-408 (2009).

[63] M. Hayashi and S. S. P. Parkin, Racetrack Memory, ”Frontiers in Spintronics: Basics”, materials and applications, pp. 373-383, CMC Publishing Co. (2009).

[64] S. S. P. Parkin, H. Yang, S-H. Yang and M. Hayashi, ”Magnetic Tunnel Junctions, Handbook of Magnetism and advanced magnetic materials”, vol. 5, John Wiley & Sons (2007).

＜**Patent Applications**＞

[65] Very thin perpendicularly magnetized film exhibiting high perpendicular magnetic anisotropy, method for manufacturing same, and application, M. Hayashi, J. Sinha, M. Kodzuka, T. Nakatani, Y. Takahashi, T. Furubayashi, S. Mitani, K. Hono, WO2013141337 (PCT/JP2013/058226), 9/26/2013.

[66] Co_2Fe-based Heusler alloy and spintronic device using same, Y. Takahashi, A. Srinivasan, B. Varaprasad, A. Rajanikanth, J. Sinha, M. Hayashi, T. Furubayashi, S. Kasai, S. Hirayama, S. Mitani, K. Hono, WO2012093587 (PCT/JP2011/079622), 12/7/2012.

7 Invited Presentations at International Conferences

[1] M. Hayashi, ”Spin conversion effects in spin orbit materials, Spin Caloritronics X, 5/22/19, Groningen, The Netherlands.

[2] M. Hayashi, ”Spin-light Interaction in Spin orbit Materials, Workshop of the Max Planck - UBC - University of Tokyo in Stuttgart, 12/9/18, Tokyo, Japan.

[3] M. Hayashi, "Spin current generation in spin orbit materials, One-Day Symposium on Spintronic Properties of Graphene and Related 2D Materials, 11/22/2018, Kashiwa, Japan.

[4] M. Hayashi, "Spin conversion effects in spin orbit materials, Kavli Institute for Theoretical Sciences: Collective Spin Dynamics in Nanostructures, 10/10/2018, Beijing, China.

[5] M. Hayashi, "Spin conversion effects in spin orbit heterostructures, SPIE Spintronics XI, 8/22/2018, San Diego, USA.

[6] M. Hayashi, "Charge and heat-spin conversions in spin orbit systems, The 5th International Conference of Asian Union of Magnetics Societies (IcAUMS), 6/6/2018, Jeju, Korea.

[7] M. Hayashi, "Current spin conversion in spin orbit materials, Workshop of the Max Planck - UBC - University of Tokyo in Stuttgart, Stuttgart, Germany, Dec. 20, 2017.

[8] M. Hayashi, "Spin Hall magnetoresistance and spin orbit torques in metallic heterostructures, SPIE Spintronics XI, San Diego, USA, Aug. 6, 2017.

[9] M. Hayashi, "Spin Orbit Effects in Metallic Heterostructures, Gordon Research Conference -Spin Dynamics in Nanostructures, Les Diablerets, Switzerland, Jul. 20, 2017.

[10] M. Hayashi, "Electrically and thermally generated spin current in heavy metals, The 13th RIEC International Workshop on Spintronics, Sendai, Japan, Nov. 20, 2015.

[11] M. Hayashi, "Control of spin current and magnetism in magnetic heterostructures, International Center for Nano-Systems (ICNS) Opening Workshop, Cambridge, UK, Jul. 13, 2015.

[12] M. Hayashi, "Spin Hall effect and chiral magnetism in metallic heterostructures, 20th International Conference on Magnetism (ICM), Barcelona, Spain, Jul. 7, 2015.

[13] M. Hayashi, "Spin orbit torques and chiral magnetism in ultrathin magnetic heterostructures, 59th Annual Magnetism & Magnetic Materials Conference (MMM), Honolulu, Nov. 4, 2014.

[14] M. Hayashi, "Spin orbit torques and chiral magnetic texture in magnetic heterostructures, SPIE Spintronics VII, San Diego, Aug. 20, 2014.

[15] M. Hayashi, "Spin orbit effects in ultrathin magnetic heterostructures, 8th International Conference on Physics and Applications of Spin Phenomena in Solids (PASPS VIII), Washington DC, Jul. 29, 2014.

[16] M. Hayashi, J. Torrejon, J. Kim, J. Sinha, S. Mitani, S. Takahashi, S. Maekawa, M. Yamanouchi, H. Ohno, "Current induced spin orbit torques and chiral magnetic texture in magnetic heterostructures, The 12th RIEC International workshop on Spintronics, Sendai, Japan, Jun. 25, 2014.

[17] M. Hayashi, "Spin orbit torques in Ta—CoFeB—MgO magnetic heterostructures, 58th Conference on Magnetism and Magnetic Materials (MMM), Denver, CO, Nov. 7, 2013.

[18] M. Hayashi, "Magnetization switching using spin orbit torques in CoFeB—MgO magnetic heterostructures. 224th ECS meeting, San Francisco, CA, Oct. 30, 2013.

[19] M. Hayashi, "Spin orbit torques and current induced domain wall motion in magnetic heterostructures. Concepts in Spintronics, Kavli Institute for Theoretical Physics, Santa Barbara, CA, Oct. 19, 2013.

[20] M. Hayashi, "Current induced spin orbit torques in CoFeB—MgO magnetic heterostructures. Donostia International Conference on Nanoscaled Magnetism and Applications (DICNMA), San Sebastian, Spain, Sep. 10, 2013.

[21] M. Hayashi, "Vector measurements of the current induced effective fields in Ta—CoFeB—MgO heterostructures. APS March Meeting, Baltimore, MD, Mar. 19, 2013.

[22] M. Hayashi, "Current induced spin orbit torques in magnetic heterostructures. International Workshop on Spin-Orbit Induced Torque (SOIT), Saudi-Arabia, Feb. 24, 2013.

[23] M. Hayashi, "Current induced torques in magnetic heterostructures. The 3rd CSIS Int. Symposium on Spintronics-based VLSIs and the 11th RIEC Int. Workshop on Spintronics, Sendai, Japan, Jan. 31, 2013.

[24] M. Hayashi, "Magnetization Dynamics in Perpendicularly Magnetized CoFeB Nanostructures, International conference of Young Researcher on Advanced Materials (ICYRAM), Singapore, Jul. 4, 2012.

[25] M. Hayashi, "Current driven domain wall motion in perpendicularly magnetized CoFeB nanostructures, International symposium on the dynamics of domain walls, Hamburg, Germany, Jun. 1, 2012.

[26] M. Hayashi, "Current induced magnetization dynamics in CoFeB/MgO nanostructures. 2nd CSIS International Symposium on Spintronics-based VLSIs and the 8th RIEC International Workshop on Spintronics, Sendai, Japan, Feb. 2, 2012.

8 Teaching Accomplishment

Student awards:

- Takuya Kawada, Best student presentation award, Finalist, Annual conference on magnetism and magnetic materials, Nov. 6, 2019.
- Hana Hirose, English presentation award, Japan society of applied physics meeting, Mar. 10, 2019.
- Hana Hirose, Best student presentation award, Japan society of applied physics meeting, Mar. 9, 2019.

9 Contribution to Academic Community

9.1 Editorial Activities

- Scientific Reports, Editorial Board Member, 2016-
- IEEE Magnetic Letters, Editorial Board Member, 2014-2018

9.2 Organization of Professional Societies

9.3 Organization and Advisory of Conferences

- Program committee member, Conference of Magnetism & Magnetic Materials, 2016
- Program committee member, Joint Intermag-MMM, 2013

10 Outreach

- 講義, 高校生のための冬休み講座, 東京大学理学系研究科, 12/26/2019.
- 見学対応, 緑丘高校, 11/3/2018.
- 見学対応, 東北大学工学部応用物理学科, 3/29/2016.
- 出展, Nanotech 2015, 1/29/2015.

11 Committee Service

- 人材委員会, 委員, 国立研究開発法人物質・材料研究機構
- 特定課題推進員研究業績評価委員会, 委員, 国立研究開発法人日本原子力研究開発機構

11.1 External Committees

- 研究奨励賞審査委員, 日本物理学会領域 3

11.2 University Committees

理学系研究科キャンパス計画委員会, 委員, 2019
フォトンサイエンス国際卓越大学院プログラム, 副指導教員, 2018-

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	1	South Korea
Master Course	0	
Doctor Course	2	China
Foreign researchers hosted	6	India, South Korea, Spain, China, Malaysia
Students sent abroad	0	
Researchers sent abroad	0	
Foreign visitors	3	Netherlands, Germany, Spain

Kentaro Kitagawa、北川 健太郎

1 Education and Professional Experiences

Education

2002	B.S. (Physics)	Kyoto University
2004	MSc. (Physics)	Kyoto University
2007	Ph.D. (Physics)	Kyoto University

Professional Appointments

2005−2007	JSPS research fellow (DC2)	
2007−2010	JSPS postdotoral research fellow	Institute for Solid State Physics, University of Tokyo
2010−2012	Specially appointed fellow	Institute for Solid State Physics, University of Tokyo
2012−2015	Lecturer	Kochi University
2015−	Lecturer	The University of Tokyo

2 Research Highlights

We are exploring novel electronic phenomena in solid state, including spin liquid and Dirac electron ground states. We employed newly developed experimental technique for nuclear magnetic resonance (NMR) spectroscopy and magnetometry under ultrahigh-pressure condition to uncover exotic topological ground state and quantum magnetic phase transitions.

Realization of spin liquid, where quantum spins fluctuates at abosolute zero, should be a milestone in the field of quantum spin physics. One dimensional spin liquid has been commonly accepted, while in two or three dimensions, typical known frustrated quantum spin liquid materials, like triangular compounds, is not based on an exactly solvable lattice model. After a theoretical achievement of the exaclty solvable spin liquid state on a honeycomb lattice by Alexei Kitaev, a materialization of this Kitaev honeycomb model has been intensively pursuit. We have been focussed on two-or-three-dimensonal honeycomb-based iridates, where spin-orbit-entangled 1/2 pseudospin brings key mechanisms to realize Kitaev model. We discovered that 2D honeycomb iridate $H_3LiIr_2O_6$ is indeed spin liquid, as the first material of such a liquid down to 50 mK by specific heat, magnetic susceptibility, and NMR experiments. This ground breaking result was published in 2018.

Three dimensional, hyper-honeycomb iridate β-$LiIr_2O_3$ is also a promising candidate for Kitaev spin liquid, by suppressing antiferromagnetism using pressure as much as 2 GPa. This material seems to feature substantial Kitaev-type interation exceptionally, as opposed to other honeycomb d^5 systems, including above-mentioned $H_3LiIr_2O_6$. Our high-pressure NMR and magnetization measurement revealed that supposed high-pressure spin-liquid phase is not true one, but spin-singlet dimer state. From this finding, we demonstrated strong competition between pseudospin-1/2 antiferromagnetism and non-magnetic dimerization in spin-orbit-coupled d^5 systems.

Strong spin-orbit coupling shows up as non-parabolic dispersions in semimetals. We have demonstrated a realization of three-dimensional Dirac electrons in anti-perovskite oxide Sr_3PbO, which is evidenced by the quantum-limit characters in the magnetoresistance under high magnetic fields. To establish Dirac-type dispersions, we have carried out ^{207}Pb NMR experiments on single-crystal samples with different carrier densities. It was found that the temperature dependence of NMR relaxation rate certainly reflects three-dimensional Dirac-type density of states. Chiral anomaly is a phenomenon peculiar to this quantum-limit physics, and we have found a sign reversal of magnetoresistance with respect to direction of applied megnetic field. The anisotropic transport caused by magnetic field needs to be further considered in relation to the chiral anomaly and current jetting effect.

3 Selected Papers

- K. Kitagawa, T. Takayama, Y. Matsumoto, A. Kato, R. Takano, Y. Kishimoto, S. Bette, R. Dinnebier, G. Jackeli, and H. Takagi, Nature **554**, 341 (2018)
  This paper already gained 57 citations.

- S. Bette, T. Takayama, K. Kitagawa, R. Takano, H. Takagi, and R. E. Dinnebier, Dalton Trans. **46**, 15216 (2017)
  This paper already gained 15 citations.

- K. Matsubayashi, T. Hirayama, T. Yamashita, S. Ohara, N. Kawamura, M. Mizumaki, N. Ishimatsu, S. Watanabe, K. Kitagawa, and Y. Uwatoko, Phys. Rev. Lett. **114**, 086401 (2015)
  This paper gained 21 citations.

- T. Hanaguri,K. Kitagawa, K. Matsubayashi, Y. Mazaki, Y. Uwatoko, and H. Takagi, Physical Review B**85**, 214505-1-9 (2012)
  This work was selected as "Editors' Suggestion" in PRB. This paper gained 73 citations.

- G. Sala, C. Castelnovo, R. Moessner, S. L. Sondhi,K. Kitagawa, M. Takigawa, R. Higashinaka, and Y. Maeno, Phys. Rev. Lett. **108**, 217203 (2012)
  This paper gained 18 citations.

4 Honors, Awards and Professional Society Memberships

2012 Young Scientist Award of the Physical Society of Japan, Division 8

2019 Outstanding Paper Award of the Physical Society of Japan: Kentaro Kitagawa, Naoyuki Katayama, Kenya Ohgushi, Makoto Yoshida, and Masashi Takigawa, J. Phys. Soc. Jpn. 77, 114709 (2008).

5 Research Plan

We proceed to explore new topological state of matter in spin-orbit coupled strongly correlated electron systems. Real Kitaev spin liquid, yet to be realized, is our mail goal, as a next step following our report for an approximate liquid $H_3LiIr_2O_6$ in 2018. Majorana excitations sitting on the liquid ground state can provide us a new playground of quantum physics, new composite-particle anyon statistics and topological quantum computation. Our research within next couple of years aims to access this new frontier physics by developing new magnetic compounds and experimental techniques under multi-extreme conditions.

Pseudospin-1/2 Kitaev Candidate Materials:
Two ingredients are desired to realize Kitaev spin liquid as a true ground state: psedopsin-1/2 object and Kitaev-type anisotropic bond-dependent interactions. $4d^5$ and $5d^5$ low-spin states in edge-shared octahedral environment have been believed to be promising candidates to include these requirement, thanks to spin-orbit entangled 1/2 psedopsin and interfering 90-degree $d-p-d$ superexhange paths. However, thourgh our previous investigations on iridates, we noticed that ground-state control on d^5 honeycomb protypes using pressure is difficult, because all known candidates seem to dimerize into non-magnetic Ru_2 or Ir_2 under high pressures. On the other hand, exiting honeycomb liquid $H_3LiIr_2O_6$ inevitably contains a few percent of impurities which hinders from observing genuine gapped spin excitations during specific-heat, magnetization, and NMR measurements. Therefore, we are going to explore a new field for pseuspin-1/2 and Kitaev materials, and primary candidate for this is lanthanoid. Our preminary NMR experiments for $4f^1$ Kitaev candidate, Na_2PrO_3, revealed that non-collinear antiferromagnetic ground state is consistent with that expected near the antiferromagnetic Kitaev liquid in a phase diagram. Since it is easier to fabricate very clean single crystals of $4f^1$ and $4f^{13}$ honeycomb candidate materials, compared with d^5 protypes, and inner-core $4f$ magnetisms can be generally easy to be controled by pressure, we believe lanthanoid honeycomb compounds are the most promising Kitaev candidtates combind with highpressure phase-diagram surveys.

Ultrahigh-Pressure Experimental Development:
High pressure is a way to push ground state of matter into interesting direction, through change of lattice constants or inter-atomic interactions without causing any structural disorder. This contrasts to alternative method, chemical substitution on atoms which prones to mask quasi-particle excitations with local impurity effects. Because an excitation is 'smoking gun' when proving a thought exotic ground state, employing a pressure as a tuning parameter is straightforward to draw quantum phase diagram. However, high-pressure determination of magnetic phase diagram for insulator has been difficult, due to lack of experimental method that accommodates very limited space of high-pressure area. We have previously developed two ways: NMR and magnetization measurements up to 10 GPa. This year, we are improving our high-pressure NMR probe further by incorporating homemade ^{4}He-^{3}He dilution line which enables research of ultralow-temperature $4f$ physics. Magnetization probe is also being optimized to detect very weak pseudospin-1/2 (para)magnetism by employing recently developed perfectly non-magnetic tungsten carbide material. These state-of-the-art eyes for high-pressure magnetisms are expexcted to greatly enhance future quantum magnetism research.

6 Publications and Patents

< Refereed Original Papers >

[1] G. Sala, C. Castelnovo, R. Moessner, S. L. Sondhi,K. Kitagawa, M. Takigawa, R. Higashinaka, and Y. Maeno: Magnetic Coulomb Fields of Monopoles in Spin Ice and Their Signatures in the Internal Field Distribution, Phys. Rev. Lett. **108**, 217203 (2012).

[2] T. Hanaguri,K. Kitagawa, K. Matsubayashi, Y. Mazaki, Y. Uwatoko, and H. Takagi: Scanning tunneling microscopy/spectroscopy of vortices in LiFeAs, Phys. Rev. B **85**, 214505 (2012).

[3] Tatsunori Okada, Hideyuki Takahashi, Yoshinori Imai,Kentaro Kitagawa, Kazuyuki Matsubayashi, Yoshiya Uwatoko, and Atsutaka Maeda: Microwave surface-impedance measurements of the electronic state and dissipation of magnetic vortices in superconducting LiFeAs single crystals, Phys. Rev. B **86**, 064516 (2012).

[4] Hideyuki Takahashi, Tatsunori Okada, Yoshinori Imai,Kentaro Kitagawa, Kazuyuki Matsubayashi, Yoshiya Uwatoko, and Atsutaka Maeda: Investigation of the superconducting gap structure in $SrFe_2(As_{0.7}P_{0.3})_2$by magnetic penetration depth and flux flow resistivity analysis, Phys. Rev. B **86**, 144525 (2012).

[5] Masahiro Matsumura, Naoya Tomita, Junichirou Matsuoka, Yasuki Kishimoto, Harukazu Kato,Kentaro Kitagawa, Takashi Nishioka, Hiroshi Tanida, and Masafumi Sera: Ru-NQR Study for Novel Phase Transition in $CeRu_2Al_{10}$, J. Phys. Soc. Jpn.**83**, 103705 (2014).

[6] Kazuhiro Yamada,Kentaro Kitagawa, and Masato Takahashi: Field-swept^{33}S NMR study of elemental sulfur, Chem. Phys. Lett. **618**, 20 (2015).

[7] K. Matsubayashi, T. Hirayama, T. Yamashita, S. Ohara, N. Kawamura, M. Mizumaki, N. Ishimatsu, S. Watanabe, K. Kitagawa, and Y. Uwatoko: Pressure-Induced Valence Crossover and Novel Metamagnetic Behavior near the Antiferromagnetic Quantum Phase Transition of $YbNi_3Ga_9$, Phys. Rev. Lett. **114**, 086401 (2015).

[8] Kazuhiro Yamada, Daisuke Aoki, Kentaro Kitagawa, and Masato Takahashi: Frequency-swept solid-state ^{33}S NMR of an organosulfur compound in an extremely low magnetic field, Chem. Phys. Lett. **630**, 86 (2015).

[9] Akito Sakai, Kentaro Kitagawa, Kazuyuki Matsubayashi, Makoto Iwatani, and Philipp Gegenwart: T/B scaling without quasiparticle mass divergence: $YbCo_2Ge_4$, Phys. Rev. B **94**, 041106(R)(2016)

[10] S. Bette, T. Takayama, K. Kitagawa, R. Takano, H. Takagi, and R. E. Dinnebier: Solution of the heavily stacking faulted crystal structure of the honeycomb iridate $H_3LiIr_2O_6$, Dalton Trans. **46**, 15216 (2017).

[11] H. Tanida, K. Kitagawa, N. Tateiwa, M. Sera, and T. Nishioka: Pressure studies on the antiferromagnetic Kondo semiconductor $Ce(Ru_{1-x}Rh_x)_2Al_{10}$ $(x = 0, 0.1)$, Phys. Rev. B **96**, 235131 (2017).

[12] S. Suetsugu, K. Hayama, A. W. Rost, J. Nuss, C. Mhle, J. Kim, K. Kitagawa, and H. Takagi: Magnetotransport in Sr_3PbO anti-perovskite with three-dimensional Dirac electrons, Physical Review B **98**, 115203 (2018).

[13] K. Kitagawa, T. Takayama, Y. Matsumoto, A. Kato, R. Takano, Y. Kishimoto, S. Bette, R. Dinnebier, G. Jackeli, and H. Takagi: A spinorbital-entangled quantum liquid on a honeycomb lattice, Nature **554**, 341 (2018).

< Conference Proceedings >

[14] Kentaro Kitagawa, Yuji Mezaki, Kazuyuki Matsubayashi, Yoshiya Uwatoko, and Masashi Takigawa: Phase diagram and superconductivity of NaFeAs studied by single-crystal ^{75}As-NMR under pressure up to 7.3 GPa, J. Phys. Soc. Jpn. Conf. Proc., Proceedings of the International Conference on Strongly Correlated Electron Systems (SCES2013) **3**, 015031, (2014).

[15] Kazuyuki Matsubayashi, Toshiki Tanaka, Junichirou Suzuki, Akito Sakai, Satoru Nakatsuji, Kentaro Kitagawa, Yasunori Kubo, Yoshiya Uwatoko: Heavy fermion superconductivity under pressure in the quadrupole system $PrTi_2Al_{20}$, J. Phys. Soc. Jpn. Conf. Proc., Proceedings of the International Conference on Strongly Correlated Electron Systems (SCES2013) **3**, 011077, (2014).

[16] Kento Yokota, Takashi Nishioka, Kentaro Kitagawa, Harukazu Kato, and Masahiro Matsumura: Magnetic Properties of New Dilute Rare Earth Compounds $R_2Ru_3Al_{15}$, J. Phys. Soc. Jpn. Conf. Proc., Proceedings of the International Conference on Strongly Correlated Electron Systems (SCES2013) **3**, 011051, (2014).

[17] Yasuki Kishimoto, Masakazu Mizoo, Masahiro Matsumura, Harukazu Kato, Kentaro Kitagawa, and Takashi Nishioka: Co-NQR Study for Complex Magnetic Order in Non-Centrosymmetric $CeCoGe_3$, J. Phys. Soc. Jpn. Conf. Proc., Proceedings of the International Conference on Strongly Correlated Electron Systems (SCES2013) **3**, 011087, (2014).

[18] T. Okada, H. Takahashi, Y. Imai, K. Kitagawa, K. Matsubayashi, Y. Uwatoko, and A. Maeda: Magnetic penetration depth and flux-flow resistivity measurements on $NaFe_{0.97}Co_{0.03}As$ single crystals, Physica C: Superconductivity and its Application, Proceedings of the 25th International Symposium on Superconductivity (ISS 2012) Advances in Superconductivity XXV **494**, 109 (2013).

[19] T. Okada, Takahashi, Y. Imai, K. Kitagawa, K. Matsubayashi, Y. Uwatoko, and A. Maeda: Low energy excitations inside the vortex core of LiFe(As, P) single crystals investigated by microwave-surface impedance, Physica C: Superconductivity and its Application, Proceedings of the 25th International Symposium on Superconductivity (ISS 2012) Advances in Superconductivity XXV **484**, 27 (2013).

＜**Review Papers**＞

[20] 北川健太郎、松林和幸、後藤弘匡、松本健彦、上床美也、八木健彦、瀧川　仁: 容積効率にこだわった高圧セルによる 10 GPa 級 NMR 測定, 高圧力の科学と技術 22 巻, 198-205 頁, 2012 年.

7 Invited Presentations at International Conferences

[1] K. Kitagawa: Spin liquid-like state in complex Ir oxides, (MPI Ringberg Symposium on High Temperature Superconductivity, Ringberg, Germany, Nov. 10, 2015).

[2] K. Kitagawa: New spin liquids on honeycomb iridates as seen by NMR, (JKT workshop on correlated electron systems, Tokyo, Japan, Feb. 20, 2016).

[3] K. Kitagawa: New spin liquids on honeycomb iridates as seen by NMR, (5th International Conference on Superconductivity and Magnetism (ICSM2016), Fethiye,Turkey, Apr. 24-30, 2016)

[4] K. Kitagawa: Strong spin-orbit coupling and exotic magnetism in complex Ir oxides, (2016 Hefei Conference on Novel Phenomena in High Magnetic Fields (2016nphmf), Hefei, China, Oct 29-Nov 1, 2016).

[5] K. Kitagawa: New $J_{\rm eff}$=1/2 Quantum Liquid on Honeycomb Lattice, (1st Asia Pacific Workshop on Quantum Magnetism (APWQM 2017), Seoul National University, Seoul, Korea, Aug. 28, 2017).

[6] K. Kitagawa: Quantum Spin Liquid Phenomena in Honeycomb and Hyperhoneycomb Iridates, (International Workshop on Frontiers of Research in Quantum Materials, Max Planck Institute for Solid State Research, Stuttgart, Germany, Dec. 19, 2017).

[7] K. Kitagawa: Quantum Liquid and Phase Diagram of Honeycomb and Hyperhoneycomb Iridates, (TMS-EPiQS 2nd Alliance Workshop: Topological magnets and topological superconductors, 京都大学北部キャンパス（京都）, Jan. 13, 2018).

[8] K. Kitagawa: Quantum Spin Liquid in 5d Electron Honeycomb Compound $H_3LiIr_2O_6$, (2019 Joint MMM-Intermag Conference, Washington DC, USA, Jan. 15, 2019).

8 Teaching Accomplishment

- 末次翔太、ポスター賞、The 18th Taiwan-Japan-Korea Symposium on Strongly Correlated Electron Systems (TJK18), Caesar Park Hotel, Kenting, Taiwan, Feb. 23, 2018.

9 Contribution to Academic Community

9.1 Organization and Advisory of Conferences

- 平成 25-26 日本物理学会領域 3 運営委員

10 Outreach

- 小学図書館ニュース監修及び執筆、北川健太郎、「磁石の不思議はまだまだ続く」、2018 年 9 月 28 日
- プレスリリース　北川 健太郎,　木 英典: スピン-軌道量子液体の発見, http://www.s.u-tokyo.ac.jp/ja/info/5772/, 2018 年 2 月 15 日.

10.1 University Committees

理学図書館物理学図書委員会 委員　2016 年 –
理学部オープンキャンパス実行委員会　委員　2017 年 –2018 年

11 Internationalization Statistics

	Number	Country
Number	Country	
Foreign students advised		
Bachelor Course	4	Canada, Korea,Germany
Master Course	3	Germany
Doctor Course	1	Germany
Foreign researchers hosted	2	Germany, India
Students sent abroad	4	Germany
Researchers sent abroad	1	Germany, USA
Foreign visitors	2	Canada, Korea

Kensuke Kobayashi、小林 研介

1 Education and Professional Experiences

Education

1994	B.S. (Physics)	The University of Tokyo
1996	MSc. (Physics)	The University of Tokyo
1999	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1999−1999	Assistant Professor	The University of Tokyo
1999−2005	Assistant Professor	Institute for Solid State Physics, The University of Tokyo
2004−2005	Researcher	ETH Zurich, Switzerland
2005−2012	Associate Professor	Institute for Chemical Research, Kyoto University
2012−	Professor	Osaka University
2019−	Professor	The University of Tokyo

2 Research Highlights

By virtue of nanofabrication technique we are able to investigate fascinating behaviors of "mesoscopic system", namely, electronic devices that work in quantum regime. Since 1980's they have been serving as ideal test-beds to demonstrate various quantum effects in a controllable and thus transparent way, as the electron transport through a single quantum site can be precisely probed and tuned. Especially, the Landauer-Büttiker formalism embodies this advantage of mesoscopic physics as has been successfully applied to many mesoscopic conductors (e.g. Aharonov-Bohm ring, quantum dot etc.), through which mesoscopic physics has been established.

Researchers in this field have mostly focused on the electric current, which is the average number of electrons that pass through the system for a finite time. These days, however, fluctuation (or "noise") in electric current, namely the fluctuation of the number of electrons passing through the system, is invoking great interest. We have built a unique noise measurement system [Appl. Phys. Lett. 103, 172104 (2013)], and have applied it to various mesoscopic systems. In the following, we mention two research highlights.

The first one is on the "spin shot noise" [Phys. Rev. Lett. 114, 016601 (2015)]. In 1918, Schottky argued that the electric flow in a vacuum tube fluctuates in a unique way such that the spectral density of the fluctuation is proportional to the unit of charge and to the mean current. This is the shot noise, the direct consequence of the discreteness of the electron charge. Now, as an electron possesses not only charge but also spin, one may ask how the discreteness of electron spin affects the current fluctuation. Although such spin shot noise has been discussed theoretically in various contexts, it has never been proven experimentally. We demonstrated the detection of shot noise induced by non-equilibrium spin accumulation in a lateral all-semiconductor spin valve device, which proves the relevance of the concept of spin shot noise. By utilizing the Landauer-Büttiker formalism, we successfully extracted charge and spin currents and charge and spin noise and found that the spin degree of freedom is preserved in the tunneling process. Given the importance of shot noise in various fields, especially in device technology and mesoscopic physics, spin shot noise could not only serve as a unique probe to explore non-equilibrium electrons transport but also shed new light on the emerging field of spin noise spectroscopy.

The second topic is the elucidation of non-equilibrium fluctuations of the Kondo effect [Nature Phys. 12, 230 (2016); Phys. Rev. Lett. 118, 196803 (2017); 121, 247703 (2018)]. This effect is a typical many body effect associated with spin, and therefore, its realization in a quantum dot (QD) in 1998 has made it possible to test various theoretical predictions for Kondo physics. A single Kondo state can be formed in a quantum dot coupled to the leads. By tuning several parameters such as the number of spins in the dot, the temperature, the magnetic field, and the source-drain voltage, we can precisely address the behavior of the Kondo state from equilibrium to far-from-equilibrium. Especially, the non-equilibrium aspects of Kondo physics are recently attracting great interest. To understand how many-body states behave in the non-equilibrium still remains a big challenge in modern physics. We experimentally tuned a single-carbon-nanotube quantum dot in an ideal Kondo state in both SU(2) and SU(4) cases, and have successfully established non-equilibrium universal properties of the Kondo state. We detected an enhancement of the current fluctuations, which is perfectly explained by an effective charge for quasi-particles induced by residual interaction in the strongly-correlated local Fermi liquid. Our achievement will pave a new road toward fully controlling quantum many body states.

3 Selected Papers

- T. Hata, R. Delagrange, T. Arakawa, S. Lee, R. Deblock, H. Bouchiat, K. Kobayashi, and M. Ferrier: Enhanced Shot Noise of Multiple Andreev Reflections in a Carbon Nanotube Quantum Dot in SU(2) and SU(4) Kondo regimes.
  Physical Review Letters **121,** 247703/1-5 (2018).
  This work is the first experimental study to clarify the quantum fluctuation of the system where two different singlets, namely the Kondo singlet and the Cooper pair, coexist.

- M. Ferrier, T. Arakawa, T. Hata, R. Fujiwara, R. Delagrange, R. Deblock, Y. Teratani, R. Sakano, A. Oguri, and K. Kobayashi: Quantum Fluctuations along Symmetry Crossover in a Kondo-Correlated Quantum Dot.
  Physical Review Letters **118,** 196803/1-5 (2017).
  We clarify quantum fluctuations along symmetry crossover between SU(4) and SU(2) in a Kondo-correlated quantum dot.

- M. Ferrier, T. Arakawa, T. Hata, R. Fujiwara, R. Delagrange, R. Weil, R. Deblock, R. Sakano, A. Oguri, and K. Kobayashi: Universality of non-equilibrium fluctuations in strongly correlated quantum liquids.
  Nature Physics **12,** 230-235 (2016).
  In this experimental study we for the first time confirmed the universality of non-equilibrium fluctuations of the Kondo effect. The paper has been cited 35 times.

- S. Matsuo, S. Takeshita, T. Tanaka, S. Nakaharai, K. Tsukagoshi, T. Moriyama, T. Ono, and K. Kobayashi: Edge mixing dynamics in graphene p-n junctions in the quantum Hall regime.
  Nature Communications **6,** 8066/1-6 (2015).
  We have elucidated the edge mixing dynamics in graphene pn junctions in the quantum Hall regime.

- T. Arakawa, J. Shiogai, M. Ciorga, M. Utz, D. Schuh, M. Kohda, J. Nitta, D. Bougeard, D. Weiss, T. Ono, and K. Kobayashi: Shot noise induced by nonequilibrium spin accumulation.
  Physical Review Letters **114,** 016601/1-5 (2015).
  This work was selected as one of Highlights "Editors' Suggestion" in PRL as the first experimental demonstration of the spin shot noise.

4 Honors, Awards and Professional Society Memberships

- The 15th Marubun Award for Research Promotion, Marubun Research Promotion Foundation (2012).
- The 16th Ryogo Kubo Memorial Prize, Inoue Foundation for Science (2012).
- 2nd Presidential Awards for Achievement in Research, Osaka University (2013).
- 10th JSPS PRIZE, the Japan Society for the Promotion of Science (2014).
- Japan Academy Medal, the Japan Academy (2014).
- 3rd Presidential Awards for Achievement in Research, Osaka University (2014).
- 4th Presidential Awards for Achievement in Research, Osaka University (2015).
- Osaka University Distinguished Professor (2017).
- Yazaki Academic Award, Yazaki Memorial Foundation for Science and Technology (2019).
- 37th Osaka Science Prize, Osaka Prefecture, the city of Osaka, and the Osaka Science & Technology Center (2019).

5 Research Plan

Solid-state physics treats various phenomena where many electrons behave in a quantum mechanical way. To understand how the quantum and many-body effects emerge is at its heart. In fact, the history of solid-state physics has seen various discoveries of quantum effects and many-body effects. Since 1980's, there has also been significant progress about experimental methods. A representative example is the study of mesoscopic systems (artificial quantum systems made of submicron-sized electric circuits), which microfabrication technology has enabled us. In the early days, the main focus was to observe electronic interference based on a single-particle picture, such as Aharonov-Bohm effect, in the transport experiments, but now, through precise experiments with high reproducibility, various quantum many-body effects can be realized. With such a research method, quantum many-body effects have now become the targets not only to be"clarified" but also to be "controlled". The realization of the Kondo effect in quantum dots is a beautiful example. With this triggered, we performed the experiments related to the phase and coherence of the Kondo state and the non-equilibrium Kondo effect. To explore the Kondo effect in such a way had been impossible before.

Based on the above recognition, we will further promote research on precise solid-state science based on control of quantum many-body effects in mesoscopic systems. Our research has the following three features.

1. By measuring a single site with artificially excluding extrinsic conditions, quantitative precise comparison with theory is possible.

2. We can realize quantum many-body phenomena by artificially adjusting the parameters such as magnetic field and electric field effect. Depending on the combination of parameters, it is also possible to reach an extreme condition that is impossible in ordinary materials.

3. Continuous control from equilibrium to non-equilibrium at a single site is possible. This is a decisive advantage for exploring non-equilibrium physics.

The study of the non-equilibrium Kondo state mentioned above makes full use of these advantages. In future research as well, we will continue to improve the measurement method. We use electric measurement, especially our homemade sensitive current fluctuation measurement system, but we will also work on development of new measurement methods in parallel with progress of research. Currently, noise measurement in high frequency (quantum) regime and single electron control technology are being developed. At the same time, it is also important to enjoy the diversity of materials. Actually, in addition to conventional semiconducting two-dimensional electron systems, we work on Bi_2Se_3, graphene, magnetic tunnel junction, nanotube, spin glass, high-Tc superconductor, frustrated system, and so on.

One of the topics we continue to address is the Kondo effect in quantum dots in the non-equilibrium region, as we have been diligently pursuing this topic as an important fundamental one for many years since early 2000's. Our experimental work using current noise measurements since 2011 aims at elucidating the whole picture of the Kondo effect in a non-equilibrium steady state, and it has steadily progressed. Currently, we are studying fluctuation of the Andreev-Kondo effect, where two types of electron pair, the Cooper pair and the Kondo singlet, coexist. By continuing the research in this direction, we will stimulate both the experimentalists and the theorists, and create a new research trend in the strongly correlated non-equilibrium systems. In addition, we will continue to fabricate mesoscopic systems consisting of various materials. Furthermore, by combining current noise measurement and single electron control technology, it will become possible to trace the behavior of non-equilibrium and transient quantum liquids (for example, real-time evolution of the Kondo state), demonstration of non-commutativity by quasi-particle collision experiments, detection of the edge states of topological insulator, and so on.

Compared with the long and rich history of conventional solid-sate physics, such a precise material science using the advantages of mesoscopic systems is still in its dawn. There is a high possibility that surprising new phenomena are waiting for us. We enjoy the diversity of materials, explore the opportunities of mesoscopic devices for controlling quantum many-body effects, and conduct unique accurate measurements to find out a vast frontier from equilibrium to far-from-equilibrium.

6 Publications and Patents

< Refereed Original Papers >

[1] T. Arakawa, T. Tanaka, K. Chida, S. Matsuo, Y. Nishihara, D. Chiba, K. Kobayashi, T. Ono, A. Fukushima, and S. Yuasa: Low-frequency and shot noises in CoFeB/MgO/CoFeB magnetic tunneling junctions.
Physical Review B **86,** 224423 (2012).

[2] D. Chiba, M. Kawaguchi, S. Fukami, N. Ishiwata, K. Shimamura, K. Kobayashi, and T. Ono: Electric-field control of magnetic domain-wall velocity in ultrathin cobalt with perpendicular magnetization.
Nature Communications **3,** 888 (2012).

[3] K. Chida, M. Hashisaka, Y. Yamauchi, S. Nakamura, T. Arakawa, T. Machida, K. Kobayashi, and T. Ono: Shot noise induced by electron-nuclear spin-flip scattering in a nonequilibrium quantum wire.
Physical Review B **85,** 041309 (2012).

[4] K.-J. Kim, D. Chiba, K. Kobayashi, S. Fukami, M. Yamanouchi, H. Ohno, S.-G. Je, S.-B. Choe, and T. Ono: Observation of magnetic domain-wall dynamics transition in Co/Ni multilayered nanowires.
Applied Physics Letters **101,** 022407 (2012).

[5] M. Kohda, S. Nakamura, Y. Nishihara, K. Kobayashi, T. Ono, J. Ohe, Y. Tokura, T. Mineno, and J. Nitta: Spin-orbit induced electronic spin separation in semiconductor nanostructures.
Nature Communications **3,** 1082 (2012).

[6] K. Kondou, N. Ohshima, D. Chiba, S. Kasai, K. Kobayashi, and T. Ono: Experimental detection of domain wall propagation above the Walker field.
Journal of Physics: Condensed Matter **24,** 024217 (2012).

[7] T. Koyama, K. Ueda, K. J. Kim, Y. Yoshimura, D. Chiba, K. Yamada, J. P. Jamet, A. Mougin, A. Thiaville, S. Mizukami, S. Fukami, N. Ishiwata, Y. Nakatani, H. Kohno, K. Kobayashi, and T. Ono: Current-induced magnetic domain wall motion below intrinsic threshold triggered by Walker breakdown.
Nature Nanotechnology **7,** 635-9 (2012).

[8] S. Matsuo, T. Koyama, K. Shimamura, T. Arakawa, Y. Nishihara, D. Chiba, K. Kobayashi, T. Ono, C.-Z. Chang, K. He, X.-C. Ma, and Q.-K. Xue: Weak antilocalization and conductance fluctuation in a submicrometer-sized wire of epitaxial Bi_2Se_3.
Physical Review B **85,** 075440 (2012).

[9] Y. Nishihara, S. Nakamura, K. Kobayashi, T. Ono, M. Kohda, and J. Nitta: Shot noise suppression in InGaAs/InGaAsP quantum channels.
Applied Physics Letters **100,** 203111 (2012).

[10] K. Sekiguchi, K. Yamada, S. M. Seo, K. J. Lee, D. Chiba, K. Kobayashi, and T. Ono: Time-domain measurement of current-induced spin wave dynamics.
Physical Review Letters **108,** 017203 (2012).

[11] K. Shimamura, D. Chiba, S. Ono, S. Fukami, N. Ishiwata, M. Kawaguchi, K. Kobayashi, and T. Ono: Electrical control of Curie temperature in cobalt using an ionic liquid film.
Applied Physics Letters **100,** 122402 (2012).

[12] J. Shiogai, M. Ciorga, M. Utz, D. Schuh, T. Arakawa, M. Kohda, K. Kobayashi, T. Ono, W. Wegscheider, D. Weiss, and J. Nitta: Dynamic nuclear spin polarization in an all-semiconductor spin injection device with (Ga,Mn)As/n-GaAs spin Esaki diode.
Applied Physics Letters **101,** 212402 (2012).

[13] K. Tanabe, D. Chiba, J. Ohe, S. Kasai, H. Kohno, S. E. Barnes, S. Maekawa, K. Kobayashi, and T. Ono: Spin-motive force due to a gyrating magnetic vortex.
Nature Communications **3,** 845 (2012).

[14] T. Tanaka, T. Arakawa, K. Chida, Y. Nishihara, D. Chiba, K. Kobayashi, T. Ono, H. Sukegawa, S. Kasai, and S. Mitani: Signature of Coherent Transport in Epitaxial Spinel-Based Magnetic Tunnel Junctions Probed by Shot Noise Measurement.
Applied Physics Express **5,** 053003 (2012).

[15] K. Ueda, T. Koyama, R. Hiramatsu, D. Chiba, S. Fukami, H. Tanigawa, T. Suzuki, N. Ohshima, N. Ishiwata, Y. Nakatani, K. Kobayashi, and T. Ono: Temperature dependence of carrier spin polarization determined from current-induced domain wall motion in a Co/Ni nanowire.
Applied Physics Letters **100,** 202407 (2012).

[16] Y. Utsumi, D. S. Golubev, M. Marthaler, G. Schn, and K. Kobayashi: Work fluctuation theorem for a classical circuit coupled to a quantum conductor.
Physical Review B **86,** 075420 (2012).

[17] T. Arakawa, Y. Nishihara, M. Maeda, S. Norimoto, and K. Kobayashi: Cryogenic amplifier for shot noise measurement at 20 mK.
Applied Physics Letters **103,** 172104 (2013).

[18] K. Chida, T. Arakawa, S. Matsuo, Y. Nishihara, T. Tanaka, D. Chiba, T. Ono, T. Hata, K. Kobayashi, and T. Machida: Observation of finite excess noise in the voltage-biased quantum Hall regime as a precursor for breakdown.
Physical Review B **87,** 155313 (2013).

[19] K. J. Kim, R. Hiramatsu, T. Koyama, K. Ueda, Y. Yoshimura, D. Chiba, K. Kobayashi, Y. Nakatani, S. Fukami, M. Yamanouchi, H. Ohno, H. Kohno, G. Tatara, and T. Ono: Two-barrier stability that allows low-power operation in current-induced domain-wall motion.
Nature Communications **4,** 2011 (2013).

[20] S. Matsuo, K. Chida, D. Chiba, T. Ono, K. Slevin, K. Kobayashi, T. Ohtsuki, C.-Z. Chang, K. He, X.-C. Ma, and Q.-K. Xue: Experimental proof of universal conductance fluctuation in quasi-one-dimensional epitaxial Bi_2Se_3 wires.
Physical Review B **88,** 155438 (2013).

[21] K. Nakano, K. Tanabe, R. Hiramatsu, D. Chiba, N. Ohshima, S. Kasai, T. Sato, Y. Nakatani, K. Sekiguchi, K. Kobayashi, and T. Ono: Real-time observation of electrical vortex core switching.
Applied Physics Letters **102,** 072405 (2013).

[22] K. Chida, T. Hata, T. Arakawa, S. Matsuo, Y. Nishihara, T. Tanaka, T. Ono, and K. Kobayashi: Avalanche electron bunching in a Corbino disk in the quantum Hall effect breakdown regime.
Physical Review B **89,** 235318/1-4 (2014).

[23] K. Tanabe, R. Matsumoto, J.-i. Ohe, S. Murakami, T. Moriyama, D. Chiba, K. Kobayashi, and T. Ono: Real-time observation of Snell's law for spin waves in thin ferromagnetic films.
Applied Physics Express **7,** 053001 (2014).

[24] T. Tanaka, T. Arakawa, M. Maeda, K. Kobayashi, Y. Nishihara, T. Ono, T. Nozaki, A. Fukushima, and S. Yuasa: Leak current estimated from the shot noise in magnetic tunneling junctions.
Applied Physics Letters **105,** 042405/1-4 (2014).

[25] K. Yamada, T. Sato, Y. Nakatani, S. Kasai, D. Chiba, K. Kobayashi, A. Thiaville, and T. Ono: Switching of magnetic vortex core in elliptical disks by nanosecond field pulses.
Applied Physics Express **7,** 063008 (2014).

[26] T. Arakawa, J. Shiogai, M. Ciorga, M. Utz, D. Schuh, M. Kohda, J. Nitta, D. Bougeard, D. Weiss, T. Ono, and K. Kobayashi: Shot noise induced by nonequilibrium spin accumulation.
Physical Review Letters **114,** 016601/1-5 (2015).

[27] H. Hata, T. Moriyama, K. Tanabe, K. Kobayashi, R. Matsumoto, S. Murakami, J.-i. Ohe, D. Chiba, and T. Ono: Micromagnetic simulation of spin wave propagation in a ferromagnetic film with different thicknesses.
Journal of the Magnetics Society of Japan **39,** 151-155 (2015).

[28] S. Matsuo, S. Nakaharai, K. Komatsu, K. Tsukagoshi, T. Moriyama, T. Ono, and K. Kobayashi: Parity effect of bipolar quantum Hall edge transport around graphene antidots.
Scientific Reports **5,** 11723/1-7 (2015).

[29] S. Matsuo, S. Takeshita, T. Tanaka, S. Nakaharai, K. Tsukagoshi, T. Moriyama, T. Ono, and K. Kobayashi: Edge mixing dynamics in graphene p-n junctions in the quantum Hall regime.
Nature Communications **6,** 8066/1-6 (2015).

[30] M. Ferrier, T. Arakawa, T. Hata, R. Fujiwara, R. Delagrange, R. Weil, R. Deblock, R. Sakano, A. Oguri, and K. Kobayashi: Universality of non-equilibrium fluctuations in strongly correlated quantum liquids.
Nature Physics **12,** 230-235 (2016).

[31] T. Hata, T. Arakawa, K. Chida, S. Matsuo, and K. Kobayashi: Giant Fano factor and bistability in a Corbino disk in the quantum Hall effect breakdown regime.
Journal of Physics: Condensed Matter **28,** 055801/1-7 (2016).

[32] T. Muro, Y. Nishihara, S. Norimoto, M. Ferrier, T. Arakawa, K. Kobayashi, T. Ihn, C. Rssler, K. Ensslin, C. Reichl, and W. Wegscheider: Finite Shot Noise and Electron Heating at Quantized Conductance in High-mobility Quantum Point Contacts.
Physical Review B **93,** 195411/1-7 (2016).

[33] J. Stigloher, M. Decker, H. S. Krner, K. Tanabe, T. Moriyama, T. Taniguchi, H. Hata, M. Madami, G. Gubbiotti, K. Kobayashi, T. Ono, and C. H. Back: Snell's Law for Spin Waves.
Physical Review Letters **117,** 037204/1-5 (2016).

[34] S. Takeshita, S. Matsuo, T. Tanaka, S. Nakaharai, K. Tsukagoshi, T. Moriyama, T. Ono, T. Arakawa, and K. Kobayashi: Anomalous behavior of $1/f$ noise in graphene near the charge neutrality point.
Applied Physics Letters **108,** 103106/1-4 (2016).

[35] K. Tanabe, R. Matsumoto, J.-I. Ohe, S. Murakami, T. Moriyama, D. Chiba, K. Kobayashi, and T. Ono: Observation of magnon Hall-like effect for sample-edge scattering in unsaturated YIG.
physica status solidi (b) **253,** 783-787 (2016).

[36] Y. Teratani, R. Sakano, R. Fujiwara, T. Hata, T. Arakawa, M. Ferrier, K. Kobayashi, and A. Oguri: Field-Enhanced Kondo Correlations in a Half-Filling Nanotube Dot: Evolution of an SU(N) Fermi-Liquid Fixed Point.
Journal of the Physical Society of Japan **85,** 094718/1-18 (2016).

[37] M. Ferrier, T. Arakawa, T. Hata, R. Fujiwara, R. Delagrange, R. Deblock, Y. Teratani, R. Sakano, A. Oguri, and K. Kobayashi: Quantum Fluctuations along Symmetry Crossover in a Kondo-Correlated Quantum Dot.
Physical Review Letters **118,** 196803/1-5 (2017).

[38] S. Iwakiri, Y. Niimi, and K. Kobayashi: Dynamics of pure spin current in high-frequency quantum regime.
Applied Physics Express **10,** 053001/1-4 (2017).

[39] T. Hata, R. Delagrange, T. Arakawa, S. Lee, R. Deblock, H. Bouchiat, K. Kobayashi, and M. Ferrier: Enhanced Shot Noise of Multiple Andreev Reflections in a Carbon Nanotube Quantum Dot in SU(2) and SU(4) Kondo regimes.
Physical Review Letters **121,** 247703/1-5 (2018).

[40] S. Iwakiri, Y. Niimi, and K. Kobayashi: Erratum: "Dynamics of pure spin current in high-frequency quantum regime", *Applied Physics Express* **11,** 119201 (2018).

[41] S. Norimoto, S. Nakamura, Y. Okazaki, T. Arakawa, K. Asano, K. Onomitsu, K. Kobayashi, and N.-h. Kaneko: Fano effect in the transport of an artificial molecule.
Physical Review B **97,** 195313/1-8 (2018).

[42] A. Sawada, S. Faniel, S. Mineshige, S. Kawabata, K. Saito, K. Kobayashi, Y. Sekine, H. Sugiyama, and T. Koga: Direct extraction of electron parameters from magnetoconductance analysis in mesoscopic ring array structures.
Physical Review B **97,** 195303/1-11 (2018).

[43] S. Suzuki, H. Taniguchi, T. Kawakami, M. Cosset-Cheneau, T. Arakawa, S. Miyasaka, S. Tajima, Y. Niimi, and K. Kobayashi: Electrical contacts to thin layers of $Bi_2Sr_2CaCu_2O_{8+\delta}$.
Applied Physics Express **11,** 053201/1-4 (2018).

[44] H. Taniguchi, S. Suzuki, T. Arakawa, H. Yoshida, Y. Niimi, and K. Kobayashi: Fabrication of thin films of two-dimensional triangular antiferromagnet Ag_2CrO_2 and their transport properties.
AIP Advances **8,** 025010/1-6 (2018).

[45] S. Iwakiri, S. Sugimoto, Y. Niimi, K. Kobayashi, Y. K. Takahashi, and S. Kasai: Observation of the magnetization metastable state in a perpendicularly magnetized nanopillar with asymmetric potential landscape.
Applied Physics Letters **115,** 092407 (2019).

[46] M. Tokuda, N. Kabeya, K. Iwashita, H. Taniguchi, T. Arakawa, D. Yue, X. Gong, X. Jin, K. Kobayashi, and Y. Niimi: Spin transport measurements in metallic Bi/Ni nanowires.
Applied Physics Express **12,** 053005/1-4 (2019).

[47] M. Ferrier, R. Delagrange, J. Basset, H. Bouchiat, T. Arakawa, T. Hata, R. Fujiwara, Y. Teratani, R. Sakano, A. Oguri, K. Kobayashi, and R. Deblock: Quantum Noise in Carbon Nanotubes as a Probe of Correlations in the Kondo Regime.
Journal of Low Temperature Physics (2019) (in press).

＜Conference Proceedings＞

[48] S. Matsuo, T. Koyama, K. Shimamura, T. Arakawa, Y. Nishihara, D. Chiba, K. Kobayashi, T. Ono, C.-Z. Chang, K. He, X.-C. Ma, and Q.-K. Xue: Conductance fluctuation and weak antilocalization in epitaxial Bi_2Se_3.
AIP Conference Proceedings **1566,** 193-194 (2013).

[49] K. Chida, M. Hashisaka, Y. Yamauchi, S. Nakamura, T. Arakawa, T. Machida, K. Kobayashi, and T. Ono: Bias voltage dependence of the electron spin depolarization in quantum wires in the quantum Hall regime detected by the resistively detected NMR.
AIP Conference Proceedings **1566,** 279-280 (2013).

[50] Y. Nishihara, S. Nakamura, K. Kobayashi, T. Ono, M. Kohda, and J. Nitta: Shot noise at the quantum point contact in InGaAs heterostructure.
AIP Conference Proceedings **1566,** 311-312 (2013).

＜Review Papers＞

[51] K. Kobayashi: What can we learn from noise? – Mesoscopic nonequilibrium statistical physics –
Proceedings of the Japan Academy, Series B **92,** 204-221 (2016).

[52] K. Kobayashi: New Explorer at Exotic Boundary: How Superconductivity and Quantum Hall Effect Go Together.
JPSJ News and Comments **16,** 01/1-2 (2019).

[53] 阪野塁、小栗章、小林研介「量子ドットの近藤効果による非平衡電流の完全計数統計」、固体物理 Vol. 47, 475 (2012).

[54] 小林研介「『ゆらぎ』を通して物理の本質に迫る」、生産と技術 Vol. 65, 55 (2013).

[55] 小林研介「メゾスコピック非平衡統計力学」、数理科学 No. 600, 7 (2013).

[56] 小林研介「熱力学第 2 法則と『ゆらぎの定理』の検証実験」、パリティVol. 29, No.5, 44 (2014).

[57] 松尾貞茂、小林研介「グラフェン pn 接合におけるパリティ効果の発見」、パリティ Vol. 31, No. 7, 56 (2016).

[58] 小林研介、「ゆらぎで探る量子液体」、パリティ Vol. 32, No. 11, 16 (2017).

[59] 小林研介、「雑音は何を教えてくれるのか? —メゾスコピック系における量子輸送と雑音—」、熱測定 (Netsu Sokutei) 45 (1), 16 (2018).

[60] 荒川智紀、小林研介、「スピン流とそのゆらぎ」、日本物理学会誌 Vol. 74, 222 (2019).

＜ **Books** ＞

[61] 小林研介「物理っておもしろい？ー等身大の魅力」、「先生、物理っておもしろいんですか？」パリティ編集委員会 (編集)、丸善出版（2015/5/25）所収。

[62] 木村剛、小林研介、田島節子監修、大阪大学インタラクティブ物質科学・カデットプログラム物性物理 100 問集出版プロジェクト編集、「物性物理 100 問集」、大阪大学出版会（2016/12/12）。

[63] 小林研介「ゆらぎと雑音の魅力」、「科学立国 日本を築く PartII 次代を拓く気鋭の研究者たち」、榊裕之（監修）、一般財団法人丸文財団選考委員会（編集）、日刊工業新聞社（2017/3/11）所収。

7 Invited Presentations at International Conferences

[1] K. Kobayashi: “Current Noise and Fluctuation Theorem in Mesoscopic Systems”, 2012 RCIQE International Workshop for Green Electronics (Sapporo, Hokkaido, Japan, March 5-6, 2012).

[2] K. Kobayashi: “Current noise and fluctuation theorem in mesoscopic systems”, East Asia Joint Symposia on Statistical Physics (Suzhou, China, 18-20 March, 2012).

[3] K. Kobayashi: “Current Noise and Fluctuation Theorem in Mesoscopic Systems”, Workshop on Nonequilibrium Transport in Low-Dimensional Systems (A Research Workshop of the Israel Science Foundation) (Kfar Blum, Israel, April 29 - May 3, 2012).

[4] K. Kobayashi: “Non-equilibrium Noise in Mesoscopic Systems”, International Workshop on the Science of Nanostructures: New Frontiers in the Physics of Quantum Dots (Chernogolovka, Moscow, Russia, September 10-14, 2012).

[5] K. Kobayashi: “Second Law of Thermodynamics”, Thirteenth Japanese-American Kavli Frontiers of Science Symposium (Japan Society for the Promotion of Science - U.S. National Academy of Sciences) (Irvine, California, USA, November 29 - December 4, 2012).

[6] K. Kobayashi: “Current Noise and ’Fluctuation Theorem’ in Mesoscopic Systems”, GCOE International Symposium on Physical Sciences Frontier (Tokyo, Japan, December 8-9, 2012).

[7] K. Kobayashi: “Shot Noise in Spin-dependent Transport through Mesoscopic Systems”, 3rd Japan-Israel Binational Workshop on Quantum Phenomena (Okinawa, Japan, March 11-13, 2013).

[8] K. Kobayashi: “Current Fluctuation in a Kondo-correlated Quantum Dot”, Workshop on Interferometry and Interactions in Non-equilibrium Meso- and Nano- Systems (Trieste, Italy, April 8-12, 2013).

[9] K. Kobayashi: “Spin-dependent Shot Noise in Mesoscopic Systems”, 22nd International Conference on Noise and Fluctuations (ICNF) (Montpellier, France, June 24-28, 2013).

[10] K. Kobayashi: “Fluctuation Theorem in a Quantum Coherent Conductor”, the 25th International Conference on Statistical Physics of the International Union for Pure and Applied Physics (IUPAP) (StatPhys25) (Seoul, Korea, July 22 - 26, 2013).

[11] K. Kobayashi: “Experimental Test of Fluctuation Theorem in Quantum Regime”, Frontiers of Quantum and Mesoscopic Thermodynamics 2013 (FQMT’13) (Prague, Czech Republic, July 29 - August 3, 2013).

[12] K. Kobayashi: "Current Fluctuation in Quantum Transport", Workshop on "Nanoscience: Materials Phenomena at the Small Scale" (NIMS, Tsukuba, October 9-11, 2013).

[13] K. Kobayashi: "Nonequilibrium Current Fluctuation in Quantum Device", Kavli Futures Symposium: Nanomaterials Science in Asian Perspective (Seoul, Korea, June 19-20, 2014).

[14] K. Kobayashi: "Nonequilibrium Kondo Effect in a Quantum Dot", Yukawa International Seminar 2014 (YKIS2014): "Nonequilibrium Phenomena in Novel Quantum States" (Kyoto, Japan, December 3-5, 2014).

[15] K. Kobayashi: "Nonequilibrium Fermi Liquid in a Kondo-correlated Quantum Dot", APCTP 2014 Workshop on Frontiers of Physics (Muju, Korea, December 20-23, 2014).

[16] K. Kobayashi: "Fluctuations in Mesoscopic Systems", Tutorial Lecture, IGER International Symposium on Science of Molecular Assembly and Biomolecular Systems 2015 : Spins in Action (Nagoya, Japan, March 26-27, 2015).

[17] T. Arakawa, M. Maeda, T. Ono, J. Shiogai, M. Kohda, J. Nitta, M. Ciorga, M. Utz, D. Schuh, D. Bougeard, D. Weiss, and K. Kobayashi: "Shot noise induced by spin accumulation", ISSP International Workshop on New Perspectives in Spintronic and Mesoscopic Physics (NPSMP2015) (Kashiwa, Japan, June 1-19, 2015).

[18] K. Kobayashi, M. Ferrier, T. Arakawa, T. Hata, R. Fujiwara, R. Delagrange, R. Weil, R. Deblock, R. Sakano, and A. Oguri: "Non-equilibrium Fermi Liquid in a Kondo-correlated Quantum Dot Probed by Shot Noise", the 21st International Conference on Electronic Properties of Two-Dimensional Systems (EP2DS-21) (Sendai, Japan, July 26-31, 2015).

[19] M. Ferrier, T. Arakawa, T. Hata, R. Fujiwara, R. Delagrange, R. Weil, R. Deblock, R. Sakano, A. Oguri, and K. Kobayashi, "Universality of non-equilibrium fluctuations in strongly correlated quantum liquids", Frontiers of Quantum and Mesoscopic Thermodynamics 2015 (FQMT'15) (Prague, Czech Republic, July 27 - August 1, 2015).

[20] K. Kobayashi, M. Ferrier, T. Arakawa, T. Hata, R. Fujiwara, R. Delagrange, R. Weil, R. Deblock, R. Sakano, and A. Oguri: "Universality of Nonequilibrium Behavior in Strongly Correlated Quantum Liquids", the International Symposium on Nanoscale Transport and Technology (ISNTT2015) (Atsugi, Japan, November 17-20, 2015).

[21] K. Kobayashi: "Edge dynamics in graphene pn junctions in the quantum Hall regime probed by the shot noise", Workshop on Computational Nano-Materials Design and Realization for Energy-Saving and Energy-Creation Materials (Toyonaka, Osaka, Japan, March 25-26, 2016).

[22] K. Kobayashi, M. Ferrier, T. Arakawa, T. Hata, R. Fujiwara, R. Delagrange, R. Weil, R. Deblock, R. Sakano, and A. Oguri: "Non-equilibrium Fluctuations of Quantum Liquids in the Kondo Regime", China-Japan International Workshop on Quantum Technologies 2016 (QTech2016) (Beijing, China, May 13-14, 2016).

[23] K. Kobayashi: "Current Fluctuations in Mesoscopic Systems" [invited lecture], 45th International Conference on the Physics of Semiconductors, Jaszowiec 2016 Conference (Szczyrk, Poland, June 18-24, 2016).

[24] M. Ferrier, T. Hata, T. Arakawa, Y. Teratani, R. Sakano, A. Oguri, and K. Kobayashi, "Noise detection of the field enhancement of Kondo correlations in a carbon nanotube quantum dot", The 22nd International Conference on High Magnetic Fields in Semiconductor Physics (HMF-22) (Sapporo, Hokkaido, Japan, July 24-29, 2016).

[25] K. Kobayashi: "Symmetry Control in the Kondo Effect", Spintronics and Core-to-Core Workshop 2017 (Toyonaka, Osaka, Japan, March 21-22, 2017).

[26] K. Kobayashi: "Spin-dependent Current Fluctuations in Mesoscopic Conductors", 9th International School and Conference on Spintronics and Quantum Information Technology (Spintech IX) (Fukuoka, Japan, June 4-8, 2017).

[27] K. Kobayashi: "Fluctuations along Symmetry Crossover in a Kondo-correlated Quantum Dot", Frontiers of Quantum and Mesoscopic Thermodynamics 2017 (FQMT'17) (Prague, Czech Republic, July 9 - July 15, 2017).

[28] K. Kobayashi: "Shot Noise Induced by Nonequilibrium Spin Accumulation", Nanophysics, from Fundamentals to Applications: Reloaded (Quy Nhon, Vietnam, July 30 - August 5, 2017).

[29] M. Ferrier, R. Delagrange, T. Hata, T. Arakawa, R. Sakano, A. Oguri, K. Kobayashi, and R. Deblock: "Universal Fluctuations and Quantum Noise Measurement in a Kondo-Correlated Quantum Dot Out-of-Equilibrium", International Conference on Magnetism (ICM 2018) (San Francisco, USA, July 15-20, 2018).

[30] K. Kobayashi: "Non-equilibrium Fluctuations in Strongly Correlated Quantum Liquids", International Symposium in Honor of Professor Nambu for the 10th Anniversary of his Nobel Prize in Physics (Osaka, Japan, December 12-13, 2018).

8 Teaching Accomplishment

- T. Arakawa received Inoue Research Award for Young Scientists for his outstanding doctoral thesis from Inoue Foundation for Science (2015).
- Two students received Osaka University Faculty of Science Award: M. Yokoi (2015), and H. Watanabe (2016).
- T. Hata received Springer Theses Award for his outstanding Ph.D. research from Springer Nature (2018).
- T. Hata won the best poster award in ISSP International Symposium on New Perspectives in Spintronic and Mesoscopic Physics (NPSMP2015) (Kashiwa, Japan, June 10-12, 2015).
- N. Kabeya and Lee Sanghyun won PASPS9 Young Researcher Best Poster Awards in the 9th International Conference on Physics and Applications of Spin Phenomena in Solids (PASPS 9) (Kobe, Japan, August 8-11, 2016).
- H. Taniguchi won Student Presentation Finalists in INTERMAG 2018 (Singapore, April 23-27, 2018).
- 9 graduate students won Research Fellowships for Young Scientists of Japan Society for the Promotion of Science (JSPS): T. Arakawa (2012), Y. Nishihara (2013), T. Tanaka (2013), T. Hata (2015), M. Yokoi (2017), S. Norimoto (2017), S. Iwakiri (2018), S. Suzuki (2019), and M. Tokuda (2020).
- 6 graduate students won the research fellowships of the Interactive Materials Science Cadet Program of Osaka University, which is part of the Program for Leading Graduate Schools scheme, coordinated by the Ministry of Education, Culture, Sports, Science and Technology of Japan: T. Hata (2013), S. Norimoto (2014), M. Yokoi (2016), S. Iwakiri (2016), Lee Sanghyun (2016), and A. Oshima (2017).
- 2 graduate students won SCAT Research Fellowships of the Support Center for Advanced Telecommunications Technology Research (SCAT), Foundation: H. Taniguchi (2017), and Lee Sanghyun (2018).
- H. Taniguchi of my group was accepted in Young Researchers Support Project with Osaka University Foundation for the Future for his oral presentation in INTERMAG 2018 (Singapore, April 23-27, 2018).

9 Contribution to Academic Community

9.1 Editorial Activities

- Associate Editor of Journal of the Physical Society of Japan (2018-).

9.2 Organization of Professional Societies

- Board of Director the Physical Society of Japan (2015-2017).

9.3 Organization and Advisory of Conferences

- Local organizing committee of ICAUMS2012 (The 2nd International Conference of the Asia Union of. Magnetics Societies) (2011-2013).
- Session chair of the 13th Japanese-American Frontiers of Science (JAFoS) Symposium (2012).
- Planning Group Member (PGM) of the 14th Japanese-American Frontiers of Science (JAFoS) Symposium (2012-2014).
- Local organizing committee of the 8th International Symposium on Metallic Multilayers (MML2013) (2013).
- Local organizing committee of Physics and Applications of Spin-related Phenomena in Semiconductors (PASPS-18) (2013).
- Editorial Committee of SSDM2014 (2014 International Conference on Solid State Devices and Materials) (2014).
- Planning Group Member (PGM) of the 15th Japanese-American Frontiers of Science (JAFoS) Symposium (2014-2015).
- Symposium Vice Chair of International Symposium on Fluctuation and Structure out of Equilibrium 2015 (SFS2015) (2013-2015).
- Advisory Committee of the 1st International Symposium Interactive Materials Science Cadet Program (2013-2014).
- Organizer of ISSP International Symposium on New Perspectives in Spintronic and Mesoscopic Physics (NPSMP2015) (2015).
- Co-chair of Planning Group Member (PGM) of the 15th Japanese-American Frontiers of Science (JAFoS) Symposium (2016).
- International Advisory Committee of the 9th SPINTECH (2016-2017).
- Co-chair of 9th International Conference on the Physics and Applications of Spin-Related Phenomena in Solids (PASPS 9) (2016).
- Local organizing committee of the 72nd Annual Meeting of The Physical Society of Japan (2016-2017).
- International Advisory Committee of International Conference Nanophysics, from Fundamentals to Applications: Reloaded (2016-2017).

- Program committee of 29th International Conference on Low Temperature Physics (LT29) (2016-).
- Organizing committee of Yamada Science Foundation Junjiro Kanamori Memorial International Symposium – New Horizon of Magnetism – (2017).
- International advisory committee of the 10th International School and Conference on Physics and Applications of Spin Phenomena in Solids (PASPS10) (2017-2018).
- Organizing committee of CSRN-Osaka Annual Workshop 2018 (2018).
- Program committee of the 21st International Conference on Electron Dynamics in Semiconductors (EDISON21) (2019).
- Advisory board of the International Conference on Advanced Materials (ICAM2019) (2019).
- International advisory committee of ICSNN 2020 (International Conference on Superlattices, Nanostructures and Nanodevices) (2019-).

10 Outreach

- Kobayashi group: https://meso.phys.s.u-tokyo.ac.jp/en/
- researchmap: https://researchmap.jp/read0057036/?lang=english
- 小林研介「電子一個を操作する」（大阪大学理学部オープンキャンパス、大阪大学、2012 年 8 月 17 日）。
- 小林研介「エレクトロニクス:真空管からナノテクノロジーまで」（大阪大学 Saturday Afternoon Physics SAP2012、2012 年 11 月 10 日、大阪大学）。
- 小林研介「現代エレクトロニクスへの招待　– 電子一個を操作する –」（宝塚北高等学校生対象、2012 年 11 月 22 日、大阪大学）。
- 小林研介「ナノテクノロジー最前線　– 電子一個を操作する –」（倉吉東高等学校生対象、2013 年 10 月 22 日、大阪大学）。
- 小林研介「量子の世界への旅立ち – その発見から応用まで –」（大阪大学 Saturday Afternoon Physics SAP2013 基幹講義、2013 年 10 月 26 日、大阪大学）。
- 小林研介「エレクトロニクス:真空管からナノテクノロジーまで」（大阪大学 Saturday Afternoon Physics SAP2013、2013 年 11 月 16 日大阪大学）。
- 小林研介「電子をあやつる：エレクトロニクスの過去・現在・未来」（高大連携プログラム、大阪大学理学部オープンキャンパス、2014 年 8 月 5 日、大阪大学）。
- 小林研介：「ゆらぎは語る – 人工量子系と熱力学第二法則」、2014 年度日本物理学会科学セミナー（東京大学、2014 年 8 月 6-7 日）。

- 小林研介「現代物理学への招待 – 量子の発見」（大阪大学理学部オープンキャンパス、2014 年 8 月 12 日、大阪大学）。

- 小林研介「量子の世界への旅立ち – 原子を見つめる、原子をあやつる –」（大阪大学 Saturday Afternoon Physics SAP2014 基幹講義、2014 年 10 月 25 日、大阪大学）。

- 小林研介「エレクトロニクス:真空管からナノテクノロジーまで」（大阪大学 Saturday Afternoon Physics SAP2014「研究室をのぞいてみよう」、2014 年 11 月 15 日、大阪大学）。

- 小林研介「研究をするということ」（出張講義、ヴィアトール学園洛星高等学校、2014 年 11 月 22 日）。

- 小林研介 :「現代物理学への招待 – 量子の発見とその応用」（出張講義、私立明星高等学校、2015 年 7 月 9 日）。

- 小林研介「量子の世界への旅立ち – 量子力学の発見とその応用 – 」（大阪大学 Saturday Afternoon Physics SAP2015 基幹講義、2015 年 10 月 24 日、大阪大学）。

- 小林研介 :「現代物理学への招待 – 量子力学の発見とその応用」（西宮市民会館、兵庫県西宮市、2016 年 10 月 9 日）。

- 小林研介 :「現代物理学への招待 – 量子力学の発見とその応用」（日本物理学会第 13 回 Jr. セッション、大阪大学、2017 年 3 月 18 日）。

- 小林研介「物質の世界への旅立ち – 電子一個を制御する」（大阪大学 Saturday Afternoon Physics SAP2017、2017 年 10 月 21 日、大阪大学）。

- 小林研介、「ゆらぎは語る – 人工量子系における非平衡物理学」、第 56 回玉城嘉十郎教授記念公開学術講演会（京都大学益川ホール、2017 年 10 月 27 日）。

- 小林研介、「電子をあやつる！ – 身のまわりのエレクトロニクスと物理学」、朝日カルチャーセンター中之島教室「物質の物理学」（大阪府大阪市中之島、2018 年 10 月 6 日）。

- 小林研介、「電子をあやつる – 量子力学とエレクトロニクス」、大阪大学大学院理学研究科 公開講座 サイエンスナイト 2018（大阪大学、2018 年 10 月 17 日）。

- 小林研介、「電子一個を操作する」、出前講義（鹿児島県立鶴丸高等学校、2018 年 10 月 26 日）。

- 「室温付近で成功　電圧印加で金属磁石をスイッチ」、電波新聞（2012 年 3 月 26 日日刊 3 面）。

- 「運動する磁気渦に誘起されたスピン起電力の実時間観測」、京都新聞（2012 年 5 月 23 日 23 面）および日刊工業新聞（2012 年 5 月 23 日 21 面）。

- 「電圧で局所的な磁極反転スピードが 20 倍に向上」、京都新聞（2012 年 6 月 7 日 23 面）、日刊工業新聞（2012 年 6 月 7 日 21 面）および科学新聞（2012 年 6 月 22 日 4 面）に掲載。

- 「東北大など、半導体中でシュテルン-ゲルラッハのスピン分離実験を実現」、マイナビニュース（2012 年 9 月 26 日 20 時 14 分）http://news.livedoor.com/article/detail/6989447/

- 「物理科学　この一年」特集「磁気コア運動によるスピン起電力」、月刊誌パリティ2013 年 01 月号。
- 「『磁壁』移動時のエネルギー 電流と磁場使用で差」、京都新聞（2013 年 6 月 18 日 23 面）。
- 「強磁性ナノ細線の障壁、電流と磁場で差異－京大など発見」、日刊工業新聞（2013 年 6 月 18 日 23 面）。
- 「第 10 回日本学術振興会賞に 25 氏」「ゆらぎの定理 世界初の実証」、科学新聞（2014 年 1 月 1 日 6 面）。
- 「学士院奨励賞に 6 人」、朝日新聞（2014 年 1 月 15 日朝刊 33 面）。
- 「6 人に学術奨励賞」、読売新聞（2014 年 1 月 15 日朝刊　33 面）。
- 「学士院学術奨励賞決定　成果耀く若手 6 氏　今後に期待」、科学新聞（2014 年 1 月 17 日 2 面）。
- 「ＭＥＭＯ：学士院奨励賞に 6 研究者」、毎日新聞（2014 年 1 月 24 日、東京朝刊 17 頁）。
- 「学術振興会賞　学士院学術奨励賞　第 10 回受賞式」、科学新聞（2014 年 2 月 21 日 5 面）。
- 「グラフェンにパリティ効果」、科学新聞（2015 年 7 月 10 日 4 面）。
- 「阪大など　パリティ効果発見　グラフェン研究進展」、日刊産業新聞（2015 年 7 月 9 日 11 面）。
- 「不思議な量子液体の挙動　世界最高水準技術で解明 – 阪大などの研究グループが世界初 – 」、科学新聞（2015 年 12 月 11 日 1 面）。 –
- 「朝日カルチャーセンター　電子や量子の世界を解説」、朝日新聞（2018 年 9 月 26 日 朝刊 26 面 大阪版）。
- 「矢崎科学技術振興記念財団　平成 30 年度　研究助成金贈呈式開催」、科学新聞（2019 年 3 月 22 日、2 面）他、計 10 誌に掲載。
- 「大阪科学賞に栗栖氏・小林氏」（朝日新聞 2019 年 09 月 26 日 朝刊 33 頁）他、計 4 誌に掲載。

11 Committee Service

11.1 External Committees

- 日本学術振興会 科学研究費委員会専門委員 (2014-2016).
- 日本学術振興会 学術システム研究センター 専門研究員 (2018-).
- 日本物理学会 第 9 回若手奨励賞審査委員 (2014).
- 日本物理学会 寄付金管理委員会委員長 (2015-2016).
- 日本物理学会 第 71 期情報システム運用委員会委員 (2015-2016).

- 日本物理学会 第 71 期ホームページ運用小委員会委員 (2015-2016).
- 日本物理学会 第 10 回若手奨励賞審査委員 (2015).
- 日本物理学会 第 12 回 Jr. セッション第 1 次審査委員 (2016).
- 日本物理学会 領域副代表 (領域 4) (2016).
- 日本物理学会 第 72 期情報システム運用委員会委員 (2016-2017).
- 日本物理学会 第 72 期ホームページ運営小委員会委員長 (2016-2017).
- 日本物理学会 第 72 期広報委員会 委員長 (2016-2017).
- 日本物理学会 第 11 回若手奨励賞審査委員 (2016).
- 日本物理学会 第 13 回 Jr. セッション第 1 次審査委員 (2017).
- 日本物理学会 代議員 (第 73-74 期) (2017-2019).
- 日本物理学会 領域代表 (領域 4) (2017-2018).
- 日本物理学会 第 73 期ホームページ運営小委員会委員 (2017-2018).
- 日本物理学会 第 12 回若手奨励賞審査委員長 (2017).
- 日本物理学会 第 14 回 Jr. セッション第 1 次審査委員 (2018).
- 日本物理学会 学生優秀発表賞 (領域 4) 一次審査審査委員 (2018).
- 日本物理学会 学生優秀発表賞 (領域 4) 一次審査員・二次審査員 (2019).
- 学技術振興機構 戦略的創造研究推進事業 さきがけ「量子の状態制御と機能化」領域アドバイザー (2016-).
- 公益財団法人 住友財団「基礎科学研究助成事業」選考委員 (2016-).
- 東京大学物性研究所 共同利用施設専門委員会 委員 (2016-).
- 京都大学化学研究所「共同利用・共同研究拠点」共同研究委員会委員 (2016-).
- 雑誌「固体物理」誌友 (2016-2017).
- 凝縮系科学賞 選考委員 (2018-).
- 雑誌「固体物理」誌友 (2018-2019).
- 凝縮系科学賞 運営委員 (2019-).

11.2 University Committees

Satoru Nakatsuji、中辻 知

1 Education and Professional Experiences

Education

1996	B.S. (Engineering)	Kyoto University
1998	MSc. (Physics)	Kyoto University
2001	Ph.D. (Physics)	Kyoto University

Professional Appointments

2019−present	Professor	The University of Tokyo Department of Physics, School of Science
2016−present	Professor	ISSP, The University of Tokyo
2017−present	Research Professor	Johns Hopkins University
2019−present	Fellow	CIFAR
2016−2017	Visiting Associate Professor	Johns Hopkins University
2012−2015	PRESTO Researcher	Japan Science and Technology Corporation
2012−2015	Visiting Associate Professor	Osaka University Department of Physics

2 Research Highlights

We have made signicant progress in clarifying novel phases in correlated matters by the combination of state-of-art techniques to create new materials, and to probe their properties with a wide variety of high precision measurements. Our major achievements can be classied into three following categories.

2.1 Strange metal and exotic superconductivity

Extensive work for d- and f-electron systems has almost routinely conrmed that strange metal and exotic superconductivity appear at a magnetic quantum critical point. Breaking this rule, we have established that the Yb-based heavy fermion superconductor, β-YbAlB4 we discovered [NaturePhysics2008] as a new material, is the rst example of a metal that exhibits quantum criticality without tuning [Science2011], namely, at ambient condition, as a result of the formation of a quantum critical phase [Science2015,ScienceAdvances2018]. Another breakthrough has been provided by the rst observation of a strange metal phase due to the strong hybridization between the quadrupole moment and conduction electrons in PrTr2Al20 (Tr=Ti,V) [J.Phys.Soc.Jpn.2011, J.Phys.Soc.Jpn.2012]. We have established the rst case of a quantum criticality associated with nonmagnetic quadrupole ordering and an associated heavy fermion superconductivity [PRL2012, PRL2014, PRB2015]. We are the pioneer who has synthesized the single crystals of PrTr2Al20 and β-YbAlB4, which has enabled the above breakthrough.

2.2 Spin liquids

One of the most extreme cases of the entanglement may be found in spin liquid. Two classes of quantum liquid candidates have been discovered. First, we found a spin ice state with signicant quantum uctuations, namely, a quantum spin ice state in Pr2Zr2O7 and Pr2Ir2O7. [PRL2006, NatureCommun2013, NatureMaterials2014, J.Phys.Soc.Jpn.2018]. Obviously, the key for the above successes is the high-quality single crystals that we have grown by Xenon floating zone and our original KF flux methods, respectively. The other is the spin-orbital liquid. We have recently discovered a spin-orbital liquid state in Ba3CuSb2O9 based on the crystals grown by our new flux growth methods [Science2012, NatureCommun2013, PNAS2015, PRB2015, PRB2016, JPCM208].

2.3 Topological magnetic metals

Although discovered in inversion-symmetry breaking systems, Weyl semimetals induced by collective magnetic order had remained hypothetical until recently. With this regard, we have made several breakthroughs. First, we have discovered the rst case of the anomalous Hall eects (AHE) in a spin liquid state in Pr2Ir2O7 [Nature2010, PRL2011]. This is the first observation of AHE without magnetization and made before the prediction of the magnetic Weyl semimetal [Wan et.al.,PRBvol.83,205101,2011]. The discovery was possible as my group was the first that established the crystal growth method in pyrochlore iridates, which later became a topical system. Moreover, we found that this material harbors the Luttinger semimetal [NatureCommun2015,NatureCommun2017], in which the underlying band structure exhibits a quadratic band touching between the valence and conduction bands at the Fermi energy. We established the thin film growth method of Pr2Ir2O7 and reported strain-induced Weyl semimetal state[PNAS2019].

Strikingly, we have further discovered that antiferromagnets may exhibit AHE for the first time, with vanishingly small magnetization, in Mn3Sn and Mn3Ge [Nature2015, PRApplied2016]. On top, we found that these topological magnets host the magnetic Weyl metals [NatureMaterials2017] and exhibits anomalous Nernst eect (ANE) [NaturePhysics2017]. Moreover, this time-reversal symmetry (TRS) breaking also allows us to detect large magneto-optical Kerr eect and to visualize magnetic domains for the rst time in an antiferromagnetic metal [NaturePhotonics2018], and moreover, to observe the first case of the spin Hall effect that breaks TRS [Nature2019]. We have also succeeded in growing a high-quality thin film of Mn3Sn that exhibits AHE by a sputtering method [APL2018]. We further found one order magnitude higher ANE in Co2MnGa, in comparison with the previously reported value for ferromagnets, ascribable to the quantum Lifshitz transition between type-I and type-II Weyl fermions [NaturePhysics2018]. This paves the path for designing the Weyl magnet useful for energy harvesting technology.

3 Selected Papers

- “Giant anomalous Nernst effect and quantum critical scaling in a ferromagnetic semimetal”, A. Sakai, Y. P. Mizuta, A. A. Nugroho, R. Sihombing, T. Koretsune, M-T. Suzuki, N. Takemori, R. Ishii, D. N. Hamane, R. Arita, P. Goswami, S. Nakatsuji Nature Physics 14, 1119-1124 (2018). [45 citations]

- “Large magneto-optical Kerr effect and imaging of magnetic octupole domains in an antiferromagnetic metal”, T. Higo, H. Man, D. B. Gopman, L. Wu, T. Koretsune, O. M. J. van ’t Erve, Yury P. Kabanov, D. Rees, Y. Li, M-T. Suzuki, S. Patankar, M. Ikhlas, C. L. Chien, R. Arita, R. D. Shull, J. Orenstein, S. Nakatsuji Nature Photonics, 12, 73-78 (2018). [50 citations]

- “Large anomalous Nernst effect at room temperature in a chiral antiferromagnet”, M. Ikhlas, T. Tomita, T. Koretsune, M-T. Suzuki, D. Nishio-Hamane, R. Arita, Y. Otani, S. Nakatsuji Nature Physics. 13, 1085-1090 (2017). [65 citations]

- “Evidence for magnetic Weyl fermions in a correlated metal”, K. Kuroda, T. Tomita, M.-T. Suzuki, C. Bareille, A. A. Nugroho, P. Goswami, M. Ochi, M. Ikhlas, M. Nakayama, S. Akebi, R. Noguchi, R. Ishii, N. Inami, K. Ono, H. Kumigashira, A. Varykhalov, T. Muro, T. Koretsune, R. Arita, S. Shin, Takeshi Kondo and S. Nakatsuji, Nature Materials. 16, 1090-1095 (2017). [60 citations]

- “Large anomalous Hall effect in a non-collinear antiferromagnet at room temperature”, S. Nakatsuji, N. Kiyohara, T. Higo, Nature. 527, 212-215 (2015). [198 citations]

- “Spin-Orbital Short-Range Order on a Honeycomb-Based Lattice”, S. Nakatsuji, K. Kuga, K. Kimura, R. Satake, N. Katayama, E. Nishibori, H. Sawa, R. Ishii, M. Hagiwara, F. Bridges, T. U. Ito, W. Higemoto, Y. Karaki, M. Halim, A. A. Nugroho, J. A. Rodriguez-Rivera, M. A. Green and C. Broholm, Science. 336, 559-563 (2012). [92 citations]

4 Honors, Awards and Professional Society Memberships

2018 The 23rd Outstanding Paper Award of the Physical Society of Japan
2015 Japan Academy Medal
2015 JSPS Award
2012 MEXT Young Scientists’ Prize, Japan

5 Research Plan

A conceptional breakthrough is often made by a merger of different classes of research field. In fact, our recent subject “Weyl magnet” was born out of two different research streams in the condensed matter physics, namely, “topology” and “correlated electron systems”. On the other hand, discovery of new compounds often leads to much deeper understanding of the topic and opening a new field of science. We will facilitate another leap of research by carrying out such interdisciplinary and new materials studies.

5.1 Topological magnetic metals and the topological antiferromagnetic spintronics

We will lead the research frontier of correlated topological quantum matter in the direction of topological magnetic metals and the topological antiferromagnetic spintronics. Our research has recently identified a few candidates of topological magnets. Taking further steps, here we propose the projects to design and establish new members of topological magnets, and to clarify (I) the role of topology in correlated electrons in the bulk based on the single crystal growth and (II) the interface effects using spintronics probes based on thin film fabrication. Going beyond the phenomenology of noninteracting electrons, our exploration of novel correlation effects in topological magnets will focus on the dynamic evolution of ground states due to external perturbations. Fabrication of high-quality single crystals and films of new materials will allow us to probe and control their electronic structure, magnetic phases, correlations and collective modes through various methods.

(I) Bulk study on the role of topology in correlated electrons
In metallic systems, topological dynamics arises from singularities in the electrons’ energy dependence on spin and momentum, e.g. nodal points (Weyl and quadratic band-touching nodes), and nodal lines. The originally envisioned Weyl fermions induced by magnetism have been recently identified in a few candidate materials including the non-collinear antiferromagnet Mn3Sn and the Luttinger semimetal Pr2Ir2O7. Here we will seek new topological magnets, in particular, new magnetic Weyl and Luttinger semimetals, and investigate them with various techniques to observe unconventional electromagnetic properties expected from nontrivial distributions of Berry curvature in the correlated topological phases. Growth and development of single crystals of topological magnets will be performed using a variety of techniques, including flux, Bridgman, floating zone, and Czochralski methods. The method of crystal preparation must always be closely tailored to the individual properties of the material concerned. Well characterized and large single crystals will allow us to closely probe exotic excitations expected in the topological correlated phases. The search for candidate topological magnets will be informed by the state-of-art first principles calculations in collaboration with theorists, and neutron scattering in collaboration. The magnetic structure determined by elastic neutron scattering measurements will be essential for the first-principles calculations, which will provide initial insight about the underlying features of the band structures at the DFT level. We will carry out the following comprehensive set of experiments on our new Weyl/Luttinger semimetals: (i) measurements of quantum critical response associated with a quantum phase transition, such as topological Lifshitz transition, (ii) neutron scattering to probe spin waves and their damping, orbital magnetism and anomalous magnetic excitations associated with inter-Weyl node scattering in collaboration, (iii) ARPES to identify the location of nodal points in momentum space via collaborations, and (iv) infrared reflectivity measurements and Raman scattering to explore the charge dynamics unique to Weyl/Luttinger semimetal states, including its chiral anomaly through its suggested effect on Raman-active phonons in magnetic field. Moreover, chemical doping and ionic gating will be used to tune the Fermi level to the energy of nodal points and thus expose their anomalous effects on dynamics and the hypothetical non-Fermi liquid phase.

(II) Study of the interface effects based on the fabrication of thin films

The large Berry curvature associated with Weyl fermions may persist up to the transition temperatures of a magnetic Weyl semimetal or “Weyl magnets”, and thus may provide useful functions particularly when they are beyond room temperature. In particular, spintronics techniques for clarifying the interface effects are available for the study of Weyl magnets. This allows us to clarify the novel effects coming from the surface Fermi “arcs” of the Weyl semimetals. In fact, our recent study on Mn3Sn has revealed a new type of spin Hall effect, whose sign and magnitude can be controlled by magnetization, in contrast with the conventional analog. Our research targets include i) characterization and manipulation of magnetic Weyl states by electric/spin currents and THz laser, and ii) to deepen our understanding of the new type of spin Hall effect and energy conversion between thermal heat, electric and spin currents expected for Weyl magnets (e.g. Spin Seebeck effect, Anomalous Nernst effect, and Spin-Orbit Torque effect). For this purpose, thin film fabrication is essential for exploring novel functions by injecting high-density electric and spin currents through interface. For the film growth of new intermetallic Weyl magnets, we have found that the sputtering method is handy and suited as it allows us to change and add elements and to tune the Fermi energy as well as transition temperature. We will grow high-quality epitaxial films by tuning the condition and selecting the appropriate kind/form of substrates. The manipulation of domain walls by currents will be made by in-situ observation of domain walls using magneto-optical techniques, combined with transport measurements. Furthermore, the charge/spincurrent control of the domain walls of Weyl magnets would generate the space and time dependence of strong Berry curvature, leading to emergent electromagnetism. Thin films with highly flat surface will be fabricated to prepare well-defined interface between Weyl magnets and a heavy metal (e.g. Pt) or ferromagnet (e.g. Py) to perform the experiments using the spin Seebeck and spin pumping geometries. As topological semimetals have attracted recent significant attention as next-generation main active materials to achieve high-density and ultrafast spintronics devices, our study will set the grounds for the application of Weyl magnets for future topological spintronics.

5.2 Physics of Multipole Systems

A significant advance in understanding of the multipoles and their diverse arrangements at atomic sites has been made for the f-electron based materials, and the community in Japan has made significant contributions in the research field. While most of the examples have been limited to the systems with fully localized multipoles, our discovery of new materials in the class of 1-2-20 systems has made breakthrough to realize the strong quantum entanglement between the localized multipoles and conduction electrons, leading to a new metallic state due to *itinerant* multipoles and exotic superconductivity. Our study has found that the itinerant multipoles may stabilize not only a strange metal phase where the concept of quasi-particle is no longer valid but a “high-temperature” superconductivity that has a critical temperature much higher than BCS expectation based on the Fermi energy. Thus, we will aim at establishing several textbook cases for novel quantum phases emergent from a quantum phase transition between itinerant-localized states of multipoles; non-Fermi-liquid phase that is stabilized through the possible multi-channel Kondo effect (quadrupolar Kondo effect), itinerant multipolar phases including octupolar phase, and unconventional superconductivity on the verge of the quantum critical point associated with a multipolar ordering. In the long term, our study on the mechanism behind these phenomena will help us to design new materials that have enhanced temperature scale for the strange metal phase and superconductivity and help us to find another class of high-temperature superconductors.

Recently, our discovery of the large anomalous Hall effect in antiferromagnets has led to the formation of the concept of the cluster multipole, which is found useful to capture the size of symmetry breaking made by a magnetic texture. In fact, the ferroic-order of the cluster octupole made of six neighboring spins breaks the time-reversal symmetry and thus allows the system to exhibit anomalous Hall effect. This indicates that the multipole should be a useful tool to design functional antiferromagnets. Thus, the combination of the topology of the electronic structure and the multipole arrangement in the real space spin texture may well lead to a series of discoveries of new types of functional antiferromagnets. Furthermore, this idea of multipole should be not only useful to design/understand the bulk properties, but also applicable to find interesting functions at interface for spintronics. Thus, our interdisciplinary research, ranging from topology, correlated electron systems, and spintronics, will lead the new field of topological antiferromagnetic spintronics by fabricating new materials and new nanoscale structures and demonstrating that new functions can be designed by using the concept of multipole and topology.

6 Publications and Patents

[1] "Linear polarization-dependent core-level photoemission spectroscopy in Yb-based valence fluctuating system", Kentaro Kuga, Yuina, Kanai, Hidenori Fujiwara, Kohei Yamagami, SatoruHamamoto, Yuichi Aoyama, Akira Sekiyama, Atsushi Higashiya, Toshiharu Kadono,Shin Imada, Atsushi Yamasaki, Kenji Tamasaku, Makina Yabashi, Tetsuya Ishikawa,Satoru Nakatsuji, Takayuki Kiss, J. Electron. Spectrosc. Relat. Phenom. (2019)

[2] "Unveiling hidden multipolar orders with magnetostriction", Adarsh S. Patri, Akito Sakai, SungBin Lee, Arun Paramekanti, Satoru Nakatsujiand Yong Baek Kim, Nat. Commun. 10, 4092 (2019).

[3] "Field-Induced Switching of Ferro-Quadrupole Order Parameter in PrTi2Al20", Takanori Taniguchi, Kazumasa Hattori, Makoto Yoshida1, Hikaru Takeda, Shota Nakamura, Toshiro Sakakibara, Masaki Tsujimoto, Akito Sakai, Yosuke Matsumoto, Satoru Nakatsuji, and Masashi Takigawa, J. Phys. Soc. Jpn. 88, 084707 (2019).

[4] "新しい熱電変換技術：磁性体の異常ネルンスト効果", 酒井明人、中辻知, O pluse E, 7-8 月号, 546-549 (2019).

[5] "Giant anisotropic magnetoresistance due to purely orbital rearrangement in the quadrupolar heavy fermion superconductor PrV2Al20", Yasuyuki Shimura, Qiu Zhang, Bin Zeng, Daniel Rhodes, Rico Schnemann, Masaki Tsujimoto, Yosuke Matsumoto, Akito Sakai, Toshiro Sakakibara, Koji Araki, Wenkai Zheng, Qiong Zhou, Luis Balicas, and Satoru Nakatsuji Phys. Rev. Lett. 122, 256601 (2019). "Scanning tunneling microscopy on cleaved Mn3Sn(0001) surface", Hung-Hsiang Yang, Chi-Cheng Lee, Yasuo Yoshida, Muhammad Ikhlas, Takahiro Tomita, Agustinus Nugroho, Taisuke Ozaki, Satoru Nakatsuji and Yukio Hasegawa, Sci. Rep. 9, 9677 (2019).

[6] "Terahertz conductivity of the magnetic Weyl semimetal Mn3Sn films" , Bing Cheng, Youcheng Wang, D. Barbalas, Tomoya Higo, S. Nakatsuji, and N. P. Armitage, Appl. Phys. Lett. 115, 012405 (2019).

[7] "Strain-induced spontaneous Hall effect in an epitaxial thin film of a Luttinger semimetal", Takumi Ohtsuki, Zhaoming Tian, Akira Endo, Mario Halim, Shingo Katsumoto,Yoshimitsu Kohama, Koichi Kindo, Mikk Lippmaa, and Satoru Nakatsuji, PNAS (2019).

[8] "Energy-harvesting materials based on the anomalous Nernst effect", Masaki Mizuguchi and Satoru Nakatsuji, Science and Technology of Advanced Materials 20, 262-275 (2019) .

[9] "Magnetic and magnetic inverse spin Hall effects in a non-collinear antiferromagnet", Motoi Kimata, Hua Chen, Kouta Kondou, Satoshi Sugimoto, Prasanta K. Muduli, Muhammad Ikhlas, Yasutomo Omori, Takahiro Tomita, Allan. H. MacDonald, Satoru Nakatsuji and Yoshichika Otani, nature 565, 627630 (2019) .

[10] 「量子効果で 10 倍以上の磁気熱電効果を室温で実現」, 酒井　明人、中辻 知、 クリーンエネルギー vol.28 No.1 34-38 (2019).

[11] 「ワイル磁性体 Co2MnGa における室温巨大異常ネルンスト効果」, 酒井明人, J-Physics No. 07, 47-49 (2019).

[12] 「ワイル反強磁性体 Mn3Sn における巨大な磁気光学カー効果と拡張磁気八極子ドメインの直接観測」, 肥後友也、J-Physics No. 07, 94 (2019).

[13] 「反強磁性体において実現した室温での巨大異常ネルンスト効果-磁気ワイルフェルミオンが織りなすトポロジカル現象-」, 冨田崇弘, 肥後友也, 中辻知, 固体物理, Vol.54, P.85-99 (2019).

[14] 「ワイル磁性体 Mn3Sn における巨大な異常ネルンスト効果」, 冨田崇弘, 日本磁気学会・第 217 回研究会資料, P23-28 (2018).

[15] "Crystal Structure in Quadrupolar Kondo Candidate PrTr2Al20 (Tr = Ti and V)", D. Okuyama, M. Tsujimoto, H. Sagayama, Y. Shimura, A. Sakai, A. Magata, S. Nakatsuji, T. J. Sato J. Phys. Soc. Jpn 88, 015001 (2018).

[16] "Anomalous Hall effect in thin films of the Weyl antiferromagnet Mn3Sn", T. Higo, D. Qu, Yufan Li, C. L. Chien, Y. Otani, and S. Nakatsuji, Appl. Phys. Lett. 113, 202402 (2018). Featured Articles

[17] "Large enhancement of the spin Hall effect in Mn metal by Sn doping", D. Qu, T. Higo, T. Nishikawa, K. Matsumoto, K. Kondou, D. Nishio-Hamane, R. Ishii, P. K. Muduli, Y. Otani, and S. Nakatsuji Phys. Rev. Materials 2, 102001(R) (2018). Editor's Suggestion

[18] "トポロジーを利用した反強磁性スピントロニクスとエネルギーハーベスティング" 中辻 知, まぐね １３ (No. 5), 216-222 (2018).

[19] "Spin-Orbital Entangled Liquid State in the Copper Oxide Ba3CuSb2O9", Huiyuan Man, Mario Halim, Hiroshi Sawa, Masayuki Hagiwara, Yusuke Wakabayashiand Satoru Nakatsuji Journal of Physics: Condensed Matter (2018).

[20] "Giant anomalous Nernst effect and quantum critical scaling in a ferromagnetic semimetal", Akito Sakai, Yo Pierre Mizuta, Agustinus Agung Nugroho, Rombang Sihombing, Takashi Koretsune, Michi-To Suzuki, Nayuta Takemori, Rieko Ishii, Daisuke Nishio-Hamane, Ryotaro Arita, Pallab Goswami and Satoru Nakatsuji Nature Physics 14, 11191124 (2018).

[21] "Valence fluctuating compound α-YbAlB4 studied by 174Yb Mssbauer spectroscopy and X-ray diffraction using synchrotron radiation", Momoko Oura, Shugo Ikeda, Ryo Masuda, Yasuhiro Kobayashi, Makoto Seto, Yoshitaka Yoda, Naohisa Hirao, Saori I. Kawaguchi, Yasuo Ohishi, Shintaro Suzuki, Kentaro Kuga, Satoru Nakatsuji and Hisao Kobayashi Physica B: Condensed Matter 536, 162-164 (2018).

[22] "Magnetic Excitations across the Metal-Insulator Transition in the Pyrochlore Iridate Eu2Ir2O7", Sae Hwan Chun, Bo Yuan, Diego Casa, Jungho Kim, Chang-Yong Kim, Zhaoming Tian, Yang Qiu, Satoru Nakatsuji, and Young-June Kim Phys. Rev. Lett. 120, 177203 (2018).

[23] "Discovery of Emergent Photon and Monopoles in a Quantum Spin Liquid", Yoshifumi Tokiwa, Takuya Yamashita, Daiki Terazawa, Kenta Kimura, YuichiKasahara, Takafumi Onishi, Yasuyuki Kato, Mario Halim, Philipp Gegenwart,Takasada Shibauchi, Satoru Nakatsuji, Eun-Gook Moon and Yuji Matsuda, J. Phys. Soc. Jpn. 87, 064702 (2018).

[24] "Relaxation calorimetry at very low temperatures for systems with internal relaxatio", Yosuke Matsumoto and Satoru Nakatsuji Review of Scientific Instruments 89, 033908 (2018).

[25] "Quantum valence criticality in a correlated metal",Kentaro Kuga, Yosuke Matsumoto, Mario Okawa, Shintaro Suzuki, TakahiroTomita, Keita Sone, Yasuyuki Shimura, Toshiro Sakakibara, Daisuke Nishio-Hamane,Yoshitomo Karaki, Yasutaka Takata, Masaharu Matsunami, Ritsuko Eguchi,Munetaka Taguchi, Ashish Chainani, Shik Shin, Kenji Tamasaku, YoshinoriNishino, Makina Yabashi, Tetsuya Ishikawa and Satoru Nakatsuji, Science Advances 4, eaao3547 (2018).

[26] "Large magneto-optical Kerr effect and imaging of magnetic octupole domains in an antiferromagnetic metals",Tomoya Higo, Huiyuan Man, Daniel B. Gopman, Liang Wu, Takashi Koretsune, Olaf M. J. van 't Erve, Yury P. Kabanov, Dylan Rees, Yufan Li, Michi-To Suzuki, Shreyas Patankar, Muhammad Ikhlas, C. L. Chien, Ryotaro Arita, Robert D. Shull, Joseph Orenstein and Satoru Nakatsuji Nature Photonics 12, 73-78 (2018).

[27] "Kondo hybridization and quantum criticality in β- YbAlB4 by laser ARPES,Cdric Bareille", Shintaro Suzuki, Mitsuhiro Nakayama, Kenta Kuroda, Andriy H. Nevidomskyy, Yosuke Matsumoto, Satoru Nakatsuji, Takeshi Kondo, and Shik Shin, Phys. Rev. B 97, 045112 (2018).

[28] 「複合環境下での 16/18T マグネットの利用」, 冨田崇弘, 志村恭通, 中辻知, J-Physics ニュースレター, No.3, P.16-17, (2017).

[29] "Frustrated magnetism in the Heisenberg pyrochlore antiferromagnets AYb2X4 (A = Cd, Mg, X = S, Se)", T. Higo, K. Iritani, M. Halim, W. Higemoto, T. U. Ito, K. Kuga, K. Kimura, S. Nakatsuji, Phys. Rev. B 95, 174443 (2017).

[30] "Dielectric anomalies and interactions in the three-dimensional quadratic band touching Luttinger semimetal Pr2Ir2O7", Bing Cheng, T. Ohtsuki, Dipanjan Chaudhuri, S. Nakatsuji, Mikk Lippmaa and N. P. Armitage, Nature Communications 8, 2097 (2017).

[31] "Anomalous Nernst effect in a microfabricated thermoelectric element made of chiral antiferromagnet Mn3Sn", Hideki Narita, Muhammad Ikhlas, Motoi Kimata, Agustinus Agung Nugroho, Satoru Nakatsuji, and YoshiChika Otani, Applied Physics Letters 111, 202404 (2017).

[32] "Large anomalous Nernst effect at room temperature in a chiral antiferromagnet", Muhammad Ikhlas, Takahiro Tomita, Takashi Koretsune, Michi-To Suzuki, Daisuke Nishio-Hamane, Ryotaro Arita, Yoshichika Otani and Satoru Nakatsuji, Nature Physics 13, 1085-1090 (2017).

[33] "Evidence for magnetic Weyl fermions in a correlated metal", K. Kuroda, T. Tomita, M.-T. Suzuki, C. Bareille, A. A. Nugroho, P. Goswami,M. Ochi, M. Ikhlas, M. Nakayama, S. Akebi, R. Noguchi, R. Ishii, N. Inami,K. Ono, H. Kumigashira, A. Varykhalov, T. Muro, T. Koretsune, R. Arita,S. Shin, Takeshi Kondo and S. Nakatsuji, Nature materials 16, 1090-1095 (2017).

[34] "Large spontaneous Hall effects in chiral topological magnets", S. Nakatsuji and T. Higo and M. Ikhlas and T. Tomita and Z. Tian, Philosophical Magazine (2017).

[35] "Specific heat and electrical resistivity at magnetic fields in antiferromagnetic heavy fermion CeAl2", T. Ebihara, M. Tsuchiya, Y. Saitoh, J. Jatmika, M. Tsujimoto, Y. Shimura, Y. Matsumoto and S. Nakatsuji, Journal of Physics: Conference Series 807, 012011 (2017).

[36] "Anisotropic Thermal Expansion of α-YbAlB4", Yosuke Matsumoto, K. Kuga, T. Tomita, R. Kchler and S. Nakatsuji, Journal of Physics: Conference Series 807, 022005 (2017).

[37] 「反強磁性体における巨大異常ホール効果」, 中辻知, 応用物理 86 (４月号), 310 (2017). "Thermal Hall Effect in a Phonon-Glass Ba3CuSb2O9", K. Sugii, M. Shimozawa, D. Watanabe, Y. Suzuki, M. Halim, M. Kimata, Y. Matsumoto, S. Nakatsuji, and M. Yamashita, Phys. Rev. Lett. 118, 145902 (2017).

[38] "Disordered Route to the Coulomb Quantum Spin Liquid: Random Transverse Fields on Spin Ice in Pr2Zr2O7", J.-J. Wen, S.M. Koohpayeh, K.A. Ross, B.A. Trump, T.M. McQueen, K. Kimura, S. Nakatsuji, Y. Qiu, D.M. Pajerowski, J.R.D. Copley, and C.L. Broholm, Phys. Rev. Lett. 118, 107206 (2017).

[39] "Orthogonal magnetization and symmetry breaking in pyrochlore iridate Eu2Ir2O7", Tian Liang, Timothy H. Hsieh, Jun J. Ishikawa, Satoru Nakatsuji, Liang Fu and N. P. Ong, Nature Physics 13, 599 (2017).

[40] "Lifetime-Broadening-Suppressed X-ray Absorption Spectrum of β-YbAlB4 Deduced from Yb 3d $\rightarrow$ 2p Resonant X-ray Emission Spectroscopy", Naomi Kawamura, Noriko Kanai, Hisashi Hayashi, Yasuhiro H. Matsuda, Masaichiro Mizumaki, Kentaro Kuga, Satoru Nakatsuji, and Shinji Watanabe, J. Phys. Soc. Jpn. 86, 014711 (2017).

[41] "Collective versus local Jahn-Teller distortion in Ba3CuS2O9: Raman scattering study", Natalia Drichko, Collin Broholm, K. Kimura, R. Ishii, and Satoru Nakasutjio, Phys. Rev. B 93, 184425 (2016).

[42] 中辻知, 「物性科学ハンドブック-概念・現象・物質-」, 東京大学物性研究所編集, (朝倉書店), 「13. 強相関電子系の物質開発：序説 」929-931(2016).

[43] 中辻知, 「物性科学ハンドブック-概念・現象・物質-」, 東京大学物性研究所編集, (朝倉書店), 「13.3 金属間化合物における強相関電子系：重い電子系」 989-1007 (2016).

[44] "Large anomalous Hall effect in a non-collinear antiferromagnet at room temperature", S. Nakatsuji, N. Kiyohara, T. Higo, Nature, article summary (2016).

[45] "NMR Observation of Ferro-Quadrupole Order in PrTi2Al20", Takanori Taniguchi, Makoto Yoshida, Hikaru Takeda, Masashi Takigawa, Masaki Tsujimoto, Akito Sakai, Yosuke Matsumoto, and Satoru Nakatsuji, J. Phys. Soc. Jpn. 85, 113703 (2016).

[46] "Pressure-induced magnetic transition exceeding 30 K in the Yb-based heavy-fermion β- YbAlB4", Takahiro Tomita, Kentaro Kuga, Yoshiya Uwatoko, and Satoru Nakatsuji, Phys. Rev. B 94, 245130 (2016).

[47] "Multiband electronic transport in α-Yb1- x Sr x AlB4 [x=0, 0.19(3)] single crystals", H. Ryu, M. Abeykoon, E. Bozin, Y. Matsumoto, S. Nakatsuji and C. Petrovic, J. Phys. Condens. Matter 28, 42 (2016).

[48] ”Slater to Mott Crossover in the Metal to Insulator Transition of Nd2Ir2O7, M. Nakayama”, Takeshi Kondo, Z. Tian, J.J. Ishikawa, M. Halim, C. Bareille, W. Malaeb, K. Kuroda, T. Tomita, S. Ideta, K. Tanaka, M. Matsunami, S. Kimura, N. Inami, K. Ono, H. Kumigashira, L. Balents, S. Nakatsuji, and S. Shin, Phys. Rev. Lett.117, 056403 (2016). Editors' Suggestion Quantum criticality and inhomogeneous magnetic order in Fe-doped α-YbAlB4, D. E. MacLaughlin, K. Kuga, Lei Shu, O. O. Bernal, P.-C. Ho, S. Nakatsuji, K. Huang, Z. F. Ding, C. Tan, and Jian Zhang, Phys. Rev. B 93, 214421 (2016).

[49] ”Giant Anomalous Hall Effect in the Chiral Antiferromagnet Mn3Ge”, N. Kiyohara, T. Tomita, and S. Nakatsuji, Phys. Rev. Applied 5, 064009 (2016).

[50] ”パイロクロア型イリジウム酸化物 Nd2Ir2O7 における磁場印加方向に敏感な金属-絶縁体転移”, 小濱芳允、Zhaoming Tian、冨田崇弘、石川洵、金道浩一、石塚大晃、中辻　知, 固体物理、Vol. 51 pp. 339-355 (2016).

[51] ”Chemical and orbital fluctuations in Ba3CuSb2O9”, Y. Wakabayashi, D. Nakajima, Y. Ishiguro, K. Kimura, T. Kimura, S. Tsutsui, A. Q. R. Baron, K. Hayashi, N. Happo, S. Hosokawa, K. Ohwada, and S. Nakatsuji, Phys. Rev. B 93, 245117 (2016).

[52] ”Low-Energy Excitations and Ground State Selection in Quantum Breathing Pyrochlore Antiferromagnet Ba3Yb2Zn5O11”, T. Haku, K. Kimura, Y. Matsumoto, M. Soda, M. Sera, D. Yu, R. A. Mole, T.Takeuchi, S. Nakatsuji, Y. Kono, T. Sakakibara, L.-J. Chang, Phys. Rev. B 93, 220407 (2016).

[53] ”Dimensional Reduction in Quantum Dipolar Antiferromagnets”, P. Babkevich, M. Jeong, Y. Matsumoto, I. Kovacevic, A. Finco, R. Toft-Petersen, C. Ritter, M. Mnsson, S. Nakatsuji, and H.M. Rnnow, Phys. Rev. Lett. 116, 197202 (2016).

[54] ”Quantum Criticality Beneath the Superconducting Dome in β-YbAlB4”, T. Tomita, K. Kuga, Y. Uwatoko and S. Nakatsuji, Journal of Physics: Conference Series 683, 012007 (2016).

[55] ”Site-selective 11B NMR studies on YbAlB4”, S. Takano, M. S. Grbic, K. Kimura, M. Yoshida, M. Takigawa, E. C. T. O'Farrell, K. Kuga, S. Nakatsuji and H. Harima, Journal of Physics: Conference Series 683, 012008 (2016).

[56] ”High Magnetic Transition Temperature and Semiconductor like Transport Properties of Mn-doped α-YbAlB4”, S. Suzuki, T. Tomita, Y. Shimura, K. Kuga, Y. Matsumoto and S. Nakatsuji, Journal of Physics: Conference Series 683, 012009 (2016).

[57] ”Very Low Temperature Magnetoresistance in the Quadrupole Ordered System PrV2Al20”, Y. Shimura, M. Tsujimoto, B. Zeng, Q. Zhang, L. Balicas, A. Sakai, and S. Nakatsuji, Journal of Physics: Conference Series 683, 012012 (2016).

[58] ”Heavy Fermion Superconductivity in Non-magnetic Cage Compound PrV2Al20”, Yosuke Matsumoto, Masaki Tsujimoto, Takahiro Tomita, Akito Sakai and Satoru Nakatsuji, Journal of Physics: Conference Series 683, 012013 (2016).

[59] ”Low-temperature thermal expansion measurements in PrV2Al20”, A. Magata, Y. Matsumoto, M. Tsujimoto1, T. Tomita1, R. Kuchler, A. Sakai and S. Nakatsuji, Journal of Physics: Conference Series 683, 012014 (2016).

[60] ”Single crystal 27Al-NMR study of the cubic Γ 3 ground doublet system PrTi2Al20”, T. Taniguchi, M. Yoshida, H. Takeda, M. Takigawa, M. Tsujimoto, A. Sakai, Y. Matsumoto and S. Nakatsuji, Journal of Physics: Conference Series 683, 012016 (2016).

[61] ”Experimental exploration of novel semimetal state in strong anisotropic Pyrochlore iridate Nd2lr2O7 under high magnetic field”, Z. M. Tian, Y. Kohama, T. Tomita, J. Ishikawa, H. Mairo, K. Kindo and S. Nakatsuji, Journal of Physics: Conference Series 683, 012024 (2016).

[62] ”Frustrated magnetism in a Mott insulator based on a transition metal chalcogenide”, S. Kawamoto, T. Higo, T. Tomita, S. Suzuki, Z. M. Tian, K. Mochitzuki, A. Matsuo, K. Kindo and S. Nakatsuji, Journal of Physics: Conference Series 683, 012025 (2016).

[63] ”Magnetic and Transport Properties of Frustrated γ-MnPd alloys”, T. Higo, N. Kiyohara, K. Iritani,

[64] "Strong orbital fluctuations in multipolar ordered states of PrV2Al20", Yosuke Matsumoto, Masaki Tsujimoto, Takahiro Tomita, Akito Sakai, Satoru Nakatsuji, J. Magn. Magn. Mater. 400, 66-69 (2016).

[65] "Pressure-Induced Local Structural Changes in Heavy Fermion β-YbAlB4", Yui Sakaguchi, Shugo Ikeda, Kentaro Kuga, Shintaro Suzuki, Satoru Nakatsuji, Naohisa Hirao, Yasuo Ohishi, and Hisao Kobayashi, Journal of the Physical Society of Japan 85, 023602 (2016).

[66] "Field-induced quantum metalinsulator transition in the pyrochlore iridate Nd2Ir2O7", Zhaoming Tian, Yoshimitsu Kohama, Takahiro Tomita, Hiroaki Ishizuka,Timothy H. Hsieh, Jun J. Ishikawa, Koichi Kindo, Leon Balents and SatoruNakatsuji, Nature Physics 12, 134 (2016).

[67] "Perturbation on hyperfine-enhanced141 Pr nuclear spin dynamics associated with antiferroquadrupolar order in PrV2Al20", T. U. Ito, W. Higemoto, A. Sakai, M. Tsujimoto, and S. Nakatsuji, Phys. Rev. B 92, 125151 (2015).

[68] "Unconventional quantum criticality in β-YbAlB4 detached from its magneticallyordered phase", Takahiro Tomita, Kentaro Kuga, Yoshiya Uwatoko, Piers Coleman and Satoru Nakatsuji, Physics Procedia 75, 482-487 (2015).

[69] "Optical evidence for a Weyl semimetal state in pyrochlore Eu2Ir2O7", A. B. Sushkov, J. B. Hofmann, G. S. Jenkins, J. Ishikawa, S. Nakatsuji, S. Das Sarma, and H. D. Drew, Phys. Rev. B 92, 241108(R) (2015).

[70] "Observation of the orbital quantum dynamics in the spin-1/2 hexagonal antiferromagnet Ba3CuSb2O9", Yibo Han, Masayuki Hagiwara, Takehito Nakano, Yasuo Nozue, Kenta Kimura, Mario Halim, and Satoru Nakatsuji, Phys. Rev. B 92, 180410(R) (2015).

[71] "Quadratic Fermi node in a 3D strongly correlated semimetal", Takeshi Kondo, M. Nakayama, R. Chen, J. J. Ishikawa, E.-G. Moon, T. Yamamoto, Y. Ota, W. Malaeb, H. Kanai, Y. Nakashima, Y. Ishida, R. Yoshida, H. Yamamoto, M. Matsunami, S. Kimura, N. Inami, K. Ono, H. Kumigashira, S. Nakatsuji, L. Balents and S. Shin, Nature Communications 6, 10042 (2015).

[72] "X-ray Absorption Spectroscopy in the Heavy Fermion Compound α-YbAlB4 at High Magnetic Fields", Taku T. Terashima, Yasuhiro H. Matsuda, Kentaro Kuga, Shintaro Suzuki, Yosuke Matsumoto, Satoru Nakatsuji, Akihiro Kondo, Koichi Kindo, Naomi Kawamura, Masaichiro Mizumaki, Toshiya Inami, J. Phys. Soc. Jpn. 84, 114715 (2015)

[73] "Large anomalous Hall effect in a non-collinear antiferromagnet at room temperature", Satoru Nakatsuji, Naoki Kiyohara, Tomoya Higo, Nature 527, 212-215 (2015).

[74] "Spin Fluctuations from Hertz to Terahertz on a Triangular Lattice", Yusuke Nambu, Jason S. Gardner, Douglas E. MacLaughlin, Chris Stock, Hitoshi Endo, Seth Jonas, Taku J. Sato, Satoru Nakatsuji, and Collin Broholm, Physcial Review Letters 115, 127202 (2015).

[75] "Large trigonal-field effect on spin-orbit coupled states in a pyrochlore iridate", Daisuke Uematsu, Hajime Sagayama, Taka-hisa Arima, Jun J. Ishikawa, Satoru Nakatsuji, Hidenori Takagi, Masahiro Yoshida, Jun'ichiro Mizuki, and Kenji Ishii, Phys. Rev. B 92, 094405 (2015).

[76] "Unstable spin-ice order in the stuffed metallic pyrochlore Pr2+xIr2- xO7-δ ", D. E. MacLaughlin, O. O. Bernal, Lei Shu, Jun Ishikawa, Yosuke Matsumoto, J.-J. Wen, M. Mourigal, C. Stock, G. Ehlers, C. L. Broholm, Yo Machida, Kenta Kimura, Satoru Nakatsuji, Yasuyuki Shimura, and Toshiro Sakakibara, Phys. Rev. B 92, 054432 (2015). Editors' Suggestion

[77] "Intact quasiparticles at an unconventional quantum critical point", M. L. Sutherland, E. C. T. O'Farrell, W. H. Toews, J. Dunn, K. Kuga, S. Nakatsuji, Y. Machida, K. Izawa, and R. W. Hill, Phys. Rev. B 92, 041114 (2015). Viewpoint in Physics.

[78] "Strange metal without magnetic criticality", Takahiro Tomita, Kentaro Kuga, Yoshiya Uwatoko, Piers Coleman, Satoru Nakatsuji, Science 349, 506-509 (2015).

[79] "Absence of Jahn- Teller transition in the hexagonal Ba3CuSb2O9 single crystal", Naoyuki Katayama, Kenta Kimura, Yibo Han, Joji Nasu, Natalia Drichko, Yoshiki Nakanishi, Mario Halim, Yuki Ishiguro, Ryuta Satake, Eiji Nishibori, Masahito Yoshizawa, Takehito Nakano, Yasuo Nozue, Yusuke Wakabayashi, Sumio Ishihara, Masayuki Hagiwara, Hiroshi Sawa, and Satoru Nakatsuji, Proc. Natl. Acad. Sci. USA 112, 93059309 (2015).

[80] "Field-induced quadrupolar quantum criticality in PrV2Al20", Yasuyuki Shimura, Masaki Tsujimoto, Bin Zeng, Luis Balicas, Akito Sakai, and Satoru Nakatsuji, Phys. Rev. B 91, 241102(R) (2015).

[81] "電子軌道の量子ゆらぎによる新しい超伝導, 松本 洋介, パリティ 30, 31-33 (2015).

[82] "Conduction electron spin resonance in the α-Yb1-xFexAlB4 (0 x 0.50) and α-LuAlB4 compounds", L. Holanda, G. Lesseux, E. Magnavita, R. Ribeiro, S. Nakatsuji, K. Kuga, Z. Fisk, S. Oseroff, R. Urbano, C. Rettori and P. Pagliuso, J. Phys.: Condens. Matter 27, 255601/1-5 (2015).

[83] "Magnetization Anomaly due to the Non-Coplanar Spin Structure in NiS2", T. Higo and S. Nakatsuji, J. Phys. Soc. Jpn. 84, 053702 (2015).

[84] "High Pressure Measurements of the Resistivity of β-YbAlB4", T. Tomita, K. Kuga, Y. Uwatoko and S. Nakatsuji, J. Phys.: Conf. Ser. 592, 012019 (2015).

[85] "Synchrotron X-ray spectroscopy study on the valence state and magnetization in α-YbAl1-xFexB4 (x = 0.115) at low temperatures and high magnetic fields", T. Terashima, Y. H. Matsuda, K. Kuga, S. Suzuki, Y. Matsumoto, S. Nakatsuji, A. Kondo, K. Kindo, N. Kawamura, M. Mizumaki and T. Inami, J. Phys.: Conf. Ser. 592, 012020 (2015).

[86] "Anomalous specific heat behaviour in the quadrupolar Kondo system PrV2Al20", M. Tsujimoto, Y. Matsumoto and S. Nakatsuji, J. Phys.: Conf. Ser. 592, 012023 (2015).

[87] "Anomalous Enhancement of Seebeck Coefficient in Pr-Based 1-2-20 System with Non-Kramers Doublet Ground States", Y. Machida, T. Yoshida, T. Ikeura, K. Izawa, A. Nakama, R. Higashinaka, Y. Aoki, H. Sato, A. Sakai, S. Nakatsuji, N. Nagasawa, K. Matsumoto, T. Onimaru and T. Takabatake, J. Phys.: Conf. Ser. 592, 012025 (2015).

[88] "Shubnikov-de Haas Oscillation in the cubic Γ3-based heavy fermion superconductor PrV2Al20", Yasuyuki Shimura, Masaki Tsujimoto, Akito Sakai, Bin Zeng, Luis Balicas and Satoru Nakatsuji, J. Phys.: Conf. Ser. 592, 012026 (2015).

[89] "Antiferromagnetic transition of the caged compound TmTi2Al20", Naoki Kase, Yasuyuki Shimura, Shunichiro Kittaka, Toshiro Sakakibara, Satoru Nakatsuji, Tomohito Nakano, Naoya Takeda and Jun Akimitsu, J. Phys.: Conf. Ser. 592, 012052 (2015).

[90] "Anisotropic transverse magnetoresistivity in α-YbAlB4", Yosuke Matsumoto, Jinpyo Hong, Kentaro Kuga and Satoru Nakatsuji, J. Phys.: Conf. Ser. 592, 012086 (2015).

[91] "High-Field Multi-Frequency ESR in the Rare-Earth Spinel Compound CdYb2S4", D. Yoshizawa, T. Kida, S. Nakatsuji, K. Iritani, M. Halim, T. Takeuchi, M. Hagiwara, Appl Magn Reson , published online: 15 Feb 2015.

[92] "Field Evolution of Quantum Critical and Heavy Fermi-Liquid Components in the Magnetization of the Mixed Valence Compound β-YbAlB4", Yosuke Matsumoto, Kentaro Kuga, Yoshitomo Karaki, Yasuyuki Shimura, Toshiro Sakakibara, Masashi Tokunaga, Koichi Kindo, and Satoru Nakatsuji, Journal of the Physical Society of Japan 84, 024710 (2015).

[93] "Heavy-Fermion Superconductivity in the Quadrupole Ordered State of PrV2Al20", Masaki Tsujimoto, Yosuke Matsumoto, Takahiro Tomita, Akito Sakai, and Satoru Nakatsuji, Physcial Review Letters 113, 267001 (2014).

[94] "銅酸化物磁性体におけるスピン・軌道の特異な量子状態", 澤　博、中辻　知, 固体物理、Vol. 49 pp. 533-543 (2014).

[95] "Experimental realization of a quantum breathing pyrochlore antiferromagnet", K. Kimura, S. Nakatsuji, and T. Kimura, Physical Review B 90, 060414(R) (2014). "Editors' Suggestion"

[96] "Magnetic and Thermal Properties of the Single Crystalline Pr2Zr2O7 in a [111] Field", Kenta Kimura, Satoru Nakatsuji, JPS Conf. Proc. 3, 014027 (2014) .

[97] "Electronic Structure of Quantum Spin-Liquid Coupound Ba3CuSb2O9", Takuya Sugimoto, Takashi Mizokawa, Hiroki Wadati, Kou Takubo, Andrea Damascelli, Tom Z. Regier, George A. Sawatzky, Naoyuki Katayama, Hiroshi Sawa, Kenta Kimura, Satoru Nakatsuji, JPS Conf. Proc. 3, 014007 (2014) .

[98] "Two Magnetic Phases in α-YbAl1- xFexB4", Kentaro Kuga, Shintaro Suzuki, Satoru Nakatsuji, JPS Conf. Proc. 3, 012013 (2014) .

[99] "Magnetization and Specific Heat of the Cage Compound PrV2Al20", K. Araki, Y. Shimura, N. Kase, T. Sakakibara, A. Sakai, S. Nakatsuji, JPS Conf. Proc. 3, 011093 (2014) .

[100] "Heavy Fermion Superconductivity under Pressure in the Quadrupole System PrTi2Al20", Kazuyuki Matsubayashi, Toshiki Tanaka, Junichirou Suzuki, Akito Sakai, Satoru Nakatsuji, Kentaro Kitagawa, Yasunori Kubo, Yoshiya Uwatoko, JPS Conf. Proc. 3, 011077 (2014) .

[101] "Suppression of the Heavy Fermion State in Magnetic Fields in the Mixed Valent α-YbAIB4", Yosuke Matsumoto, Kuga Kentaro, Satoru Nakatsuji, JPS Conf. Proc. 3, 011076 (2014) .

[102] "Sample Dependence of the Quadrupolar Transition in the Nonmagnetic Cubic Γ 3 Compound PrV2Al20", Masaki Tsujimoto, Akito Sakai, Satoru Nakatsuji, JPS Conf. Proc. 3, 011074 (2014) .

[103] "Superconducting Properties of the Ferroquadrupolar Cubic Γ 3 Compound PrTi2Al20", Akito Sakai, Kentaro Kuga, Satoru Nakatsuji, JPS Conf. Proc. 3, 011066 (2014) .

[104] "Structural and Magnetic Properties of α-Yb(Al1- xFex)B4 under Hydrostatic Pressure", Yui Sakaguchi, Shugo Ikeda, Kentaro Kuga, Satoru Nakatsuji, Naohisa Hirao, Yasuo Ohishi, Hisao Kobayashi, JPS Conf. Proc. 3, 011059 (2014) .

[105] "Magnetization of Yb-Based Mixed-Valent Compounds at Megagauss Fields", T. Terashima, Y. H. Matsuda, K. Kuga, Y. Matsumoto, S. Nakatsuji, K. Yoshimura, T. Nakahigashi, JPS Conf. Proc. 3, 011027 (2014) .

[106] "Quantum criticality in a metallic spin liquid", Y. Tokiwa, J. J. Ishikawa, S. Nakatsuji and P. Gegenwart, Nature Materials 13, 356359 (2014) .

[107] "Conduction electron spin resonance in AlB2, L. M. Holanda, L. Mendona-Ferreira, R. A. Ribeiro, J. M. Osorio-Guilln, G. M. Dalpian, K. Kuga, S. Nakatsuji, Z. Fisk, R. R. Urbano, P. G. Pagliuso and C. Rettori, J. Phys.: Condens. Matter 25, 216001 (2013).

[108] "Magnetic excitations and c-f hybridization effect in PrTi2Al20 and PrV2Al20", Yo Tokunaga, Hironori Sakai, Shinsaku Kambe, Akito Sakai, Satoru Nakatsuji, and Hisatomo Harima, Physical Review B 88, 085124 (2013).

[109] "Single-crystal study on the low-temperature magnetism of the pyrochlore magnet Pr2Zr2O7", Kenta Kimura, Satoru Nakatsuji, A. Agung Nugroho, Journal of the Korean Physical Society 63, 719-721 (2013).

[110] "Magnetic order induced by Fe doping in the intermediate valence system β-YbAlB4" , K. Kuga and S. Nakatsuji, Journal of the Korean Physical Society 63, 549-550 (2013).

[111] "Low temperature transport properties of the quadrupolar Kondo lattice system PrTi2Al20" ,Akito Sakai, Satoru Nakatsuji, Journal of the Korean Physical Society 63, 398-400 (2013).

[112] "Mssbauer spectroscopy of Fe-doped valence-fluctuating α-YbAlB4" , Y. Sakaguchi, S. Ikeda, H. Kobayashi, K. Kuga, K. Sone and S. Nakatsuji, Journal of the Korean Physical Society 62, 2146-2149 (2013).

[113] "Synchrotron X-ray spectroscopy study on the valence state in α- and β-YbAlB4 at low temperatures and high magnetic fields", Y. H. Matsuda, T. Nakamura, K. Kuga, S. Nakatsuji, S. Michimura, T. Inami, N. Kawamura and M. Mizumaki, Journal of the Korean Physical Society 62, 1778-1781 (2013).

[114] ”Chemical effects of high-resolution Yb L γ 4 emission spectra: a possible probe for chemical analysis,H”. Hayashi, N. Kanai, N. Kawamura, Y. H. Matsuda, K. Kuga, S. Nakatsuji, T. Yamashita and S. Ohara, X-Ray Spectrometry 42, 450-455 (2013).

[115] ”Dynamical spinorbital correlation in the frustrated magnet Ba3CuSb2O9”, Yuki Ishiguro, Kenta Kimura, Satoru Nakatsuji, Satoshi Tsutsui, Alfred Q. R. Baron, Tsuyoshi Kimura, and Yusuke Wakabayashi, Nature Communications 4, 2022 (2013).

[116] ”Quantum fluctuations in spin-ice-like Pr2Zr2O7”, K. Kimura, S. Nakatsuji, J-J. Wen, C. Broholm, M. B. Stone, E. Nishibori, and H. Sawa, Nature Communications 4, 1934 (2013).

[117] ”Evidence of a High-Field Phase in PrV2Al20 in a [100] Magnetic Field”, Yasuyuki Shimura, Yasuo Ohta, Toshiro Sakakibara, Akito Sakai, and Satoru Nakatsuji, J. Phys. Soc. Jpn. 82, 043705 (2013).

[118] ”Determination of long-range all-in-all-out ordering of Ir4+ moments in a pyrochlore iridate Eu2Ir2O7by resonant x-ray diffraction”, H. Sagayama, D. Uematsu, T. Arima, K. Sugimoto, J. J. Ishikawa, E. O ’ Farrell and S. Nakatsuji, Physical Review B 87, 100403 (2013).

[119] ”銅酸化物における乱れに強い量子液体状態”, 中辻 知, 澤 博, 「超伝導現象と高温超伝導体」 第 3 章 1 節 NTS 出版社.

[120] ”Structure and physical properties of single crystal PrCr2Al20 and CeM2Al20 (M=V, Cr): A comparison of compounds adopting the CeCr2Al20 structure type”, Michael J. Kangasa, Devin C. Schmitta, Akito Sakaia, Satoru Nakatsuji, Julia Y. Chan, Journal ofSolid State Chemistry 196, 274-281 (2012).

[121] ”Magnetic order induced by Fe substitution of Al site in the heavy-fermion systems α-YbAlB4 and β-YbAlB4”, Kentaro Kuga, Gregory Morrison, LaRico Treadwell, Julia Y. Chan, and Satoru Nakatsuji, Physical Review B 86, 224413 (2012).

[122] ”T/B scaling of magnetization in the mixed valent compound β-YbAlB4”, Yosuke Matsumoto, S Nakatsuji, K Kuga, Y Karaki, Y Shimura, T Sakakibara, A H Nevidomskyy, and P Coleman, Journal of Physics: Conference Series 391, 012041 (2012).

[123] ”Shubnikov-de Haas oscillations in the heavy fermion α-YbAlB4, E.C.T. O’Farrell1”, D.A. Tompsett, N. Horie, S. Nakatsuji and M. L. Sutherland, Journal of Physics: Conference Series 391, 012053 (2012).

[124] ”Thermal properties of the nonmagnetic cubic Γ 3 Kondo lattice systems PrTr2Al20 (Tr = Ti, V)”, Akito Sakai and Satoru Nakatsuji, Journal of Physics: Conference Series 391, 012058 (2012)

[125] ”Field Dependence of the Specific Heat in a Heavy-Fermion Superconductor CeIrIn5”, Yuya Aoki, Shunichiro Kittaka, Toshiro Sakakibara, Akito Sakai, Satoru Nakatsuji, Yasumasa Tsutsumi, Masanori Ichioka, and Kazushige Machida, Journal of the Physical Society of Japan 81, SB014 (2012).

[126] ”Low Temperature Properties of the Cubic Kondo Lattice Systems SmTr2Al20 (Tr = Ti, V, Cr)”, Akito Sakai and Satoru Nakatsuji, Journal of the Physical Society of Japan 81, SB049 (2012).

[127] ”Microscopic Evidence for Long-Range Magnetic Ordering in the Γ 8 Ground Quartet Systems SmTr2Al20 (Tr: Ti, V, Cr)”, T. U. Ito, W. Higemoto, K. Ninomiya, A. Sakai and S. Nakatsuji, Journal of the Physical Society of Japan 81, SB050 (2012).

[128] ”Yb 系の重い電子化合物における量子臨界性と超伝導”, 中辻知, 固体物理 47, pp.521-535 (2012).

[129] ”Ferroquadrupolar ordering in PrTi2Al20”, Taku J. Sato, Soshi Ibuka, Yusuke Nambu, Teruo Yamazaki, Tao Hong, Akito Sakai, and Satoru Nakatsuji, Physical Review B 86, 184419 (2012).

[130] ”Spin dynamics and spin freezing in the triangular lattice antiferromagnets FeGa2S4 and NiGa2S4”, S. Zhao, P. Dalmas de Reotier, A. Yaouanc, D. MacLaughlin, J. Mackie, O. Bernal, Y. Nambu, T. Higo and S. Nakatsuji, Physical Review B 86, 064435 (2012).

[131] ”Pressure-Induced Heavy Fermion Superconductivity in the Nonmagnetic Quadrupolar System PrTi2Al20”, K. Matsubayashi, T. Tanaka, A. Sakai, S. Nakatsuji, Y. Kubo, and Y. Uwatoko, Physcial Review Letters 109, 187004 (2012).

[132] ”Evolution of c-f Hybridization and Two-Component Hall Effect in β-YbAlB4”, E. C. T. O’Farrell, Y. Matsumoto, and S. Nakatsuji, Physcial Review Letters 109, 176405 (2012).

[133] ”Thermoelectric Response Near a Quantum Critical Point of β-YbAlB4 and YbRh2Si2: A Comparative Study”, Y. Machida, K. Tomokuni, C. Ogura, K. Izawa, K. Kuga, S. Nakatsuji, G. Lapertot, G. Knebel, J.-P. Brison, and J. Flouquet, Physcial Review Letters 109, 156405 (2012).

[134] ”Superconductivity in the Ferroquadrupolar State in the Quadrupolar Kondo Lattice PrTi2Al20”, Akito SAKAI, Kentaro KUGA, and Satoru NAKATSUJI, Journal of the Physical Society of Japan 81, 083702 (2012).

[135] ”磁気秩序なしに起こる新しいホール効果, 中辻知, パリティ 27 7 月号，pp.11-17 (2012).

[136] ”Discovery of the Novel Quantum Liquid Robust Against Disorder in Pseudo-Honeycomb Lattice Antiferromagnet Ba3CuSb2O9”, N. Katayama, R. Satake, E. Nishibori, H. Sawa and S. Nakatsuji, SPring-8 Information 17, No. 4, 297-303 (2012).

[137] ”Continuous transition between antiferromagnetic insulator and paramagnetic metal in the pyrochlore iridate Eu2Ir2O7”, Jun J. Ishikawa, Eoin C. T. O’Farrell, and Satoru Nakatsuji, Physical Review B 85, 245109 (2012).

[138] ”Pressure-tuned insulator to metal transition in Eu2Ir2O7, F. F. Tafti, J. J. Ishikawa, A. McCollam, S. Nakatsuji, and S. R. Julian, Physical Review B 85, 205104 (2012).

[139] ”Spin-Orbital Short-Range Order on a Honeycomb-Based Lattice”, S. Nakatsuji, K. Kuga, K. Kimura, R. Satake, N. Katayama, E. Nishibori, H. Sawa, R. Ishii, M. Hagiwara, F. Bridges, T. U. Ito, W. Higemoto, Y. Karaki, M. Halim, A. A. Nugroho, J. A. Rodriguez-Rivera, M. A. Green, C. Broholm, Science 336, 559 (2012) (Abstract, Reprint, Full text).

[140] ”Evidence for an exotic magnetic transition in the triangular spin system FeGa2S4, P. Dalmas de Reotier1, A. Yaouanc1, D. E. MacLaughlin, Songrui Zhao, T. Higo, S. Nakatsuji, Y. Nambu, C. Marin, G. Lapertot, A. Amato, and C. Baines, Physical Review B 85, 140407(R) (2012).

[141] ”New magnetic phase diagram of (Sr,Ca)2RuO4, J. P. Carlo, T. Goko, I. M. Gat-Malureanu”, P. L. Russo, A. T. Savici, A. A. Aczel, G. J. MacDougall, J. A. Rodriguez, T. J.Williams, G. M. Luke, C. R.Wiebe, Y. Yoshida, S. Nakatsuji, Y. Maeno, T. Taniguchi and Y. J. Uemura, Nature Materials 11, 323-328 (2012).

[142] ”Superconducting gap structure of CeIrIn5 from field-angle-resolved measurements of its specific heat”, Shunichiro Kittaka, Yuya Aoki, Toshiro Sakakibara, Akito Sakai, Satoru Nakatsuji, Yasumasa Tsutsumi, Masanori Ichioka, and Kazushige Machida, Phys. Rev. B 85, 060505(R) (2012).

＜ **Patent Applications** ＞

[1] 62/528236・中辻　知,　酒井明人・熱電変換素子・国立大学法人東京大学・2017-07-03 出願

[2] 特開 WO2017/018391・中辻知・メモリ素子・国立大学法人東京大学・2016-07-25 出願

[3] 特開 2017084854 中辻　知・大谷義近・国立大学法人東京大学・2015-10-23 出願

[4] 特開 2008-277727（Ｐ２００７-２２８８６１）・中辻　知、榊原俊郎、前野悦輝・β-ＹｂＡｌＢ４、β-ＹｂＡｌＢ４を有してなる磁気冷凍作業物質及びその製造方法、並びにそれを用いた磁気冷凍方法及び磁気冷凍装置・国立大学法人 東京大学、国立大学法人京都大学・2007-9-4 出願

7 Invited Presentations at International Conferences

[1] International workshop on “Heavy Fermion Physics: Perspective and Outlook” (Institute of Physics, Chinese Academy of Sciences, Beijing, China, 2012 January) “Spin Liquid and Quantum Criticality in 4f-based Itinerant Magnets”

[2] RIKEN-APW-APCTP Joint Workshop on "Recent Trends in Correlated Matter Physics" (Wako, Saitama, Japan, 2012 January) " Novel Magnetism due to Quantum Fluctuations on Geometrically Frustrated Lattices "

[3] Annual Meeting of Physical Society of Japan, Symposium " Next Generation of Material Science Innovated by Novel Materials" (Kasei Univ. Hyogo, 2012 March) "Atomic Valence and its Fluctuation in Strongly Correlated Metals: Novel Quantum Criticality "

[4] International Workshop on "Impurities and Textures in Unconventional Magnets" (MPIPKS, Dresden, 2012 April) " Novel spin orbital states in quasi-2D frustrated magnets "

[5] International Workshop on " Itinerant Spin-Orbital Systems: From Magnetic Frustration to Novel Superconductivity " (MPIPKS, Dresden, 2012 May) " Novel magnetism due to quantum fluctuations on geometrically frustrated lattices "

[6] The 19th International Conference on Magnetism (ICM2012, Busan, Korea, 2012 July) " Anomalous metals with strong valence / orbital fluctuations "

[7] 12th Japanese-German Symposium on " Emergent Phenomena in Novel Quantum Phases of Condensed Matter " （Shuzenji, Izu, Japan, 2012 July）" Anomalous Metal due to Orbital Fluctuations in PrTr2Al20 (Tr = Ti, V) "

[8] International Workshop on Innovations in Strongly Correlated Electron Systems (ICTP, Trieste, Italy, 2012 August) " Unconventional Quantum Criticality and Anomalous metals with strong valence / orbital fluctuations "

[9] International Conference on Quantum Criticality and Novel Phases (QCNP 12, Dresden, Germany, 2012 August) " Anomalous metals with strong valence / orbital fluctuations "

[10] KITP Workshop on Exotic Phases of Frustrated Magnets (KITP, Santa Barbara, USA, 2012 October) " Spin-orbital quantum magnetism on a honeycomb based lattice "

[11] Workshop on Quantum Spin Systems (Kyoto Univ., Kyoto, Japan, 2012 September) " Quantum Magnetism in Ba3CuSb2O9 "

[12] QS2C Theory Forum: International Symposium on "Strongly Correlated Quantum Science" (Univ. Tokyo, Tokyo, Japan, 2013 January) " Anomalous metallic phases with strong valence / orbital fluctuations "

[13] American Physical Society March Meeting, (Baltimore, USA, 2013 March). "Spin-orbital short-range order in the honeycomb-based quantum magnet Ba3CuSb2O9 "

[14] APCTP Workshop on "Bad Metal Behavior and Mott Quantum Criticality" (APCTP, Pohang, Korea, 2013 July) " Quantum Fluctuations, Chirality and Anomalous Metallic Behaviour in Spin Ices "

[15] International Workshop on "Spin Orbit Entanglement: Exotic States of Quantum Matter in Electronic Systems " (Max Planck Institute for the Physics of Complex Systems, Dresden, Germany, 2013 July) " Quantum Fluctuations and Anomalous Semi-metallic Behavior in Pr based Spin Ices "

[16] Autumn Meeting of Physical Society of Japan, Symposium " Quantum Spin Ice: Dynamics and Quantum Electrodynamics of Magnetic Monopoles " (Tokushima Univ. Japan, 2013 September) " Quantum Fluctuations and Quantum Criticality in Pr-based Spin Ice Materials "

[17] International Conference on "Quantum Criticality: Experiment and Theory" (Freudenstadt-Lauterbad, Germany, 2013 September) " Anomalous metallic phases without magnetic criticality "

[18] CIFAR Quantum Materials Program Meeting, (Vancouver, Canada, 2013, October) " Quantum fluctuations, spin chirality, and anomalous metal phase in spin ice materials "

[19] Workshop on Frustration and Topology in Condensed Matter Physics, (National Cheng Kung University, Tainan, 2014 February) " Quantum Fluctuations, Chirality Anomalous Metallic Behavior in Pr2Tr2O7 "

[20] OIST International Workshop on Novel Quantum Materials and Phases (OIST, Okinawa, Japan, May 13-17, 2014) “ Topological excitations and anomalous semi-metallic phase in Pr based pyrochlore oxides ”

[21] Aspen Summer Workshop 2014 “Modern Trends in Quantum Magnetism” (Aspen Center for Physics, Aspen CO, USA, May 25 - June 22, 2014) “ Strange metal without magnetic criticality ”

[22] Gordon Research Conference, “ Correlated Electron Systems: Textures, Topology, and Strong Interactions” (Mount Holyoke College, South Hadley MA, USA, June 22-27, 2014) "Emergent Non-Fermi-Liquid Phases Without Magnetic Criticality"

[23] 7th International Conference on Highly Frustrated Magnetism 2014 (Cambridge University, UK, July 7-11, 2014) Plenary Talk “ Emergent excitations in spin liquids through coupling with electrons and orbitals ”

[24] 13th Bilateral German-Japanese Symposium on “ Interplay of Spin- and Orbital Degrees of Freedom in Strongly Correlated Electron Systems ” (Ringberg Castle, Rottach-Egern, Germany, 13-16 July 2014) “ Anomalous Metal and Unconventional Superconductivity in the quadrupolar Kondo system PrTr2Al20 (Tr = Ti, V) ”

[25] 2014 Autumn Meeting of Japanese Physical Society, Symposium “ Next Generation of Heavy Electron Materials ” (Chubu Univ. Japan September 7- 10 2014) “ Orbital Ordering and Heavy Fermion Superconductivity in PrTr2Al20 ”

[26] Edgar Lscher Seminar 2015 “Neues aus der Festkrperphysik”, (Hotel-Sport Klosters/Schweiz, Switzerland 07 13. February 2015) Colloquium “ Quantum Melting of Spin Ice ”

[27] 2015 American Physical Society March Meeting, Invited Session: Emergent Quantum Phases and Their Transitions in Correlated Electron Systems, (March 26, 2015; San Antonio, Texas, USA) “ Strange metal without magnetic instability in β-YbAlB4 ”

[28] Symposium on strongly correlated electron materials (Rice University, Houston, Texas, Dates: 11/20/2015-11/21/2015) “ Exotic topological states near a quantum metal-insulator transition in pyrochlore iridates ”

[29] International Workshop on “ Topological Phenomena in Novel Quantum Matter: Laboratory Realization of Relativistic Fermions and Spin Liquids (Max Planck Institute for the Physics of Complex Systems, Dresden, Germany 2016/2/29-2016/3/3) Colloquium “ Novel Topological Phases in Correlated Electron Systems ”

[30] International conference on strongly correlated electron systems 2016, (Hangzhou, China, May 9, 2016) “ Large anomalous Hall effect in chiral antiferromagnets at room temperature ”

[31] Annual Conference of the Institute for Complex Adaptive Matter, (Kent State University, Ohio, May 16-18, 2016), Plenary talk “ Novel Topological Phases in Correlated Electron Systems ”

[32] International Conference on Strongly Correlated Electron Systems, (Zhejiang university, Hangzhou, China, May 11, 2016) “ Large anomalous Hall effect in chiral antiferromagnets at room ”

[33] Annual Conference of the Institute for Complex Adaptive Matter, (Ohio, USA, May 16, 2016) “Plenary talk “ Novel Topological Phases in Correlated Electron Systems ”

[34] Correlated Electron Systems Gordon Research Conference, (Mount Holyoke College, South Hadley, USA, June 27, 2016) “ Novel Topological Phases and Quantum Criticality in Correlated Electron Systems ”

[35] International symposium Quantum Criticality and Topology in Itinerant Electron Systems, (New Mexico, USA, Aug 15, 2016) Review talk “Novel Topological Phases in Correlated Electron Systems”

[36] The CEMS-QPEC Symposium on “Emergent Quantum Materials,” (Ito International Research Center, Tokyo, Japan, January 20, 2017) “ Anomalous transport in topological magnets ”

[37] Quantum Criticality and Novel Phases 2017, (Harnack-Haus of the Max Planck Society, Berlin, Germany, February 26- March 1, 2017) “ Multipolar Quantum Criticality in 4f Electron Systems ”

[38] International Conference on Topological Materials Science 2017 (TopoMat2017) (Tokyo Institute of Technoloty, May 9-13) “ Anomalous Transport Phenomena in Non-Collinear Antiferromagnets ”

[39] ISSP Regular Workshop ”Forefront of research for electronic properties observed and controlled with light.- strong correlation, topology, low dimension, dynamics ” June 12, 2017

[40] Gordon Research Conference Topological and Correlated Matter, (The Hong Kong University of Science and Technology, June 20, 2017) “ Anomalous Transport in Topological Frustrated Magnets ”

[41] The 14th International Conference on Muon Spin Rotation, Relaxation and Resonance, (Hokkaido University, June 26, 2017) “ Topological correlated phases in geometrically frustrated magnets ”

[42] Strongly Correlated Electron Systems, 2017, (The Clarion Congress Hotel, Prague, July 20, 2017) “ Quadrupolar quantum criticality and heavy fermion superconductivity in PrT2Al20 ”

[43] 2nd Junjiro Kanamori Memorial Symposium “ Topological correlated phases in frustrated magnets ” September 27-29 2017 Univ. of Tokyo

[44] The Quantum Material Symposium 2017, (Harnack-Haus of the Max Planck Society, Berlin, Germany, October 4, 2017) “ Exotic phenomena in topological frustrated magnets ”

[45] 15th RIEC International Workshop on Spintronics (Dec. 12th and 13th Tohoku University) ”Anomalous Transport Properties of Weyl Antiferromagnets”

[46] American Physical Society: March meeting, (Los Angeles Convention Center, March 5, 2018) “Anomalous Transverse Transport in Mn3X Non-collinear Antiferromagnets ”

[47] Quantum Materials Program Meeting Montreal, (Montreal, Canada, May 30- June 1, 2018) “ Novel functional magnets based on multipoles and topology ”

[48] ISSP International Workshop Present and Future of Neutron Scattering Research on Condensed Matter Physics∼Future Perspective of US-Japan Cooperative Program on Neutron Scattering∼ (ISSP June 4-5 2018, Kashiwa Tokyo) ”Large Transverse Responses at Room Temperature in the Weyl Antiferromagnets Mn3X”

[49] 3rd JHU Summer School on Materials Growth and Design: Exotic Magnetic States in Quantum Materials (June 17th-22nd, 2018, Johns Hopkins University) ”Metallic Quantum Magnets and Quantum Criticality” ”Transport Physics of Quantum Magnets”

[50] Correlated Electron Systems Gordon Research Conference, (Mount Holyoke College, June 24 29, 2018) “ Quantum Critical Phases Due to Multipolar Dynamics ”

[51] 21st International Conference on Magnetism, (San Francisco Moscone Center, July 16 21, 2018) Plenary Talk “ Topological Weyl Semimetal: from multipole to room temperature functions ”

[52] Symposium ”Exploration of Spin-Orbit Physics driven by Augmented Multipoles”, The Physical Society of Japan, 2018 Autumn Meeting, (Doshisha University, Kyotanabe Campus, September 9-12, 2018) Magnetic Octupole Control of Large Electric and Magnetic Responses in Weyl Magnets”

[53] Colloquium, (Cologne University, Germany, October 31, 2018) “ Topological Metals in Geometrically Frustrated Magnets ”

[54] 2nd International Conference of SFB 1143 on ”Correlated Magnetism: From Frustration To Topology”, (Penck Hotel Dresden, October 31-November 2, 2018) “ Novel transport properties in topological and frustrated Weyl magnets ”

[55] The 19th Japan-Korea-Taiwan Symposium on Strongly Correlated Electron Systems (JKT19) (Jan 11-13, 2019) “ Novel Spintronic Functions in Topological Frustrated Magnets Mn3X ”

[56] RIKEN CEMS Colloquium, (理化学研究所, February 27, 2019) “ Topological Weyl Magnets and Room Temperature Functions ”

[57] EFRC Workshop ”Institute for Quantum Matter”, (Johns Hopkins University, March 20, 2019), “ Overview: Topological Magnetic Semimetal ”

[58] International Workshop on Constrained Many-body Dynamics, (MPI-PKS Dresden, Germany, March 26-30, 2019) " Quantum Metamagnetic Transition in a Spin Ice System "

[59] Colloquium, Seoul National University (April 13, 2019) " Topological Weyl Magnets and Room Temperature Functions "

[60] Antiferromagnetic Spintronics: from topology to neuromorphic computing, Mainz, Germany (October 8-10, 2019) " Large Spintronic Responses in Weyl Antiferromagnets "

[61] The 43rd Annual Conference on MAGNETICS in Japan, KYOTO University Yoshida Campus (September 25-27, 2019) " Topological Spintronics using Weyl Antiferromagnets "

[62] International Conference on Strongly Correlated Electron System 2019, Okayama Convention Center (September 27, 2019) " Multipole control of electric and magnetic responses in Weyl magnets "

[63] Antiferromagnetic Spintronics: from topology to neuromorphic computing, Spin Phenomena Interdisciplinary Center (SPICE), Mainz, Germany(2019/10/9) " Large Spintronic Responses in Weyl Antiferromagnets "

8 Teaching Accomplishment

9 Contribution to Academic Community

9.1 Editorial Activities

- Editor, J of Phys. Soc. Jpn. Proceeding 2019

9.2 Organization of Professional Societies

- Fellow, Canadian Institute for Frontier Science Thrust Leader, Institute for Quantum Matter, Energy Frontier Research Center

9.3 Organization and Advisory of Conferences

- Program committee, International Conference, Highly Frustrated Magnetism HFM2020 (Fudan University, China)
- Symposium Organizer, Theory of Correlated Topological Materials/Topological Phases and Functionality of Correlated Electron Systems, TPFC2019 (ISSP, Japan)
- International Advisory Committee and Program Committee for SCES2019, International Conference, Strongly Correlated Electron Systems, SCES2019 (Okayama, Japan)
- Scientific Coordinator, "Frustration, Orbital Fluctuations, and Topology in Kondo Lattices and their relatives 2018" (MPI-PkS Dresden)
- Scientific Coordinator, " Novel phenomena in quantum materials driven by multipoles and topology 2018" (ISSP Japan)
- Steering and Program Committee for HFM2018, International Conference on Highly Frustrated Magnetism HFM2017 (UC Davis, USA)
- International Advisory Committee, International Conference, Strongly Correlated Electron Systems, SCES2017 (The Clarion Congress Hotel , Prague)
- Symposium Organizer, Theory of Correlated Topological Materials/Topological Phases and Functionality of Correlated Electron Systems, TPFC2017 (ISSP, Japan)
- International advisory committee, International Conference, Quantum Criticality and Novel Phases QCNP2017 (Dresden, Germany)
- International Workshop Organizer, Anomalous Transport in Multipolar and Topological Materials 2016 (Johns Hopkins University, USA)
- International Advisory Committee, International Conference, Strongly Correlated Electron Systems, SCES2016 (Hangzhou, China)

- International Advisory Committee, International Conference on Highly Frustrated Magnetism HFM2016 (Taipei, Taiwai)
- Symposium Organizer, 59th Annual Magnetism and Magnetics Materials (MMM) Conference 2014 (Honolulu, Hawaii)
- Co-organizer of Aspen Physics Summer Workshop 2014 (Aspen, USA)
- Co-organizer of Aspen Physics Winter Conference 2014 (Aspen, USA)
- Scientific Advisory Board, International Conference on Highly Frustrated Magnetism HFM2014 (University of Cambridge, UK)
- International advisory committee, International Conference, Strongly Correlated Electron Systems, SCES2014 (Mount Holyoke College, South Hadley MA, USA)
- International advisory committee, International Conference, Strongly Correlated Electron Systems, SCES2012 (ICTP, Trieste, Italy)
- Program committee, International Conference, Highly Frustrated Magnetism HFM2012 (McMaster University, Canada)
- International advisory committee, International Conference, Quantum Criticality and Novel Phases QCNP2012 (Dresden, Germany)
- International advisory committee, International Conference, Strongly Correlated Electron Systems, SCES2011 (Cambridge, UK)
- International advisory committee, International Conference, Strongly Correlated Electron Systems, SCES2010 (New Mexico, USA)
- Program committee, International Conference, Highly Frustrated Magnetism HFM 2010 (MPI-PKS, Dresden)

10 Outreach

- JST 戦略的創造研究推進事業 新技術説明会 〜製造技術・情報・材料〜 2019/3/18
- 2019 年度 The University of Tokyo Summer Internship Program in Kashiwa (UTSIP) 受入：Ms. DINH, Thi Huong Thao (Massachusetts Institute Of Technology)
- 公開授業：トポロジーが紡ぐ物理 (東京都立南多摩中等教育学校) 2018/12/27
- 2018 年度 UTSIP 受入：Mr. LIMANTA, Kevin (Massachusetts Institute of Technology)
- 2018 年度 UTSIP 受入: Ms. CHIAO-WEN, Michelle Lin (Haverford College)
- 2017 年度 東京大学柏キャンパス 一般公開 2017/10/27
- 2017 年度 UTSIP 受入:Mr.I-HSUAN,KAO (HongKong University of Science and Technology)

- 2016 年度 東京大学柏キャンパス 一般公開 2016/10/21-22
- 2014 年度 東京大学柏キャンパス 一般公開 2014/10/24-25
- 東京大学物性研究所 体験活動プログラム「最先端物質科学入門 固体の中の宇宙」2014/9/16-19
- 2013 年度 東京大学柏キャンパス 一般公開 2013/10/25 東京大学物性研究所一般公開 2013 年 10 月 25 日

11 Committee Service

11.1 External Committees

- Co-organizer of International Symposiums (MPI-PKS Workshop)2018–
- Co-organizer of International Symposiums (J-Physics) 2018–
- Co-organizer of International Symposiums (TPFC2017), 2017–
- International Advisory/Program Committee, International Conference: Strongly Correlated Electron Systems 2010-2017
- Advisory/Program Committee, International Conference:
- Highly Frustrated Magnetism 2010–2018
- Symposium Organizer, 59th Annual Magnetism and Magnetics Materials (MMM) Conference 2014
- Co-organizer of Aspen Physics Winter Conference 2013–2014
- Co-organizer of Aspen Physics Summer Workshop 2013–2014
- International Advisory/Program Committee, International Conference: Highly Frustrated Magnetism 2010–2016
- NISTEP 定点調査対応　2012 年、2013 年、2014 年、2017 年
- 科学研究費助成事業委員会　書面審査員　2013 年、2014 年、2017 年、2018 年
- Gordon and Betty Moore Foundation 書面審査委員 2014 年
- 米国エネルギー省 国立研究所予算審査　審査委員　2017 年

11.2 External Committees

量子物質グループ　グループ主任　2018 年-2019 年
人事選考委員　2014 年、2016 年-2017 年、2017 年-2018 年
国際拠点 WG 2018 年
国際交流委員会　2017 年-
図書委員会　委員　2012 年-2013 年
共同利用施設専門委員会　2011 年-2012 年
環境安全委員会　委員　2011 年-2012 年
環境安全委員会　委員長　2012 年-2013 年
安全衛生管理委員会　委員　2012 年-2013 年
工作委員会　2015 年-2018 年

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	12	Indonesia,China
Doctor Course	8	Indonesia, China, Germany
Foreign researchers hosted	48	Indonesia,USA, China, India, Taiwan, Korea
Students sent abroad	10	Germany,USA, Czech Republic, Italy, Korea,France, England Spain, China
Researchers sent abroad	46	Germany, USA, Korea, India, China, Canada
Foreign visitors	40	Germany, China, USA, Russia, Taiwan, Korea

Tohru Okamoto、岡本 徹

1 Education and Professional Experiences

Education

1987	B.S. (Physics)	The University of Tokyo
1989	MSc. (Physics)	The University of Tokyo
1992	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1992−2000	Assistant Professor	Gakushuin University
2000−	Associate Professor	The University of Tokyo

2 Research Highlights

2.1 Quantum Hall effect at cleaved semiconductor surfaces

Previously, we have performed magnetotransport measurements on two-dimensional (2D) electron systems induced by adsorbed Ag, Fe, or alkali metals at *in situ* cleaved surface of p-type InAs and InSb, and observed the integer quantum Hall effect. After that, we developed a unique system which enables a simultaneous study by scanning tunneling spectroscopy and transport measurements on a cleaved surface at low temperature (4.2 K) and high magnetic fields ($\leq$ 14 T). In 2015, we investigated an Fe-induced quantum Hall system at the cleaved InSb surfaces. The magnitude of the potential disorder obtained from the spatially averaged density of states agrees with that deduced from the Shubnikov-de Haas oscillations. We show that an enhanced Zeeman splitting in the Shubnikov-de Haas oscillations is explained by an exchange enhancement of spin splitting and potential disorder, both of which are obtained from the spatially averaged density of states.

2.2 Two-dimensional Rashba superconductor

Owing to the atomically flat surface of the cleaved GaAs substrate, we successfully grew monolayer films of Pb and In by the quench condensation technique. A single-atomic-layer metal film on an insulating substrate is an interesting system for studies of superconductivity, not only because it is a complete two-dimensional system but also because it has the broken inversion symmetry. The asymmetry of the confining potential in the direction perpendicular to the 2D plane, combined with atomic spin-orbit coupling, causes the Rashba effect, which lifts the spin degeneracy of the 2D electronic states. We studied the effect of the parallel magnetic field $H_\parallel$ on superconductivity of monolayer Pb films on GaAs(110). Superconductivity was found to occur even for $H_\parallel = 14$ T, which is much higher than the Pauli paramagnetic limiting field H_P. The observed weak $H_\parallel$ dependence of the superconducting transition temperature T_c is explained in terms of an inhomogeneous superconducting state predicted for 2D metals with a large Rashba spin splitting.

This is the first experimental study on the Rashba-type 2D superconductors in monolayer metal films.

2.3 New type of magnetic-field-induced superconductivity

It is well known that external magnetic fields and magnetic moments of impurities both suppress superconductivity. However, their combined effect on superconductivity has not been elucidated yet. We have studied the superconducting transition in ultrathin Pb films with magnetic impurities grown on a cleaved GaAs(110) surface. It was demonstrated that the transition temperature can be enhanced by external magnetic fields applied parallel to the conducting plane. Furthermore, we found that a Pb-Ce alloy, where superconductivity is totally suppressed at zero-field, actually becomes superconducting in parallel magnetic fields. Magnetic-field-induced superconductivity has been observed before in several other materials. Except for the special case of a spin-triplet superconductor URhGe, it was understood in terms of the Jaccarino-Peter (JP) mechanism. However, the JP mechanism is unlikely to account for our results. They are explained in terms of the suppression of the spin-exchange scattering rate, which can be controlled by the magnetic field.

3 Selected Papers

- M. Niwata, R. Masutomi, T. Okamoto., Physical Review Letters **119**, 257001 (2017).
  A new type of magnetic-field-induced superconductivity was demonstrated.
- R. Masutomi, T. Okamoto, Applied Physics Letters **106**, 251602 (2015).
  This work was selected as Editor's Picks in APL. A unique system which enables a simultaneous study by scanning tunneling spectroscopy and transport measurements at low temperature was developed.
- T. Sekihara, T. Miyake, R. Masutomi, T. Okamoto, Journal of Physical Society of Japan **84**, 064710 (2015).
  The work of PRL (2013) was extended to other sytems with weaker Rashba interactions.
- T. Sekihara, R. Masutomi, T. Okamoto, Physical Review Letters **111**, 057005 (2013).
  This is the first experimental study on the Rashba-type 2D superconductors in monolayer metal films.
- T. Chiba, R. Masutomi, K. Sawano, Y. Shiraki, T. Okamoto, Physical Review B **86**, 045310 (2012).
  This is the first cyclotron resonance measurement that shows the positive dependence of the scattering time on the spin polarization of a silicon two dimensional system.

4 Honors, Awards and Professional Society Memberships

5 Research Plan

We plan to continue our research on ultrathin metal films grown on semiconductor cleaved surfaces using our original technique.

5.1 Superconducting states with a spatially modulated order parameter

The combination of the Rashba spin-orbit coupling and the parallel magnetic field induces two types of 2D superconducting states with nonzero center-of-mass momentum of the Cooper pairs. One is the stripe state with an amplitude modulation of the order parameter, and the other is the helical state with a phase modulation of the order parameter. To study the inhomogeneous superconducting phases, we are constructing an experimental system which enables a simultaneous study by scanning tunneling spectroscopy and transport measurements at very low temperatures ($\geq$ 0.5 K) obtained using a ^{3}He refrigerator. We plan to perform low-temperature scanning tunneling spectroscopy and measure the superconducting gap as a function of position along the two-dimensional plane.

5.2 Multilayer systems composed of one-atomic-layer superconductors

Stacking of weakly-coupled two-dimensional planes can lead to new superconducting states. Yanase *et al.* have predicted rich $T-H_{\|}$ phase diagrams for bilayer and trilayer systems composed of Rashba two-dimensional superconductors. We are currently investigating the superconducting transition line in bilayer and trilayer systems of one-atomic-layer Pb films with spacer layers of insulating materials. Furthermore, we plan to study on bilayer systems with a spacer layer containing ferromagnetic materials at the center. The ferromagnetic spacer layer is expected to act as a spin filter that only allows spin-triplet Cooper pairs through it. The two superconducting layers are independent of each other unless they have a spin-triplet component. We will measure the superconducting temperature as a function of the magnetic field penetrating spacer layer to verify the layer coupling.

5.3 Electric-field control in ultrathin metal films

An electric double-layer transistor configuration employing an ionic liquid as electrolyte enables an electron-density change on the order of 10^{14} cm^{-2} with a small gate voltage on the order of 1 V. This method has been applied to various systems and led to the observation of novel phenomena, such as new classes of superconductors and the electrical switching of ferromagnetic states. On the other hand, due to the difficulty of device fabrication, there has been little research on materials with surfaces unstable in the atmosphere. We plan to develop methods for electric-field control in ultrathin metal films grown on a cleaved GaAs surface under ultrahigh vacuum conditions. Using this technique, we will control the asymmetry of the confinement potential in Pb monolayers to study the Rashba effect in 2D superconductors. Furthermore, we will also apply it to ultrathin ferromagnetic films to investigate the relationship between ferromagnetism and the itinerancy of electrons.

6 Publications and Patents

＜Refereed Original Papers＞

[1] M. Niwata, R. Masutomi, and T. Okamoto: Magnetic-field-induced superconductivity in ultrathin Pb films with magnetic impurities, Phys. Rev. Lett. **119**, 257001 (2017) .

[2] T. Sekihara, T. Miyake, R. Masutomi, and T. Okamoto: Effect of Parallel magnetic field on superconductivity of ultrathin metal films grown on a cleaved GaAs surface, Journal of the Physical Society of Japan **88**, 064710 (2015).

[3] R. Masutomi, and T. Okamoto: Adsorbate-induced quantum Hall system probed by scanning tunneling spectroscopy combined with transport measurements, Appl. Phys. Lett. **106**, 251602 (2015) (selected as Editor's Picks).

[4] T. Sekihara, R. Masutomi, and T. Okamoto: Two-Dimensional Superconducting State of Monolayer Pb films on GaAs (110) in a Strong Parallel Magnetic Field, Physical Review Letters **111**, 057005 (2013).

[5] T. Chiba, R. Masutomi, K. Sawano, Y. Shiraki, T. Okamoto: In-plane magnetic field dependence of cyclotron relaxation time in a Si two-dimensional electron system, Physical Review B **86**, 045310 (2012).

＜Conference Proceedings＞

[6] T. Sekihara, T. Miyake, H. Ichinomiya, R. Masutomi, and T. Okamoto: Two-dimensional superconductivity with broken inversion symmetry in one-atomic-layer metal films on cleaved GaAs surfaces, JPS Conference Proceedings **3**, 015023 (2014).

[7] R. Masutomi, and T. Okamoto: Simultaneous study by scanning tunneling spectroscopy and transport measurements in adsorbate-induced two-dimensional systems, Journal of Physics: Conference Series **568**, 052020 (2014).

[8] R. Masutomi, N. Toriyama, T. Okamoto: Low-Temperature Scanning Tunneling Microscopy and Transport Measurements on Adsorbate-Induced Two-Dimensional Electron Systems, AIP Conference Proceedings **1566**, 291 (2013).

[9] R. Masutomi, T. Chiba, K. Sasaki, I. Yasuda, A. Sekine, K. Sawano, Y. Shiraki, T. Okamoto: Temperature, electron density and in-plane magnetic field dependence of cyclotron relaxation time in the two-dimensional metallic phase, Journal of Physics: Conference Series **456**, 012027 (2013).

[10] T. Sekihara, R. Masutomi, and T. Okamoto: Magnetic-field-independent superconductivity of ultrathin Pb films on cleaved GaAs surface, Journal of Physics: Conference Series **456**, 012034 (2013).

＜Review Papers＞

[11] 岡本徹、枡富龍一: 単原子層超伝導と空間反転対称性の破れ, 固体物理 **52**, 97-103 (2017).

[12] 岡本徹、枡富龍一: 劈開表面における電子輸送現象, 表面科学 **36**, 118-123 (2015).

7 Invited Presentations at International Conferences

[1] T. Sekihara, R. Masutomi, and T. Okamoto: Superconductivity of ultrathin metallic films on cleaved GaAs surfaces, The 10th Japan-Russia Seminar on Semiconductor Surfaces (Tokyo), September 26-28, 2012.

8 Teaching Accomplishment

9 Contribution to Academic Community

9.1 Editorial Activities

9.2 Organization of Professional Societies

- 日本物理学会領域４代表　2015 年 –2016 年
- 日本物理学会領域４副代表　2014 年 –2015 年
- 日本物理学会代議員　2015 年 –2017 年

9.3 Organization and Advisory of Conferences

10 Outreach

11 Committee Service

11.1 University Committees

低温センター 専門委員　2001 年 –
理学系研究科環境安全管理室室員　2011 年 –2019 年
理学系研究科寒剤管理委員会 委員長　2010 年 –

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	1	China
Doctor Course	0	
Foreign researchers hosted	0	
Students sent abroad	0	
Researchers sent abroad	0	
Foreign visitors	0	

Ryo Shimano、島野 亮

1 Education and Professional Experiences

Education

1990	B.S. (Applied Physics)	The University of Tokyo
1992	MSc. (Applied Physics)	The University of Tokyo
2000	Dr. Engineering	The University of Tokyo

Professional Appointments

1994−2004	Assistant Professor	The University of Tokyo
2004−2014	Associate Professor	The University of Tokyo
2014−	Professor	The University of Tokyo
2019−	Co-chair	The Max Planck-UBC-UTokyo Center for Quantum Materials
2019	Guest Professor	University of Paris Diderot

2 Research Highlights

My research field is laser spectroscopy of condensed matter systems. In particular, I have been focused on the development of ultrafast terahertz (THz) spectroscopy technique and its application to the study of quantum materials, which involves THz magneto-optical spectroscopy, optical pump-broadband THz probe spectroscopy, intense THz pulse light sources, THz pump -THz probe techniques, and other multi-color ultrafast spectroscopy. Our contribution to the realization of table-top intense THz pulse light source has initiated the research field of nonlinear THz phenomena and non-thermal dynamical control of electronic phases in correlated electron systems.

One of my long-standing interest is the realization of electron-hole(e-h) Bardeen-Cooper-Schrieffer (BCS) state. This state is closely related to the excitonic insulator phase, and has long been anticipated to exist in photo-excited semiconductors since the initial prediction made by Keldysh and Kopaev in 1965. To realize this unresolved pair condensation phenomena, we first tackled the problem of exciton Mott transition as it is intimately related to the BEC-BCS crossover problem in e-h system. By using the time-resolved terahertz spectroscopy we unambiguously determined the Mott-transition in the low temperature limit [7, 13]. Based on the understanding of the exciton Mott transition, we adopted a new approach to access the e-h BCS state. Starting from resonantly-excited laser-driven coherent excitons, which is equivalent to the forced exciton BEC, we continuously increased the pair density and finally confirmed that the e-h BCS state is formed above the Mott density [1].

After the development of intense THz pulse sources, we immediately started the project of THz control of quantum materials. A highlight research in this aspect is the discovery of the Higgs mode in superconductors, namely the collective amplitude mode of superconducting order parameter [5, 6, 10, 14, 15]. The existence of Higgs mode has pointed out by Anderson in 1964, whereas its experimental observation has remained elusive over a half-century. This is because the Higgs mode in superconductors does not have charge fluctuation nor electronic/magnetic dipoles and thus it does not couple to the radiation field in the linear response regime. We challenged this problem with use of an intense single-cycle THz pulse as a tool of quantum quench. After the nonadiabatic quench of superconducting order parameter induced by the intense THz pulse excitation, we succeeded in the observation of Higgs oscillation in s-wave superconductors. Subsequently, with use of a narrowband multicycle THz pulse, we discovered the nonlinear coupling between the Higgs mode and the electromagnetic field, which resembles $\gamma\gamma$ decay channel of Higgs boson in particle physics. This result has opened a new pathway to manipulate the superconducting order parameter by light.

We have also developed a highly sensitive polarization spectroscopy scheme in the THz frequency range with combining a superconducting magnet. This instrumental effort has allowed us to observe the optical quantum Hall effect in 2-dimensional electron system and also in monolayer graphene [16]. We showed the quantization of optical Hall conductivity through the observation of quantum step in Faraday and Kerr rotation in a unit of fine structure constant. This result is recognized as a pioneering work of THz magneto-optical responses in topological materials.

Finally, I would like to address my contribution to the field of multiferroics. By using the developed THz magneto-optical spectroscopy setup, we first revealed the electromagnon which is activated by the exchange-striction mechanism in multiferroic rare-earth manganites. Furthermore, we discovered the electromagnon that is relevant to the spin-current model, which corresponds to the fluctuation of ferroelectric polarization plane [22].

As highlighted above, I have made a pioneering contribution in the field of low energy terahertz spectroscopy of condensed matter systems.

3 Selected Papers

- Y. Murotani, C. Kim, H. Akiyama, L. N. Pfeiffer, K. W. West, and R. Shimano: Light-driven electron-hole Bardeen-Cooper-Schrieffer-like state in bulk GaAs, Phys. Rev. Lett. **123**, 197401 (2019). Editors' Suggestion.
  This is a hallmark experiment that demonstrates the electron-hole Bardeen-Cooper-Schrieffer state, a new type of pair condensation in semiconductors that has been anticipated over decades since the initial theoretical prediction made by Keldysh and Kopaev in 1965.

- K. Katsumi, N. Tsuji, Y. I. Hamada, R. Matsunaga, J. Schneeloch, R. D. Zhong, G. D. Gu, H. Aoki, Y. Gallais, and R. Shimano: Higgs Mode in the d-Wave Superconductor $Bi_2Sr_2CaCu_2O_{8+x}$ Driven by an Intense Terahertz Pulse, Phys. Rev. Lett. **120**, 117001 (2018). Selected for Editors' Suggestion.
  This work demonstrates the Higgs mode in *d*-wave high-T_c cuprate superconductors.
  The paper has been cited 12/25 times (Web of Science/Google Scholar).

- R. Matsunaga, N. Tsuji, H. Fujita, A. Sugioka, K. Makise, Y. Uzawa, H. Terai, Z. Wang, H. Aoki, and R. Shimano: Light-induced collective pseudospin precession resonating with Higgs mode in a superconductor, Science. **345**, 1145 (2014).

This paper revealed the nonlinear coupling between the Higgs mode and electromagnetic field, and opens a new pathway to manipulate the superconductor by light. The paper has been cited 151/229 times (Web of Science/Google Scholar).

- R. Matsunaga, Y. I. Hamada, K. Makise, Y. Uzawa, H. Terai, Z. Wang, and R. Shimano: Higgs Amplitude Mode in the BCS Superconductors $Nb_{1-x}Ti_xN$ induced by Terahertz Pulse Excitation, Phys. Rev. Lett. **111**, 057002 (2013).
  This paper has demonstrated the Higgs mode for the first time in a pure superconductor since the initial theoretical prediction made by P. W. Anderson in 1963. The paper has been cited 151/227 times (Web of Science/Google Scholar).

- R. Shimano, G. Yumoto, J. Y. Yoo, R. Matsunaga, S. Tanabe, H. Hibino, T. Morimoto, and H. Aoki: Quantum Faraday and Kerr rotations in graphene, Nature Commun. **4**, 1841 (2013).
  This paper has demonstrated that the quantum Hall effect appears in the optical (THz) frequency range, opening a new paradigm for the study of optical phenomena relevant to the topological phase in topological materials. The paper has been cited 93/123 times (Web of Science/Google Scholar).

4 Honors, Awards and Professional Society Memberships

2015 Inoue Prize for Science (received in Feb 2016)
2014 Prize of Superconductivity Science and Technology 2014 (received in Feb. 2015)

5 Research Plan

With the development of advanced ultrafast laser spectroscopy, as exemplified by intense THz light sources and carrier-envelope-phase stabilized mid-infrared light sources, we aim at the optical manipulation of quantum materials. Photoexcited electron-hole (e-h) system is my continuing interest. Having demonstrated the e-h BCS state, we further explore the macroscopic quantum character and light-matter interaction in its quantum degenerate regime: in particular we investigate the superradiance phenomena and superfluidity in this new type of pair condensation.

In a more general point of view, creation and manipulation of macroscopic quantum states are the main interest of our research. To this end, we adopt two approaches: 1) non-thermal quantum quench and 2) Floquet engineering. In the first scheme, we try the nonadiabatic control of free energy potential by dynamically tuning the interaction energy, or by nonadiabatically quenching the competing orders. We utilize the observation of Higgs mode as an ultrafast snapshot for the superconducting order parameter in nonequilibrium. Verification of light-induced superconductivity is one main interest, while search for a new light-induced ordered phase will be pursued in various quantum materials. Disentanglement of intertwined degree of freedoms and the elucidation of hidden phases in those correlated electron systems are crucial to elucidate the underlying physics of unconventional superconductors such as high-T_c curprate and iron-based superconductors. We tackle this issue by using the advanced ultrafast laser spectroscopy technique with selectively exciting particular excitations of lattice, charge, and spin excitations.

In the second approach, we will develop the Floquet engineering in correlated electron systems. This is going to become a completely new scheme to create/control a new matter of state in nonequilibrium. Along this line, we will challenge in particular the Floquet topological phase transition in topological materials that includes topological superconductors. A project aiming at this new direction supported by JST (CREST) has just started. As a project leader I will focus on this issue intensively with a scope of opening the new paradigm of nonequilibrium phenomena in condensed matter systems. The international collaborations that include the Max Planck-UBC-UTokyo Center for Quantum Materials will be further strengthened for this purpose.

6 Publications and Patents

< Refereed Original Papers >

[1] Y. Murotani, C. Kim, H. Akiyama, L. N. Pfeiffer, K. W. West, and R. Shimano: Light-driven electron-hole Bardeen-Cooper-Schrieffer-like state in bulk GaAs, Phys. Rev. Lett. **123**, 197401 (2019). Selected for Editors' Suggestion.

[2] N. Yoshikawa, M. Takayama, N. Shikama, T. Ishikawa, F. Nabeshima, A. Maeda, R. Shimano: Charge carrier dynamics of FeSe thin film investigated by terahertz magneto-optical spectroscopy, Phys. Rev. B **100**, 035110 (2019).

[3] H. Niwa, N. Yoshikawa, K. Tomari, R. Matsunaga, D. Song, H. Eisaki, R. Shimano: Light-induced nonequilibrium response of the superconducting cuprate $La_{2-x}Sr_xCuO_4$, Phys. Rev. B **100**, 104507 (2019). Editor's Suggestion

[4] S. Nakamura, Y. Iida, Y. Murotani, R. Matsunaga, H. Terai, and R. Shimano: Infrared activation of Higgs mode by supercurrent injection in a superconductor NbN, Phys. Rev. Lett. **122**, 257001 (2019).

[5] Y. Murotani and R. Shimano: Nonlinear optical response of collective modes in multiband superconductors assisted by nonmagnetic impurities, Phys. Rev. B **99**, 224510 (2019).

[6] R. Matsunaga, N. Tsuji, K. Makise, H. Terai, H. Aoki, and R. Shimano: Polarization-resolved terahertz third-harmonic generation in a single-crystal superconductor NbN: Dominance of the Higgs mode beyond the BCS approximation, Phys. Rev. B **96**, 020505(R) (2017).

[7] F. Sekiguchi and R. Shimano: Rate Equation Analysis of the Dynamics of First-order Exciton Mott Transition, J. Phys. Soc. Jpn. **86**, 103702 (2017).

[8] Y. Murotani, M., Takayama, F. Sekiguchi, C. Kim, H. Akiyama, and R. Shimano: Terahertz field-induced ionization and perturbed free induction decay of excitons in bulk GaAs, J. Phys. D: Appl. Phys. **51**, 114001 (2018).

[9] G. Yumoto, R. Matsunaga, H. Hibino, and R. Shimano: Ultrafast Terahertz Nonlinear Optics of Landau Level Transitions in a Monolayer Graphene, Phys. Rev. Lett. **120**, 107401 (2018).

[10] K. Katsumi, N. Tsuji, Y. I. Hamada, R. Matsunaga, J. Schneeloch, R. D. Zhong, G. D. Gu, H. Aoki, Yann Gallais, and Ryo Shimano: Higgs Mode in the d-Wave Superconductor $Bi_2Sr_2CaCu_2O_{8+x}$ Driven by an Intense Terahertz Pulse, Phys. Rev. Lett. **120**, 117001 (2018).

[11] Ryusuke Matsunaga and Ryo Shimano: Nonlinear terahertz spectroscopy of Higgs mode in s-wave superconductors, Phys. Scr. **92**, 024003 (2017).

[12] F. Sekiguchi, T. Mochizuki, C. Kim, H.i Akiyama, L. N. Pfeiffer, K. W. West, and R. Shimano: Anomalous metal phase emergent on the verge of an exciton Mott transition, Phys. Rev. Lett. **118**, 067401 (2017).

[13] F. Sekiguchi and R. Shimano: Excitonic correlation in the Mott crossover regime in Ge, Phys. Rev. B **91**, 155202 (2015).

[14] R. Matsunaga, N. Tsuji, H. Fujita, A. Sugioka, K. Makise, Y. Uzawa, H. Terai, Z. Wang, H. Aoki, and R. Shimano: Light-induced collective pseudospin precession resonating with Higgs mode in a superconductor, Science **345**, 1145 (2014).

[15] R. Matsunaga, Y. I. Hamada, K. Makise, Y. Uzawa, H. Terai, Z. Wang, and R. Shimano: Higgs Amplitude Mode in the BCS Superconductors $Nb_{1-x}Ti_xN$ induced by Terahertz Pulse Excitation, Phys. Rev. Lett. **111**, 057002 (2013).

[16] R. Shimano, G. Yumoto, J. Y. Yoo, R. Matsunaga, S. Tanabe, H. Hibino, T. Morimoto, and H. Aoki: Quantum Faraday and Kerr rotations in graphene, Nature Commun. **4**, 1841 (2013).

[17] J. Y. Yoo and R. Shimano: Lifetime Measurement of Excitons in Si by Terahertz Time-domain Spectroscopy with High Spectral Resolution, J. Infrared Milli. Terahz. Waves **35**, 110 (2013).

[18] R. Matsunaga and R. Shimano: Nonequilibrium BCS state dynamics induced by intense terahertz pulses in a superconducting NbN film, Phys. Rev. Lett. **109**, 187002 (2012).

[19] T. Suzuki and R. Shimano: Exciton Mott transition in Si revealed by terahertz spectroscopy, Phys. Rev. Lett. **109**, 046402 (2012).

[20] S. Bordacs, I. Kezsmarki, D. Szaller, L. Demko, N. Kida, H. Murakawa, Y. Onose, R. Shimano, T. Room, U. Nagel, S. Miyahara, N. Furukawa, and Y. Tokura: Y. Taguchi, T. Arima, and Y. Tokura: Chirality of matter shows up via spin excitations, Nature Physics **8**, 734 (2012).

[21] R, Shimano, S, Watanabe, and R. Matsunaga: Intense terahertz pulse-induced nonlinear responses in carbon nanotubes, J. Infrared Milli. Terahz. Waves **33**, 861 (2012). (invited paper).

[22] Y. Takahashi, R. Shimano, Y. Kaneko, H. Murakawa, and Y. Tokura: Magnetoelectric resonance with electromagnons in a perovskite helimagnet, Nature Physics **8**, 121 (2012).

＜Review Papers＞

[23] Ryo Shimano and Naoto Tsuji: Higgs mode in Superconductors, Annual Rev. of Cond. Matt. Phys.**11** 2020(advanced online version).

7 Invited Presentations at International Conferences

[1] Ryo Shimano: Higgs mode in conventional and unconventional superconductors, The Hamburg Photon Science Colloquium at Max Planck Institute for the Structure and Dynamics of Matter, Center for Free-Electron Laser Science (CFEL), DESY, Hamburg, Germany, Feb. 9, 2019.

[2] Ryo Shimano: Light-induced Nonequilibrium Dynamcis in Superconductors, Max Planck-UBC-UTokyo Centre for Quantum Materials Workshop 2018, Koshiba Hall, The University of Tokyo, Dec. 10, 2018.

[3] Ryo Shimano: Photo-induced nonequilibrium dynamics in superconductors, ENS-UT Workshop on Physics, Ecole Normale Superieure, Paris, France, Sept. 27, 2018.

[4] Ryo Shimano: Higgs mode in conventional and unconventional superconductors, The International Symposium on Quantum Fluids and Solids (QFS2018) Ito International Research Center (IIRC), The University of Tokyo, July 28, 2018.

[5] Ryo Shimano: Exciton Mott transition: towards the understanding of phase diagram of e-h system, The 12th International Conference on Excitonic and Photonic Processes in Condensed Matter and Nano Materials (EXCON 2018), Nara Kasugano International Forum, Nara City, July 9, 2018.

[6] Ryo Shimano: Higgs mode in conventional and unconventional superconductors, Colloquium at The Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany, June 11, 2018.

[7] Ryo Shimano: A light-induced nonequilibrium phenomena in high Tc cuprate superconductors, International Workshop on Frontiers of Research in Quantum Materials, Max Planck Institute, Stuttgart, Dec 18, 2017.

[8] Ryo Shimano: A light-induced metastable phase in superconducting $La_{2-x}Sr_xCuO_4$, International Workshop on Ultrafast dynamics and metastability, Georgetown Univ., Washington, USA, Nov. 15, 2017.

[9] Ryo Shimano: THz study of photoexcited dynamics in high Tc superconductors, International Workshop on Non-Linear Effects and Short-Time Dynamics in Novel Superconductors and Correlated Spin-Orbit Coupled Systems, Center for Theoretical Physics of Complex Systems, Institute for Basic Science, Daejeon, Korea, Sept. 18, 2017.

[10] Ryo Shimano: Extreme Nonlinear Optical in Graphene in the THz range, CLEO Pacific Rim, Marina Bay Sands Expo and Convention Center, Sigapore, Aug. 1, 2017.

[11] Ryo Shimano: Ultrafast THz nonlinear optics in a Landau-quantized graphene, 2017 PKU-UTokyo NanoCarbon Workshop, Univ. of Tokyo, July 28, 2017.

[12] Ryo Shimano: Higgs mode in conventional and unconventional superconductors, 6th International Conference on Photoinduced Phase Transitions, Sendai, Japan, June 9, 2017.

[13] Ryo Shimano: Nonlinear THz spectroscopy of collective modes in superconductors, Low Energy Electrodynamics in Solids 2016, Shiga, Japan, June 2, 2016.

[14] Ryo Shimano: Ultrafast Nonlinear Terahertz Spectroscopy of Quantum Condensates in Solids, CLEO:2016, San Jose, USA, June 7, 2016.

[15] Ryo Shimano: Study of nonequilibrium responses in quantum matter - from QHE to superconductor, International Symposium on New Horizons in Condensed Matter Physics, Tokyo, Japan, June 18, 2016.

[16] Ryusuke Matsunaga and Ryo Shimano: Higgs amplitude mode in superconductors studied by nonlinear terahertz spectroscopy, Spectroscopies in Novel Superconductors, Stuttgart, Germany, June 21, 2016.

[17] Ryusuke Matsunaga: Collective Higgs amplitude mode in superconductors studied by strong terahertz pulse, International Conference on Dynamical Processes in Excited States of Solids, Paris, France, July 21, 2016.

[18] Ryo Shimano: Ultrafast spectroscopy of Higgs modes in superconductors, International Research School: Electronic States and Phases Induced by Electric or Optical Impacts IMPACT 2016, Aug 26, 2016.

[19] Fumiya Sekiguchi, Changsu Kim, Hidefumi Akiyama, and Ryo Shimano: Exciton Mott transition in GaAs studied by terahertz spectroscopy, Ultrafast Phenomena and Nanophotonics XXI, San Francisco, USA, Jan. 28, 2017.

[20] Go Yumoto and Ryo Shimano: Nonlinear optical responses of non-equidistant Landau levels in graphene in terahertz frequency range, The 6th International Workshop on Far-Infrared Technologies and The 2nd International Symposium on Development of High Power Terahertz Science and Technology, Fukui, Japan, Mar. 9, 2017.

[21] Ryo Shimano: Terahertz responses of graphene in the quantum Hall regime, MRS Spring meeting, Sanfrancisco, USA, Apr. 7, 2015.

[22] Ryo Shimano: Higgs mode in superconductors revealed by nonlinear THz spectroscopy, CROF2015, Greece, Jul. 14, 2015.

[23] Ryo Shimano: Quantum Faraday effect in graphene, Nanocarbon WS of PKU-UTokyo, Tokyo, Japan, Jul. 21, 2015.

[24] Ryo Shimano: Nonlinear Terahertz Spectroscopy of Higgs Mode in Superconductors, Nonlinear Optics 2015, Hawaii, USA, Jul. 29, 2015.

[25] Ryo Shimano: Time-resolved study of Higgs amplitude mode in s-wave superconductors, Materials and Mechanisms of Superconductivity 2015 (M2S), Geneva, Switzerland, Aug. 25, 2015.

[26] Ryo Shimano: Higgs mode spectroscopy of conventional and unconventional superconductors, Ringberg Symposium on High Temperature Superconductivity and Correlated-Electron Systems, Munich, Germany, Oct. 15, 2015.

[27] Ryo Shimano: Nonlinear Higgs Mode Spectroscopy of Superconductors by Intense THz Pulses, Ultrafast Phenomena in Cooperative Systems, Gordon Research Conference, Lucca, Italy, Feb. 16, 2016.

[28] Ryo Shimano: Higgs mode in superconductors, Physics Workshop: LMU-UT, Tokyo, Japan, Mar. 1, 2016.

[29] Ryo Shimano: Time-resolved study of Higgs mode in superconductors, APS March meeting, Baltimore, USA, Mar. 17, 2016.

[30] Ryo Shimano: Higgs amplitude mode in s-wave superconductors, The 7th International Conference on Spontaneous Coherence in Excitonic Systems (ICSCE), Kanagawa, Japan, Apr. 22, 2014

[31] Ryo Shimano: Ultrafast dynamics of Higgs amplitude mode in s-wave superconductors induced by terahertz pulse excitation, 5th International Conference on Photoinduced Phase Transitions and Co-operative Phenomena (PIPT), Bled, Slovenia, Jun. 9, 2014

[32] Ryo Shimano: Observation of Higgs mode in s-wave superconductors, The intererernational workshop "Higgs Mode in Condensed Matter and Quantum Gases", Univ. of Kyoto, Kyoto, Japan, Jun. 24, 2014

[33] Ryo Shimano: Observation of Higgs Amplitude Mode in Superconductors, The 11th edition of Low Energy Electrodynamics in Solids (LEES), Loire Valley, France, Jul. 3, 2014

[34] Ryo Shimano, Ryusuke Matsunaga, Yuki Hamada, Arata Sugioka, Hiroyuki Fujita, Kazumasa Makise, Yoshinori Uzawa, Hirotaka Terai, Zhen Wang, Naoto Tsuji, and Hideo Aoki: Higgs Mode and Terahertz Nonlinear Optics in Superconductors, 19th International Conference on Ultrafast Phenomena (UP), Okinawa, Japan, Jul. 10, 2014.

[35] Ryo Shimano: Quantum Faraday effect in graphene, The 4th International Workshop on Nanocarbon Photonics and Optoelectronics (NPO), Polvijarvi, Finland, Jul. 28, 2014

[36] Ryo Shimano: Optical Quantum Hall effect in monolayer graphene, Japan-Korea Joint Symposium on Semiconductor Physics and Technology-Nano-carbon materials incluidng graphene- The 75th JSAP Autumn Meeting, Hokkaido Univ., Hokkaido, Japan, Sep. 17 2014

[37] Ryo Shimano: Real-time observation of Higgs mode in superconductors, Fujihara seminar,Real-time Dynamcis of Physical Phenomena and Manipulation by External Fields, Tomakomai, Japan, Sep. 26, 2014

[38] Ryo Shimano: Observation of Higgs mode in superconductors, ENS-UTokyo WS, Paris, France, Dec.9 2014

[39] Ryo Shimano: Observation of Higgs mode in superconductors, International Workshop on Non-equilibrium Dynamics of Low-dimensional Electronic Systems, Leipzig, Germany, Jan. 15, 2015

[40] Ryusuke Matsunaga and Ryo Shimano: Higgs amplitude mode in s-wave superconductors revealed by terahertz pump-terahertz probe spectroscopy, SPIE Photonics West OPTO: Ultrafast Phenomena and Nanophotonics XIX, San Francisco, USA, Feb. 10, 2015.

[41] Ryo Shimano: Higgs mode in superconductors, The sixth international workshop on Optical Terahertz Science and Technology(OTST), San Diego, USA, Mar. 11, 2015,

[42] Ryo Shimano: Photo-induced ultrafast nonequilibrium dynamics of superconductors, Ecole Normal Superiure- Univ. of Tokyo Workshop, Komaba, Tokyo, Dec.3, 2013.

[43] Ryo Shimano: Terahertz magneto-optics of the integer quantum Hall effect in a GaAs two-dimensional electron gas system,The 20th International Conference on "High Magnetic Fields in Semiconductor Physics", HMF-20, Chamonix Mont-Blanc, France, July 23, 2012.

[44] Ryo Shimano: Exciton Mott transition revealed by Terahertz spectroscopy, 2012 DYCE International Workshop, Kussharo Prince Hotel, Hokkaido, Japan, Aug. 7, 2012.

8 Teaching Accomplishment

- Kota Katsumi (D2) received the Yong Researchers Award at the International Conference of Spectroscopies in Novel Superconductors 2019(June 2019)
- Ryusuke Matsunaga(Previous Assistant Prof.) received the Young Scientist Award by Minister of MEXT (April 2018).
- Kota Katsumi (M2) received the School of Science Research Award for AY 2017(Mar 2018).
- Masayuki Takayama(D2) received the Best Poster Award at Annual Workshop of Cryogenic Research Center(Feb 2018).
- Kaito Tomari(M2) received the Best Poster Award at the International Conference of Low-Energy Electrodynamics in Solids 2016 (June 2016).
- Fumiya Sekiguchi(D3)received the School of Science Research Award for AY 2015(Mar 2016).
- Ryusuke Matsunaga(Previous Assistant Prof.) received the Prize of Superconductivity Science and Technology 2014 (Feb. 2015).
- Hiroyuki Fujita and Shin Sugioka received the Faculty of Science Award for AY 2013(Mar. 2014).

9 Contribution to Academic Community

9.1 Editorial Activities

Journal of Physical Society of Japan, Head editor 2017-

9.2 Organization and Advisory of Conferences

- Program Committee Member

  CLEO/Europe-EQEC 2019, June 2327, 2019. Munich, Germany
  CLEO/Europe-EQEC 2017, June 2529, 2017.Munich, Germany
  LEES2016 , Low Energy Electrodynamics in Solids, May 29 - June 3, 2016. Shiga, Japan.
  CLEO2014, June 8-13, 2014. San Jose, USA

- Organizing Committee of International Conferences

  Paris Ultrafast 2019, Co-chair, Ultrafast and Nonlinear Dynamics of Quantum Materials, June 4-7, 2019. Paris, France
  SNS 2019, Specrtroscopies in Novel Superconductors, June 16 - 21, 2019. Tokyo, Japan
  Fujihara Seminar 2014, Real-time Dynamics of Physical Phenomena and Manipulation by External Fields, Sept. 23-27, 2014. Hokkaido, Japan

10 Outreach

11 Committee Service

11.1 Advisory

Examination Committee of Ryogo Kubo Memorial Prize, Inoue Foundation, 2014-
Advisory Committee of PREST, JST, 2019-

11.2 University Committees

低温センター　運営委員会　運営委員 2014-
低温センター　専門委員会　専門委員 2014-
低温センター　編集委員会　委員長 2014-
低温センター　環境安全管理室室長 2014-
低温センター　部局研究倫理担当者 2014-

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	2	USA, Canada
Master Course	0	
Doctor Course	1	Korea
Foreign researchers hosted	2	France
Students sent abroad	5	Germany, France, USA, UK
Researchers sent abroad	1	Germany
Foreign visitors	9	France, Germany,China,USA, Canada, Finland, Korea

Hidenori Takagi、高木 英典

1 Education and Professional Experiences

Education

1983	B.S. (Applied Physics)	The University of Tokyo
1985	MSc. (Applied Physics)	The University of Tokyo
1989	Ph.D. (Applied Physics)	The University of Tokyo

Professional Appointments

1986 – 1990	Assistant Professor	The University of Tokyo
1990 – 1992	Postdoctoral member of technical staff	AT&T Bell Laboratories
1992 – 1994	Lecturer	The University of Tokyo
1994 – 1999	Associate Professor	The University of Tokyo
2002 – 2014	Chief Scientist & Director	RIKEN Advanced Science Institute (cross appointment)
1999 –	Professor	University of Tokyo (2015 – cross appointment)
2013 –	Director	Max Planck Institute for Solid State Research (2019 – Managing director, 2013 – 2014 cross appointment)
2014 –	Alexander von Humboldt Professor (W3)	University of Stuttgart (cross appointment)

Visiting, Guest Appointments

1996 – 1998	Associate Professor	Kyoto University
2001 – 2006	Team Leader	AIST
2007	Visiting Professor	Universite de Paris Sud

2 Research Highlights

My group has been aiming to discover/rediscover novel transition metal compounds, which host exotic phases of correlated electrons and elucidate the physics behind the formation of these phases. The dominant but not only keyword in the materials exploration during 2012-2019 was "spin-orbital entangled matter" formed by the very strong spin-orbit coupling in $4d$ and $5d$ transition metal compounds. We are proud to have delivered many (new) materials of interest to the community, including $H_3LiIr_2O_6$ (spin orbital quantum liquid), β-Li_2IrO_3 (three-dimensional honeycomb magnet), $SrIrO_3$ (correlated three dimensional Dirac electron system), Sr_3PbO (three-dimensional Dirac electron system with giant orbital diamagnetism) and Ta_2NiSe_5 (excitonic insulator).

Exotic magnetism in localized spin-orbital entangled materials has been explored. The obvious and simplest playground was spin-orbital entangled $J_{\text{eff}} = \frac{1}{2}$ moments for $5d^5$ Ir^{4+} compounds. $J_{\text{eff}} = \frac{1}{2}$ behaves like quantum $S = \frac{1}{2}$ moment but its internal structure comprising of spin and orbital moments gives rise to a rich and complex interactions among them. Sr_2IrO_4 was established as the first example of spin-orbital Mott insulator with $J_{\text{eff}} = \frac{1}{2}$ moments [Science **323**, 1329-1332 (2009). Cited 705 times.]. We showed that its magnetism could be captured unexpectedly by an isotropic Heisenberg model, despite the strong spin-orbit coupling [Phys. Rev.Lett. **108**, 247212 (2012), cited 115 times.]. We then attempted to materialize a Kitaev quantum spin liquid made of Majorana fermions using the extremely anisotropic coupling between the spin-orbital entangled $J_{\text{eff}} = \frac{1}{2}$ moments [Nature Reviews Physics 1, 264 - 280 (2019).]. Two-dimensional $J_{\text{eff}} = \frac{1}{2}$ honeycomb magnets Na_2IrO_3 and Li_2IrO_3 were proposed to be such candidate materials. To our disappointment, however, these compounds showed magnetic ordering at low temperatures, instead of a liquid state, due to the presence of non-Kitaev interactions. We therefore developed a three-dimensional analogue of the $J_{\text{eff}} = \frac{1}{2}$ honeycomb magnet, β-Li_2IrO_3 [Phys. Rev. Lett. **114**, 077202 (2015). Cited 178 times], with a structure we named "hyperhoneycomb", as an alternative approach to the Kitaev spin liquid. Magnetic ordering, however, was again discovered in the hyperhoneycomb. Even with this finding, we did not give up on our goal of materializing the Kitaev spin liquid. Finally, we discovered that another two-dimensional $J_{\text{eff}} = \frac{1}{2}$ honeycomb magnet, $H_3LiIr_2O_6$, is a spin-orbital quantum liquid [Nature, **554**, 341345 (2018). Cited 57 times.], and this is one of the most appealing achievements of my group during 2012-2019.

Itinerant spin-orbital (semi)materials in which topological physics plays an important role were explored in parallel. The $J_{\text{eff}} = \frac{1}{2}$ perovskite $SrIrO_3$ is a correlated topological Dirac node semimetal, which we demonstrated using $SrIrO_3/SrTiO_3$ superlattice films [Phys. Rev. Lett. **114**, 247209 (2015). Cited 80 times.]. We demonstrated the presence of three-dimensional Dirac electrons and their giant orbital diamagnetism in the semimetal Sr_3PbO [Physical Review B [98], 115203 (2018).]. "Excitonic insulator" is an old yet new keyword in the exploration of semimetals. We discovered that nearly zero-gap semiconductor Ta_2NiSe_5 is an excitonic insulator [Nature Commun. **8**, 14408 (2017). Cited 40 times] and a superconductor in the pressure-induced semimetallic phase.

3 Selected papers

- **Concept and realization of Kitaev quantum spin liquids**
  H. Takagi, T. Takayama, G. Jackeli, G. Khaliullin, and S. N. Nagler
  Nature Reviews Physics **1**, 264-280 (2019).
  This is a review of rapidly growing field written for the 1st volume of Nature Review Phsyics.

- **A spin-orbital-entangled quantum liquid on a honeycomb lattice**
  K. Kitagawa, T. Takayama, Y. Matsumoto, A. Kato, R. Takano, Y. Kishimoto, S. Bette, R. Dinnebier, G. Jackeli, and H. Takagi
  Nature **554**, 341-345 (2018).
  The paper reports the discovery of the first quantum spin-orbital liquid on honeycomb lattice, whcih has bin cites ∼60 times one year after publication.

- **Zero-gap semiconductor to excitonic insulator transition in Ta_2NiSe_5**
  Y. F. Lu, H. Kono, T. I. Larkin, A. W. Rost, T. Takayama, A. V. Boris, B. Keimer, and H. Takagi
  Nature Communications **8**, 14408 (2017).
  This work reports the discovery of the most convincing candidate for a long debated excitonic insulator. Cited ∼40 times.

- **Hyperhoneycomb iridate β-Li_2IrO_3 as a platform for Kitaev magnetism**
  T. Takayama, A. Kato, R. Dinnebier, J. Nuss, H. Kono, L. S. I. Veiga, G. Fabbris, D. Haskel, and H. Takagi
  Phys. Rev, Lett. **114**, 077202 (2015).
  This paper reports the discovery of the three-dimensional analogue fo two-dimensional honeycomb Kitaev magnet, which has been cited ∼180 times.

- **Engineering a spin-orbital magnetic insulator by tailoring superlattices**
  J. Matsuno, K. Ihara, S. Yamamura, H. Wadati, K. Ishii, V. V. Shankar, Hae-Young Kee, and H. Takagi
  Phys. Rev. Lett. **114**, 247209 (2015).
  This is the first demonstration of "correlated" Dirac electrons in perovskite iriddate, which has been cited ∼80 times.

4 Honors, Awards and Professional Society Memberships

- 2013 Alexander von Humboldt Professor
- 2014 Highly Cited Researcher, Thomson Reuters
- 2017 Outstanding Referee, Physical Society of Japan

5 Research Plan

So far our exploration of spin orbital entangle matter was confined within $5d^5$ system with $J_{\mathrm{eff}} = \frac{1}{2}$ moments. Equally exotic states of matter, distinct from the $J_{\mathrm{eff}} = \frac{1}{2}$ spin-orbital entangled state, can be anticipated in $4d$ and $5d$ transition metal compounds with different numbers of electrons. We would like to extend our exploration further to discover novel quantum phases of spin-orbital entangled electrons. Projects in the next a few years will include the followings.

From $\mathbf{J}_{\text{eff}} = \frac{1}{2}$ paradigm to $\mathbf{J}_{\text{eff}} = \mathbf{0}$ Mott insulator and excitonic magnetism; $\mathbf{5}\boldsymbol{d}^4$ spin-orbital entangled state.

In a $5d^4$ (t_{2g}^4) Mott insulator, the Hund's coupling yields local $S = 1$ and $L_{\text{eff}} = 1$ moments. Spin-orbit coupling in the large U limit should then lead to a nonmagnetic ground state with $J_{\text{eff}} = 0$, which interestingly is a Mott insulator without a dipole moment. G. Khaliullin, my close colleague, theoretically proposed that by increasing the electron hopping, the excited $J_{\text{eff}} = 1$ triplet states could condense, forming an unconventional magnetic ground state called an *excitonic magnet.* The excitonic magnetism becomes even more exotic if it is realized on the same edge-shared honeycomb network as the $5d^5$ Kitaev candidates. Due to the bond-dependent nature of the interactions, a hallmark of spin-orbital entangled system, the excitonic magnetism is proposed to result in a *spin-superfluid* state and/or a *nematic dimerized* state.

From $\mathbf{J}_{\text{eff}} = \frac{1}{2}$ paradigm to zero-magnetic moment $\mathbf{J}_{\text{eff}} = \frac{3}{2}$ multipoles; $\mathbf{5}\boldsymbol{d}^1$ spin-orbital entangled state

$5d^1$ Mott insulators with one electron in the t_{2g} orbital may open an avenue of research devoted to multipolar degrees of freedom in transition metals, going beyond the dipolar paradigm. In $5d^1$ Mott insulators, the electron is in the $J_{\text{eff}} = \frac{3}{2}$ quartet and the intriguing character of $J_{\text{eff}} = \frac{3}{2}$ states is "*zero*" *magnetic dipolar moment* ($\langle \mathbf{M} \rangle = 0$), arising from the cancellation of spin- and orbital- moments. The absence of a dipolar moment reveals the higher multipoles, such as the charge quadrupole and the magnetic octupole, which are often invisible to conventional experimental probes. As such a hidden ordering of interacting multipoles may be anticipated. The materialization of the ideal $J_{\text{eff}} = \frac{3}{2}$ state and the experimental verification of hidden multipolar ordering remains a challenge. $5d^1$ and $4d^1$ transition-metal (Os^{7+} and Mo^{5+}) oxides with double-perovskite structure were studied, but a clear signature of multipolar ordering was not observed. New $5d^1$ compounds that better realise the $J_{\text{eff}} = \frac{3}{2}$ state are required. Furthermore, it was recently proposed that placing $5d^1$ $J_{\text{eff}} = \frac{3}{2}$ multipoles on the edge-shared honeycomb network, may lead to a gapless *SU(4) spin-orbital liquid.*

6 Publications and Patents

6.1 Refeered Original Papers

[1] **Transport and thermodynamic evidence for a marginal Fermi-liquid state in $ZrZn_2$**, M. Sutherland, R. P. Smith, N. Marcano, Y. Zou, S. E. Rowley, F. M. Grosche, N. Kimura, S. M. Hayden, S. Takashima, M. Nohara, and H. Takagi, Physical Review B **85**, 035118 (2012).

[2] **In-situ Annular Bright-Field Imaging of Structural Transformation of Spinel LiV_2O_4 Crystals into Defective $Li_xV_2O_4$**, S. Lee, Y. Oshima, S. Niitaka, H. Takagi, Y. Tanishiro, and K. Takayanagi, Japanese Journal of Applied Physics **51**, 020202 (2012).

[3] **Enhancement of the Jahn-Teller distortion by magnetization in manganites**, Y. Y. Chu, H. H. Wu, S. C. Liu, H.-H. Lin, J. Matsuno, H. Takagi, J. H. Huang, J. van den Brink, C. T. Chen, and D. J. Huang, Applied Physics Letters **100**, 112406 (2012).

[4] **Photoemission Spectroscopy of Ta_2NiSe_5**, Y. Wakisaka, T. Sudayama, K. Takubo, T. Mizokawa, N. L. Saini, M. Arita, H. Namatame, M. Taniguchi, N. Katayama, M. Nohara, and H. Takagi, Journal of Superconductivity and Novel Magnetism **25**, 1231-1234 (2012).

[5] **Metal-Insulator transition and superconductivity in the binary pnictides RuPn (Pn=P, As, Sb)**, D. Hirai, T. Takayama, D. Hashizume and H. Takagi, Physical Review B **85**, 140509 (2012).

[6] **Visualization of the emergence of the pseudogap state and the evolution to superconductivity in a lightly hole-doped Mott insulator**, Y. Kohsaka, T. Hanaguri, M. Azuma, M. Takano, J. C. Davis, and H. Takagi, Nature Physics **8**, 534-538 (2012).

[7] **Crossover from coherent to incoherent scattering in spin-orbit dominated Sr_2IrO_4**, M. Fatih Cetin, P. Lemmens, V. Gnezdilov, D. Wulferding, D. Menzel, T. Takayama, K. Ohashi, and H. Takagi, Physical Review B **85**, 195148 (2012).

[8] **Scanning tunneling microscopy/spectroscopy of vortices in LiFeAs**, T. Hanaguri, K. Kitagawa, K. Matsubayashi, Y. Mazaki, Y. Uwatoko, and H. Takagi, Physical Review B **85**, 214505 (2012).

[9] **Strong Coupling Superconductivity at [8.4]K in an Antiperovskite Phosphide $SrPt_3P$**, T. Takayama, K. Kuwano, D. Hirai, Y. Katsura, A. Yamamoto, and H. Takagi, Physical Review Letters **108**, 237001 (2012).

[10] **Two-Dimensional Heisenberg Behavior of $J_{\rm eff} = \frac{1}{2}$ Isospins in the Paramagnetic State of the Spin-Orbital Mott Insulator Sr_2IrO_4**, S. Fujiyama, H. Ohsumi, T. Komesu, J. Matsuno, B. J. Kim, M. Takata, T. Arima, and H. Takagi, Physical Review Letters **108**, 247212 (2012).

[11] **Electric-Field-Induced Superconductivity at [9.4]K in a layered transition metal disulphide MoS_2**, K. Taniguchi, A. Matsumoto, H. Shimotani, and H. Takagi, Applied Physics Letters **101**, 042603 (2012).

[12] **An orbital-selective spin liquid in a frustrated heavy fermion spinel LiV_2O_4**, Y. Shimizu, H. Takeda. M. Tanaka, M. Itoh, S. Niitaka, and H. Takagi, Nature Communications **3**, 981 (2012).

[13] **Decrease of upper critical field with underdoping in cuprate superconductors**, J. Chang, N. Doiron-Leyraud, O. Cyr-Choinire, G. Grissonnanche, F. Lalibert, E. Hassinger, J.-Ph. Reid, R. Daou, S. Pyon, T. Takayama, H. Takagi, and L. Taillefer, Nature Physics **8**, 751-756 (2012).

[14] **Weak antiferromagnetism of $J_{\rm eff} = \frac{1}{2}$ band in bilayer iridate $Sr_3Ir_2O_7$**, S. Fujiyama, K. Ohashi, H. Ohsumi, K. Sugimoto, T. Takayama, T. Komesu, M. Takata, T. Arima, and H. Takagi, Physical Review B 86, 174414 (2012).

[15] **Evidence for a $\cos(4\phi)$ Modulation of the Superconducting Energy Gap of Optimally Doped $FeTe_{0.6}Se_{0.4}$ Single Crystals Using Laser Angle-Resolved Photoemission Spectroscopy**, K. Okazaki, Y. Ito, Y. Ota, Y. Kotani, T. Shimojima, T. Kiss, S. Watanabe, C.-T. Chen, S. Niitaka, T. Hanaguri, H. Takagi, A. Chainani, and S. Shin, Physical Review Letters **109**, 237011 (2012).

[16] **Angle-dependent spectral weight transfer and evidence of a symmetry-broken in-plane charge response in $Ca_{1.9}Na_{0.1}CuO_2Cl_2$**, R. Schuster, S. Pyon, M. Knupfer, M. Azuma, M. Takano, H. Takagi, and B. Bchner, Physical Review B **86**, 245112 (2012).

[17] **Quantifying covalency and metallicity in correlated compounds undergoing metal-insulator transitions**, A. Chainani, A. Yamamoto, M. Matsunami, R. Eguchi, M. Taguchi, Y. Takata, H. Takagi, S. Shin, Y. Nishino, M. Yabashi, K. Tamasaku, and T. Ishikawa, Physical Review B **87**, 045108 (2013).

[18] **Orbital reformation with vanadium trimerization in d^2 triangular lattice $LiVO_2$ revealed by ^{51}V NMR**, T. Jin-no, Y. Shimizu, M. Itoh, S. Niitaka, and H. Takagi, Physical Review B **87**, 075135 (2013).

[19] **Resonant X-ray Diffraction Study of the Strongly Spin-Orbit-Coupled Mott Insulator $CaIrO_3$**, K. Ohgushi, J. Yamaura, H. Ohsumi, K. Sugimoto, S. Takeshita, A. Tokuda, H. Takagi, M. Takata, and T. Arima, Physical Review Letters **110**, 217212 (2013).

[20] **Optical excitation of Josephson plasma solitons in a cuprate superconductor**, A. Dienst, E. Casandruc, D. Fausti, L. Zhang, M. Eckstein, M. Hoffmann, V. Khanna, N. Dean, M. Gensch, S. Winnerl, W. Seidel, S. Pyon, T. Takayama, H. Takagi, and A. Cavalleri, Nature Materials **12**, 535-541 (2013).

[21] **Photo-assisted aromatic VOC sensing by a p-NiO:Li/n-ZnO transparent heterojunction sensor element**, Y. Nakamura, Y. Ishikura, Y. Morita, H. Takagi, and S. Fujitsu, Sensors and Actuators B: Chemical **187**, 578-585 (2013).

[22] **Memory Effect in a Topological Surface State of Bi_2Te_2Se**, Y.-S. Fu, T. Hanaguri, S. Yamamoto, K. Igarashi, H. Takagi, and T. Sasagawa, ACS Nano **7**, 4105-4110 (2013).

[23] **Spectroscopic indications of polaronic behavior of the strong spin-orbit insulator $Sr_3Ir_2O_7$**, P. D. C. King, T. Takayama, A. Tamai, E. Rozbicki, S. M. Walker, M. Shi, L. Patthey, R. G. Moore, D. Lu, K. M. Shen, H. Takagi, and F. Baumberger, Physical Review B **87**, 241106 (2013).

[24] **MgSrSi-Type Compounds as a Possible New Family of Thermoelectric Materials**, Y. Katsura and H. Takagi, Journal of Electronic Materials **42**, 1365-1368 (2013).

[25] **Electronic superlattice revealed by resonant scattering from random impurities in $Sr_3Ru_2O_7$**, M. A. Hossain, I. Zegkinoglou, Y.-D. Chuang, J. Geck, B. Bohnenbuck, A. G. Cruz Gonzalez, H.-H. Wu, C. Schler-Langeheine, D. G. Hawthorn, J. D. Denlinger, R. Mathieu, Y. Tokura, S. Satow, H. Takagi, Y. Yoshida, Z. Hussain, B. Keimer, G. A. Sawatzky, and A. Damascelli, Scientific Reports **3**, 02299 (2013).

[26] **Comprehensive Macroscopic Investigation on Hexagonal C14 Laves-Type Ru-Based Superconductors ARu_2 (A = Lu, Y, Sc) with Effective Electron Correlation**, S. Niitaka, E. Minamitani, Y. Kim, H. Takagi, and K. Kono, Journal of the Physical Society of Japan **82**, 124703 (2013).

[27] ***A*-Type Antiferro-Orbital Ordering with $I4_{1/a}$ Symmetry and Geometrical Frustration in the Spinel Vanadate MgV_2O_4**, S. Niitaka, H. Ohsumi, K. Sugimoto, S. Lee, Y. Oshima, K. Kato, D. Hashizume, T. Arima, M. Takata, and H. Takagi, Physical Review Letters **111**, 267201 (2013).

[28] **A new "zero-strain" material for electrochemical lithium insertion**, Y. Gu, K. Taniguchi, R. Tajima, S. Nishimura, D. Hashizume, A. Yamada, and H. Takagi, Journal of Materials Chemistry A **1**, 6550-6552 (2013).

[29] **5*d* iridium oxide as a material for spin-current detection**, K. Fujiwara, Y. Fukuma, J. Matsuno, H. Idzuchi, Y. Niimi, Y. Otani, and H. Takagi, Nature Communications **4**, 3893 (2013).

[30] **Electronic state of spin-orbit coupled Mott insulator Sr_2IrO_4**, T.-H. Arima, H. Takagi, Seramikkusu **48**, 459-463 (2013).

[31] **Observation of rebirth of metallic paths during resistance switching of metal nanowire**, K. Horiba, K. Fujiwara, N. Nagamura, S. Toyoda, H. Kumigashira, M. Oshima, and H. Takagi, Applied Physics Letters **103**, 193114 (2013).

[32] **Thermoelectric properties of semi-metallic $Ru_2Sn_{3-\delta}$ with low thermal conductivity**, H. Kawasoko, T. Takayama, H. Takagi, Applied Physics Express **7**, 115801 (2014).

[33] **Synchrotron X-ray powder diffraction and convergent beam electron diffraction studies on the cubic phase of MgV_2O_4 spinel**, S. Niitaka, S. Lee, Y Oshima, K. Kato, D. Hashizume, M. Takata, H. Takagi, Journal of Solid State Chemistry **215**, 184-188 (2014).

[34] **Superconductivity in an electron band just above the Fermi level: possible route to BCS-BEC superconductivity**, K. Okazaki, Y. Ito, Y. Ota, Y. Kotani, T. Shimojima, T. Kiss, S. Watanabe, C.-T. Chen, S. Niitaka, T. Hanaguri, H. Takagi, A. Chainani, and S. Shin, Scientific Reports **4**, 4109 (2014).

[35] **Superconductivity at [6]K and the Violation of Pauli Limit in $Ta_2Pd_xS_5$**, Y. Lu, T. Takayama, A. Bangura, Y. Katsura, D. Hashizume, and H. Takagi, Journal of the Physical Society of Japan **83**, 23702 (2014).

[36] **Superconductivity at [3.7]K in Ternary Silicide Li_2IrSi_3**, D. Hirai, R. Kawakami, O. V. Magdysyuk, R. E. Dinnebier, A. Yaresko, and H. Takagi, Journal of the Physical Society of Japan **83**, 103703 (2014).

[37] **Spin-Orbit Fluctuations in Frustrated Heavy-Fermion Metal LiV_2O_4**, K. Tomiyasu, K. Iwasa, H. Ueda, S. Niitaka, H. Takagi, S. Ohira-Kawamura, T. Kikuchi, Y. Inamura, K. Nakajima, and K. Yamada
Physical Review Letters **113**, 236402 (2014).

[38] **Spin-Orbit coupling induced semi-metallic state in the 1/3 hole-doped hyper-kagome $Na_3Ir_3O_8$**, T. Takayama, A. Yaresko, A. Matsumoto, J. Nuss, K. Ishii, M. Yoshida, J. Mizuki, and H. Takagi, Scientific Reports **4**, 6818 (2014).

[39] **Spin and Orbital Contributions to Magnetically Ordered Moments in 5*d* Layered Perovskite Sr_2IrO_4**, S. Fujiyama, H. Ohsumi, K. Ohashi, D. Hirai, B. J. Kim, T. Arima, M. Takata, and H. Takagi, Physical Review Letters 112, 016405 (2014).

[40] **Low-energy magnetic excitations in the spin-orbital Mott insulator Sr_2IrO_4**, S. Bahr, A. Alfonsov, G. Jackeli, G. Khaliullin, A. Matsumoto, T. Takayama, H. Takagi, B. Bchner, and V. Kataev, Physical Review B 89, 180401 (2014).

[41] **Phase diagram and optical conductivity of $La_{1.8-x}Eu_{0.2}Sr_xCuO_4$**, M. Autore, P. Di Pietro, P. Calvani, U. Schade, S. Pyon, T. Takayama, H. Takagi, and S. Lupi, Physical Review B **90**, 035102 (2014).

[42] **Imaging the two-component nature of Dirac-Landau levels in the topological surface state of Bi_2Se_3**, Y.-S. Fu, M. Kawamura, K. Igarashi, H. Takagi, T. Hanaguri, and T. Sasagawa, Nature Physics **10**, 815-819 (2014).

[43] **Fano Resonances in the Infrared Spectra of Phonons in Hyperkagome $Na_3Ir_3O_8$**, D. Prpper, A. N. Yaresko, T. I. Larkin, T. N. Stanislavchuk, A. A. Sirenko, T. Takayama, A. Matsumoto, H. Takagi, B. Keimer, and A. V. Boris, Physical Review Letters **112**, 087401 (2014).

[44] **Excitonic Bose-Einstein condensation in Ta_2NiSe_5 above room temperature**, K. Seki, Y. Wakisaka, T. Kaneko, T. Toriyama, T. Konishi, T. Sudayama, N. L. Saini, M. Arita, H. Namatame, M. Taniguchi, N. Katayama, M. Nohara, H. Takagi, T. Mizokawa, and Y. Ohta, Physical Review B **90**, 155116 (2014).

[45] **Electronic Structure of a Quasi-Freestanding MoS_2 Monolayer**, T. Eknapakul, P. D. C. King, M. Asakawa, P. Buaphet, R.-H. He, S.-K. Mo, H. Takagi, K. M. Shen, F. Baumberger, T. Sasagawa, S. Jungthawan, and W. Meevasana, Nano Letters **14**, 1312-1316 (2014).

[46] **Direct phase-sensitive identification of a *d*-form factor density wave in underdoped cuprates**, K. Fujita, M. H. Hamidian, S. D. Edkins, C. K. Kim, Y. Kohsaka, M. Azuma, M. Takano, H. Takagi, H. Eisaki, S.-I. Uchida, A. Allais, M. J. Lawler, E.-A. Kim, S. Sachdev, and J. C. S. Davis, Proceedings of the National Academy of Sciences of the United States of America **111**, E3026-E3032 (2014).

[47] **Direct observation of spin-polarized bulk bands in an inversion-symmetric semiconductor**, J. M. Riley, F. Mazzola, M. Dendzik, M. Michiardi, T. Takayama, L. Bawden, C. Granerd, M. Leandersson, T. Balasubramanian, M. Hoesch, T. K. Kim, H. Takagi, W. Meevasana, P. Hofmann, M. S. Bahramy, J. W. Wells, and P. D. C. King, Nature Physics **10**, 835-839 (2014).

[48] **Commensurate structural modulation in the charge- and orbitally ordered phase of the quadruple perovskite $(NaMn_3)Mn_4O_{12}$**, A. Prodi, A. Daoud-Aladine, F. Gozzo, B. Schmitt, O. Lebedev, G. van Tendeloo, E. Gilioli, F. Bolzoni, H. Aruga-Katori, H. Takagi, M. Marezio, and A. Gauzzi, Physical Review B **90**, 180101 (2014).

[49] **Reversible Electrochemcal Insertion/Extraction of Mg and Li Ions for Orthorhombic Mo_9Se_{11} with Cluster Structure**, K. Taniguchi, T. Yoshino, Y. Gu, Y. Katsura, and H. Takagi, Journal of the Elctrochemical Society **162**, A198-A202 (2015).

[50] **Fabrication of (111)-oriented $Ga_{0.5}Sr_{0.5}IrO_3/SrTiO_3$ superlattices a designed playground for honeycomb physics**, D. Hirai, J. Matsuno, and H. Takagi, APL Materials **3**, 041508 (2015).

[51] **Phase Interface Structures in $Li_{1+x}Rh_2O_4$ Zero Strain Cathode Material Analyzed by Scanning Transmission Electron Microscopy**, A. Nakamura, Y. Gu, K. Taniguchi, N. Shibata, H.Takagi, and Y. Ikuhara, Chemistry of Materials **27**, 938-943 (2015).

[52] **Hyperhoneycomb iridate β-Li_2IrO_3 as a Platform for Kitaev Magnetism**, T. Takayama, A. Kato, R.E. Dinnebier, J. Nuss, H. Kono, L. Veiga, G. Fabbris, D. Haskel, and H. Takagi, Physical Review Letters **114**, 077202 (2015).

[53] **Thermal Conductivity across the Metal-Insulator Transition in the Single-Crystalline Hyper-kagome Antiferromagnet $Na_{3+x}Ir_3O_8$**, B. Fauqu, X. Xu, A. F. Bangura, E. C. Hunter, A. Yamamoto, K. Behnia, A. Carrington, H. Takagi, N. E. Hussey, and R. S. Perry Physical Review B **91**, 075129 (2015).

[54] **Two distinct kinetic regimes for the relaxation of light-induced superconductivity in $La_{1.675}Eu_{0.2}Sr_{0.125}CuO_4$**, C. R. Hunt, D. Nicoletti, S. Kaiser, T. Takayama, H. Takagi, and A. Cavalleri, Physical Review B **91**, 020505(R) (2015).

[55] **Two distinct kinetic regimes for the relaxation of light-induced superconductivity in $La_{1.675}Eu_{0.2}Sr_{0.125}CuO_4$ (vol 91, 020505, 2015) correction**, C. R. Hunt, D. Nicoletti, S. Kaiser, T. Takayama, H. Takagi, and A. Cavalleri, Physical Review B **91**, 059901 (2015).

[56] **Evidence for ordered magnetic moments at oxygen sites in antiferromagnetic Sr_2IrO_4 and $Sr_3Ir_2O_7$**, M. Miyazaki, R. Kadono, M. Hiraishi, A. Koda, K. M. Kojima, K. Ohashi, T. Takayama, and H. Takagi, Physical Review B **91**, 155113 (2015).

[57] **$Y_2Ti_2O_5S_2$ as a high performance anode material for Li ion batteries**, H. Oki, and H. Takagi, Solid State Ionics **276**, 80-83 (2015).

[58] **Tilting structures in inverse-perovskites, M_3TtO (M= Ca, Sr, Ba, Eu; Tt = Si, Ge, Sn, Pb)**, J. Nuss, C. Mhle, K. Hayama, V. Abdolazimi, and H. Takagi, Acta Crystallographica B **71**, 300-312 (2015).

[59] **Programmable persistent interfacial metallic state induced by frozen ions in inorganic-glass solid electrolyte**, K. Taniguchi, T. Fukamichi, K. Itaka, and H. Takagi, Advanced Functional Materials **25**, 3043-3048 (2015).

[60] **Engineering a spin-orbital magnetic insulator by tailoring superlattices**, J. Matsuno, K. Ihara, S. Yamamura, H. Wadati, K. Ishii, V. V. Shankar, Hae-Young Kee, and H. Takagi, Physical Review Lett. **114**, 247209 (2015).

[61] **Imaging ambipolar two-dimensional carriers induced by the spontaneous electric polarization of a polar semiconductor BiTeI**, Y. Kohsaka, M. Kanou, H. Takagi, T. Hanaguri, and T. Sasagawa Physical Review B **91**, 245312 (2015).

[62] **Magnetic fluctuations and possible formation of a spin-singlet cluster under pressure in the heavy-fermion spinel LiV_2O_4 probed by ^{7}Li and ^{5}1V NMR**, H. Takeda, Y. Kato, M. Yoshimura, Y. Shimizu, M. Itoh, S. Niitaka, and H. Takagi, Physical Review B **92**, 045103 (2015).

[63] **Semimetallic transport properties of epitaxially stabilized perovskite $CaIrO_3$ films**, D. Hirai, J. Matsuno, D. Nishio-Hamane, and H. Takagi, Applied Physics Letters **107**, 012104 (2015).

[64] **Rechargeable magnesium-ion battery based on a $TiSe_2$-cathode with *d-p* orbital hybridized electronic structure**, Y. Gu, Y. Katsura, T. Yoshino, H. Takagi, and K. Taniguchi, Scientific Reports **5**, 12486 (2015).

[65] **Negative electronic compressibility and tunable spin splitting in WSe_2**, J. M. Riley, W. Meevasana, L. Bawden, M. Asakawa, T. Takayama, T. Eknapakul, T. K. Kim, M. Hoesch, S.-K. Mo, H. Takagi, T. Sasagawa, M. S. Bahramy, and P. D. C. King
Nature Nanotechnology **10**, 1043-1047 (2015).

[66] **Rechargeable Mg-battery cathode TiS_3 with *d-p* orbital hybridized electronic structures**, K. Taniguchi, Y. Gu, Y. Katsura, T. Yoshino, and H. Takagi, Applied Physics Express **9**, 011801 (2016)

[67] **Critical Doping for the Onset of Fermi-Surface Reconstruction by Charge-Density-Wave Order in the Cuprate Superconductor $La_{2-x}Sr_xCuO_4$**, S. Badoux, S. A. A. Afshar, B. Michon, A. Ouellet, S. Fortier, D. LeBoeuf, T. P. Croft, C. Lester, S. M. Hayden, H. Takagi, K. Yamada, D. Graf, N. Doiron-Leyraud, and L. Taillefer, Physical Review X **6**, 021004 (2016)

[68] **Origin and distribution of charge carriers in $LaAlO_3$-$SrTiO_3$ oxide heterostructure in the high carrier density limit**, S. Mukherjee and B. Pal, D. Choudhury, I. Sarkar and W. Drube, M. Gorgoi, O. Karis, H. Takagi, J. Matsuno, and D. D. Sarma
Physical Review B **93**, 245124 (2016).

[69] **Pseudospin transport in the $J_{\mathrm{eff}} = \frac{1}{2}$ antiferromagnet Sr_2IrO_4**, F. Steckel, A. Matsumoto, T. Takayama, H. Takagi, B. Buchner, and C. Hess, EPL **114**, 57007 (2016).

[70] **Molecular beam epitaxy of three-dimensional Dirac material Sr_3PbO**, D. Samal, H. Nakamura, and H. Takagi, Appl. Phys. Lett. Materials **4**, 076101 (2016).

[71] **Optical anisotropy of the $J_{\mathrm{eff}} = \frac{1}{2}$ Mott insulator Sr_2IrO_4**, D. Prpper, A. N. Yaresko, M. Hppner, Y. Matiks, Y.-L. Mathis, T. Takayama, A. Matsumoto, H. Takagi, B. Keimer, and A. V. Boris, Physical Review B **94**, 035158 (2016).

[72] **Three-dimensional electronic structures and the metal-insulator transition in Ruddlesden-Popper iridates**, A. Yamasaki, H. Fujiwara, S. Tachibana, D. Iwasaki, Y. Higashino, C. Yoshimi, K. Nakagawa, Y. Nakatani, K. Yamagami, H. Aratani, O. Kirilmaz, M. Sing, R. Claessen, H. Watanabe, T. Shirakawa, S. Yunoki, A. Naitoh, K. Takase, J. Matsuno, H. Takagi, A. Sekiyama, and Y. Saitoh, Physical Review B **94**, 115103 (2016).

[73] **Nearly-free-electron system of monolayer Na on the surface of single-crystal $HfSe_2$**, T. Eknapul, I. Fongkaew, S. Siriroj, R. Vidyasagar, J. D. Denlinger, L. Bawden, S.-K. Mo, P.D. C. King, H. Takagi, S. Limpijumnong, and W. Meevasana, Physical Review B **94**, 201121(R) (2016).

[74] **Manipulation of electronic structure via alteration of local orbital environment in $[(SrIrO_3)_m, (SrTiO_3)]$ (m = 1, 2, and 8) superlattices**, S. Kim, C. Kim, L. Sandilands, C. Sohn, J. Matsuno, H. Takagi, K. Kim, Y. Lee, S. Moon, and T. Noh
Physical Review B **94**, 245113 (2016).

[75] **Model analysis of magnetic susceptibility of Sr_2IrO_4: A two-dimensional $J_{\mathrm{eff}} = \frac{1}{2}$ Heisenberg system with competing interlayer couplings**, T. Takayama, A. Matsumoto, G. Jackeli, and H. Takagi, Physical Review B **94**, 224420 (2016).

[76] **Zero-gap semiconductor to excitonic insulator transition in Ta_2NiSe_5**, Y. Lu, H. Kono, T. Larkin, A. Rost, T. Takayama, A. Boris, B. Keimer , and H. Takagi, Nature Communications **8**, 14408 (2017).

[77] **$S=\frac{1}{2}$ quantum critical spin ladders produced by orbital ordering in Ba_2CuTeO_6**, A. S. Gibbs, A. Yamamoto, A. N. Yaresko, K. S. Knight, H. Yasuoka, M. Majumder, M.Baenitz, P. J. Saines, J. R. Hester, D. Hashizume, A. Kondo, K. Kindo, and H. Takagi, Physical Review B **95**, 104428 (2017).

[78] **Metal-insulator transition and magnetic fluctuations in polycrystalline $Ru_{1-x}Rh_xP$ investigated by ^{3}1P NMR**, S. Li, Y. Kobayashi, M. Itoh, D. Hirai, and H. Takagi, Physical Review B **95**, 155137 (2017)

[79] **Long-range interactions in the effective low-energy Hamiltonian of Sr_2IrO_4: A core-to-core resonant inelastic x-ray scattering study**, S. Agrestini, C.-Y. Kuo, M. Moretti Sala, Z. Hu, D. Kasinathan, K.-T. Ko, P. Glatzel, M. Rossi, J.-D. Cafun, K. Kvashnina, A. Matsumoto, T. Takayama, H. Takagi, L. H. Tjeng, and M. Haverkort, Physical Review B **95**, 205123 (2017).

[80] **Giant exciton Fano resonance in quasi-one-dimensional Ta_2NiSe_5**, T. Agrestini, A. Yaresko, D. Prpper, K. Kikoin, Y.-F. Lu, T. Takayama, Y.-L. Mathis, A. Rost, H. Takagi, B. Keimer, and A. Boris
Physical Review B **95**, 195144 (2017).

[81] **Pulsed laser deposition for the synthesis of monolayer WSe_2**, A. Mohammed, H. Nakamura, P. Wochner, S. Ibrahimkutty, A. Schulz, K. Mller, U. Starke, B. Stuhlhofer, G. Cristiani, G. Logvenov, and H. Takagi, Appl. Phys. Lett. **111**, 073101 (2017).

[82] **Phosphide-Tetrahedrite $Ag_6Ge_10P_{12}$: Thermoelectric Performance of a Long-Forgotten Silver-Cluster Compound**, J. Nuss, U. Wedig, W. Xie, P. Yordanov, J. Bruin, R. Hbner, A. Weidenkaff, and H. Takagi, Chem. Mater. **29**, 6956 6965 (2017).

[83] **Ultrafast Electronic Band Gap Control in an Excitonic Insulator**, S. Mor, M. Herzog, D. Gole, P. Werner, M. Eckstein, N. Katayama, M. Nohara, H. Takagi, T. Mizokawa, C. Monney, and J. Sthler, Physical Review Lett. **119**, 086401 (2017).

[84] **Pressure tuning of bond-directional exchange interactions and magnetic frustration in the hyperhoneycomb iridate β-Li_2IrO_3**, L. Veiga, M. Etter, K. Glazyrin, F. Sun, C. Escanhoela, G. Fabbris, J. Mardegan, P. Malavi, Y. Deng, P. Stavropoulos, H.-Y. Kee, W. Yang, M. van Veenendaal, J. Schilling, T. Takayama, H. Takagi, and D. Haskel, Physical Review B **96**, 140402 (2017).

[85] **Solution of the heavily stacking faulted crystal structure of the honeycomb iridate $H_3LiIr_2O_6$**, S. Bette, T. Takayama, K. Kitagawa, R. Takano, H. Takagi, and R. Dinnebier, Dalton Transactions **46**, 15216 15227 (2017).

[86] **Pseudogap phase of cuprate superconductors confined by Fermi surface topology**, N. Doiron-Leyraud, O. Cyr-Choinire, S. Badoux, A. Ataei, C. Collignon, A. Gourgout, S. Dufour-Beausjour, F. Tafti, F. Lalibert, M.-E. Boulanger, M. Matusiak, D. Graf, M. Kim, J.-S. Zhou, N. Momono, T. Kurosawa, H. Takagi, and L. Taillefer, Nature Communications **8**, 2044 (2017).

[87] **Magnetism of the$A$-site ordered perovskites $CaCu_3Cr_4O_{12}$ and $LaCu_3Cr_4O_{12}$**, J. Sugiyama, H. Nozaki, I. Umegaki, K. Miwa, W. Higemoto, E. J. Ansaldo, J. H. Brewer, H. Sakurai, M. Isobe, H. Takagi, and M. Mnsson
Physical Review B **97**, 024416 (2018).

[88] **Pseudogap temperature T^* of cuprate superconductors from the Nernst effect** O. Cyr-Choinire, R. Daou, F. Lalibert, C. Collignon, S. Badoux, D. LeBoeuf, J. Chang, B. Ramshaw, D. Bonn, W. Hardy, R. Liang, J.-Q. Yan, J.-G. Cheng, J.-S. Zhou, J. Goodenough, S. Pyon, T. Takayama, H. Takagi, Y. Tanaka, N. Doiron-Leyraud, and L. Taillefer
Physical Review B **97**, 064502 (2018).

[89] **A spin-orbital-entangled quantum liquid on a honeycomb lattice**, K. Kitagawa, T. Takayama, Y. Matsumoto, A. Kato, R. Takano, Y. Kishimoto, S. Bette, R. Dinnebier, G. Jackeli, and H. Takagi, Nature **554**, 341345 (2018).

[90] **Charge disproportionation of mixed-valent Cr triggered by Bi lone-pair effect in the *A*-site-ordered perovskite $\mathbf{BiCu_3Cr_4O_{12}}$**, M. Etter, M. Isobe, H. Sakurai, A. Yaresko, R. E. Dinnebier, H.Takagi, Physical Review B **97**, 195111 (2018).

[91] **Coherent Order Parameter Oscillations in the Ground State of the Excitonic Insulator $\mathbf{Ta_2NiSe_5}$**, D. Werdehausen, T. Takayama, M. Hppner, G. Albrecht, A. W. Rost, Y. Lu, D. Manske, H. Takagi, and S. Kaiser, Sci. Adv. 2018; 4 :eaap86, 1 - 7 (2018).

[92] **Inhibition of the photoinduced structural phase transition in the excitonic insulator $\mathbf{Ta_2NiSe_5}$**, S. Mor, M. Herzog, J. Noack, N. Katayama, M. Nohara, H. Takagi, A. Trunschke, T. Mizokawa, C. Monney, and J. Sthler, Physical Review B **97**, 115154 (2018).

[93] **Neutron Scattering Length Determination by means of Total Scattering**, A. C. Hannon, A. S. Gibbs, and H. Takagi, Journal of Applied Crystallography **51**, 854-866 (2018).

[94] **Direct Observation of Orbital Hybridisation in a Cuprate Superconductor**, C. Matt, D. Sutter, A. Cook, Y. Sassa, M. Mnsson, O. Tjernberg, L. Das, M. Horio, D. Destraz, C. Fatuzzo, K. Hauser, M. Shi, M. Kobayashi, V. Strocov, T. Schmitt, P. Dudin, M. Hoesch, S. Pyon, T. Takayama, H. Takagi, O. Lipscombe, S. Hayden, T. Kurosawa, N. Momono, M. Oda, T. Neupert, and J. Chang Nature Communications **9**, 972 (2018).

[95] **Probing the $\mathbf{J_{\rm eff}=0}$ ground state and the Van Vleck paramagnetism of the $\mathbf{Ir^{5+}}$ ions in the layered $\mathbf{Sr_2Co_{0.5}Ir_{0.5}O_4}$**, S. Agrestini, C.-Y. Kuo, K. Chen, Y. Utsumi, D. Mikhailova, A. Rogalev, F. Wilhelm, T. Frster, A. Matsumoto, T. Takayama, H. Takagi, M. W. Haverkort, Z. Hu, and L. H. Tjeng, Physical Review B **97**, 214436 (2018).

[96] **Photo-excited Dynamics in the Excitonic Insulator $\mathbf{Ta_2NiSe_5}$**, D. Werdehausen, T. Takayama, G. Albrecht, Y. Lu, H. Takagi, and S. Kaiser, J. Phys.: Condens. Matter **30**, 305602 (2018).

[97] **Infrared phonon spectra of quasi-one-dimensional $\mathbf{Ta_2NiSe_5}$ and $\mathbf{Ta_2NiS_5}$**, T. I. Larkin, R. D. Dawson, M. Hppner, T. Takayama, M. Isobe, Y.-L. Mathis, H. Takagi, B. Keimer, and A. V. Boris, Physical Review B **98**, 125113 (2018).

[98] **Roles of carrier doping, band gap, and electron relaxation time in the Boltzmann transport calculations of a semiconductor's thermoelectric properties**, Y. Katsura, H. Takagi, and K. Kimura, Materials Transactions **59**, 1013 - 1021 (2018).

[99] **Direct observation of strain-induced orbital valence band splitting in $\mathbf{HfSe_2}$ by sodium intercalation**, T. Eknapakul, I. Fongkaew, S. Siriroj, W. Jindata, S. Chaiyachad, S.-K. Mo, S. Thakur, L. Petaccia, H. Takagi, S. Limpijumnong, and W. Meevasana, Physical Review B **97**, 201104(R) (2018).

[100] **Nature of the charge carriers in $\mathbf{LaAlO_3}$-$\mathbf{SrTiO_3}$ oxide heterostructures probed using hard X-ray photoelectron spectroscopy**, S. Mukherjee, B. Pal, I. Sarkar, A. van Roekeghem, W. Drube, H. Takagi, J. Matsuno, S. Biermann, and D. D. Sarma, Europhysics Letters **123**, 47003 (2018).

[101] **Magnetotransport in $\mathbf{Sr_3PbO}$ anti-perovskite with three-dimensional Dirac electrons**, S. Suetsugu, K. Hayama, A. W. Rost, J. Nuss, C. Mhle, J. Kim, K. Kitagawa, and H. Takagi, Physical Review B **98**, 115203 (2018).

[102] **Three-Dimensional Fermi Surface of Overdoped La-based Cuprates**, M. Horio, K. Hauser, Y. Sassa, Z. Mingazheva, D. Sutter, A. Cook, E. Nocerino, O. K. Forslund, M. Mnsson, O. Tjernberg, M. Kobayashi, V. Strocov, S. Pyon, T. Takayama, H. Takagi, O. J. Lipscombe, S. M. Hayden, T. Neupert, C. E. Matt, and J. Chang, Physical Review Lett., **121**, 077044 (2018).

[103] **Spin dynamics of coupled spin ladders near quantum criticality in $\mathbf{Ba_2CuTeO_6}$**, D. Macdougal, A.S. Gibbs, T. Ying, S. Weel, H. C. Walker, D. Voneshen, F. Mila, H. Takagi, and R. Coldea, Physical Review B **98**, 174410 (2018).

[104] **Photo-induced semimetallic states realised in electron-hole coupled insulators**, K. Okazaki, Y. Ogawa, T. Suzuki, T. Yamamoto, T. Someya, S. Michimae, M. Watanabe, Y. Lu, M. Nohara, H. Takagi, N. Katayama, H. Sawa, M. Fujisawa, T. Kanai, N. Ishii, J. Itatani, T. Mizokawa & S. Shin, Nature Communications **9**, 4322 (2018).

[105] **Monoclinic $SrIrO_3$ A Dirac semimetal produced by non-symmorphic symmetry and spin-orbit coupling**, T. Takayama, A. Yaresko, H. Takagi, Journal of Physics: Condensed Matter **31**, 074001 (2018).

[106] **Thermodynamic signatures of quantum criticality in cuprates**, B. Michon, C. Girod, S. Badoux, J. Kacmarck, Q. Ma, M. Dragomir, H. A. Dabgovska, B. D. Gaulin, J.-S. Zhou, S. Pyon, T. Takayama, H. Takagi, S. Verret, N. Doiron-Leyraud, C. Marcenat, L. Taillefer, T. Klein , Nature **567**, 218 - 222 (2019).

[107] **Long-range magnetic ordering in rocksalt-type high-entropy oxides**, M. P. Jimenez-Segura, T. Takayama, D. Brardan, A. Hoser, M. Reehuis, H. Takagi, and N. Dragoe, Appl. Phys. Lett. **114**, 122401 (2019).

[108] **Magnetic phase diagram of $K_2Cr_8O_{16}$ clarified by high-pressure muon spin spectroscopy**, O. K. Forslund, D. Andreica, Y. Sassa, H. Nozaki, I. Umegaki, E. Nocerino, V. Jonsson, O. Tjernberg, Z. Guguchia, Z. Shermadini, R. Khasanov, M. Isobe, H. Takagi, Y. Ueda, J. Sugiyama, and M. Mnsson, Scientific Reports **9**, 1141 (2019).

[109] **Pressure-induced collapse of the spin-orbital Mott state in the hyperhoneycomb iridate β-Li_2IrO_3**, T. Takayama, A. Krajewska, A. S. Gibbs, A. N. Yaresko, H. Ishii, H. Yamaoka, K. Ishii, N. Hiraoka, N. P. Funnell, C. L. Bull, and H. Takagi , Phys. Rev. B **99**, 125127 (2019).

[110] **Spin waves and spin-state transitions in a ruthenate high-temperature antiferromagnet**, H. Suzuki, H. Gretarsson, H. Ishikawa, K. Ueda, Z. Yang, H. Liu, H. Kim, D. Kukusta, A. Yaresko, M. Minola, J. A. Sears, S. Francoual, H.-C. Wille, J. Nuss, H. Takagi, B. J. Kim, G. Khaliullin, H. Yavas, and B. Keimer, Nature Materials **18**, 563 - 567 (2019).

[111] **Crystal structure and stacking faults in the layered honeycomb, delafossite-type materials $Ag_3LiIr_2O_6$ and $Ag_3LiRu_2O_6$**, S. Bette, T. Takayama, V. Duppel, A. Poulain, H. Takagi, R. E. Dinnebier, Dalton Transactions **48**, 9250 - 9259 (2019).

[112] **Black Current: Structure, Characterization, and Optoelectronic Properties of $Ce_3Cl_3[MoO_6]$**, K. V. Dorn, B. Blaschkowski, H. Bamberger, J. van Slageren, K. Doll, R. Claus, Y. Matsumoto, H. Takagi, and I. Hartenbach, Chem. Eur. J. **25**, 7921 - 7926 (2019).

[113] **Giant thermal Hall conductivity in the pseudogap phase of cuprate superconductors**, G. Grissonnanche, A. Legros, S. Badoux, E. Lefranois, V. Zatko, M. Lizaire, F. Lalibert, A. Gourgout, J.-S. Zhou, S. Pyon, T. Takayama, H. Takagi, S. Ono, N. Doiron-Leyraud, and L. Taillefer, Nature **571**, 376 - 380 (2019).

[114] **Ordering of hidden multipoles in spin-orbit entangled $5d^1$ Ta chlorides**, H. Ishikawa, T. Takayama, R. K. Kremer, J. Nuss, R. Dinnebier, K. Kitagawa, K. Ishii, and H. Takagi, Phys. Rev. B **100**, 045142 (2019).

[115] **Pressure-induced structural dimerization in the hyperhoneycomb iridate β-Li_2IrO_3 at low temperatures**, L. S. I. Veiga, K. Glazyrin, G. Fabbris, C. D. Dashwood, J. G. Vale, H. Park, M. Etter, T. Irifune, S. Pascarelli, D. F. McMorrow, T. Takayama, H. Takagi, and D. Haskel, Phys. Rev. B. **100**, 064104 (2019).

< Conference Proceedings >

[116] **Concept and realization of Kitaev Quantum Spin Liquids**
H. Takagi, T. Takayama, G. Jackeli, G. Khaliullin, and S. N. Nagler
Nature Reviews Physics **1**, 264 - 280 (2019).

< Review Papers >

< **Books** >

< **Patent Aplications** >

7 Invited Presentations at International Conferences

[1] **Spin-orbit coupling, electron correlations and exotic magnetic couplings in 5*d* Ir oxides**, H. Takagi, APS Spring meeting, Boston, USA, 27/02/2012.

[2] **Spin-orbit coupling, electron correlations and exotic magnetic couplings in 5*d* Ir oxides**, H. Takagi, KJT12 meeting om strongly correlated electron systems, Kao Sienmg 16/03/2012.

[3] **Emergent phases of correlated electrons in transition metal oxides**, H. Takagi, Joint Colloquium National Tawain University, Taiwan, 10/04/2012.

[4] **YBCO, spin gap, pseudo-gap and Nano-stripe as a hidden order - progress in 25 years**, H. Takagi, mini-symposium on "25 years after YBCO, what has it done for science and society?" Hua Lieng, Taiwan, 12/04/2012.

[5] **Emergent phases of correlated electrons in transition metal oxides**, (Workshop Colloquium), H. Takagi, International Workshop on Itinerant Spin-Orbital Systems: From Magnetic Frustration to novel Superconductivity, Dresden, Germany, 22/05/2012.

[6] **Electronic Phase Change and Entropic Functions in Transition Metal Oxides**, H. Takagi and Seiji Niitaka, Nature Conference on Frontiers in Electronic Materials: Correlation Effects and Memristive Phenomena, Aachen, Germany, 18/06/2012.

[7] **Imaging the emergence of the pseudo-gap state in a lightly hole-doped Mott insulator $\mathbf{Ca_{2-x}Na_xCuO_2Cl_2}$**, H. Takagi, International Seminar and Workshop on Quantum Matter from the Nano- to the Macroscale, Dresden, Germany, 21/06/2012.

[8] **Materials Physics View on New Superconductors**, (Plenary), H. Takagi, International Conference on Materials and Mechanisms of Superconductivity (M2S), Washington DC, USA 31/07/2012.

[9] **An overview of quantum spin liquid: from toy of theorists to reality**, H. Takagi, Innovations in Strongly Correlated Electron Systems: School and Workshop, Trieste, Italy 06/08/2102.

[10] **Discovery of Superconductivity in 4*d* and 5*d* transition metal compounds**, H. Takagi, International Symposium on Physics and Chemistry of Novel Superconductors and Related Materials, Okayama, Japan, 01/10/ 2012.

[11] **Materials overview**, H. Takagi, Exotic Phase of Frustrated Magnetics, Santa Barbara, USA, 08/10/2012.

[12] **Emergent pseudo-gap phase in lightly doped high-Tc cuprate**, H. Takagi, Discussion meeting on new functionalities in electronic and magnetic materials, Bangalore, India, 19/10/2012.

[13] **Emergent phases of correlated electrons in transition metal oxides**, H. Takagi, Summit of Material Science (Material Science Week), Sendai, Japan, 28/11/2012.

[14] **Search for new superconductor in the iron age dream, reality & our struggle**, Gordon conference on superconductivity, Les Diablerets, Switzerland, 12/05/2013/5.

[15] **New 5*d* & 4*d* oxides and chalcogenides: From exotic magnet, excitonic insulator to superconductor**, H. Takagi, Telluride conference, Telluride, CO, USA, 16/07/2013.

[16] **Novel 5*d* compounds: From exotic magnet, excitonic insulator to superconductor**, H.Takagi, MPI-PKS on Spin Orbit Entanglement: Exotic States of Quantum Matter in Electronic Systems, Dresden, Germany, 26/7/2013.

[17] **Phase Change Functions in Correlated Transition Metal Oxides**, H. Takagi, ICAM workshop on Digital Design of Materials-The Way Forward for Materials Science?, Boston, MA, USA, 27/09/2013.

[18] **Phase sensitive Imaging of Complex Electrons in High-Tc Superconductors**, H. Takagi, Otto Hahn lecture, University of Hamburg, Hamburg, Germany, 17/12/2013.

[19] **Exotic electronic phases derived from semi-metals**, (Plenary), H. Takagi, KJT workshop on Spectroscopy of Quantum Materials (QMS), Muju, Korea 24/02/2014.

[20] **Exotic magnetism of $\mathbf{J}_{\text{eff}} = \frac{1}{2}$ iso-spins in complex Ir oxides**, H. Takagi, APS March Meeting, Denver, CO, USA, 04/03/2014

[21] **Spin-orbit coupling induced exotic phases in complex Ir oxides: From quantum spin liquid to semimetal**, Japan-Indo WS, Tokyo, Japan, 24/03/2014.

[22] **Exotic magnetism of $\mathbf{J}_{\text{eff}} = \frac{1}{2}$ iso-spins in complex Ir oxides**, H. Takagi, DPG Dresden, Germany, 02/04/2014.

[23] **Exotic magnetism produced by strong spin-orbit coupling in complex Ir oxides**, H. Takagi, Workshop on Correlated oxides & oxide interfaces, Minneapolis, USA, 02/05/2014.

[24] **Spin-orbit coupling and electron correlations - exotic magnetism of $\mathbf{J}_{\text{eff}} = \frac{1}{2}$ iso-spins in complex Ir oxides**, (Plenary), H. Takagi, The 13th International Conference on Muon Spin Rotation, Relaxation and Resonance, μSR 2014, Grindelwald, Switzerland, 03/06/2014.

[25] **Novel electronic phases produced by strong spin-orbit coupling in complex Ir oxides**, H. Takagi, Gordon Research Conference on Correlated Electron Systems, Mount Holyoke, MA, USA, 23/06/2014.

[26] **Exotic magnetism of $\mathbf{J}_{\text{eff}} = \frac{1}{2}$ iso-spins in complex Ir oxides**, H. Takagi, SCES, Grenoble, France, 08/07/2014

[27] **Materializing exotic phases of complex Ir oxides**, H. Takagi, Summer school on " Topological Aspects of Condensed Matter Physics " , Ecole de Physique des Houches, Les Houches, France, 12/08/2014.

[28] **Exotic magnetism produced by strong spin-orbit coupling in complex Ir oxides**, H.Takagi, Research Frontier of Transition-metal Compounds Opened by Advanced Spectroscopies IMR workshop on Research Frontier of Transition-metal Compounds Opened by Advanced Spectroscopies, Sendai, Japan 02/10/2014.

[29] **Personal perspectives on oxide research**, H. Takagi, International Workshop on "Single Crystals: growth and physico-chemical properties", Orsay, France, 18/12/2014.

[30] **3D Dirac electrons in anti-perovskite $\mathbf{Sr_3PbO}$**, H. Takagi, Dirac Electrons in Solids, Tokyo, Japan, 14/01/2015.

[31] **Strong spin-orbit coupling meets with honeycomb physics in complex Ir oxides**, H. Takagi, TKJ Workshop on strongly correlated electron systems, Hshinchu, Taiwan, 28/03/2015

[32] **Exploring new superconductor in the vicinity of an electronic order**, H. Takagi, UK-Japan Cambridge workshop, Cambridge, UK, 14/04/2015.

[33] **Strong spin-orbit coupling meets with honeycomb physics in complex Ir oxides**, H. Takagi, Correlated Oxides Conference, Ohio, USA, 04/05/2015.

[34] **Newly discovered superconducting materials**, H. Takagi, Gordon Research Confererence Hongkong, 24/05/2015.

[35] **$5d$ transition metal oxide and chalcogenides correlated Dirac electrons, excitonic state and superconductivity**, H. Takagi, Telluride, CO, USA, 15/06/2015.

[36] **Correlated electron research in Germany**, H. Takagi, Workshop on Soft Condensed Matter Physics, Shonan Village, Japan 04/07/2015.

[37] **Materials Overview**, H. Takagi, Novel States in Spin-Orbit Coupled Quantum Matter Conference, KITP Santa Barbara, USA, 31/07/2015.

[38] **From correlated Dirac electrons to spin liquid in complex Ir oxides**, H. Takagi, School and Workshop on Strongly Correlated Electronic Systems Novel Materials and Novel Theories (smr 2705), Trieste, Italy, 17/08/2015.

[39] **Synthesis of novel SC**, H. Takagi, 11th International Conference on Materials and Mechanisms in Superconductivity (M2S-XI), Geneva, Switzerland, 26/08/2015.

[40] **Exotic electronic states produced by strong spin-orbit coupling in complex Ir oxides**, H. Takagi, BIRS, Strongly interacting topological phases, Banff, Canada, 23/09/2015.

[41] **Spin-orbit coupling and electron correlations in complex 5*d* Ir oxides**, (Plenary), H. Takagi, Korrelationstage 2015 Dresden, Germany, 28/09/2015.

[42] **Control of dimensionality and carrier concentration in Dirac-node semimetal $SrIrO_3$ using super-lattice structure**, H. Takagi, JKT16-workshop on correlated electron systems, Tokyo, Japan, 20/02/2016.

[43] **From Kitaev spin liquid to Dirac-node semimetal spin-orbit coupling induced electronic phases in complex Ir oxides**, H. Takagi, Workshop " Topmat16 ", MPI for Physics of Complex Systems, Dresden, Germany, 03/03/2016.

[44] **Engineering correlated Dirac electrons in $SrIrO_3/SrTiO_3$ superlattice**, H. Takagi, MRS Spring Meeting 2016, Phoenix, Arizona, USA, 30/03/2016.

[45] **Electronic Phase Change and Entropic Functions in Transition Metal Oxides**, H. Takagi, MRS Spring Meeting 2016, Phoenix, Arizona, USA, 31/03/2016.

[46] **Quantum spin liquid state in honeycomb-based complex iridium oxides**, H. Takagi, Gordon Research Conference on Correlated Electron Systems, Mount Holyoke, USA, 26/06/2016.

[47] **Chemistry and physics of complex iridium oxides**, H. Takagi, International Symposium on Structure-Property Relationship in Solid Materials-2016, Nantes, France, 04/07/2016.

[48] **Exploring the signature of Kitaev spin liquid in complex iridium oxides with honeycomb-related structure**, H.Takagi, Condensed Matter Physics in the City 2016, London, UK, 12/07/2016.

[49] **Exotic magnetism produced by strong spin-orbit coupling in complex Ir oxides**, H.Takagi, Swiss Physical Society Meeting, Lugano, Switzerland, 24/08/2016.

[50] **Strong spin-orbit coupling and exotic magnetism in complex Ir oxides**, (Plenary), H. Takagi, 8th International Conference on Highly Frustrated Magnetism, Taipei, Taiwan, 10/09/2016.

[51] **Spin-orbit coupling meets with electron correlations a guided tour to exotic electronic states of 5*d* transition metal oxides**, H. Takagi, 2nd PKU-IMPRS Joint Workshop on Condensed Matter Science, Beijing, PR China, 14/11/2016.

[52] **Spin-orbit coupling meets with electron correlations a guided tour to exotic electronic states of 5*d* transition metal oxides**, H. Takagi, Material Physics, 5 years of IBS, Daejeon, Korea, 17/11/2016.

[53] **Quantum Liquid state of $J_{\mathrm{eff}} = \frac{1}{2}$ isospins**, H. Takagi, 17th Korea-Taiwan-Japan Workshop on Strongly Correlated Electron Systems, Yongpyong Resort, Korea, 18/02/2017.

[54] **Correlated Topological Phases in Complex Ir Oxides**, H.Takagi, International Conference on Topological Materials Science 2017 (TopoMat2017)", Tokyo Institute of Technology, Tokyo, Japan, from May 9 to 13, 2017.

[55] **Quantum Liquid state of $J_{\mathrm{eff}} = \frac{1}{2}$ isospins in complex Ir oxides**, H. Takagi, SPICE workshop Mainz, Germany, 07/06/2017.

[56] **Correlated Topological Phases in Complex Ir Oxides**, H.Takagi, Gordon Research Conference on "Topological & Correlated Matter: From Fundamentals to New Discoveries", Hong Kong University of Science and Technology, China, 20/06/2017.

[57] **Topological quantum spin liquid - "Zen" world**, H. Takagi, Competing Interactions and Colossal Responses in Transition Metal Compounds, Telluride Intermediate School, Telluride, USA, 30/06/2017.

[58] **Quantum Liquid state of $\mathbf{J}_{\text{eff}} = \frac{1}{2}$ isospins in complex Ir oxides**, H. Takagi, Beyond! Topology and Materials - at Ringberg Castle, Kreuth, Germany, 10/07/2017.

[59] **Engineering correlated Dirac electrons in $\mathbf{SrIrO_3/SrTiO_3}$ superlattice**, H. Takagi, Symposium on the epitaxy of complex oxides, 21st American Conference on Crystal Growth and Epitaxy (ACCGE-21), Santa Fe, USA, 01/08/2017.

[60] **Spin-orbital entangled quantum spin liquid on honeycomb lattice**, H.Takagi, KITP conference on " Order, Fluctuations, and Strong Correlations: New Platforms and Developments " , KITP, University of California Santa Barbara, Santa Barbara, USA, 03/08/2017.

[61] **Quantum Liquid state of $\mathbf{J}_{\text{eff}} = \frac{1}{2}$ isospins in complex Ir oxides**, (Half-Plenary), H. Takagi, 28th International Conference on Low Temperature Physics, Gothenburg, Sweden, 12/08/2017.

[62] **Zero-gap semiconductor to excitonic insulator transition in $\mathbf{Ta_2NiSe_5}$**, H. Takgi, European Materials Research Society (E-MRS) Fall Meeting, Warsaw, Poland, 18/09/2017.

[63] **Quantum Liquid state of $\mathbf{J}_{\text{eff}} = \frac{1}{2}$ isospins in complex Ir oxides**, H. Takagi, Junjiro Kanamori Memorial International Symposium New Horizon of Magnetism, Koshiba Hall, The University of Tokyo, Tokyo, Japan, 27/09/2017.

[64] **Spin-orbit coupling meets with electron correlations - A guided tour to complex iridium oxides**, H. Takagi, Solid State Chemistry Meeting, Nagoya, Japan, 11/11/2017.

[65] **Spin-orbital entangled quantum liquid on honeycomb lattice**, H. Takagi, High Temperature Superconductivity Unifying Themes in Diverse Materials, Aspen Winter Conference, Aspen Colorado, USA, 16/01/2018.

[66] **Exotic spin-orbital entangled state in $4d$ and $5d$ transition metal oxides - beyond $\mathbf{J}_{\text{eff}} = \frac{1}{2}$ physics**, H. Takagi, TJK Kenting, 22/02/2018.

[67] **Interplay of spin-orbit coupling and electron correlations in $4d$ and $5d$ transition metal oxides**, H. Takagi, 5th International Workshop on Complex Oxides, Capri, Italy, 22/05/2018.

[68] **Spin-orbital entangled quantum liquid in $\mathbf{H_3LiIr_2O_6}$**, H. Takagi, Trends in Quantum Magnetism, WE Heraeus Seminar, Bad Honnef, 05/06/2018.

[69] **When spins and charges feel frustrated...**, H. Takagi, Symposium "Innovation and Creativity in Science", Zrich, Switzerland, 8/06/2018.

[70] **Liquid and solid states of spin orbital entangled matter in $4d$ and $5d$ transition metal oxides**, H. Takagi, Telluride workshop on Enhanced Functionalities in 4 and 5d Containing Material from Large Spin-Orbit Coupling, Telluride, USA, 28/06/2018.

[71] **Spin-orbital quantum liquid on honeycomb lattice**, H. Takagi, TEMM2018, Oxford, UK, 24/07/2018.

[72] **Qunatum Spin Liquid**, H. Takagi, Advanced School and Workshop on Correlations in Electron Systems: from Quantum Criticality to Topology, ICTP, Trieste, Italy, 15/08/2018.

[73] **Excitonic transition (and $q = 0$ CDW) in $\mathbf{Ta_2NiSe_5}$**, H. Takagi, E-MRS meeting, Warsaw, Poland, 18/09/2018.

[74] **Exploring novel quantum phases in $5d$ transition metal oxides**, H. Takagi, CIFAR meeting on quantum materials, Toronto, Canada, 19/11/2018.

[75] **Exotic Phase of spin-orbital entangled matter**, H. Takagi, MPI-UBC-UTokyo workshop, Tokyo, Japan, 10/12/2018.

[76] **Exotic Phase of spin-orbital entangled matter**, H. Takagi, MPI-UBC-UTokyo workshop, Tokyo, Japan, 10/12/2018.

[77] **Excitonic Transition in the layered chalcogenide Ta_2NiSe_5**, H. Takagi, JKT 2019, Waseda, Japan, 12/01/2019.

[78] **A spinorbital-entangled quantum liquid on a honeycomb lattice**, H. Takagi, APS March Meeting 2019, Boston, USA, 07/03/2019.

[79] **Exotic spin-orbital entangled phases on honeycomb lattice**, H. Takagi, PCTS conference, " Strongly Correlated Systems & Interactions in Quantum Matter " , Princeton, USA, 27/04/2019.

[80] **Exotic spin-orbital entangled phases in 4d and 5d transition metal oxides**, H. Takagi, Conference on Strongly Correlated Quantum Materials, Santa Fe, USA, 30/04/2019.

[81] **Exotic spin-orbital entangled phases in 4d and 5d transition metal oxides**, H.Takagi, Workshop "Low-dimensional emergent phenomena in correlated systems and topological quantum matter", Tbilisi, Georgia, 02/06/2019.

[82] **Exotic spin-orbital entangled phases in 4d and 5d transition metal oxides**, H. Takagi, MPI-PKS Workshop "Quantum Criticality and Topology in Correlated Electron Systems", Dresden, Germany, 05-09.08.2019

[83] **Exotic spin-orbital entangled phases in 5d and 4d transition metal oxides**, H. Takagi, 26th Int. Workshop on Oxide Electronics (iWOE 26), Kyoto, Japan, 29.09.-02.10.2019.

[84] **Giant orbital diamagnetism of three-dimensional Dirac electrons in Sr_3PbO antiperovskite**, H. Takagi, ICTP workshop, Trieste, Italy, 21/10/2019.

8 Teaching Accomlishments

Under my supervision, 5 students had completed PhD during the period of 2012−2018 and 2 students are completing in FY 2019. Among the 5 PhDs completed, 3 PhDs are currently working as an assistant professor at university (Tokyo, Tohoku and TIT) 2 PhDs are working in industry (Bridgeston and SAPIX).

I have been appoited jointly between University of Tokyo and Max Planck Institute in Germany since 2013 and paid an effort in establishing MPI(Max Planck)-UBC(Univ. British Columbia)-UTokyo center for qunatum materials. (Tokyo joined on-going and successful program between MPI and UBC in 2017). In addition to the exchange of Postdocs and Graduate students, the program also promotes the internship for undergraduate students. 6 undergraduate students had spent 5 months (2 semesters) as the course "special experiment" at MPI. So far, all the students very much appreciate their experience of working a reserach project in abroad. In 2020, the lecture course "material science" given by MPI directors in volved in the center (including myself) will launch.

9 Contribution to Academic Community

9.1 Editorial Activities

9.2 Organization of Professional Societies

9.3 Organization and Adcisory of Conferences

Organized workshop/conference

- Workshop on "strong correlations" in 2012, 2015, 2018 at International Center of Theoretical Physics, Trieste, Italy.
- MPI/TMS joint workshop on topological material science 2017.
- Core to core workshop on solid state chemistry 2016.
- Japan/Korea/Taiwan (JKT) workshop on correlated electron systems 2016.
- Chair of Gordon conference on correlations and topology 2021 (elected).

Served as a member of international advisory and/or as a member of program committee

- International Conference on Low temperature Physics (2008, 2011 and 2014).
- International Conference on Materials and Mechanisms of Superconductivity (2012, 2015 and 2018).
- International Conference on Strongly Correlated Electron Systems (SCES) (2007 − every year).

- Spectroscopy of Novel Superconductors (SNS) 2016 and 2019.

- Highly Frustrated Magnetism (HFM) 2016, 2018 and 2020.

10 Outreach

Public lecture on "Superconducting technology to protect environment of our earth" 2017 Symposium on life, Tokyo. The same lecture will be delivered at the public lecture of International conference on low temperature physics in 2020.

11 Committee service

11.1 External Committees

- Member of International Advisory Committee, Canadian Institute for Advanced

- Research (CIFAR), Canada 2008 − 2019

- Member of International Advisory Committee, ARC Center of excellence in Future

- Low Energy Electronics Technologies (FLEET), Australia 2017 −

- ESF College of Expert Reviewers 2018 −

- a member of Institute Review for Johns Hopkins Institute for Quantum Matter, Johns Hopkins University (2013)

- a member of Institute Review for ISSP, University of Tokyo (2016)

- a member of Institute Review for RIKEN Nishina center (2016 and 2018)

- a member of Institute Review for Forschungszentrum Jlich (2017)

- a member of Institute Review for RIKEN Spring-8 (2017)

- a member of Institute Review for IMR Tohoku University (2018)

11.2 University Committees

A member of admission committe, graduate school program "MERIT" 2013 − 2019
ISSP advisory committee 2012 − 2014
Cryogenic center advisory committe 2013 − 2015
Played a leading role in establishing MPI(Max Planck)-UBC(Univ. British Columbia)-UTokyo center for qunatum materials (2017 −)

Internationalization Statistics

		Number	Country
Foreign students advised			
UBC3 SNU1	Bachelor Course	4	Canada, Korea
Nieman, Shinatani	Master Course	2	Germany
Marian	Doctor Course	1	Germany
Foreign researchers hosted		6	UK, Germany, India
Gibbs, Rost, Mayuk, Jackeli, Nuss, Ishikawa			
Students sent abroad		10	Germany
B8 D2			
Researchers sent abroad		3	Germany, USA
Hirai, Ohta, Kitagawa			
Foreign visitors		40	Germany, Canada,
UBC, KJT, etc.			UK, France, USA,
			Korea, Taiwan

General Physics

Mio Murao、村尾 美緒

1 Education and Professional Experiences

Education

1991	B.S. (Physics)	Ochanomizu University
1993	MSc. (Physics)	Ochanomizu University
1996	Ph.D. (Physics)	Ochanomizu University

Professional Appointments

1996	Postdoctoral Research Fellow	Harvard University
1996−1998	JSPS Postdoctoral Fellow for Research Abroad	Imperial College, London
1998−1999	EPSRC Research Associate	Imperial College, London
1999−2001	Special Postdoctoral Researcher	RIKEN
2003−2007	PRESTO Researcher (Joint position)	JST
2004−2012	Visiting Associate Professor	National Institute of Informatics
2001−2015	Associate Professor of Physics	The University of Tokyo
2007−2015	Associate Professor of NanoQuine (Joint position)	The University of Tokyo
2015−2016	Professor of NanoQuine (Joint position)	The University of Tokyo
2015−	Professor of Physics	The University of Tokyo

2 Research Highlights

Quantum information processing seeks to perform tasks which are impossible or not efficient with the use of conventional *classical* information, by using *quantum* information described by quantum mechanical states. Quantum computation, quantum cryptography, and quantum communications have been extensively studied in this context over the last 25 years. The ultimate goal of the field is to understand how and why quantum information processing outperforms the classical counterpart and also what is the fundamental limit of information processing allowed under quantum mechanics. In our group, we have been working on theoretical approaches to quantum information for the last 18 years. We have been covered a wide range of topics, namely, entanglement theory [1, 5, 8, 10, 15, 18, 30, 40, 45] quantum information processing in general probabilistic theory [2, 11], quantum information theory [25, 33, 36, 37, 41], distributed quantum computation [6, 19, 38, 42, 44, 46, 47, 50], quantum algorithms [3, 12, 22, 23, 24, 27, 29, 35, 48, 49, 53], measurement theory [3, 4, 13], contextuality in quantum mechanics [14, 16, 17, 20, 21, 31], quantum thermodynamics [28], Bell non-locality and EPR steering [34, 39, 43], measurement-based quantum computation [7, 9, 26], quantum network coding [32, 62, 63, 64], quantum control theory [51] and quantum certification [52] (the reference numbers correspond to the numbers shown in Publications and Patents). In the following, I have selected some of the highlights of the research results we have obtained since 2012.

1. *Quantum algorithms and protocols*: Advantages of quantum computation appear only when the algorithms exploit quantum properties such as coherent superposition of states and entanglement, otherwise they can be simulated by classical computation. Finding the tasks where quantum computation has advantages is highly nontrivial, as is finding the algorithms or protocols to solve these tasks. We focused on seeking tasks with quantum inputs and outputs rather than solving classical computational problems using quantum computers and we discovered a wide range of new tasks and their solutions in the past 7 years [3, 12, 13, 24, 27, 29, 32, 35, 48, 49, 51, 53]. Among them, the following protocol and algorithms are especially noteworthy.

   - A quantum protocol for precision-guaranteed parameter estimation of quantum states with finite samples [13].
   - A quantum algorithm for performing a projective measurement on the energy eigenbasis for a quantum system with *unknown* Hamiltonian [27].
   - Universal algorithms to transform an *unknown* unitary operation to its conjugated unitary operation [48], transposed and inverted unitary operations [53] by calling the unitary operation multiple times without identifying the unknown unitary operation.

2. *Distributed quantum information processing*: Distributed quantum information processing is a network of quantum operations distributed in space and time to perform non-local quantum operations between spatially separated parties. Connections in the network can be regarded as consisting of two types of resource, one type is quantum but static, entanglement, creating non-local correlation between different spaces, and the other type is classical but time-ordered, classical communication, classically connecting spacetime. On one hand, from a computational perspective, reducing the cost of these resources is essential for efficient distributed quantum computation. On the other hand, from a physical perspective, the analysis of such resources provides a novel understanding of the properties of space (memory size) and time (depth of gates) in terms of quantum information processing. We have analyzed distributed quantum information processing in a wide range of settings [6, 19, 26, 32, 33, 36, 40, 42, 45, 46, 47, 50]. In particular I select these works to illustrate the opening of new research directions in quantum information.

   - Presenting network coding for quantum computation over butterfly and cluster networks [32].
   - Presenting a tradeoff relationship between the complexity of the causal order structure and entanglement in distributed implementation of a class of two-qubit unitary gates for the first time in an asymptotic scenario [50].

3 Selected Papers

- T. Sugiyama, P. S. Turner and M. Murao, *"Precision-guaranteed quantum tomography"*, Phys. Lev. Lett. 111, 160406 (2013):

This paper presents a new method for evaluating the accuracy of quantum measurements for finite samples. It was selected as an Editors' suggestion in Phys. Rev. Lett.

- S. Nakayama, A. Soeda and M. Murao, *"Quantum algorithm for universal implementation of projective measurement of energy",* Phys. Rev. Lett. 114, 190501 (2015):
This paper presents a new quantum algorithm to perform projective measurement of energy for an unknown Hamiltonian system without calculating eigenstates.

- S. Akibue and M. Murao, *"Network coding for distributed quantum computation over cluster and butterfly networks"*, IEEE Trans. Inf. Theory 62, 6620 - 6637 (2016):
This paper presented efficient quantum network coding for implementing non-local operations over butterfly and cluster networks.

- E. Wakakuwa, A. Soeda and M. Murao, *"Complexity of causal order structure in distributed quantum information processing: More rounds of classical communication reduce entanglement cost"*, Phys. Rev. Lett. 122, 190502 (2019):
This paper reveals a new counterintuitive property of quantum information processing distributed in space and time in terms of a tradeoff between entanglement and complexity of the causal structure of quantum operations.

- M. T. Quintino, X. Dong, A. Shimbo, A. Soeda and M. Murao, *"Reversing unknown quantum transformations: A universal protocol for inverting general unitary operations"*, accepted for publication in Phys. Rev. Lett. (2019):
This paper presents higher order quantum operations, a novel concept for developing functional quantum programming. This work has been selected as a talk at Quantum Information Processing 2020, which is one of the top conferences in the field of quantum information and very competitive to get a talk.

4 Research Plan

The ultimate goal of my research is to understand how and why quantum information processing outperforms the classical counterpart and also what is the fundamental limit of information processing allowed under quantum mechanics by improving our understanding of quantum mechanics from the viewpoint of information. We consider that a quantum computer is not just a machine to run computational algorithms but also a machine to perform any operations allowed by quantum mechanics. We analyze what kinds of new properties and effects may appear in a quantum system from an operational point of view and propose new applications and algorithms for information processing, communication, precise measurement, and quantum state control. In particular, we mainly focus on the following topics related to higher order quantum operations as we are supported by the MEXT Quantum Leap Flagship Program to develop quantum softwares using higher order quantum operations for the next 4-9 years.

1. *Toward quantum functional programming*: We had proposed the idea of higher order quantum operations, which implement supermaps, maps of maps, using universal quantum circuits and calling the input map multiple times. Supermaps of unitary operations are basic

building blocks for functional quantum programming, but it is also shown that many useful supermaps are not implementable by quantum mechanics if the input map is called only once. We had a breakthrough for this no-go theorem by restricting the maps to be unitary operations and calling the same unitary operations multiple times. Currently, we have only discovered algorithms to implement conjugation, transposition, and inversion of the unitary operations and controllization of divisible unitary operations. Important future steps are to find out other useful supermaps of unitary operations implementable in a quantum circuit and to exhibit usefulness of functional quantum programming using implementable supermaps. It would be interesting to explore the use of controlled-supermaps in functional quantum programming.

2. *Quantum programmable materials*: We apply the idea of higher order quantum operations to quantum process processors, which transforms a given Hamiltonian to another Hamiltonian. Such transformation of Hamiltonians is useful for Hamiltonian simulations with limited power of quantum computers and also robust control of Hamiltonians to implement desired unitary operations irrespective of unknown parameters in the Hamiltonian. Applications to many-body Hamiltonian systems should be also considered, which will lead to design quantum programmable materials, materials with flexible functionality depending on the higher order quantum operation. Another possible application will be a programmable quantum sensor or a tester to perform quantum measurements on a quantum process with a built-in quantum computer, which directly calculating a function without revealing unnecessary classical information about the process.

3. *Indefinite causal order in higher order quantum operations*: The causal order structure of the multiple uses of unitary operations affects the performance of higher order quantum operations. In addition to the parallel and sequential (adoptive) structures, we have started investigating the indefinite causal order structure, which has been recently extensively studied in possible connection with quantum gravity. In our study of the universal inversion algorithm of unitary operations, we show that the indefinite causal order structure improves the implementability of the supermap. However, the properties of the indefinite causal order structure in the case of multiple calls of the same unitary operations have not been well understood yet. Therefore, we proceed with our study for characterizing higher order quantum operations implementable with indefinite causal order.

5 Publications and Patents

< Refereed Original Papers >

[1] Y. Nakata, P. S. Turner and M. Murao, *"Phase-random states: ensembles of states with fixed amplitudes and uniformly distributed phases in a fixed basis"*, Phys. Rev. A **86**, 012301 (2012).

[2] E. Wakakuwa and M. Murao, *"The chain rule implies Tsirelson's bound: an approach from generalized mutual information"*, New J. of Phys. **14**, 113037 (2012).

[3] T. Sugiyama, P. S. Turner, M. Murao, *"Adaptive experimental design for one-qubit state estimation with finite data based on a statistical update criterion"*, Phys. Rev. A **85**, 052107 (2012).

[4] T. Sugiyama, P. S. Turner, and M. Murao, *Effect of non-negativity on estimation errors in one-qubit state tomography with finite data"*, New J. Phys. 14, 085005 (2012).

[5] J. Hide, Y. Nakata, M. Murao, *"Entanglement and the Interplay between Staggered Fields and Couplings"*, Phys. Rev. A **85**, 042303, (2012).

[6] A. Soeda and M. Murao, *"Comparing globalness of bipartite unitary operations acting on quantum information: delocalization power, entanglement cost, and entangling power"*, Math. Struct. Comp. Science **23**, 454 (2013).

[7] K. Fujii, Y. Nakata, M. Ohzeki and M. Murao, *"Measurement-Based Quantum Computation on Symmetry Breaking Thermal States"*, Phys. Rev. Lett. **110**, 120502 (2013). selected as an Editors' suggestion.

[8] M. Hajdušek and M. Murao, *"Direct evaluation of pure graph state entanglement"*, New J. Phys. **15**, 013039 (2013).

[9] D. Markham, J. Anders, M. Hajdušek and V. Vedral, *"Topological features of good resources for measurement-based quantum computation"*, Math. Struc. Comp. Sci. **23**, 441 (2013).

[10] T. Eberle, V. Haendchen, J. Duhme, T. Franz, F. Furrer, R. Schnabel and R. F. Werner, *"Gaussian Entanglement for Quantum Key Distribution from a Single-Mode Squeezing Source"*, New J. Phys. **15**, 053049 (2013).

[11] . A. J. P. Garner, O. C. O. Dahlsten, Y. Nakata, M. Murao and V. Vedral, *"A general framework for phase and interference"*, New J. Phys. **15**, 093044 (2013).

[12] . Y. Nakata and M. Murao, *"Diagonal-unitary 2-designs and their implementations by quantum circuits"*, International . Journal of Quantum Information **11**, 1350062 (2013).

[13] . T. Sugiyama, P. S. Turner, and M. Murao, *"Precision-guaranteed quantum tomography"*, Phys. Rev. Lett. **111**, 160406 (2013), selected as an Editors' suggestion.

[14] A. Soeda, P. Kurzyński, R. Ramanathan, A. Grudka, J. Thompson, and D. Kaszlikowski, *"On the problem of contextuality in macroscopic magnetization measurements"*, Phys. Lett. A **377**, 2856 (2013).

[15] S.-Y. Lee, J. Thompson, P. Kurzyński, A. Soeda, and D. Kaszlikowski,*"Coherent states of composite bosons"*, Phys. Rev. A **88**, 063602 (2013).

[16] P. Kurzyński, A. Soeda, J. Thompson, and D. Kaszlikowski, *"Contextuality in Bosonic Bunching"*, Phys. Rev. Lett. **112**, 020403 (2014).

[17] M. Markiewicz, P. Kurzyński, J. Thompson, S.-Y. Lee, A. Soeda, T. Paterek, and D. Kaszlikowski, *"Unified approach to contextuality, nonlocality, and temporal correlations"*, Phys. Rev. A **89**, 042109 (2014).

[18] K. Kato, F. Furrer and M. Murao, *"Information-theoretical formulation of anyonic entanglement*, Phys. Rev. A **90**, 062325 (2014).

[19] A. Soeda, S. Akibue, and M. Murao, *"Two-party LOCC convertibility of quadpartite states and Kraus-Cirac number of two-qubit unitaries"*, J. Phys. A: Math. Theor. **47**, 424036 (2014); Special issue on '50 years of Bell's theorem'.

[20] P. Kurzński, A. Soeda, J. Thompson, and D. Kaszlikowski, *"Contextuality in bosonic bunching"*, Phys. Rev. Lett. **112**, 020403 (2014).

[21] P. Kurzński, A. Soeda, J. Thompson, and D. Kaszlikowski, *"Reply to Comment on 'Contextuality in bosonic bunching'"*, Phys. Rev. Lett. **113**, 138902 (2014).

[22] L. A. Rozema, D. H. Mahler, A. Hayat, P. S. Turner and A. M. Steinberg, *"Quantum Data Compression of a Qubit Ensemble"*, Phys. Rev. Lett. **113**, 160504 (2014); Selected for "top ten breakthroughs in 2014" by Physics World.

[23] Y. Nakata and M. Murao, *"Diagonal quantum circuits: their computational power and applications"*, Eur. Phys. J. Plus **129**, 152 (2014).

[24] Y. Nakata, M. Koashi and M. Murao, *"Generating a state t-design by diagonal quantum circuits"*, New J. Phys. **16**, 053043 (2014).

[25] R. Blume-Kohout and P. S. Turner, *"The Curious Nonexistence of Gaussian 2-Designs"*, Comm. Math. Phys. **326**, 755 (2014).

[26] J. Miyazaki, M. Hajdusek and M. Murao, *"Analysis of the trade-off between spatial and temporal resources for measurement-based quantum computation"*, Phys. Rev. A **91**, 052302 (2015).

[27] S. Nakayama, A. Soeda, and M. Murao, *"Quantum algorithm for universal implementation of projective measurement of energy"*, Phys. Rev. Lett. **114**, 190501 (2015).

[28] S. Jevtic, T. Rudolph, D. Jennings, Y. Hirono, S. Nakayama, and M. Murao, *Exchange Fluctuation Theorem for correlated quantum systems"*, Phys. Rev. E **92**, 042113 (2015).

[29] K. Nakago, M. Hajdusek, S. Nakayama, and M. Murao, *"Parallelizable adiabatic gate teleportation"*, Phys. Rev. A **92**, 062315 (2015).

[30] K. Kato, F. Furrer, and M. Murao *"Information-theoretical analysis of topological entanglement entropy and multipartite correlations*, Phys. Rev. A **93**, 022317 (2016).

[31] J. Thompson, P. Kurzynski, S-Y. Lee, A. Soeda, and D. Kaszlikowski, *"Recent Advances in Contextuality Tests"*, Open Syst. Inf. Dyn. **23**, 1650009 (2016).

[32] S. Akibue and M. Murao, *"Network coding for distributed quantum computation over cluster and butterfly networks"*, IEEE Trans. Inf. Theory **62**, 6620 - 6637 (2016).

[33] E. Wakakuwa, A. Soeda, M. Murao, *"Markovianizing Cost of Tripartite Quantum States"*, IEEE Trans. Inf. Theory **63**, 1280 - 1298 (2017).

[34] F. Hirsch, M.T. Quintino, T. Vértesi, M. Navascués, and Nicolas Brunner, *"Better local hidden variable models for two-qubit Werner states and an upper bound on the Grothendieck constant KG(3)"*, Quantum **1**, 3 (2017).

[35] Y. Matsuzaki, S. Nakayama, A. Soeda, S. Saito and M. Murao, *"Projective measurement of energy on an ensemble of qubits with unknown frequencies"*, Phys. Rev. A **95**, 062106 (2017).

[36] E. Wakakuwa, A. Soeda and M. Murao, *"The Cost of Randomness for Converting a Tripartite Quantum State to be Approximately Recoverable"*, IEEE Trans. on Information Theory **63**, 5360 - 5371 (2017).

[37] E. Wakakuwa, A. Soeda and M. Murao, *"A Coding Theorem for Bipartite Unitaries in Distributed Quantum Computation"*, IEEE Trans. on Information Theory **63**, 5372 - 5403 (2017).

[38] S. M. Barnett, A. Beige, A. Ekert, B. M. Garraway, C. H. Keitel, V. Kendon, M. Lein, G. J. Milburn, H. M. Moya-Cessa, M. Murao, J. K. Pachos, G. M. Palma, E. Paspalakis, S. J. D. Phoenix, B. Piraux, M. B. Plenio, B. C. Sanders, J. Twamley, A. Vidiella-Barranco, and M. S. Kim, *"Journeys from Quantum Optics to Quantum Technology*, Progress in Quantum Electronics **54**, 19 (2017).

[39] J. Bavaresco, M. T. Quintino, L. Guerini, T. O. Maciel, D. Cavalcanti and M. T. Cunha, *"Most incompatible measurements for robust steering tests"*, Phys. Rev. A **96**, 022110 (2017).

[40] H. Yamasaki, A. Soeda and M. Murao, *"Graph-associated entanglement cost of a multipartite state in exact and finite-block-length approximate constructions"*, Phys. Rev. A **96**, 032330 (2017).

[41] S. Kim, J. Wang, A. Kumar, A. Soeda, and J. Wu, *"Logically reversible measurements: Construction and application"*, Phys. Lett. A **381**, 3460 (2017).

[42] S. Akibue, M. Owari, G. Kato and M. Murao, *"Entanglement assisted classical communication can simulate classical communication without causal order"*, Phys. Rev. A **96**, 062331 (2017).

[43] F. Hirsch, M.T. Quintino, N. Brunner, *"Quantum measurement incompatibility does not imply Bell nonlocality"*, Phys. Rev. A **97**, 012129 (2018).

[44] Y. Lee, R. Takagi, H. Yamasaki, G. Adesso, and S. Lee, *"State exchange with quantum side information"*, Phys. Rev. Lett. **122**, 010502 (2018). "

[45] H. Yamasaki, A. Pirker, M. Murao, W. Dür, B. Kraus, *"Multipartite entanglement outperforms bipartite entanglement under limited quantum system sizes"*, Phys. Rev. A 98, 052313 (2018), selected to be an Editors' Suggestion

[46] H. Yamasaki and M. Murao, *"Quantum state merging for arbitrarily-small-dimensional systems"*, IEEE Trans. on Information Theory **65**, 3950-3972 (2019).

[47] H. Yamasaki and M. Murao, *"Distributed Encoding and Decoding of Quantum Information over Networks"*, Adv. Quantum Technol. **2**, 1800066 (2019).

[48] J. Miyazaki, A. Soeda and M. Murao, *"Complex conjugation supermap of unitary quantum maps and its universal implementation protocol"*, Phys. Rev. Research **1**, 013007 (2019).

[49] X. Dong, M. T. Quintino, A. Soeda and M. Murao, *"Implementing positive maps with multiple copies of an input state"*, Phys. Rev. A **99**, 052352 (2019).

[50] E. Wakakuwa, A. Soeda and M. Murao, *"Complexity of causal order structure in distributed quantum information processing: More rounds of classical communication reduce entanglement cost"*, Phys. Rev. Lett. **122**, 190502 (2019).

[51] R. Sakai, A. Soeda, M. Murao and D. Burgarth, *"Robust controllability of two-qubit Hamiltonian dynamics"*, Phys. Rev. A **100**, 042305 (2019).

[52] J. Bavaresco, M. Araujo, C. Brukner and M. T. Quintino, *"Semi-device-independent certification of indefinite causal order"*, Quantum **3**, 176 (2019).

[53] M. T. Quintino, X. Dong, A. Shimbo, A. Soeda and M. Murao, *"Reversing unknown quantum transformations: A universal protocol for inverting general unitary operations"*, accepted for publication in Phys. Rev. Lett. (2019).

< Conference Proceedings >

[54] M. Mhalla, M. Murao, S. Perdrix, M. Someya and P. S. Turner, *"Which graph states are useful for quantum information processing?"*, in Theory of Quantum Computation, Communication, and Cryptography, Lecture Notes in Computer Science **6745**, Springer, pp. 174-187 (2014).

[55] Y. Nakata, P. S. Turner and M. Murao, *"Entanglement of phase-random states"*, AIP Conference Proceedings 1633, 32 (2014).

[56] E. Wakakuwa and M. Murao, *"Generalized Mutual Information and Tsirelson's Bound"*, AIC Conference Proceedings 1633, 47 (2014).

[57] T. Sugiyama, P. S. Turner and M. Murao, *"Understanding boundary effects in quantum state tomography – One qubit case"*, AIP Conference Proceedings 1633, 87 (2014).

[58] S. Akibue and M. Murao, *"Implementability of two-qubit unitary operations over the butterfly network and the ladder network with free classical communication"*, AIP Conference Proceedings 1633, 141 (2014).

[59] M. Hajdušek and M. Murao, *"Evaluation of multipartite entanglement in graph states"*, AIP Conference Proceedings 1633, 168 (2014).

[60] A. Soeda, Y. Kinjo, P. S. Turner and M. Murao, *"Implementing controlled-unitary operations over the butterfly network"*, AIP Conference Proceedings 1633, 180 (2014).

[61] S. Nakayama, A. Soeda and M. Murao, *"Universal construction of controlled-unitary gates using dynamical decoupling and the quantum Zeno effect"*, AIP Conference Proceedings 1633, 183 (2014).

＜**Patent Applications**＞

[62] Japanese Patent Registered on a multi-cast quantum network coding method over butterfly networks: 国内特許 (取得)、特許番号 5614658、発明の名称 (バタフライネットワーク上でのマルチキャスト量子ネットワーク符号化方法)、発明者 (尾張正樹、加藤豪、村尾美緒)、出願日 (２０１２年３月２６日)、特許出願人 (日本電信電話株式会社、国立大学法人東京大学)、特許登録（２０１４年９月１９日）

[63] Japanese Patent Registered on a multi-cast quantum network coding method: 国内特許 (取得)、特許番号 5936073、発明等の名称（マルチキャスト量子ネットワーク符号化方法)、発明者 (尾張正樹、加藤豪、村尾美緒)、出願日（２０１３年３月２８日)、特許出願人 (日本電信電話株式会社、国立大学法人東京大学)、特許登録（２０１６年５月２０日）

[64] Japanese Patent Registered on a multi-cast quantum network coding method: 国内特許 (取得)、特許番号 6183958、発明等の名称（マルチキャスト量子ネットワーク符号化方法)、発明者 (加藤豪、尾張正樹、村尾美緒)、出願日（２０１４年５月１９日)、特許出願人 (日本電信電話株式会社、国立大学法人東京大学)、登録日（２０１７年８月４日）

6 Invited Presentations at International Conferences

[1] M. Murao, *Universal construction of controlled-unitary gate for unknown Hamiltonian dynamics*, International Workshop on Cooperative Quantum Dynamics and Its Control (CQDC'12), Juelich (Germany), October 2012

[2] M. Murao, *Causal order manipulation in adiabatic and measurement-based quantum computation*, Workshop on Quantum Metrology, Interaction, and Causal Structure 2013, Beijing (China), December 2013

[3] M. Murao, *Causal order manipulation in quantum computation*, JFLI meeting on quantum information and computation, Tokyo (Japan), March 2014

[4] F. Furrer, *Entropic Formulation of Heisenberg's Measurement-Disturbance Relation*, JFLI meeting on quantum information and computation, Tokyo (Japan), March 2014

[5] M. Murao, *Entanglement as a resource for deterministically simulating acausal classical correlations*, Workshop on Quantum Metrology, Interaction and Causal Structure 2014, Beijing (China), December 2014

[6] S. Nakayama, A. Soeda, and M. Murao, *Computational quantum algorithms and projective measurement of energy*, Quantum Information Workshop, Tokyo (Japan), February 2015

[7] K. Kato, Fabian F. and Mi. Murao, *Merging Marginal Quantum Markov States and Application to Topological Orders*, Workshop on Quantum Marginals and Numerical Ranges, Guelph (Canada), August 2015

[8] M. Murao, *Implementation of projective measurement of energy without knowing Hamiltonian*, UTokyo-ANU Workshop on Quantum Information and Control, Tokyo (Japan), March 2016

[9] M. Murao, *Entanglement assisted classical communication simulates "classical communication" without causal order*, Hong Kong workshop on quantum information and foundation, Hong Kong May (China), May 2016

[10] M. Murao, *Entanglement assisted classical communication simulates "classical communication" without causal order*, The 3rd Seefeld workshop on Quantum Information, Seefeld (Austria), July 2016

[11] A. Soeda, *Universal controllization–its no-go and remedy for projective measurement of energy*, Quantum Information Science Workshop, Busan (Korea), November 2016

[12] M.T. Quintino, *Genuine n-wise Measurement Incompatibility and Device Independent Certificates of Incompatibility*, FQXi Workshop: Quantum Incompatibility 2017, Maria Laach (Germany), August 2017

[13] M. Murao, *Higher order quantum operations of unitaries and their implications*, The 17th Asian Quantum Information Science Conference (AQIS2017), Singapore (Singapore), September 2017

[14] M Murao, *Higher order quantum operations of unitaries*, 4th Seefeld workshop on Quantum Information (2018), Seefeld (Austria), July 2018

[15] M. Murao, *Higher order quantum operations of unitaries*, Hong Kong - Shen Zhen Workshop on Quantum Information Science, Shenzhen (China), May 2018

[16] M. Murao, *Using quantum computers for manipulating and analyzing quantum systems*, The Bristol Quantum Information Technologies Workshop (BQIT2018), Bristol (UK), April 2018

[17] M. Murao, *Using quantum computers for analyzing quantum physics*, International Conference on Challenges in Quantum Information Science (CQIS 2018), Tokyo (Japan), April 2018

[18] A. Soeda, *Higher-order quantum operations on unitary operations with multiple calls*, 2018 International Workshop on Quantum Information, Quantum Computing and Quantum Control, Shanghai (China), November 2018

[19] J. Bavaresco, M. Araujo, C. Brukner, M.T. Quintino, *Semi-device-independent certification of indefinite causal order*, Quantum Maiwar 2018, Brisbane (Australia), November 2018

[20] M. Murao, *Causal structure of blackboxes in higher order quantum operations*, Quantum Maiwar 2018, Brisbane (Australia), November 2018

[21] Q. Dong, M.T. Quintino, A. Soeda and M. Murao, *Implementing positive maps with multiple copies of an input state*, PAQIS2018, Aiti (Japan), September 2018

[22] M.T. Quintino, Q. Dong, A. Shimbo, A. Soeda and M. Murao, *Reversing unknown quantum transformations:A universal protocol for inverting general unitary operations,* PAQIS2018, Aiti (Japan), September 2018

[23] H. Yamasaki and M. Murao, *Partial quantum information and two-way classical communication*, PAQIS2018, Aiti (Japan), September 2018

[24] M. Murao, *Higher order quantum operations of blackbox unitaries*, International Symposium on Quantum Theory and Symetreis (QTS2019), Montreal (Canada), July 2019

[25] M.. Murao, *Using quantum computers for processing quantum systems*, Young Researchers Forum on Quantum Information Science, Hsinchu (Taiwan), August 2019

[26] M. Murao, *Higher order quantum operations of blackbox unitaries*, 57th Annual Allerton Conference 2019, Monticello (USA), September 2019

7 Teaching Accomplishment

Since the beginning of 2012, 9 Ph.D. students and 2 Master students are graduated under my supervision during the last 7 years. Currently, I am supervising 2 master students and 1 Ph.D. student. I have been providing a strong international research environment for my students with foreign postdoctoral researchers. We accept three USTEP exchange students from Germany, Sweden, and Austria, and will accept another student from Switzerland and a long term visiting student from Austria. I have extensively trained their ability to participate in technical discussions in English and arranged many collaborations with international and interdisciplinary researchers. I have encouraged students to travel abroad for collaborations and conferences. As a result, my students' accomplishments and abilities have been well-recognized also outside Japan. Most of the students have had experience collaborating with non-Japanese coworkers and writing papers with them. As a notable example, Dr. Kohtaro Kato obtained the prestigious Internship at Microsoft Research at Seattle in 2015 while he was a Ph.D. student and worked there with Dr. Fernando Brandao for three months. Eventually, Dr. Brandao moved to Caltech as a professor and currently, Dr. Kato is working at Caltech as a postdoc in his group. One of the Ph.D. students, Dr. Takanori Sugawara won the School of Science Encouragement Award in March 2012.

8 Contribution to Academic Community

8.1 Editorial Activities

- Editorial Board Member of The Journal of Physics A, 2016−
- Advisory Editor of Springer Book Series, 2016−

8.2 Organization of Professional Societies

- Director of The Physical Society of Japan, 2018−2020

8.3 Organization and Advisory of Conferences

- Co-Chair, The 7th Conference of Theory of Quantum Computation, Communication, and Cryptography, May 17th to 19th, 2012, Tokyo, Japan

9 Outreach

- 2015 年 7 月 24 日 東京大学の女子中高生の理系進路選択支援事業「東大理学部で考える女子中高生の未来」での女子中高生向けの一般向け講演「論理的思考を鍛えて科学を楽しむ」(A public lecture on "Training logical thinking and enjoy science!" for junior and high school female students on July 24th, 2015 at School of Science, The University of Tokyo)

- 2016 年 11 月 19 日 茨城県立水戸第一高等学校において女子高校生に向けの講演「科学者の道を歩んできて一理系キャリアへの招待ー」(A public lecture on “A path to a scientist – invitation to a carrier in Science” for junior and high school female students on November 19th, 2016 at Mito-daiichi High School in Ibaraki Prefecture)

10 Committee Service

10.1 External Committees

- Advisory Board Member of The JSPS Frontiers of Science Symposium 2012−
- Member of The Science Council of Japan, 2017−
- Advisory Board Member, Austrian Academy of Sciences ESQ, 2019−

10.2 University Committees

Member, Office for Gender Equality, The University of Tokyo, 2006−2016
Member, School of Science International Exchange Committee, 2004−2017
Member, School of Science Global Science Course Faculty Committee 2014−2018
Assistant Dean, School of Science (理学系研究科研究科長補佐) 2015−2016
Chair, Committee for Gender Equality, School of Science, 2015−2016
Member, School of Science Library Committee, 2018−

11 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	3	Germany, Sweden, Austria
Doctor Course	1	Germany
Foreign researchers hosted	7	Canada, Slovakia, France, Switzerland, Brazil, Germany, Hungary
Students sent abroad	16	Austria, UK, Spain, Germany, France, Switzerland, USA, Singapore, China, Australia, Canada
Researchers sent abroad	42	Singapore, China, Austria, UK, Germany, France, Spain, Canada, Italy, Australia, Hong Kong, Brazil Slovakia, Switzerland
Foreign visitors	68	UK, USA, Italy, Germany, Switzerland, Brazil, Slovakia, Canada, Australia, China, Taiwan, Canada, Hungary, Poland, France, Finland, Russia, New Zealand

Masahito Ueda、上田 正仁

1 Education and Professional Experiences

Education

1986	B.S. (Physics)	The University of Tokyo
1988	MSc. (Physics)	The University of Tokyo
1991	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1988−1994	Researcher	NTT Basic Research Laboratories
1994−2000	Associate Professor	Hiroshima University
2000−2008	Professor	Tokyo Institute of Technologies
2008−	Professor	The University of Tokyo

2 Research Highlights

My research highlights since 2012 include establishment of (1) information thermodynamics [2, 7], (2) exploration of topological aspects in Bose-Einstein condensates [91, 92, 93, 94], and (3) complete classification of non-Hermitian topological phases [75, 90]. Let me explain each of these achievement.

(1) James Clark Maxwell pointed out that if there were a creature (Maxwell's demon) who were able to measure the velocity of a molecule, he could decrease the entropy of the system in contradiction with the second law of thermodynamics. This issue had remained a paradox for more than one and half century. There were a number of attempts most notably by Szilard, Landauer and Bennett to resolve the problem. Szilard attributed the problem to the energy cost of measurement whereas Landauer and Benett ascribed it to the erasure of information. However, the controversy continued because the quantitative evaluation of the energy cost of measurement had remained elusive. We have combined the Jarzynski equality with quantum theory of measurement to show that actually both the energy cost of measurement and that of the erasure can can be important depending on the physical situation and the net sum always exceeds the free-energy gain due to the action of the demon. This work has now developed into the field known as information thermodynamics.

(2) Cold atom systems have unprecedented controllability to manipulate quantum degenerate gases. Over the past decade or so, we have exploited this degrees of freedom to predict a number of topological excitations such as chiral spin vortices, non-Abelian vortices and knots. Many of our predictions have been demonstrated experimentally. Most notably, our prediction of knots has recently been observed in a Bose-Einstein condensate (D. S. Hall, et al., Nat. Phys. vol.12, 478 (2016)).

(3) Non-Hermitian physics has seen a remarkable development in the optical system because there are gain and loss media for photons which make an effective description of the photonic system non-Hermitian. We have pointed out that in cold atom systems one can, in principle, measure

individual quantum trajectories in real time and that we can exactly simulate non-Hermitian dynamics by postselection of null-measurement outcomes. Here an interesting question arises as to what topological excitations can be envisaged once we relax the resctrction of Hermiticity. In the Hermitian case, there are 10 classes (Altrand-Zirnbauer classification). In the non-Hermitian case, we have demonstrated that some of these classes are unified and ramified to produce a total of 38 classes. I believe that such a complete classification will serve as a starting point to investigate topological phenomena in open quantum systems.

3 Selected Papers

- Kohei Kawabata, Sho Higashikawa, Zongping Gong, Yuto Ashida, and Masahito Ueda, Nat. Commun. 10, 297 (2019)
  This work was selected as Editors' Highlights.
- Zongping Gong, Yuto Ashida, Kohei Kawabata, Kazuaki Takasan, Sho Higashikawa, and Masahito Ueda, Phys. Rev. X 8, 031079 (2018)
  This work was focused by Viewpoint: Physics 11, 96 by Miguel A. Bandres and Mordechai Segev and categorized by Web of Science as a hot paper. [cited 83 times]
- Kohei Kawabata, Yuto Ashida, Hosho Katsura, and Masahito Ueda, Phys. Rev. B 98, 085116 (2018)
  This work was selected as Editors' Suggestion and is categorized as highly cited by Web of Science [cited 36 times].
- Zongping Gong, Sho Higashikawa, and Masahito Ueda, Phys. Rev. Lett. 118, 200401 (2017)
  This work was selected as Editor's choice.
- Dan M. Stamper-Kurn and Masahito Ueda, Reviews of Modern Physics 85, 1191-1244 (2013)
  This work is categorized as highly cited by Web of Science [cited 367 times]

4 Honors, Awards and Professional Society Memberships

2009 JSPS Prize, Japan Society for the Promotion of Science
2008 Nishina Memorial Prize, Nishina Memorial Foundation
2007 The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, Prizes for Science and Technology (Research Category)
2002 Matsuo Prize, Matsuo Foundation

5 Research Plan

In the future, I will continue my efforts to explore fundamental and foundational aspects of (low-energy) physics. In particular, I wish to study open quantum many-body phenomena and develop methods to do so. Such physics frontier necessarily involves quantum measurement, feedback control, information processing and nonequilibrium thermodynamics.In my humble opinion, combining these different techniques into a single coherent theory is a challenge we must face in order to investigate and control nonequilibrium physics. For example, ultracold atomic systems inevitably suffer atomic losses due to inelastic collisions. Usually such a loss is considered to be detrimental to interesting physical phenomena. I have been and will be interested in investigating the positive aspects of dissipation in the context of open many-body physics.I think that we can harness dissipation if we can control it through quantum measurement and feedback. To do so, we should go beyond the Hermitian formalism of quantum mechanics to non-Hermitian and Lindblad regimes. Another example includes a superflow in the presence of disorder which undergoes a transition to a superfluid turbulent state beyond a critical velocity. I hope to understand the nature of the transition and develop a solid method which is beyond the linear response theory.

I am also interested in extending the frontiers of physics by integrating physics and artificial intelligence. In detail, I am interested in why deep learning works so well in many different areas of optimization and classification problems. I have a hunch that it must be closely related to the renormalization group concept, but I also feel that a simple application of the RG will not lead to fruitful insights. Rather, I think that we should expand the concept of the RG in a way to accoomdate the current deep learning technologies. I am also interested in constructing explainable AI, that is, the AI that can explain the origin of the outcome. After all, this what physicists aspire to do.

6 Publications and Patents

< Refereed Original Papers >

[1] Shingo Kobayashi, Michikazu Kobayashi, Yuki Kawaguchi, Muneto Nitta, and Masahito Ueda, Nucl. Phys. B vol. 856, 577-606 (2012)

[2] Takahiro Sagawa and Masahito Ueda, Physical Review E vol. 85, 021104 (2012) [16 pages]

[3] Naoyuki Sakumichi, Norio Kawakami, and Masahito Ueda, Physical Review A vol. 85, 043601 (2012) [19 pages]

[4] Pascal Naidon, Emiko Hiyama, and Masahito Ueda, Physical Review A vol. 86, 012502 (2012) [7 pages]

[5] Shingo Kobayashi, Yuki Kawaguchi, Muneto Nitta, and Masahito Ueda, Physical Review A vol. 86, 023612 (2012) [14 pages]

[6] Z. F. Xu, Y. Kawaguchi, L. You, and M. Ueda, Physical Review A vol. 86, 033628 (2012) [8 pages] (selected as PRA Kaleidoscope Images)

[7] Takahiro Sagawa and Masahito Ueda, Phys. Rev. Lett. vol. 109, 180602 (2012) [5 pages]

[8] Shunsuke Furukawa and Masahito Ueda, Physical Review A vol. 86, 031604 (2012) [4 pages].

[9] Emi Yukawa and Masahito Ueda, Physical Review A vol. 86, 063614 (2012) [11 pages]

[10] Nguyen Thanh Phuc, Yuki Kawaguchi and Masahito Ueda, Annals of Physics 328, 158-219 (2013)

[11] Tatsuhiko N. Ikeda, Yu Watanabe and Masahito Ueda, Physical Review E vol. 87, 012125 (2013) [5 pages]

[12] Shunsuke Furukawa and Masahito Ueda, Physical Review Letters vol. 111, 090401 (2013) [5 pages]

[13] Hiroki Saito, Yuki Kawaguchi and Masahito Ueda, Special Section on Condensed Matter Analogues of Cosmology, J. Phys.: Condens. Matter vol. 25 (2013) 404212 [8 pages]

[14] Emi Yukawa, Masahito Ueda, and Kae Nemoto, Physical Review A vol. 88, 033629 (2013) [7 pages]

[15] Yui Kuramochi, Yu Watabane, and Masahito Ueda, J. Phys. A: Math. Theor. vol. 46 425303 (2013) [19 pages]

[16] Nguyen Thanh Phuc, Yuki Kawaguchi and Masahito Ueda, Physical Review A vol. 88, 043629 (2013) [18 pages]

[17] Ken Funo, Yu Watanabe, and Masahito Ueda, Physical Review E vol. 88, 052121 (2013) [6 pages]

[18] Ken Funo, Yu Watanabe, and Masahito Ueda, Physical Review A vol. 88, 052319 (2013) [7 pages]

[19] Takahiro Sagawa and Masahito Ueda, New Journal of Physics vol. 15 125012 (2013) [23 pages]

[20] Shingo Kobayashi, Nicolas Tarantino and Masahito Ueda, Phys. Rev. A vol. 89, 033603 (2014) [11 pages]

[21] Naoyuki Sakumichi, Yusuke Nishida, and Masahito Ueda, Phys. Rev. A 89, 033622 (2014) [17 pages]

[22] Pascal Naidon, Shimpei Endo, Masahito Ueda, Phys. Rev. Lett. vol. 112, 105301 (2014) [5 pages]

[23] Pascal Naidon, Shimpei Endo, Masahito Ueda, Phys. Rev. A vol. 90, 022106 (2014) [9 pages]

[24] Shunsuke Furukawa and Masahito Ueda, Phys. Rev. A vol. 90, 033602 (2014) [11 pages]

[25] Yûto Murashita, Ken Funo, and Masahito Ueda, Phys. Rev. E vol. 90, 042110 (2014) [12 pages]

[26] Yuto Ashida, Ken Funo, Yûto Murashita and Masahito Ueda, Phys. Rev. E vol. 90, 052125 (2014) [8 pages]

[27] Nguyen Thanh Phuc, Yuki Kawaguchi, and Masahito Ueda, Phys. Rev. Lett. vol. 113, 230401 (2014) [5 pages]

[28] Yusuke Horinouchi and Masahito Ueda, Phys. Rev. Lett. vol. 114, 025301 (2015) [5 pages] Editors' Suggestion

[29] Tatsuhiko N. Ikeda, Naoyuki Sakumichi, Anatoli Polkovnikov, and Masahito Ueda, Annals of Physics, vol. 354, pp. 338-352 (2015)

[30] Yui Kuramochi and Masahito Ueda, Phys. Rev. A vol. 91, 032110 (2015) [13 pages]

[31] Ken Funo, Yûto Murashita, and Masahito Ueda, New J. Phys. vol. 17, 075005 (2015) [26 pages]

[32] Tatsuhiko N. Ikeda and Masahito Ueda, Phys. Rev. E vol. 92, 020102(R) (2015) [6 pages]

[33] Yuto Ashida and Masahito Ueda, Phys. Rev. Lett. vol. 115, 095301 (2015) [6 pages] (Editor's suggestion)

[34] Nguyen Thanh Phuc, Gen Tatara, Yuki Kawaguchi and Masahito Ueda, Nature Communications vol. 6, Article number: 8135 DOI: 10.1038/ncomms9135

[35] Shuhei Yoshida and Masahito Ueda, Phys. Rev. Lett. vol. 115, 135303 (2015) [5 pages]

[36] Shunsuke Furukawa and Masahito Ueda, New J. Phys. vol. 17, 115014 (2015)

[37] Eriko Kaminishi, Takashi Mori, Tatsuhiko N. Ikeda and Masahito Ueda, Nature Physics vol. 11, 1050-1056 (2015).

[38] Ken Funo and Masahito Ueda, Phys. Rev. Lett. vol. 115, 260601 (2015) [5 pages]

[39] Yuto Ashida and Masahito Ueda, Opt. Lett. vol. 41, pp. 72-75 (2016)

[40] Ryusike Hamazaki, Tatsuhiko N. Ikeda, and Masahito Ueda, Phys. Rev. E vol. 93, 032116 (2016) [8 pages]

[41] Tomohiro Shitara, Yui Kuramochi, and Masahito Ueda, Phys. Rev. A vol. 93, 032134 (2016) [5 pages]

[42] Masahito Ueda, Nature Physics vol. 12, pp. 530-531 (2016)

[43] Sho Higashikawa and Maahito Ueda, Phys. Rev. A vol. 94, 013613 (2016) [21 pages]

[44] Shuhei Yoshida and Masahito Ueda, Phys. Rev. A vol. 94, 033611 (2016) [5 pages]

[45] Yuto Ashida, Shunsuke Furukawa and Masahito Ueda, Phys. Rev. A vol. 94, 053615 (2016) [11 pages]

[46] Konstantin Tiurev, Pekko Kuopanportti, András Márton Gunyhó, Masahito Ueda, and Mikko Möttönen, Phys. Rev. A vol. 94, 053616 (2016) [7 pages]

[47] Yusuke Horinouchi and Masahito Ueda, Phys. Rev. A vol. 94, 050702(R) (2016) [6 pages]

[48] Hiroaki Ishizuka, Tomoya Hataya, Masahito Ueda, and Naoto Nagaosa, Phys. Rev. Lett. vol. 117, 216601 (2016) [5 pages]

[49] Ken Funo, Tomohiro Shitara and Masahito Ueda, Phys. Rev. E vol. 94, 062112 (2016) [7 pages]

[50] Naoto Tsuji, Philipp Werner, and Masahito Ueda, Phys. Rev. A vol. 95, 011601(R) (2017) [5 pages]

[51] Nguyen Thanh Phuc, Tsutomu Momoi, Shunsuke Furukawa, Yuki Kawaguchi, Takeshi Fukuhara, and Masahito Ueda, Phys. Rev. A vol. 95, 013620 (2017) [12 pages]

[52] Yûto Murashita, Masahito Ueda, Phys. Rev. Lett. vol. 118, 060601 (2017) [5 pages]

[53] Tatsuhiko N. Ikeda, Takashi Mori, Eriko Kaminishi, and Masahito Ueda, Phys. Rev. E vol. 95, 022129 (2017) [8 pages]

[54] Yuto Ashida and Masahito Ueda, Phys. Rev. A vol. 95, 022124 (2017) [9 pages]

[55] Ken Funo, Jing-Ning Zhang, Cyril Chatou, Kihwan Kim, Masahito Ueda, and Adolfo del Campo, Phys. Rev. Lett. vol. 118, 100602 (2017) [6 pages]

[56] Shun Uchino and Masahito Ueda, Phys. Rev. Lett. vol. 118, 105303 (2017) [6 pages]

[57] Sho Higashikawa and Masahito Ueda, Phys. Rev. B vol. 95, 134520 (2017) [19 pages]

[58] Zongping Gong, Sho Higashikawa, and Masahito Ueda, Phys. Rev. Lett. vol. 118, 200401 (2017) [6 pages] (Editor's suggestion)

[59] Yuto Ashida, Shunsuke Furukawa, and Masahito Ueda, Nat. Commun. vol. 8, 15791 (2017) [6 pages]

[60] Kohaku H. Z. So and Masahito Ueda, Phys. Rev. A vol. 96, 023628 (2017) [8 pages]

[61] Yuto Murashita, Zongping Gong, Yuto Ashida, and Masahito Ueda, Phys. Rev. A vol. 96, 043840 (2017) [14 pages]

[62] Kohei Kawabata, Yuto Ashida, and Masahito Ueda, Phys. Rev. Lett. vol. 119, 190401 (2017) [6 pages]

[63] Shunsuke Furukawa and Masahito Ueda, Phys. Rev. A vol. 96, 053626 (2017) [12 pages]

[64] Naoto Tsuji, Tomohiro Shitara, and Masahito Ueda, Phys. Rev. E vol. 97, 012101 (2018) [9 pages]

[65] Naoto Kura and Masahito Ueda, Phys. Rev. A vol. 97, 012101 (2018) [9 pages]

[66] Eriko Kaminishi, Takashi Mori, Tatsuhiko N. Ikeda, and Masahito Ueda, Phys. Rev. A vol. 97, 013622 (2018) [9 pages]

[67] Zongping Gong, Ryusuke Hamazaki and Masahito Ueda, Phys. Rev. Lett. vol. 120, 040404 (2018) [6 pages]

[68] Ryusuke Hamazaki, Kazuya Fujimoto and Masahito Ueda, Phys. Rev. Lett. vol. 120, 073002 (2018) [6 pages]

[69] Ryusuke Hamazaki and Masahito Ueda, Phys. Rev. Lett. vol. 120, 080603 (2018) [6 pages]

[70] J. Bengtsson, M. Nilsson Tengstrand, A. Wacker, P. Samuelsson, M. Ueda, H. Linke, and S. M. Reimann, Phys. Rev. Lett. vol. 120, 100601 (2018) [5 pages]

[71] Y. Masuyama, K. Funo, Y. Murashita, A. Noguchi, S. Kono, Y. Tabuchi, R. Yamazaki, M. Ueda, and Y. Nakamura, Nat. Commun. vol. 9, 1291 (2018) [6 pages]

[72] Yuto Ashida and Masahito Ueda, Phys. Rev. Lett. vol. 120, 185301 (2018) [7 pages]

[73] Nguyen Thanh Phuc and Masahito Ueda, Phys. Rev. A vol. 97, 061608(R) (2018) [6 pages].

[74] Kohei Kawabata, Yuto Ashida, Hosho Katsura, and Masahito Ueda, Phys. Rev. B vol. 98, 085116 (2018) [13 pages] (Editor's choice)

[75] Zongping Gong, Yuto Ashida, Kohei Kawabata, Kazuaki Takasan, Sho Higashikawa, and Masahito Ueda, Phys. Rev. X 8, 031079 (2018) [33 pages] [Viewpoint: Miguel A. Bandres and Mordechai Segev, Physics vol.11, 96 (2018)]

[76] Yuto Ashida, Keiji Saito, and Masahito Ueda, Phys. Rev. Lett. vol. 121, 170402 (2018) [7 pages]

[77] Kohei Kawabata, Ken Shiozaki, and Masahito Ueda, Phys. Rev. B98, 165148 (2018) [12 pages]

[78] Masaya Nakagawa, Norio Kawakami, and Masahito Ueda, Phys. Rev. Lett. vol. 121, 203001 (2018) [6 pages]

[79] Shun Uchino, Masahito Ueda, and Jean-Philippe Brantut, Phys. Rev. A vol. 98, 063619 (2018) [11 pages]

[80] Zongping Gong and Masahito Ueda, Phys. Rev. Lett. vol. 121, 250601 (2018) [6 pages]

[81] Takumi Yoshino, Shunsuke Furukawa, Sho Higashikawa, and Masahito Ueda, New J. Phys. vol. 21, 015001 (2019) [23 pages]

[82] Kohei Kawabata, Sho Higashikawa, Zongping Gong, Yuto Ashida, and Masahito Ueda, Nat. Commun. vol. 10, 297 (2019) [selected as Editors' Highlights]

[83] Tao Liu, Yu-Ran Zhang, Qing Ai, Zongping Gong, Kohei Kawabata, Masahito Ueda, and Franco Nori, Phys. Rev. Lett. vol. 122, 076801(2019) [8 pages]

[84] Ryusuke Hamazaki and Masahito Ueda, Phys. Rev. E vol. 99, 042116 (2019) [12 pages])

[85] Kazuya Fujimoto, Ryusuke Hamazaki, and Masahito Ueda, Phys. Rev. Lett. vol. 122, 173001 (2019) [7 pages]

[86] Ryusuke Hamazaki and Masahito Ueda, Phys. Rev. E vol. 99, 042116 (2019) [12 pages]

[87] Sho Higashikawa, Masaya Nakagawa, and Masahito Ueda, Phys. Rev. Lett. vol. 123, 066403 (2019) [6 pages]

[88] Ryusuke Hamazaki, Kohei Kawabata and Masahito Ueda, Phys. Rev. Lett. vol. 123, 090603 (2019) [7 pages]

[89] Kazuki Yamamoto, Masaya Nakagawa, Kyosuke Adachi, Kazuaki Takasan, Masahito Ueda, and Norio Kawakami, Phys. Rev. Lett. vol. 123, 123601 (2019) [7 pages

[90] Kohei Kawabata, Ken Shiozaki, Masahito Ueda, and Masatoshi Sato, Phys. Rev. X vol. 9, 041015 (2019)

＜ **Review Papers** ＞

[91] M. Ueda, Annu. Rev. Condens. Matter Phys. vol. 3, 263-283 (2012)

[92] Yuki Kawaguchi and Masahito Ueda, Physics Reports vol. 520, pp. 253-381 (2012)

[93] Dan M. Stamper-Kurn and Masahito Ueda, Reviews of Modern Physics vol. 85, 1191-1244 (2013)

[94] Masahito Ueda, (Key Issues Review) Reports on Progress in Physics, vol. 77, No. 12, 122401 (2014) [17 pages]

[95] Takashi Mori, Tatsuhiko N. Ikeda, Eriko Kaminishi and Masahito Ueda, J. Phys. B: At. Mol. Opt. Phys. vol. 51 112001 (2018) [49 pages]

＜ **Books** ＞

[96] 沙川貴大、上田正仁『量子測定と量子制御』（サイエンス社）

7 Invited Presentations at International Conferences

[1] M. Ueda, “Topological Aspects in Ultracold Atoms” New Directions in Ultracold Atomic Systems (January 8-14, Aspen, USA, 2012)

[2] M. Ueda, “Three Universal Trimers: Efimov, Kartavtsev-Malykh, and Crossover Trimers” International Conference on Frontiers of Cold Atoms and Related Topics (May 14-17, Hong Kong, China, 2012)

[3] M. Ueda, “Topological Aspects in Ultracold Atomic Gases” International Conference on Topological Quantum Phenomena (May 16-20, Nagoya, Japan, 2012)

[4] M. Ueda, “Three Universal Trimers in Ultracold Atoms” Workshop on Quantum Simulations with Ultracold Atoms (July 16-20, Trieste, Italy, 2012)

[5] M. Ueda, “Three Universal Trimers in Ultracold Atoms” The 23rd International Conference on Atomic Physics (July 23-27, Palaiseau, France, 2012)

[6] M. Ueda, “Information Thermodynamics” Dynamics and Thermodynamics in Isolated Quantum Systems (August 20 - 24, Santa Barbara, USA, 2012)

[7] M. Ueda, “Maxwell’s Demon and Information Thermodynamics” XXVth Marian Smoluchowski Symposium on Statistical Physics: Fluctuation Relations in Nonequilibrium Regime (September 10-13, Krakow, Poland, 2012)

[8] M. Ueda, “Topological Excitations in Ultracold Atoms” Quantum Technologies Conference III (September 9-15, Warsaw, Poland, 2012) (keynote lecture)

[9] M. Ueda, "Three Universal Trimers in Ultracold Atoms" Correlations and Coherence at Different Scales (September 13-18, Ustron, Poland, 2012)

[10] M. Ueda, "Information Thermodynamics and Fluctuation Theorem" The 2013 Berkeley Mini Statistical Mechanics Meeting (January 11-13, Berkeley, USA, 2013)

[11] M. Ueda, "Topological Excitations in Ultracold Atomic Gases" QS^2C Theory Forum: International Symposium on "Strongly Correlated Quantum Science" (January 26-29, Wako, 2013)

[12] M. Ueda, "Information Thermodynamics and Fluctuation Theorem" Pushing the Boundaries with Cold Atoms (February 6, Stockholm, Sweden, 2013)

[13] M. Ueda, "Symmetry Breaking and Topological Excitations in Bose-Einstein Condensates" Zurich Physics Colloquium (March 6, Zurich, Switzerland, 2013)

[14] M. Ueda, "Information Thermodynamics and Fluctuation Theorem" Center for Quantum Information Colloqium (April 4, Singapore, 2013)

[15] M. Ueda, "Where does the Bogoliubov theory go qualitatively wrong?" The 11th US-Japan Joint Seminar (April 9-12, Nara, 2013)

[16] M. Ueda, "Information thermodynamics and fluctuation theorems" Coherent Control of Complex Quantum Systems (C3QS 2013) (May 7-12, Okinawa, Japan, 2013) organizer and speaker

[17] M. Ueda, "First-order quantum phase transition in spinor Bose-Einstein condensates" The 7 th CAS Cross-Strait and International Conference on Quantum Manipulation（June 28-30, Beijing, China, 2013)

[18] M. Ueda, "Spinor Beliaev theory and first-order phase transition in spinor condensates" The 22th International Laser Physics Workshop (July 15-19, Prague, Czech Republic, 2013)

[19] M. Ueda, "Thermodynamic Gain from Entanglement" Workshop on Information theoretic approaches to thermodynamics (September 2, Singapore, 2013)

[20] M. Ueda, "Information Thermodynamics: How the Maxwell's demon was exorcised" Workshop on Quantum Materials (December 9-11, Stuttgart, Germany, 2013)

[21] M. Ueda, "Two Different Classes of Universality in the Three-Body Parameter in Efimov Physics" CIFAR Meeting on Cold Atoms (February 18-21, Banff, Canada, 2014)

[22] M. Ueda, "Universality in Few Body Physics" Coherent Control of Complex Quantum Systems 2014 (April 14-17, 2014, Okinawa, Japan)

[23] M. Ueda,"Physical Origin of the Universality of the Three-Body Parameter in Efimov Physics" Conference on Non-equilibrium Phenomena in Condensed Matter and String Theory (June 30-July4, Trieste, Italy, 2014)

[24] M. Ueda, "Absolute Irreversibility and New Nonequilibrium Equalities" Shortcuts to Adiabaticity, Optimal Quantum Control, and Thermodynamics Conference (July 13-July 18, Telluride, USA, 2014)

[25] M. Ueda, "Absolute Irreversibility and Nonequilibrium Equalities under Feedback Control" International Conference on Control of Self-Organizing Nonlinear Systems (August 25-28, Rostock-Warnemünde, Germany, 2014)

[26] M. Ueda, "Topological Excitations of Bose-Einstein Condensates" IAS/School of Science Joint Lecture, Hong Kong University of Science and Technology (September 18, Hong Kong, 2014)

[27] M. Ueda, "Introduction to Information Thermodynamics" The 27th Workshop on Mesoscopic and Nanoscale Systems (November 21-22, Pohang, Korea, 2014)

[28] M. Ueda, "Absolute irreversibility in nonequilibrium processes under feedback control" Workshop on Quantum Information and Thermodynamics (February 23-27, Sao Paulo, Brazil, 2015)

[29] M. Ueda, "The relationship between the Onset of the Limit Cycle and the Universal Three-Body Parameter in Efimov Physics" 21st International Conference on Few Body Problems in Physics (May 18-22, Chicago, USA, 2015)

[30] M. Ueda, “Relationship between the Onset of the Limit Cycle and the Universal Three-Body Parameter in Efimov Physics” 2015 Taiwan International Symposium on Contemporary Atomic and Optical Physics (July 8-10, Hinchu, Taiwan, 2015)

[31] M. Ueda, “Resoving the Gibbs Paradox in Small Thermodynamic Systems” Themodynamics and Nonlinear Dynamics in the Information Age (July 13-17, Telluride, USA, 2015)

[32] M. Ueda, “Controlling and Probing Non-Abelianness and Quantum Mass Acquisition in Spinor Condensates” MIT-Harvard Center for Cold Atoms (CUA) seminars (featured speaker) (September 15, Boston, 2015)

[33] M. Ueda, “Entanglement Pre-Thermalization” 12th US-Japan Seminar “Many-body quantum systems from quantum gases to metrology and information processing” (September 20-24, Madison, USA, 2015)

[34] M. Ueda, “Gibbs Paradox and Entanglement Prethermalization” (keynote lecture) Third Conference in Quantum Thermodynamics (October 12-16, Porquerolles, France, 2015)

[35] M. Ueda, “Controlling and Probing Non-Abelianness and Quantum Mass Acquisition in Spinor Condensates” IAS Program and Croucher Conference on “Topological Phases in Condensed Matter and Cold Atomic Systems” (December 16-19, Hong Kong, China, 2015)

[36] M. Ueda, “Entanglement Pre-thermalization in a Bose Gas” International Symposium on “Dynamics in Artificial Quantum Systems” (January 12-14, Tokyo, Japan, 2016)

[37] M. Ueda, “Entanglement Pre-thermalization in a Bose Gas” Nanoscience Colloquium, Lund University (April 7, Lund, Sweden, 2016)

[38] M. Ueda, “The Gibbs Paradox and Entanglement Pre-thermalization in a Bose Gas” Special Condensed Matter and Quantum Information Seminar, Niels Bohr Institute (April 8, Copenhagen, Denmark, 2016)

[39] M. Ueda, “Entanglement Pre-thermalization in a Bose Gas” International Conference on the Frontiers in Atomic, Molecular, and Optical Physics (May 23-26, Shanghai, China, 2016)

[40] M. Ueda, “Gibbs Paradox and Entanglement Pre-thermalization” International Workshop on “Quantum Non-Equilibrium Phenomena” (June 6-June 18, Natal, Brazil, 2016)

[41] M. Ueda, “Entanglement Pre-thermalization in a Bose Gas” International workshop on “Information Engines at the Frontiers of Nanoscale Thermodynamics” (June 23-July 01, Telluride, USA, 2016)

[42] M. Ueda, “P-Wave Contact Tensor” KITPC/PKU Conference on the Synthetic Topological Quantum Matter (August 1-4, Beijing, China, 2016)

[43] M. Ueda, “Topological Quantum Phenomena in Spinor Bose-Einstein Condensates” (keynote) JQC Symposium & MACRO Conference (September 14-16, New Castle, UK, 2016)

[44] M. Ueda, “Quantum Many-Body Dynamics under Continuous Observation” University of Tokyo/ENS Workshop (November 16-18, Paris, France, 2016)

[45] M. Ueda, “Topological Quantum Phenomena in Spinor Bose-Einstein Condensates” (keynote) Joint 13th Asia Pacific Physics Conference and 22nd Australian Institute of Physics Congress (APPC-AIP) (December 4-8, Brisbane, Australia, 2016)

[46] M. Ueda, “Quantum Many-Body Dynamics under Continuous Observation” Quantum Dynamics: From Models to Materials (January 15-21, Aspen, USA, 2017)

[47] M. Ueda, “Quantum many-body dynamics and critical phenomena under continuous observation” 2017 Sweden-Japan International Workshop on Quantum Nanophysics and Nanoelectronics (QNANO2017) (March 23-24, Yokohama, Japan, 2017)

[48] M. Ueda, “Gibbs paradox in mesoscopic systems” Fundamental Aspects of Statistical Physics and Thermodynamics (March 27-30, Bielefeld, Germany, 2017)

[49] M. Ueda, "Quantum many-body dynamics and critical phenomena under continuous observation" International Workshop on Topological Structures in Quantum Matter (June 12-15, Hanaholmen, Finland, 2017)

[50] M. Ueda, "Quantum many-body dynamics and critical phenomena under continuous observation" Information Engines at the Frontiers of Nanoscale Thermodynamics (August 3-11, Telluride, USA, 2017)

[51] M. Ueda, "Dynamics of continuously monitored quantum many-body systems" Quantum Optics IX (September 17-23, Gdańsk, Poland, 2017)

[52] M. Ueda, "Zeno Hall effect and spin Hall effect with spin inversion symmetry" Workshop on Long-Range Interactions in Atomic Systems: Magnetic Dipoles, Rydberg Atoms and Ions (December 5-8, São Calros, Brazil, 2017)

[53] M. Ueda, "Atypicality of most few-body observables" Stellenbosch Workshop on Quantum Many-Body Systems far from Equilibrium: Quench Dynamics, Thermalization, and Many-Body Localization (March 12-16, Stellenbosch, South Africa, 2018)

[54] M. Ueda, "Atypicality of most few-body observables" KITP Quantum Thermodynamics Conference (June 25-29, Santa Barbara, USA, 2018)

[55] M. Ueda, "Zeno Hall Effect and Many-body Spin Hall Effect with Space Inversion Symmetry" Workshop on Majorana Fermions and Topological Materials Science (July 21-27, Erice, Italy, 2018)

[56] M. Ueda, "Linear and nonlinear response theory in ultracold atomic gases: Part I and PartII" International School on Linear Response and Nonequilibrium Dynamics in Quantum Many-Body Systems (August 13-16, Castle Burgbrohl, Germany, 2018)

[57] M. Ueda, "Quantum dynamics under continuous observation or dissipation" US-Japan QELS-13, the 13th Japan-US Joint Seminar on Quantum Electronics and Laser Spectroscopy (September 25-28, Kanazawa, Japan, 2018)

[58] M. Ueda, "Dynamics of continuously monitored quantum many-body systems" 685.WE-Heraeus-Seminar on Research Frontiers in Ultracold Quantum Gases (December 17-21, Bad Honnef, Germany, 2018)

[59] M. Ueda, "Nonequilibrium many-body dynamics under continuous observation" International conference on "Nonequilibrium and transport in many-body systems" (January 20-24, Weizmann Institute, Rehovot, Israel, 2019) (keynote)

[60] M. Ueda, "Nonequilibrium thermodynamics and many-body dynamics in open quantum systems" APS March Meeting 2019 (March 4-8, Boston, USA, 2019)

[61] M. Ueda, "Nonequilibrium thermodynamics and many-body dynamics in open quantum systems" Workshop on Quantum Information and Thermodynamics (March 11-22, Natal, Brazil, 2019)

[62] M. Ueda, "Nonequilibrium thermodynamics and many-body dynamics in open quantum systems" featured speaker at the Joint Quantum Semiar (JQS) (April 3, Harvard University, USA, 2019)

[63] M. Ueda, "Nonequilibrium thermodynamics and many-body dynamics in open quantum systems" Conference on Quantum Measurement: Fundamentals, Twists, and Applications (April 29-May 4, Trieste, Italy, 2019)

[64] M. Ueda, "Coarsening dynamics of spinor mixtures: universal dynamical scaling and NTFP" Workshop on Quantum Mixtures and celebration of the 70th anniversary of Sandro Stringari (July 15-17, Trento, Italy, 2019)

[65] M. Ueda, "Discrete time-crystalline order in cavity- and circuit-QED systems" Workshop on Time Crystals and Related Phenomena (September 4-6, Krakow, Poland 2019)

8 Teaching Accomplishment

Since 2012, I have mentored 14 PhD students. Of them, 7 are now assistant professors, 3 are posdocs and 4 are working in industries. Three of them were recommeded by the department for prestigeous Springer Theses. Two (one PhD and one master) got president's awards for their theses. One got JSPS Ikushi Prize which is endowed from His Majesty the Emperor Emeritus Akihito on the 20th year of his reign.

9 Contribution to Academic Community

9.1 Editorial Activities

I am an editorial board member of Annual Review of Condensed Matter Physics and Physical Review X.

9.2 Organization and Advisory of Conferences

I am on the advisory board member of a MEXT Quantum Leap Flagship Program (MEXT Q-LEAP). I am also the research supervisor of the CREST program of Japan Science and Technology Agency.

10 Outreach

I have made a number of outreach activities for junior and high school students and also served as a lecturer for national institutes and industrial research institutes for general scientific training and communication skills.

11 Committee Service

During 2015 and 2016, I served as a committee member of the Central Council for Education, MEXT.Since 2018, I have served as a member of the Quantum Science and Technology Committee of MEXT.

11.1 External Committees

- International Committee Member, The International Conferences on Recent Progress in Many-Body Theories (2005–2016)

11.2 University Committees

理学系研究科長補佐 2012 年 –2013 年
入試企画室　室員 2012 年 –2014 年
入試調査室　室員 2014 年 –2015 年

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	9	China, France, Vietnam
Doctor Course	7	China, Vietnam
Foreign researchers hosted	6	Germany, USA
Students sent abroad	20	China,Korea,Luxembourg, USA
Researchers sent abroad	3	USA
Foreign visitors	18	Aultralia, Germany, India, Singapore, Spain, Sweden, Taiwan, USA

Hirofumi Sakai、酒井 広文

1 Education and Professional Experiences

Education

1983	B.S. (Physics)	The University of Tokyo
1994	Dr. Sc. (Physics)	The University of Tokyo

Professional Appointments

April 1983−March 1992	Researcher	Electrotechnical Laboratory
April 1992−September 1999	Senior Researcher	Electrotechnical Laboratory
October 1999−July 2016	Associate Professor	The University of Tokyo
July 2016−	Professor	The University of Tokyo

2 Research Highlights

(1) Laser-field-free orientation of state-selected asymmetric top molecules [1]

With combined electrostatic and shaped laser fields with a slow turn on and rapid turn off, laser-field-free orientation of asymmetric top iodobenzene molecules with higher degrees of orientation has been achieved. In order to further increase the degrees of orientation, state-selected molecules are used as a sample. It is confirmed that higher degrees of orientation are maintained in the laser-field-free condition for 5–10 ps, which is long enough to study femtosecond–attosecond dynamics in molecules, after the rapid turn off of the laser pulse. The observation of the slow dephasing time of 5–10 ps ensures future prospects in molecular orientation techniques. This accomplishment means not only that a unique molecular sample has become available in various applications but also that the present technique can be used as a spectroscopic technique to investigate ultrafast rotational dynamics of molecules.

(2) Laser-field-free three-dimensional molecular orientation [2]

Laser-field-free three-dimensional orientation, corresponding to the complete control of spatial directions of asymmetric top molecules, is achieved with combined weak electrostatic and elliptically polarized laser fields with an 8-ns turnon and a 150-fs turnoff, which is shaped by a plasma shutter. Rotationally cold 3,4-dibromothiophene molecules are used as a sample, and their lower-lying rotational states are selected by a molecular deflector to increase the degrees of orientation. After the rapid turnoff of the pump pulse, higher degrees of orientation are maintained for 5–10 ps, which is long enough for various applications including electronic stereodynamics in molecules with femtosecond pulses.

(3) Recipe for preparing a molecular ensemble with macroscopic three-fold symmetry [3]

We propose how to prepare a molecular ensemble with macroscopic threefold symmetry. By utilizing the special laser electric field trajectory with threefold symmetry, which can be formed by superposing a counterrotating circularly polarized fundamental pulse and its second harmonic pulse, sample molecules with threefold symmetry such as BX_3 (X = F, Cl, Br, I) can be aligned with their three arms along (or in between) the laser electric fields with threefold symmetry depending on the sign of the hyperpolarizability of the sample molecule. We show that this method is feasible with practical experimental conditions as for the rotational temperature of the sample molecules and the intensities of the two wavelengths. This method will open up physics of symmetry concerning a molecular ensemble with macroscopic threefold symmetry.

(4) Orientation dependence in multichannel dissociative ionization of OCS molecules [4]

With 800-nm, 25-fs elliptically polarized ionization pulses, we observe molecular frame photoelectron angular distributions (MF-PADs) correlated with different dissociative ionization channels: $OCS^+ \rightarrow S^+ + CO$, $CO^+ + S$, $CS^+ + O$, and $O^+ + CS$. We find that the asymmetry in the MF-PAD depends on the specific dissociation channel and the laser intensities. For the dissociation channel leading to the production of O^+, the OCS molecules are more likely to be ionized when the electric field points toward the O atom, while for other dissociation channels, they are more likely to be ionized when the electric field points toward the S atom.

[1] Je Hoi Mun, Daisuke Takei, Shinichirou Minemoto, and Hirofumi Sakai, "Laser-field-free orientation of state-selected asymmetric top molecules," Phys. Rev. A **89**, 051402(R) (2014).

[2] Daisuke Takei, Je Hoi Mun, Shinichirou Minemoto, and Hirofumi Sakai, "Laser-field-free three-dimensional molecular orientation," Phys. Rev. A **94**, 013401 (2016).

[3] Hiroto Nakabayashi, Wataru Komatsubara, and Hirofumi Sakai, "Recipe for preparing a molecular ensemble with macroscopic three-fold symmetry," Phys. Rev. A **99**, 043420 (2019).

[4] Yusuke Sakemi, Shinichirou Minemoto, and Hirofumi Sakai, "Orientation dependence in multichannel dissociative ionization of OCS molecules," Phys. Rev. A **96**, 011401(R) (2017).

3 Selected Papers

- Hiroto Nakabayashi, Wataru Komatsubara, and Hirofumi Sakai, Phys. Rev. A **99**, 043420 (2019).
  We proposed how to prepare *a new class of* molecular ensemble with macroscopic threefold symmetry.

- Yusuke Sakemi, Shinichirou Minemoto, and Hirofumi Sakai, Phys. Rev. A **96**, 011401(R) (2017).
  With 800-nm, 25-fs elliptically polarized ionization pulses, we observe molecular frame photoelectron angular distributions (MF-PADs) *correlated with different dissociative ionization*

channels of OCS molecules. This work was published as a Rapid Communication in Physical Review A. Times cited: 4

- Daisuke Takei, Je Hoi Mun, Shinichirou Minemoto, and Hirofumi Sakai, Phys. Rev. A **94**, 013401 (2016).
  Laser-field-free three-dimensional orientation, corresponding to the complete control of spatial directions of asymmetric top molecules, is achieved with combined weak electrostatic and elliptically polarized laser fields with an 8-ns turnon and a 150-fs turnoff, which is shaped by a plasma shutter. This accomplishment should be regarded as the acme of the molecular orientation technique based on the combined-field technique because all the requirements (laser-field-free condition, three-dimensional control, and higher degrees of orientation) strongly desired for the molecular orientation technique are successfully achieved. Times cited: 17.

- Je Hoi Mun, Daisuke Takei, Shinichirou Minemoto, and Hirofumi Sakai, Phys. Rev. A **89**, 051402(R) (2014).
  With combined electrostatic and shaped laser fields with a slow turn on and rapid turn off, laser-field-free orientation of asymmetric top iodobenzene molecules with higher degrees of orientation has been achieved. This work was published as a Rapid Communication in Physical Review A. Times cited: 14.

- Kosaku Kato, Shinichirou Minemoto, Yusuke Sakemi, and Hirofumi Sakai, Phys. Rev. A **90**, 063403 (2014).
  With our home-built velocity map imaging spectrometer for the RABBIT technique, we observed the phase differences $\Delta\phi_{\mathrm{HH}}^{(2n)}$ between adjacent high-order harmonics generated from Ar and N_2 at the near-threshold region. Times cited: 7

4 Honors, Awards and Professional Society Memberships

October 2019 The 23rd Matsuo Foundation Takuma Hiroshi Memorial Award
May 2017 Senior Member, The Laser Society of Japan

Professional Society Memberships
The Optical Society
The Physical Society of Japan
The Japan Society of Applied Physics
The Laser Society of Japan
The Atomic Collision Society of Japan
The Spectroscopical Society of Japan

5 Research Plan

(1) Forming a gaseous crystal with three-fold symmetry

Recently, we proposed how to prepare a molecular ensemble with macroscopic three-fold symmetry, which can be regarded as a gaseous crystal with three-fold symmetry [1]. By utilizing the special laser electric field trajectory with three-fold symmetry, which can be formed by superposing a counter-rotating circularly-polarized fundamental pulse and its second harmonic pulse, sample molecules with three-fold symmetry such as BX_3 (X=F, Cl, Br, I) can be aligned with their three arms along (or in between) the laser electric fields with three-fold symmetry depending on the sign of the hyperpolarizability of the sample molecule. We are aiming at the first demonstration of the formation of a gaseous crystal with three-fold symmetry. The preparation of a molecular ensemble with macroscopic three-fold symmetry could be confirmed by observing the angular distributions of the fragment ions produced with circularly polarized femtosecond probe pulses. To observe those fragment ions produced in the circular polarization plane of the two-color pump pulse, they are to be first extracted by utilizing the ion optics technique and then to be projected onto the two-dimensional ion detector [2]. The ion images on the detector plane are recorded by a CCD camera. We have already modified our experimental apparatus.

[1] H. Nakabayashi, W. Komatsubara, and Hirofumi Sakai, "Recipe for preparing a molecular ensemble with macroscopic three-fold symmetry," Phys. Rev. A **99**, 043420 (2019).

[2] K. Mizuse, K. Kitano, H. Hasegawa, and Y. Ohshima, Sci. Adv. **1**, e1400185 (2015).

(2) Field-free molecular orientation with an intense nonresonant two-color laser pulse with a slow turn on and a rapid turn off

We aim to develop techniques for controlling one- and three-dimensional molecular orientation in the completely field-free condition. To that end, we need an all-optical technique. Actually, the proof-of-principle experiment of all-optical molecular orientation has already been demonstrated [1]. The technique is based on the combined effects of the anisotropic hyperpolarizability interaction as well as the anisotropic polarizability interaction with an intense nonresonant two-color laser field [2]. We aim to achieve both one- and three-dimensional molecular orientation. One-dimensional molecular orientation can be achieved with the polarizations of the two wavelengths parallel to each other, while three-dimensional molecular orientation can be achieved with the polarizations of the two wavelengths crossed.

[1] Keita Oda, Masafumi Hita, Shinichirou Minemoto, and Hirofumi Sakai, "All-optical molecular orientation," Phys. Rev. Lett. **104**, 213901 (2010).

[2] Tsuneto Kanai and Hirofumi Sakai, "Numerical simulations of molecular orientation using strong, nonresonant, two-color laser fields," J. Chem. Phys. **115**, 5492 (2001).

(3) Development of "electronic stereodynamics in molecules"

Some important physical phenomena such as nonsequential double ionization [1], above-threshold ionization, and high-order harmonic generation are caused by electron recollision within one optical cycle. When molecules are used as a sample, alignment and orientation dependence in these phenomena is always a matter of central concern. We therefore anticipate our competitors in developing "electronic stereodynamics in molecules" [2] by using an aligned/oriented molecular sample or by using our recently developed COincidence Velocity-map Imaging Spectrometer (COVIS) for photoelectrons and fragment ions [3]. With the COVIS apparatus, we can observe alignment/orientation dependence in the above phenomena even with a sample of randomly oriented molecules.

[1] Hirofumi Sakai, Jakob Juul Larsen, Ida Wendt-Larsen, Johannes Olesen, Paul B. Corkum, and Henrik Stapelfeldt, "Nonsequential double ionization of D_2 molecules with intense 20 fs pulses," Phys. Rev. A **67**, 063404 (2003).

[2] D. Herschbach, "Chemical stereodynamics: retrospect and prospect," Eur. Phys. J. D **38**, 3 (2006).

[3] Yusuke Sakemi, Shinichirou Minemoto, and Hirofumi Sakai, "Orientation dependence in multichannel dissociative ionization of OCS molecules," Phys. Rev. A **96**, 011401 (R) (2017).

6 Publications and Patents

< Refereed Original Papers >

[1] Je Hoi Mun, Shinichirou Minemoto, and Hirofumi Sakai, Opt. Express **27**, 19130 (2019).

[2] Je Hoi Mun, Hirofumi Sakai, and Rosario González-Férez, Phys. Rev. A **99**, 053424 (2019).

[3] Hiroto Nakabayashi, Wataru Komatsubara, and Hirofumi Sakai, Phys. Rev. A **99**, 043420 (2019).

[4] Hiroyuki Shimada, Kazma Komatsu, Wataru Komatsubara, Tomoya Mizuno, Soichiro Miyake, Shinichirou Minemoto, Hirofumi Sakai, Takuya Majima, Shigeki Owada, Tadashi Togashi, Makina Yabashi, and Akira Yagishita, J. Phys. B **52**, 065602 (2019).

[5] Shinichirou Minemoto, Hiroyuki Shimada, Kazma Komatsu, Wataru Komatsubara, Takuya Majima, Soichiro Miyake, Tomoya Mizuno, Shigeki Owada, Hirofumi Sakai, Tadashi Togashi, Makina Yabashi, Piero Decleva, Mauro Stener, Shota Tsuru, and Akira Yagishita, J. Phys. Commun. **2**, 115015 (2018).

[6] Hiroyuki Shimada, Shinichirou Minemoto, Kazma Komatsu, Wataru Komatsubara, Shintaro Yoshida, Takuya Majima, Tomoya Mizuno, Hirofumi Sakai, Shigeki Owada, Tadashi Togashi, Makina Yabashi, and Akira Yagishita, J. Phys. B **51**, 225601 (2018).

[7] Wataru Komatsubara, Shinichirou Minemoto, and Hirofumi Sakai, Phys. Rev. A **98**, 023416 (2018).

[8] Je Hoi Mun and Hirofumi Sakai, Phys. Rev. A **98**, 013404 (2018).

[9] Shinichirou Minemoto, Hiroyuki Shimada, Kazma Komatsu, Wataru Komatsubara, Takuya Majima, Tomoya Mizuno, Shigeki Owada, Hirofumi Sakai, Tadashi Togashi, Shintaro Yoshida, Makina Yabashi, and Akira Yagishita, J. Phys. B **51**, 075601 (2018).

[10] Yusuke Sakemi, Shinichirou Minemoto, and Hirofumi Sakai, Phys. Rev. A **96**, 011401(R) (2017).

[11] Daisuke Takei, Je Hoi Mun, Shinichirou Minemoto, and Hirofumi Sakai, Phys. Rev. A **94**, 013401 (2016).

[12] Shinichirou Minemoto, Takahiro Teramoto, Hiroshi Akagi, Takashi Fujikawa, Takuya Majima, Kyo Nakajima, Kaori Niki, Shigeki Owada, Hirofumi Sakai, Tadashi Togashi, Kensuke Tono, Shota Tsuru, Ken Wada, Makina Yabashi, Shintaro Yoshida, and Akira Yagishita, Sci. Rep. **6**, 38654; doi: 10.1038/srep38654 (2016).

[13] Kyo Nakajima, Takahiro Teramoto, Hiroshi Akagi, Takashi Fujikawa, Takuya Majima, Shinichirou Minemoto, Kanade Ogawa, Hirofumi Sakai, Tadashi Togashi, Kensuke Tono, Shota Tsuru, Ken Wada, Makina Yabashi, and Akira Yagishita, Sci. Rep. **5**, 14065; doi: 10.1038/srep14065 (2015).

[14] Je Hoi Mun, Daisuke Takei, Shinichirou Minemoto, and Hirofumi Sakai, Phys. Rev. A **89**, 051402(R) (2014).

[15] Kosaku Kato, Shinichirou Minemoto, Yusuke Sakemi, and Hirofumi Sakai, Phys. Rev. A **90**, 063403 (2014).

[16] Yusuke Sakemi, Kosaku Kato, Shinichirou Minemoto, and Hirofumi Sakai, Phys. Rev. A **85**, 051801(R) (2012).

< Conference Proceedings >

< Review Papers >

< Books >

< Patent Applications >

7 Invited Presentations at International Conferences

[1] Hirofumi Sakai, “Orientation dependence in multi-channel dissociative ionization of carbonyl sulfide (OCS) molecules,” EMN Meeting on Ultrafast 2016, Melbourne, Australia, October 11, 2016.

[2] Hirofumi Sakai, “Laser-field-free three-dimensional molecular orientation,” Stereodynamics 2014, St. Petersburg, Russia, August, 2014.

[3] Hirofumi Sakai, “Laser-field-free alignment and orientation of state-selected asymmetric top molecules,” International Symposium on (e, 2e), Double Photoionization and Related Topics & the 17th International Symposium on Polarization and Correlation in Electronic and Atomic Collisions, Hefei, China, August, 2013.

[4] Hirofumi Sakai, “Laser-field-free orientation of state-selected molecules,” 10th Asian International Seminar on Atomic and Molecular Physics, Taipei, Taiwan, Republic of China, October, 2012.

8 Teaching Accomplishment

- October 2018, Mr. Kazma Komatsu (M2) received the Student Excellent Presentation Award from the Physical Society of Japan.
- March 2016, Mr. Wataru Komatsubara (B4) received the 2015 Faculty of Science Encouragement Award.
- September 2015, Dr. Kosaku Kato received the 16th Young Researcher Encouragement Award from the Atomic Collision Society of Japan.
- March 2015, Mr. Kei Nakagawa (M2) received the 2014 Graduate School of Science Research Encouragement Award (Master's Course).
- May 2014, Mr. Kosaku Kato received the Young Poster Award in 2014 Annual Meeting of the Spectroscopical Society of Japan.
- March 2014, Mr. Kentaro Komori received the 2013 Faculty of Science Encouragement Award.

9 Contribution to Academic Community

9.1 Editorial Activities

Associate Editor for Frontiers in Physics, Physical Chemistry and Chemical Physics.

9.2 Organization of Professional Societies

9.3 Organization and Advisory of Conferences

10 Outreach

酒井広文、公益財団法人、平成基礎科学財団、楽しむ科学教室、第 95 回講演「光について知り、考えよう～基礎的性質から最先端レーザー技術まで～」、2015 年 12 月 5 日（土）、鳥取県立生涯学習センター県民ふれあい会館講義室。

11 Committee Service

11.1 External Committees

11.2 University Committees

前期日程入試　理学部試験場　総監督補佐 2016 年度
前期日程入試　理学部試験場　総監督 2017 年度
理学系研究科入試実施委員会　副委員長 2019 年度
理学系研究科・理学部　環境安全管理室員 2019 年度

理学系研究科技術委員会委員 2019 年度
理学系研究科入試実施委員会　委員長 2020 年度（予定）

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	7	Australia, U.S.A. (Taiwanese), Ireland, U.S.A. (Italian), United Kingdom (French), France, Russia
Master Course	2	ROK, PRC
Doctor Course	2	ROK, Bangladesh
Foreign researchers hosted	1	Bangladesh
Students sent abroad	2	Germany, United Kingdom
Researchers sent abroad	0	
Foreign visitors	8	Germany (1), U.K.(3), Switzerland(1), U.S.A.(2), Canada(1)

Yuichi Takase、高瀬 雄一

1 Education and Professional Experiences

Education

1978	B.S. (Physics)	The University of Tokyo
1983	Sc.D. (Physics)	Massachusetts Institute of Technology

Professional Appointments

1983−1992	Research Scientist	Massachusetts Institute of Technology
1992−1997	Principal Research Scientist	Massachusetts Institute of Technology
1997−	Professor	The University of Tokyo

2 Research Highlights

Thermonuclear fusion is a promising candidate for generating abundant, safe, and clean power. A magnetic configuration called the tokamak has reached the level where the International Thermonuclear Experimental Reactor (ITER) is being constructed to study the behavior of a burning plasma. The spherical tokamak (ST) offers a promising approach to increasing the efficiency by raising the plasma beta (the ratio of plasma pressure to magnetic pressure). Our group is tackling the problem of creating and sustaining ST plasmas using radio frequency (RF) waves on the TST-2 spherical tokamak. Noninductive plasma current ($I_{\rm p}$) initiation and ramp-up experiments are being conducted on TST-2 with up to 400 kW of RF power in the lower hybrid (LH) frequency range (200 MHz). It was found that the optimum wavenumber of the excited LH wave is around $n_\parallel$ =1–6 ($n_\parallel = ck_\parallel/\omega$). Experiments using the newly developed capacitively coupled combline (CCC) antenna yielded the highest current drive efficiency among the three antennas used so far. This is attributed to excitation of the LH wave with sharp wavenumber spectrum with high directivity.

A ray-tracing code GENRAY was used to investigate the optimum poloidal launch angle of the LHW. Since top-launch was found to be favorable, a new top-launch antenna was developed for better wave accessibility to the plasma core at higher density. The highest plasma current achieved with the present limiter configuration was 21, 26, 27 kA for the outboard-launch, top-launch, and reversed field top-launch scenarios, respectively. The reversed field top-launch scenario is equivalent to bottom-launch in forward-field. Numerical simulation was able to explain the difference between the above three current drive scenarios qualitatively. The top-launch antenna excites waves at high phase-velocity and the generated fast electrons are more energetic compared to the outboard-launch antenna. In the bottom-launch (reversed-field top-launch) case, the phase-velocity increases initially, which results in even more energetic fast electrons. Numerical simulation of LH current drive showed that there is an optimum density for current drive due to balancing of current drive saturation at low density and wave diffraction at high density. The simulated optimum density increased with the toroidal field strength, which was consistent with the experimental observation. Increase in the density limit was observed with the top-launch antenna, in agreement with the theoretical prediction. When the LH wave was launched from the top-side of the plasma, a strong up-shift of the poloidal wavenumber was expected above the plasma current of 16 kA for the TST-2 parameters. In the experiment, a dramatic increase of soft X-ray radiation was observed which may be consistent with the strong up-shift in the wavenumber. A hard X-ray (HXR) diagnostic was developed to measure Bremsstrahlung emission emitted by energetic electrons in LH-driven discharges. The HXR flux as well as the effective temperature was observed to increase with the plasma current. A LYSO based hard X-ray imaging diagnostic, with 4 times better time resolution compared to NaI based detectors, was designed to identify the source of hard X-ray radiation more accurately. With power modulation experiment, the existence of barely confined, and thus quickly lost fast electrons were suggested. A microwave polarimeter is being developed to measure the internal current profile which is hard to estimate only with external magnetic diagnostics. Initial measurement was performed and polarimeter phase was successfully measured, but reduction of noise is necessary. A Ka-band (26.5–40 GHz) microwave scattering diagnostic is being developed for direct measurement of the LH waves. Magnetic probes were used to study LH wave propagation. The newly installed probes at the center stack showed drastically different wave propagation characteristics between the top-launch and the outboard-launch antennas, partially consistent with the ray-tracing calculations.

AC Ohmic heating is a method for pre-ionization, heating and current drive of a plasma by applying $\sim$1 kHz voltage on the Ohmic coil. Since the flux changes little with this method, it may be possible to reduce the size of the Ohmic coil substantially. It has been shown that AC Ohmic operation can successfully pre-ionize the plasma, which in turn, can be ramped up using LHW. The break-down process was investigated in detail using visible camera with a dynamic range of 6 orders of magnitudes. A 1D model has been developed to explain the pre-ionization process. Inclusion of ExB drift and AC electric field was found to improve the agreement between the model and the experimental observation.

Our group also collaborate with other fusion experiments in Japan and abroad, including JT-60SA, LHD, LATE, QUEST, Alcator C-Mod (US), and MAST (UK). Thomson scattering measurement was performed for ECH driven discharges in QUEST. For 28 GHz ECH driven discharge, the parallel refractive index was scanned. Much higher temperature was achieved at lower parallel refractive index suggesting bulk heating. Soft X-ray imaging system is being developed as a collaboration with PPPL. Design optimization for a DIII-D H-mode discharge and a JT-60SA neutral beam driven discharge was performed. A similar system is planned to be installed on TST-2 and the design is being finalized.

3 Selected Papers

- Y. Takase, A. Ejiri, H. Kakuda, et al., Nucl. Fusion **53**, 063006 (2013).
  This paper reports the non-inductive plasma formation and plasma current generation using RF waves on TST-2.
- M. Greenwald, A. Bader, S. Baek, et al., Phys. Plasmas **21**, 110501 (2014).
  This work reviews the accomplishments of the Alcator C-Mod tokamak at MIT during the past 20 years.

- T. Shinya, Y. Takase, S. Yajima, et al., Nucl. Fusion **57**, 036006 (2016).
  This paper summarizes the comparison of plasma current start-up using different wave launching schemes.

- Y. Takase, A. Ejiri, T. Fujita, et al., Nucl. Fusion **57**, 102005 (2017).
  This paper reviews the accomplishments of spherical tokamak research in Japan.

- N. Tsujii, Y. Takase, A. Ejiri, et al., Nucl. Fusion **57**, 126032 (2017).
  This work reports the results of theoretical analyses of plasma current generation using RF waves.

4 Honors, Awards and Professional Society Memberships

The Physical Society of Japan
The Americcan Physical Society
The Japan Society of Plasma Science and Nuclear Fusion Research

5 Research Plan

Experimental results to date indicate an almost linear dependence of the driven plasma current with the toroidal magnetic field. This is attributed to the absorption of the LH wave near the periphery of the plasma which leads to a substantial loss of the current-carrying energetic electrons accelerated by the LH wave. Numerical simulation indicates that this situation improves as the toroidal magnetic field is increased because of improved accessibility of the LH wave at higher magnetic fields. The resultant higher plasma current would further improve the confinement of energetic electrons. Therefore, a substantial improvement in the driven plasma current (by an order of magnitude) is expected. The upgrade of the toroidal field coil power supply up to the 0.3 T capability for over 0.1 s has the highest priority. An additional bank of supercapacitors is being added as funding permits. A conversion of the toroidal field coils to use the rapidly developing high-temperature REBCO superconductors is also being considered. The higher toroidal field would be utilized more effectively by replacing the present 2.45 GHz ECH preionization source with a higher frequency (such as 8.2 GHz) system.

The control of the cross sectional shape of the toroidal plasma has important consequences to the stability as well as energy and particle transport. Recent experiments using a small hand-wound solenoid on the inboard midplane of the torus have demonstrated its utility to alter the triangularity of the plasma cross section by either pushing or pulling the plasma. The replacement of this coil with a small solenoid with higher current capability is planned.

A large, powerful tokamak with superconducting coils (JT-60SA), being built at Naka Fusion Institute of QST under JA-EU collaboration, is scheduled to begin plasmma operation in 2020. Since the rate of current change in superconducting coils (and therefore the inductive flux change that can be supplied) is limited, the development of a reliable plasma start-up scenario is imperative. Our group has started development and optimization of start-up scenario for JT-60SA.

This activity will continue, and our group will participate in the integrated commissioning of the JT-60SA tokamak, as well as the plasma experiments using this device.

6 Publications and Patents

< Refereed Original Papers >

[1] H. Tojo, A. Ejiri, J. Hiratsuka, T. Yamaguchi, Y. Takase, K. Itami, and T. Hatae: "First measurement of electron temperature from signal ratios in a double-pass Thomson scattering system", Rev. Sci. Instrum. **83** (2012) 023507.

[2] H. Tojo, A. Ejiri, J. Hiratsuka, T. Yamaguchi, Y. Takase, K Itami and T. Hatae: "Demonstration of in-situ relative calibration method for a Thomson scattering diagnost.ic on TST-2", Journal of Instrumentation **7** (2012) P04005.

[3] M. Ishiguro, K. Hanada, H. Liu, H. Zushi, K. Nakamura, A. Fujisawa, H. Idei, Y. Nagashima, M. Hasegawa, S. Tashima, Y. Takase, Y. Kishimoto, O. Mitarai, S. Kawasaki, H. Nakashima and A. Higashijima: "Non-inductive current start-up assisted by energetic electrons in Q-shu University experiment with steady-state spherical tokamak", Phys. Plasmas **19** (2012) 062508.

[4] T. Tokuzawa, A. Ejiri, K. Kawahata, K. Tanaka, I. Yamada, M. Yoshinuma, K. Ida, and C. Suzuki: "Microwave Doppler reflectometer system in LHD", Rev. Sci. Instrum. **83** (2012) 10E322.

[5] J. Hiratsuka, A. Ejiri, M. Hasegawa, Y. Nagashima, Y. Takase, H. Tojo, T. Yamaguchi, T. Ambo, H. Furui, T. Hashimoto, H. Kakuda, K. Kato, T. Oosako, T. Sakamoto, R. Shino, T. Shinya, M. Sonehara, T. Wakatsuki and O. Watanabe: "Off-Axis Temperature Anisotropy Measurement by Double-Pass Thomson Scattering Diagnostic System on TST-2", Plasma Fusion Res. **7** (2012) 2402092.

[6] M. Sonehara, Y. Nagashima, Y. Takase, A. Ejiri, T. Yamaguchi, T. Ambo, H. Kakuda, J. Hiratsuka, T. Sakamoto, R. Shino, T. Wakatsuki and O. Watanabe: "Fluctuation Measurement Across the Broad Range of the Low-field Side Edge Plasmas in the TST-2 Spherical Tokamak", IEEJ Transactions on Fundamentals and Materials. **132** (2012) 499.

[7] K. Hanada, H. Zushi, H. Idei, K. Nakamura, M. Ishiguro, S. Tashima, E. Kalinnikova, M. Sakamoto, M. Hasegawa, A. Fujisawa, K. Sato, N. Yoshida, H. Watanabe, K. Tokunaga, Y. Nagashima, A. Higashijima, S. Kawasaki, H. Nakashima, H. Liu, O. Mitarai, T. Maekawa, A. Fukuyama, Y. Takase and J. Qian: "QUEST Experiments Towards Steady State Operation of Spherical Tokamaks", IEEJ Transactions on Fundamentals and Materials. **132** (2012) 490.

[8] T. Wakatsuki, A. Ejiri, H. Kakuda, Y. Takase, T. Ambo, H. Furui, T. Hashimoto, J. Hiratsuka, H. Kasahara, K. Kato, R. Kumazawa, Y. Nagashima, K. Saito, T. Sakamoto, T. Seki, F. Shimpo, R. Shino, T. Shinya, M. Sonehara, O. Watanabe, T. Yamaguchi and C. P. Moeller: "X-ray Measurements during Plasma Current Start-up Experiments using the Lower Hybrid Wave on the TST-2 Spherical Tokamak" , IEEJ Transactions on Fundamentals and Materials. **132** (2012) 485.

[9] S. Kamio, K. Yamasaki, K. Takemura, Q. H. Cao, T. G. Watanabe, H. Itagaki, T. Tsutsui, K. Ishiguchi, R. Imazawa, T. Yamada, C. Z. Cheng, M. Inomoto, Y. Takase and Y. Ono: "Development of Multi-channel Doppler Spectroscopic Measurement System Using 8x8 Multianode Photomultiplier Tube Assembly", Rev. Sci. Instrum. **83** (2012) 083103.

[10] S. Kamio, K. Yamasaki, K. Takemura, Q. H. Cao, T. G. Watanabe, H. Itagaki, T. Tsutsui, K. Ishiguchi, R. Imazawa, T. Yamada, C. Z. Cheng, M. Inomoto, Y. Takase, Y. Ono: "Electron Acceleration by Magnetic Reconnection During Spherical Tokamak Merging Experiment", IEEJ Transactions on Fundamentals and Materials. **133** (2013) 166.

[11] T. Yamaguchi, A. Ejiri, J. Hiratsuka, M. Hasegawa, Y. Nagashima, K. Narihara, Y. Takase, H. Zushi and the QUEST group: "Electron Temperature Measurement on QUEST Spherical Tokamak by Thomson Scattering System", Plasma Fusion Res. **8** (2013) 1302001.

[12] Y. Takase, A. Ejiri, H. Kakuda, T. Oosako, T. Shinya, T. Wakatsuki, T. Ambo, H. Furui, T. Hashimoto, J. Hiratsuka, H. Kasahara, K. Kato, R. Kumazawa, C.P. Moeller, T. Mutoh, A. Nakanishi, Y. Nagashima, K. Saito, T. Sakamoto, T. Seki, M. Sonehara, R. Shino, H. Togashi, O. Watanabe, and T. Yamaguch: "Non-inductive plasma initiation and plasma current ramp-up on the TST-2 spherical tokamak", Nucl. Fusion **53** (2013) 063006.

[13] H. Togashi, A. Ejiri, M. Hasegawa, J. Hiratsuka, Y. Nagashima, K. Nakamura, K. Narihara, Y. Takase, H. Tojo, N. Tsujii, I. Yamada, T. Yamaguchi, and the TST-2 Team: "Injection and Confinement of a Laser Pulse in an Optical Cavity for Multi-Pass Thomson Scattering Diagnostics in the TST-2 Spherical Tokamak Device", Plasma Fusion Res. **9** (2014) 1202005.

[14] T. Shinya, A. Ejiri, Y. Takase, T. Wakatsuki, T. Oosako, N. Tsujii, H. Kakuda, H. Furui, J. Hiratsuka, T. Inada, K. Imamura, K. Nakamura, A. Nakanishi, M. Sonehara, H. Togashi, S. Tsuda, T. Yamaguchi, H. Kasahara, K. Saito, T. Seki, F. Shimpo, Y. Nagashima, O. Watanabe and T. Yamada: "Identification of Waves by RF Magnetic Probes during Lower Hybrid Wave Injection Experiments on the TST-2 Spherical Tokamak", Plasma Fusion Res. **9** 3402040 (2014).

[15] H. Togashi, A. Ejiri, J. Hiratsuka, K. Nakamura, Y. Takase, T. Yamaguchi, H. Furui, K. Imamura, T. Inada, H. Kakuda, A. Nakanishi, T. Oosako, T. Shinya, M. Sonehara, S. Tsuda, N. Tsujii, T. Wakatsuki, M. Hasegawa, Y. Nagashima, K. Narihara, I. Yamada and H. Tojo: Note: "Multi-pass Thomson scattering measurement on the TST-2 spherical tokamak", Rev. Sci. Instrum. **85** 056103 (2014)

[16] H. Furui, Y. Nagashima, Y. Takase, A. Ejiri, H. Kakuda, M. Sonehara, T. Oosako, N. Tsujii, J. Hiratsuka, K. Imamura, T. Inada, K. Nakamura, A. Nakanishi, T. Shinya, H. Togashi, S. Tsuda, T. Wakatsuki and T. Yamaguchi: "Development of a Local Current Diagnostic using a Small Rogowski Coil for a Spherical Tokamak Plasma in TST-2", Plasma Fusion Res. **9** 3402078 (2014).

[17] T. Wakatsuki, A. Ejiri, T. Shinya, Y. Takase, H. Furui, J. Hiratsuka, K. Imamura, T. Inada, H. Kakuda, H. Kasahara, Y. Nagashima, K. Nakamura, A. Nakanishi, T. Oosako, K. Saito, T. Seki, M. Sonehara, H. Togashi, S. Tsuda, N. Tsujii and T. Yamaguchi: "Plasma current start-up experiments using a dielectric-loaded waveguide array antenna in the TST-2 spherical tokamak", Nucl. Fusion **54** 093014 (2014).

[18] T. Shinya, Y. Takase, C. P. Moeller, T. Wakatsuki, T. Inada, T. Oosako, H. Kakuda, A. Ejiri, N. Tsujii, H. Furui, J. Hiratsuka, K. Imamura, K. Nakamura, A. Nakanishi, M. Sonehara, H. Togashi, S. Tsuda and T. Yamaguchi: "Plasma Density Suppression by Electron Cyclotron Wave in Lower Hybrid Wave Driven TST-2 Spherical Tokamak Plasma", Plasma Fusion Res. **9** 1202133 (2014).

[19] M. Greenwald, A. Bader, S. Baek, M. Bakhtiari, H. Barnard, W. Beck, W. Bergerson, I. Bespamyatnov, P. Bonoli, D. Brower, D. Brunner, W. Burke, J. Candy, M. Churchill, I. Cziegler, A. Diallo, A. Dominguez, B. Duval, E. Edlund, P. Ennever, D. Ernst, I. Faust, C. Fiore, T. Fredian, O. Garcia, C. Gao, J. Goetz, T. Golfinopoulos, R. Granetz, O. Grulke, Z. Hartwig, S. Horne, N. Howard, A. Hubbard, J. Hughes, I. Hutchinson, J. Irby, V. Izzo, C. Kessel, B. LaBombard, C. Lau, C. Li, Y. Lin, B. Lipschultz, A. Loarte, E. Marmar, A. Mazurenko, G. McCracken, R. McDermott, O. Meneghini, D. Mikkelsen, D. Mossessian, R. Mumgaard, J. Myra, E. Nelson-Melby, R. Ochoukov, G. Olynyk, R. Parker, S. Pitcher, Y. Podpaly, M. Porkolab, M. Reinke, J. Rice, W. Rowan, A. Schmidt, S. Scott, S. Shiraiwa, J. Sierchio, N. Smick, J. A. Snipes, P. Snyder, B. Sorbom, J. Stillerman, C. Sung, Y. Takase, V. Tang, J. Terry, D. Terry, C. Theiler, A. Tronchin-James, N. Tsujii, R. Vieira, J. Walk, G. Wallace, A. White, D. Whyte, J. Wilson, S. Wolfe, G. Wright, J. Wright, S. Wukitch, S. Zweben: "20 years of research on the Alcator C-Mod tokamak", Phys. Plasmas **21** 110501 (2014).

[20] Y. M. Peng, A. Ishida, Y. Takase, A. Ejiri, N. Tsujii, T. Maekawa, M. Uchida, H. Zushi, K. Hanada and M. Hasegawa: "Two-Fluid Equilibrium Considerations of Te/Ti $\gg 1$, Collisionless ST Plasmas Sustained by RF Electron Heating", Plasma Fusion Res. **9** 3403146 (2014).

[21] J. Hiratsuka, A. Ejiri, M. Hasegawa, Y. Nagashima, K. Nakamura, Y. Takase, H. Togashi, H. Tojo, T. Yamaguchi and TST-2 group: "Simultaneous Measurement of Plasma Pressure Anisotropy with Double-Pass Thomson Scattering Diagnostic System on TST-2", Plasma Fusion Res. **10** 1402007 (2015).

[22] T. Wakatsuki, T. Suzuki, N. Hayashi, J. Shiraishi, S. Ide, Y. Takase: "Simulation of plasma current ramp-up with reduced magnetic flux consumption in JT-60SA", Plasma Phys. Control. Fusion **57**, 065005 (2015).

[23] S. Tsuda, A. Ejiri, H. Tanaka, Y. Takase, M. Uchida, T. Maekawa, N. Tsujii and T. Takeuchi: "Measurement of Ion Temperature and Flow in RF Start-Up Plasmas in TST-2 and LATE", Plasma Fusion Res. **10**, 1202064 (2015).

[24] K. Mishra, H. Zushi, H. Idei, M. Hasegawa, T. Onchi, S. Tashima, S. Banerjee, H. Hanada, H. Togashi, T. Yamaguchi, A. Ejiri, Y. Takase, K. Nakamura, A. Fujisawa, Y. Nagashima, A. Kuzmin and QUEST team: "Self organization of high β p plasma equilibrium with an inboard poloidal magnetic field null in QUEST", Nucl. Fusion **55**, 083009 (2015).

[25] T. Shinya, Y. Takase, T. Wakatsuki, A. Ejiri, H. Furui, J. Hiratsuka, K. Imamura, T. Inada, H. Kakuda, H. Kasahara, R. Kumazawa, C. Moeller, T. Mutoh, Y. Nagashima, K. Nakamura, A. Nakanishi, T. Oosako, K. Saito, T. Seki, M. Sonehara, H. Togashi, S. Tsuda, N. Tsujii, T. Yamaguchi: "Non-inductive Plasma Start-up Experiments on the TST-2 Spherical Tokamak Using Waves in the Lower-hybrid Frequency Range", Nucl. Fusion **55**, 073003 (2015).

[26] N. Tsujii, M. Porkolab, P. T. Bonoli, E. M. Edlund, P. C. Ennever, Y. Lin, J. C. Wright, S. J. Wukitch, E. F. Jaeger, D. L. Green, and R. W. Harvey: "Validation of full-wave simulations for mode conversion of waves in the ion cyclotron range of frequencies with phase contrast imaging in Alcator C-Mod", Phys. Plasmas **22**, 082502 (2015).

[27] A. Ishida, A. Ejiri, Y. Takase, N. Tsujii, H. Togashi, Y. Yoshida, T. Shinya and S. Tsuda: "Three-fluid axisymmetric equilibrium model and application to spherical torus plasmas sustained by RF electron heating", Plasma Fusion Res. **10**, 1403084 (2015).

[28] H. Togashi, A. Ejiri, H. Homma, T. Shinya, Y. Takase, K. Toida, N. Tsujii, T. Yamaguchi, Y. Yoshida, M. Hasegawa, Y. Nagashima, H. Furui, K. Nakamura, W. Takahashi, T. Takeuchi, M. Sonehara, S. Yajima and H. Ymazaki: "First measurement of electron temperature and density profiles for spherical tokamak plasmas sustained by lower hybrid wave", Plasma Fusion Res. **10**, 1202082 (2015).

[29] T. Ii Tsujimura, S. Kubo, H. Takahashi, R. Makino, R. Seki, Y. Yoshimura, H. Igami, T. Shimozuma, K. Ida, C. Suzuki, M. Emoto, M. Yokoyama, T. Kobayashi, C. Moon, K. Nagaoka, M. Osakabe, S. Kobayashi, S. Ito, Y. Mizuno, K. Okada, A. Ejiri, T. Mutoh and the LHD Experiment Group: "Development and application of a ray-tracing code integrating with 3D equilibrium mapping in LHD ECH experiments", Nuclear Fusion **55**, 123019 (2015).

[30] A. Ejiri, Y. Taase, N. Tsujii, T. Shinya, S. Yajima, M. Sonehara, H. Furui, H. Togashi, H. Homma, K. Nakamura, T. Takeuchi, Y. Yoshida, W. Takahashi, K. Toida, and H. Yamazaki: "RF central solenoid operation for plasma production and current drive in TST-2", Plasma Fusion Res. **11**, 1202004 (2016).

[31] H. Furui, A. Ejiri, Y. Nagashima, Y. Takase, M. Sonehara, N. Tsujii, T. Yamaguchi, T. Shinya, H. Togashi, H. Homma, K. Nakamura, T. Takeuchi, S. Yajima, Y. Yoshida, K. Toida, W. Takahashi and H. Yamazaki: "A model of plasma current through a hole of Rogowski probe including sheath effects", Rev. Sci. Instrum. **87**, 043503 (2016).

[32] S. Banerjee, H. Zushi, N. Nishino, K. Mishra, Y. Mahira, S. Tashima, A. Ejiri, T. Yamaguchi, T. Onchi, Y. Nagashima, K. Hanada, K. Nakamura, H. Idei, M. Hasegawa, A. Fujisawa, A. Kuzmin and K. Matsuoka: "Observation of an edge coherent mode and poloidal flow in the electron cyclotron wave induced high βp plasma in QUEST", Phys. Plasmas **23**, 082507 (2016).

[33] H. Tojo, I. Yamada, R. Yasuhara, A. Ejiri, J. Hiratsuka, H. Togashi, E. Yatsuka, T. Hatae, H. Funaba, H. Hayashi, Y. Takase and K. Itami: "Validations of calibration-free measurements of electron temperature using double-pass Thomson scattering diagnostics from theoretical and experimental aspects", Rev. Sci. Instrum. **87**, 093502 (2016).

[34] T. Shinya, S. G. Baek, G. M. Wallace, S. Shiraiwa, Y. Takase, R. R. Parker, P. T. Bonoli, D. Brunner, I. Faust, B. L. LaBombard and S. Wukitch: "Identification of waves in the lower-hybrid frequency range in the scrape-off layer plasma of Alcator C-Mod", Nucl. Fusion **57**, 036005 (2016).

[35] T. Shinya, Y. Takase, S. Yajima, C. Moeller, H. Yamazaki, N. Tsujii, Y. Yoshida, A. Ejiri, H. Togashi, K. Toida, H. Furui, H. Homma, K. Nakamura, B. Roidl, M. Sonehara, W. Takahashi and T. Takeuchi: "Plasma current start-up experiments using outboard- and top-launch lower hybrid wave on the TST-2 spherical tokamak", Nucl. Fusion **57** 036006 (2016).

[36] K. Kuroda, R. Raman, K. Hanada, M. Hasegawa, T. Onchi, M. Ono, T. Jarboe, B.A. Nelson, M. Nagata, O. Mitarai, K. Nakamura, H. Idei, J. Rogers, S. Kawasaki, T. Nagata, A. Kuzmin, S. Kojima, O. Watanabe, A. Higashijima, Y. Takase and A. Fukuyama: "Current Start-Up Using the New CHI System", Plasma Fusion Res. **12**, 1202020 (2017).

[37] H. Furui, A. Ejiri, Y. Nagashima, Y. Takase, M. Sonehara, N. Tsujii, B. Roidl, T. Shinya, H. Togashi, H. Homma, K. Nakamura, T. Takeuchi, S. Yajima, Y. Yoshida, K. Toida, W. Takahashi and H. Yamazaki: "Measurements of edge plasma parameters during internal reconnection events in the TST-2 spherical tokamak", Physics of Plasmas **24**, 062504 (2017).

[38] Y. Takase, A. Ejiri, T. Fujita, N. Fukumoto, A. Fukuyama, K. Hanada, H. Idei, M. Nagata, Y. Ono, H. Tanaka, M. Uchida, R. Horiuchi, Y. Kamada, H. Kasahara, S. Masuzaki, Y. Nagayama, T. Oishi, K. Saito, Y. Takeiri and S. Tsuji-Iio: "Overview of spherical tokamak research in Japan", Nucl. Fusion **57**, 102005 (2017).

[39] H. Togashi, H. Yamazaki, A. Ejiri, Y. Takase, N. Tsujii, S. Yajima, Y. Yoshida and TST-2 team: "Development of a Hard X-Ray Profile Measurement System in the TST-2 Spherical Tokamak", Plasma Fusion Res. **12**, 1402030 (2017).

[40] Y. Takeiri, T. Morisaki, M. Osakabe, M. Yokoyama, S. Sakakibara, H. Takahashi, Y. Nakamura, T. Oishi, G. Motojima, S. Murakami, K. Ito, A. Ejiri, et al.: "Extension of the operational regime of the LHD towards a deuterium experiment", Nucl. Fusion **57**, 102023 (2017).

[41] N. Tsujii, Y. Takase, A. Ejiri, T. Shinya, H. Togashi, S. Yajima, H. Yamazaki, C.P. Moeller, B. Roidl, M. Sonehara, W. Takahashi, K. Toida and Y. Yoshida: "Numerical modeling of lower hybrid current drive in fully non-inductive plasma start-up experiments on TST-2", Nucl. Fusion **57**, 126032 (2017).

[42] A. Ejiri, H. Tanaka, W. Takahashi, A. Sato, Y. Takase, N. Tsujii, M. Uchida and T. Makekawa: "Observation of High Impurity Ion Temperatures in ECW/EBW Sustained Plasmas on LATE", Plasma Fusion Res. **12**, 1202041 (2017).

[43] R. Yoneda, K. Hanada, K. Nakamura, H. Idei, N. Yoshida, M. Hasegawa, T. Onchi, K. Kuroda, S. Kawasaki, A. Higashijima, T. Nagata, A. Isayama, O. Mitarai, A. Fukuyama and Y. Takase: "Effect of Magnetic Structure on RF-induced Breakdown in QUEST", Phys. Plasmas **24**, 062513 (2017).

[44] Z. Wang, K. Hanada, N. Yoshida, T. Shimoji, M. Miyamoto, Y. Oya, H. Zushi, H. Idei, K. Nakamura, A. Fujisawa, Y. Nagashima, M. Hasegawa, S. Kawasaki, A. Higashijima, H. Nakashima, K. Nagata, A. Kawaguchi, T. Fujiwara, K. Araki, O. Mitarai, A. Fukuyama, Y. Takase and K. Matsumoto: "Measurement of thickness of film deposited on the plasma-facing wall in the QUEST tokamak by colorimetry", Rev. Sci. Instrum. **88**, 093502 (2017).

[45] H. Idei, T. Kariya, T. Imai, K. Mishra, T. Onchi, O. Watanabe, H. Zushi, K. Hanada, J. Qian, A. Ejiri, M. Alam, K. Nakamura, A. Fujisawa, Y. Nagashima, M. Hasegawa, K. Matsuoka, A. Fukuyama, S. Kubo, T. Shimozuma, M. Yoshikawa, M. Sakamoto, S. Kawasaki, H. Nakashima, A. Higashijima, S. Ide, T. Maekawa, Y. Takase and K. Toi: "Fully non-inductive second harmonic electron cyclotron plasma ramp-up in the QUEST spherical tokamak", Nucl. Fusion **57**, 126045 (2017).

[46] K. Hanada, N. Yoshida, T. Honda, Z. Wang, A. Kuzmin, I. Takagi, T. Hirata, Y. Oya, M. Miyamoto, H. Zushi, M. Hasegawa, K. Nakamura, A. Fujisawa, H. Idei, Y. Nagashima, O. Watanabe, T. Onchi, K. Kuroda, H. Long, H. Watanabe, K. Tokunaga, A. Higashijima, S. Kawasaki, T. Nagata, Y. Takase, A. Fukuyama and O. Mitarai: "Investigation of hydrogen recycling in long-duration discharges and its control with a hot wall in the spherical tokamak QUEST", Nucl. Fusion **57**, 126061 (2017).

[47] A. Ejiri, Y. Takase, N. Tsujii, H. Togashi, H. Furui, T. Shinya, B. Roidl, M. Sonehara, S. Yajima, Y. Yoshida, H. Yamazaki, A. Kitayama, A. Sato, Y. Takei, Y. Tajiri, N. Matsumoto and O. Mitarai: "Pre-ionization by AC Ohmic coil operation in the TST-2 spherical tokamak", Nucl. Fusion **58**, 016012 (2017).

[48] B. Roidl, Y. Todo, Y. Takase, N. Tsujii, A. Ejiri, Y. Yoshida, S. Yajima, T. Shinya: "A simulation environment to simulate lower-hybrid-wave-driven plasmas efficiently", Computer Physics Communications **230**, 38 (2018).

[49] T. Ii Tsujimura, Y. Mizuno, T. Tokuzawa, Y. Ito, S. Kubo, T. Shimozuma, Y. Yoshimura, H. Igami, H. Takahashi, A. Ejiri, the LHD Experiment Group: ”Real-time control of electron cyclotron wave polarization in the LHD”, Fusion Engineering and Design **131**, 130 (2018).

[50] H. Yamazaki, H. Furui, K. Yamasaki, T. Ushiki, A. Ejiri, M. Inomoto, Y. Takase, Y. Ono, N. Tsujii, UTST group and TST-2 group: ”Measurement of the Local Current Density Inside a Current Sheet Using a Rogowski Coil Array on UTST Merging Plasmas”, Plasma Fusion Res. **13**, 1202093 (2018).

[51] S. Yajima, Y. Takase, A. Ejiri, N. Tsujii, H. Yamazaki, C.P. Moeller, T. Shinya, Y. Takei, Y. Tajiri, Y. Yoshida, A. Sato, A. Kitayama and N. Matsumoto: ”Current Drive Experiment Using Top/Outboard Side Lower Hybrid Wave Injection on TST-2 Spherical Tokamak”, Plasma Fusion Res. **13**, 3402114 (2018).

[52] T. Tokuzawa, H. Tsuchiya, T. Tsujimura, M. Emoto, H. Nakanishi, S. Inagaki, K. Ida, H. Yamada, A. Ejiri, K.Y. Watanabe, K. Oguri, T. Akiyama, K. Tanaka, I. Yamada, and LHD Experiment Group: ”Microwave frequency comb Doppler reflectometer applying fast digital data acquisition system in LHD”, Rev. Sci. Instrum. **89**, 10H118 (2018).

[53] L.F. Delgado-Aparicio, J. Wallace, H. Yamazaki, P. VanMeter, L. Reusch, M. Nornberg, A. Almagari, J. Maddox, B. Luethi, M. Rissi, T. Donath, D. Den Hartog, J. Sarff, P. Weix, J. Goetz, N. Pablant, K. Hill, B. Stratton, P. Efthimion, Y. Takase, A. Ejiri, and M. Ono: ”Simulation, design, and first test of a multi-energy soft x-ray (SXR) pinhole camera in the Madison Symmetric Torus (MST)”, Rev. Sci. Instrum. **89**, 10G116 (2018).

[54] H. Yamazaki, L.F. Delgado-Aparicio, R. Groebner, B. Grierson, K. Hill, N. Pablant, B. Stratton, P. Efthimion, A. Ejiri, Y. Takase, and M. Ono: ”A computational tool for simulation and design of tangential multi-energy soft x-ray pin-hole cameras for tokamak plasmas”, Rev. Sci. Instrum. **89**, 10G120 (2018).

[55] Y. Yoshimura, A. Ejiri, R. Seki, R. Sakamoto, K. Nagaoka, T. Shimozuma, H. Igami, H. Takahashi, T.I. Tsujimura, F. Warmer, K. Ynagihara, Y. Goto, K. Ida, M. Yoshinuma, T. Kobayashi, S. Kubo, M. Osakabe, T. Morisaki and the LHD Experiment Group: ”Effect of Electron Cyclotron Current Drive on the Ion Temperature in the Plasma Core Region of the Large Helical Device”, Plasma Fusion Res. **13**, 1402124 (2018).

< Conference Proceedings >

[56] A. Ejiri, T. Tokuzawa, K. Saito, T. Seki, H. Kasahara, T. Mutoh, R. Kumazawa, I. Yamada, and Y. Takase: ”Measurement of Radio Frequency Wave Induced Electron Density Fluctuations by a Microwave Reflectometer on LHD”, JPS Conf. Proc. **1** (2014) 015038.

[57] H. Furui, Y. Nagashima, Y. Takase, A. Ejiri, H. Kakuda, M. Sonehara, T. Oosako, N. Tsujii, J. Hiratsuka, K. Imamura, T. Inada, K. Nakamura, A. Nakanishi, T. Shinya, H. Togashi, S. Tsuda, T. Wakatsuki and T. Yamaguchi: ”Local current density measurement using a Rogowski probe in Tokyo Spherical Tokamak”, Rev. Sci. Instrum. **85** 11D813 (2014).

[58] H. Togashi, A. Ejiri, J. Hiratsuka, K. Nakamura, Y. Takase, T. Yamaguchi, H. Furui, K. Imamura, T. Inada, H. Kakuda, A. Nakanishi, T. Oosako, T. Shinya, M. Sonehara, S. Tsuda, N. Tsujii, T. Wakatsuki, M. Hasegawa, Y. Nagashima, K. Narihara, I. Yamada and H. Tojo: ”Demonstration of improvement in the signal-to-noise ratio of Thomson scattering signal obtained by using a multi-pass optical cavity on the Tokyo Spherical Tokamak”, Rev. Sci. Instrum. **85** 11D846 (2014).

[59] H. Togashi, A. Ejiri, H. Homma, T. Shinya, Y. Takase, K. Toida, N. Tsujii, T. Yamaguchi, Y. Yoshida, H. Furui, M. Sonehara, K. Nakamura, W. Takahashi, T. Takeuchi, S. Yajima, H. Yamazaki, M. Hasegawa, Y. Nagashima and H. Tojo: ”Thomson scattering measurements in low-density plasmas in the TST-2 spherical tokamak”, JINST **10**, C12020 (2015).

[60] A. Ejiri, T. Tokuzawa, N. Tsujii, K. Saito, T. Seki, H. Kasahara, S. Kamio, R. Seki, T. Mutoh, I. Yamada and Y. Takase: ”Measurements of ICRF wave-induced density fluctuations in LHD by a microwave reflectometer”, JINST **10**, C12032 (2015).

< Review Papers >

[61] M. Yoshida, G. Giruzzi, Y. Kamada, Y. Takase, T. Suzuki, K. Nagasaki, G. Matsunaga, M. Furukawa, K. Tanaka, K. Shinohara, M. Osakabe, H. Urano, T. Morisaki, T. Nakano, M. Sakamoto, S. Sakurai, A. Sagara, N. Hayashi, A. Fukuyama: JT-60SA リサーチプラン, プラズマ・核融合学会誌（研究最前線）J. Plasma Fusion Res. **88** (2012) 650.

[62] T. Maekawa, Y. Takase, K. Hanada, N. Yoshida, M. Nagata, Y. Ono, M. Inomoto, Y. Nagashima, Y. Nagayama: 球状トカマク研究の進展 -核融合エネルギー開発に向けて-　, プラズマ・核融合学会誌（小特集）J. Plasma Fusion Res. **88** (2012) 706.

7 Invited Presentations at International Conferences

[1] Y. Takase: TST-2: present status and future plan, The First A3 Foresight Workshop on Spherical Torus, Seoul, Korea, Jan. 14–16, 2013.

[2] Y. Takase: Plasma Start-up by LHW on TST-2, Workshop on RF Startup and Sustainment, Kasuga, Feb. 26–Mar. 1, 2013.

[3] S. G. Baek, P T. Bonoli, R. R. Parker, S. Shiraiwa, G. M. Wallace, M. Porkolab, Y. Takase, D. Brunner, I. C. Faust, A. E. Hubbard, B. L. LaBombard, and C. Lau: Characterization of onset of parametric decay instability of lower hybrid waves, 20th Topical Conference on RF Power in Plasmas, Sorrento, Italy, Jun. 25–28, 2013.

[4] Y. Takase, A. Ejiri, C. P. Moeller, T. Shinya, N. Tsujii, T. Wakatsuki, H. Furui, J. Hiratsuka, K. Imamura, T. Inada, H. Kakuda, H. Kurashina, K. Nakamura, A. Nakanishi, T. Oosako, Y.-K. M. Peng, M. Sonehara, H. Togashi, S. Tsuda, and T. Yamaguchi: RF Plasma Start-up and Plasma Current Ramp-up Studies on TST-2, 17th International Spherical Torus Workshop, University of York, York, UK, Sep. 16–19, 2013.

[5] Y. Takase: Non-inductive plasma start-up experiments on the TST-2 spherical tokamak, 18th International Spherical Torus Workshop (ISTW 2015) and 2015 US-Japan Workshop on ST Plasmas, Princeton, New Jersey, USA, Nov. 3-6, 2015.

[6] Y. Takase: RF Heating and Current Drive, 4th A3 Foresight Summer School and Workshop on Spherical Torus, Kyushu University Chikushi Campus, Kasuga, Japan, Aug. 2–5, 2016.

[7] A. Ejiri and TST-2 team: Internal reconnection events in the TST-2 spherical tokamak, The US-Japan Workshop and School on Magnetic Reconnection, Hiroshima, Japan, Mar. 19–23, 2017.

[8] N. Tsujii, Y. Takase, A. Ejiri, T. Shinya, S. Yajima, H. Yamazaki, H. Togashi, C.P. Moeller, B. Roidl, W. Takahashi, Y. Takei, K. Toida, and Y. Yoshida: Fully non-inductive plasma start-up with lower-hybrid waves using the outboard-launch and top-launch antennas on the TST-2 spherical tokamak, 22nd RF Conference, Aix en Provence, France, May 30–June 2, 2017 (EPJ Web Conf. **157**, 02009).

[9] Y. Takase: Plasma Current Start-up by the Lower Hybrid Wavein the TST-2 Spherical Tokamak, 1st Asia-Pacific Conference on Plasma Physics Chengdu, China, Sep. 18–22, 2017.

[10] A. Ejiri: Interferometer, 9th Japan-Korea Seminar on Advanced Diagnostics for Steady-State Fusion Plasmas, Toki-Nagoya, Japan, Aug. 7–10, 2018.

8 Teaching Accomplishment

9 Contribution to Academic Community

9.1 Editorial Activities

9.2 Organization of Professional Societies

- Board member, The Japan Society of Plasma Science and Nuclear Fusion Research, 2012−2017

9.3 Organization and Advisory of Conferences

プラズマ・核融合学会　第 12 回核融合エネルギー連合講演会組織委員会委員　2017−2018

10 Outreach

- 東大柏キャンパス　一般公開　2012−
- 火薬学会プロペラント部会、日大学生見学　2013
- 韓国高校生見学　2017
- 韓国ソウル大学学生見学　2017
- 米国 MIT 学生見学　2018
- 韓国ソウル大学学生見学　2018

11 Committee Service

11.1 External Committees

- 九州大学　QUEST 実験推進会議委員（コーディネーター）　2012−
- 核融合科学研究所　双方向型共同研究推進専門部会委員（部会長）　2012−
- 日本原子力研究開発機構　核融合エネルギーフォーラム委員　2012−2016
- 日本原子力研究開発機構　ITER・BA 技術推進委員会委員　2012−2016
- 日本原子力研究開発機構　ITER・BA 技術推進委員会委員　2012−2016
- 日本原子力研究開発機構　炉心プラズマ共同企画委員会委員　2012−2013
- 日本原子力研究開発機構　炉心プラズマ共同企画委員会委員長　2013−2016
- 日本学術振興会　日米科学技術協力事業核融合分野研究計画委員会委員　2012−
- 量子科学技術研究開発機構　核融合エネルギーフォーラム委員　2016−

- 量子科学技術研究開発機構　ITER・BA 技術推進委員会委員　2016–
- 量子科学技術研究開発機構　ITER 科学技術検討評価 WG 専門委員　2016–
- 量子科学技術研究開発機構　炉心プラズマ共同企画委員会委員長　2016–
- 量子科学技術研究開発機構　核融合エネルギーフォーラム調整委員会委員　2017–

11.2 University Committees

理学系研究科教育委員会　委員　2012 年
新領域創成科学研究科放射線管理委員会　委員　2012 年
新領域創成科学研究科複雑理工学専攻　副専攻長　2012 年
新領域創成科学研究科複雑理工学専攻　専攻長　2013 年
新領域創成科学研究科図書情報委員会　委員　2013 年
新領域創成科学研究科支援交流委員会　委員　2014 年
新領域創成科学研究科研究教育改善室　委員　2014 年
新領域創成科学研究科環境安全委員会　委員長　2015 年
環境安全研究センター　運営委員　2015 年
新領域創成科学研究科入試委員会　委員　2016 年
新領域創成科学研究科環境安全委員会　委員　2016 年
新領域創成科学研究科企画室　委員　2017 年
新領域創成科学研究科複雑理工学専攻　会計　2017 年
新領域創成科学研究科環境安全委員会　委員　2018 年
新領域創成科学研究科複雑理工学専攻　副専攻長　2018 年

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	6	USA, India, Germany, France, Kazafstan, Morocco
Master Course	9	USA, France, Russia, UK, New Zealand
Doctor Course	0	
Foreign researchers hosted	2	USA, Germany
Students sent abroad	22	USA, UK
Researchers sent abroad	11	USA, UK
Foreign visitors	22	USA, UK, Germany, France, China, Korea

Kazumasa A. Takeuchi、竹内 一将

1 Education and Professional Experiences

Education

2005	B.S. (Physics)	The University of Tokyo
2007	MSc. (Physics)	The University of Tokyo
2010	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

2010−2010	Research Fellow	The University of Tokyo
2010−2011	JSPS Postdoctoral Fellow for Research Abroad	CEA-Saclay
2011−2012	Project Assistant Professor	The University of Tokyo
2012−2015	Assistant Professor	The University of Tokyo
2015−2018	Associate Professor	Tokyo Institute of Technology
2018−	Associate Professor	The University of Tokyo

Visiting, Guest Appointments

2011	Visiting Researcher	CEA-Saclay

2 Research Highlights

Takeuchi Group carries out experimental studies on systems driven out of equilibrium, aiming to unveil general physical principles that characterize non-equilibrium fluctuations. We have pursued this direction along the following axes.

2.1 Universal fluctuations of growing interfaces

As a model experimental system for studying universal statistical properties of non-equilibrium systems, we have focused on growth processes of turbulence observed in electrically driven convection of nematic liquid crystal. We discovered experimental evidence that fluctuations of interfaces of the growing turbulence are precisely described by those obtained previously by exact solutions to integrable models in the one-dimensional Kardar-Parisi-Zhang (KPZ) universality class, thus establishing universality of detailed statistical properties of non-equilibrium fluctuations of the KPZ class. In particular, we showed that interface fluctuations are ruled by particular distributions called the Tracy-Widom distributions known from random matrix theory, and that the distribution depends on the initial condition (Takeuchi and Sano, J. Stat. Phys. 2012). Using this experimental system, we then studied statistical properties that remained theoretically untractable, in particular time correlation properties, and discovered approach to the KPZ stationary state (Takeuchi, Phys. Rev. Lett. 2013) as well as persistent memory effect of circular interfaces, later accompanied by theoretical explanations (De Nardis, Le Doussal, and Takeuchi, Phys. Rev. Lett. 2017). We also adapted laser holography techniques to our experimental system

(Fukai and Takeuchi, Phys. Rev. Lett. 2017). This allows us to design the initial shape of the interface arbitrarily and thereby explore the initial condition dependence of the KPZ class further by experimental means.

2.2 Development of a new microfluidic device for dense bacterial suspensions

Microfluidic devices became a common and powerful means for quantitative studies of living cells and beyond. Yet, the standard channel-type device based on PDMS remains unsuitable for long-term observations of dense bacterial suspensions, which result in heterogeneous culture conditions due to depletion of nutrients. We overcame this difficulty by developing a perfusion system with quasi-two-dimensional geometry, whose area can be set much larger than the existing devices. Growth medium is supplied uniformly though a porous membrane, thus maintaining the homogeneous culture condition even for dense bacterial suspensions. With this device we observed nontrivial ordering and fluctuations under various experimental settings with a dense collection of bacteria, involving growth, competition, environmental changes and confinements by boundaries. Motivated by one such observation, we also developed a model for competing bacterial populations and found lane formation and nontrivial ordering characteristic of the voter universality class (Shimaya and Takeuchi, Phys. Rev. E 2019).

2.3 Experimental method to characterize instability of large chaotic systems

Past and recent studies have shown that instability quantifiers of chaos, in particular the Lyapunov exponents and associated vectors, are useful to characterize various aspects of chaos (e.g., Takeuchi and Chaté, J. Phys. A 2013; Ding... Takeuchi, Phys. Rev. Lett 2016). Although those quantities have remained difficult to measure experimentally, we developed a new method of time series analysis to infer the full spectrum of Lyapunov exponents for highly symmetric systems, such as systems with global coupling (Shimizu and Takeuchi, Chaos 2018).

3 Selected Papers

- K. A. Takeuchi and M. Sano, Journal of Statistical Physics, 147, 853-890 (2012)
  This paper provided a full report of the first experimental test on predictions from exact solutions of the Kardar-Parisi-Zhang class. It has been cited 134 times (as of Oct. 24, 2019).

- K. A. Takeuchi, Physical Review Letters, 110, 210604 (2013)
  This paper reported the first experimental indication of the predicted universal property of the stationary state of the Kardar-Parisi-Zhang class.

- I. S. S. Carrasco, K. A. Takeuchi, S. C. Ferreira, and T. J. Oliveira, New Journal of Physics, 16, 123057 (2014)
  This paper was selected for IOP Publishing "IOP select".

- T. Halpin-Healy and K. A. Takeuchi, Journal of Statistical Physics, 160, 794-814 (2015)
  This paper has been cited 116 times (as of Oct. 24, 2019).
- D. Nishiguchi, I. S. Aranson, A. Snezhko, and A. Sokolov, Nature Communications, 9, 4486 (2018)
  This paper was highlighted in the Nature's collection of active matter articles. D. Nishiguchi is the assistant professor of Takeuchi Group.

4 Honors, Awards and Professional Society Memberships

2012	28th Inoue Research Award for Young Scientists, Inoue Foundation for Science
2012	6th Young Scientist Award, The Physical Society of Japan (Division 11)
2013	Young Scientist Prize, IUPAP (C3 commission)
2016	Tokyo Tech Challenging Research Award, Tokyo Institute of Technology
2017	3rd Suematsu Award, Tokyo Institute of Technology
2018	Education Prize for Young Teachers in School of Science, Tokyo Institute of Technology
2018	The Young Scientists' Prize of The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, Ministry of Education, Culture, Sports, Science and Technology

5 Research Plan

Our aim of research is to design and carry out experiments on soft and living matter that can unveil statistical characteristics of macroscopic non-equilibrium phenomena quantitatively, under controlled experimental environments, and eventually to establish an experimental branch of statistical physics that develops complementarily with theoretical approaches. Below we list some representative projects we are currently working on toward this goal.

5.1 Advancing the experimental frontier of KPZ physics

Recently, statistical properties of exact solutions to the one-dimensional Kardar-Parisi-Zhang (KPZ) class turned out to arise in much wider contexts than expected, including classical and quantum integrable systems, fluctuating hydrodynamics, and Bose-Einstein condensates. We push forward the experimental frontier of such KPZ physics, by using the growth process of electrically driven liquid crystal turbulence. We aim to realize in particular (1) experimental tests of universal statistical properties for irregular initial conditions, in particular those for the KPZ stationary state, (2) experimental measurement and theoretical understanding of spacetime correlation properties, and (3) an experimental attempt to measure large deviation properties.

5.2 Capturing structure and dynamics of topological defects in liquid crystal

The turbulent electroconvection of nematic liquid crystal plays a prominent role, not only as an experimental platform to study KPZ physics but also as exotic material that exhibits negative viscosity. It is known to consist of a large density of topological defect lines, but it has never been resolved under the turbulent condition. Here we aim to do so by high-speed confocal microscopy. To start with, we observe and characterize relaxation process of a collection of defect lines, and compare with analogous processes in other systems, such as those of quantum vortices in superfluids.

5.3 Glassy dynamics of dense bacterial suspensions

The perfusion-type microfluidic device we developed is used to explore various intriguing collective phenomena of dense bacterial suspensions. Among them we observe the formation of a glassy state of bacterial populations. We aim to determine statistical properties of this new phase experimentally, and investigate possible relationship to theoretical concepts of the motility-induced phase separation and the active jamming phenomenon. We attempt to characterize this phenomenon through extension of thermodynamic concepts, such as phase equilibria and nucleation from a metastable state.

5.4 Toward topological control of bacterial flow

We plan to unravel universal properties of collective motion of both living and nonliving matters. Specifically, we will study how bacterial collective motion self-organizes in the presence of boundaries. Although bulk properties of turbulent dynamics of dense bacterial suspensions have been investigated in detail, their behavior at edges or boundaries still remain elusive. As we reported previously, a periodic array of pillars is sufficient to arrange turbulent vortices in an antiferromagnetic manner. We extend this idea to realize topological control of bacterial collective motion, by which we can design bacterial flow fields by placing topological defects at desired positions.

5.5 Universal correlation of self-propelled particles

We will extend our knowledge on collective behavior of self-propelled colloids. Recent theoretical studies predicted the existence of universal positional correlation in dense suspensions of self-propelled colloids. We will test this prediction by using self-propelled colloids and clarify whether it is robust against the presence of hydrodynamic interactions and other experimental details.

6 Publications and Patents

＜Refereed Original Papers＞

[1] K. A. Takeuchi, J. Stat. Mech. 2012, P05007 (2012).

[2] K. A. Takeuchi and M. Sano, J. Stat. Phys. 147, 853-890 (2012).

[3] K. A. Takeuchi, Phys. Rev. Lett. 110, 210604 (2013).

[4] K. A. Takeuchi and H. Chaté, J. Phys. A: Math. Theor. 46, 254007 (2013).

[5] K. A. Takeuchi, J. Stat. Mech. 2014, P01006 (2014).

[6] I. S. S. Carrasco, K. A. Takeuchi, S. C. Ferreira, and T. J. Oliveira, New J. Phys. 16, 123057 (2014).

[7] T. Halpin-Healy and K. A. Takeuchi, J. Stat. Phys. 160, 794-814 (2015).

[8] D. Nishiguchi and M. Sano, Phys. Rev. E 92, 052309 (2015)

[9] X. Ding, H. Chaté, P. Cvitanović, E. Siminos, and K. A. Takeuchi, Phys. Rev. Lett. 117, 024101 (2016).

[10] K. A. Takeuchi and T. Akimoto, J. Stat. Phys. 164, 1167-1182 (2016).

[11] J. De Nardis, P. Le Doussal, and K. A. Takeuchi, Phys. Rev. Lett. 118, 125701 (2017).

[12] K. A. Takeuchi, J. Phys. A: Math. Theor. 50, 264006 (2017).

[13] Y. T. Fukai and K. A. Takeuchi, Phys. Rev. Lett. 119, 030602 (2017).

[14] D. Nishiguchi *et al.*, Phys. Rev. E 95, 020601(R) (2017)

[15] Y. Ito and K. A. Takeuchi, Phys. Rev. E 97, 040103(R) (2018).

[16] T. P. Shimizu and K. A. Takeuchi, Chaos 28, 121103 (2018).

[17] D. Nishiguchi *et al.*, New J. Phys. 20, 015002 (2018)

[18] D. Nishiguchi *et al.*, Nat. Commun. 9, 4486 (2018)

[19] T. Shimaya and K. A. Takeuchi, Phys. Rev. E 99, 042403 (2019).

[20] P. Kennouche, A. Charles-Orszag, D. Nishiguchi, *et al.*, EMBO J. e102145 (2019)

＜Conference Proceedings＞

[21] 竹内 一将, 第 18 回交通流のシミュレーションシンポジウム 論文集 （交通流数理研究会）, 1-4 (2012).

[22] 竹内 一将, 九州大学 応用力学研究所 研究集会報告, 23AO-S7, 68-76 (2012).

[23] 竹内 一将, 京都大学 数理解析研究所講究録, 1827, 123-139 (2013).

[24] K. A. Takeuchi, MSRI Publications, 65, 495-507 (2014).

[25] 竹内 一将, 日本結晶成長学会誌, 45(2), 45-2-05 (2018).

＜Review Papers＞

[26] 竹内 一将, 応用数理, 23, 58-67 (2013).

[27] 竹内 一将, 日本物理学会誌, 70, 599-607 (2015).

[28] 竹内 一将, 数理科学, 631, 26-31 (2016).

[29] 西口 大貴, 佐野雅己, 数理科学, 631, 39-44 (2016).

[30] 竹内 一将, 数理科学, 649, 38-44 (2017).

[31] Kazumasa A. Takeuchi, Physica A 504, 77-105 (2018).

＜Books＞

[32] Isabelle Cantat *et al.* 著, 奥村 剛 監訳, 梶谷忠志, 武居淳, 竹内一将, 山口哲生 共訳, 『ムースの物理学: 構造とダイナミクス』, 物理学叢書 110, 吉岡書店, 2016.

7 Invited Presentations at International Conferences

[1] K. A. Takeuchi, "Universal Fluctuations of Growing Interfaces - beyond scaling laws -", 'East Asia Joint Seminars on Statistical Physics 2012', Mar. 18, 2012, Soochow Univ., Suzhou (China).

[2] K. A. Takeuchi, "Experimental realization of KPZ-class interfaces: what were done and need to be done?", 'BIRS Workshop, Integrable systems, growth processes and KPZ universality', Sep. 24, 2012, Banff International Research Station, Banff (Canada).

[3] K. A. Takeuchi, "Exploring universal out-of-equilibrium scaling laws with turbulent liquid crystal", 'XXV IUPAP International Conference on Statistical Physics STATPHYS25' July 26, 2013, Seoul National University, Seoul (South Korea).

[4] K. A. Takeuchi, "Powerful and geometry-dependent universality in growing interfaces", 'Small Systems far from Equilibrium: Order, Correlations, and Fluctuations', Oct. 16, 2013, Max Planck Institute for the Physics of Complex Systems, Dresden (Germany).

[5] K. A. Takeuchi, "Critical phenomena out of equilibrium probed by liquid-crystal turbulence"", 'East Asia Joint Seminars on Statistical Physics 2013', Oct. 23, 2013, YITP, Kyoto Univ., Kyoto (Japan).

[6] K. A. Takeuchi, "Experimental evidence for universal fluctuation properties of growing interfaces", '12th Workshop on Stochastic Analysis on Large Scale Interacting Systems', Nov. 23, 2013, Univ. Tokyo, Tokyo (Japan).

[7] K. A. Takeuchi, "Exploring universal scaling laws far from equilibrium with turbulent liquid crystal", 'APS March Meeting 2014', Mar. 4, 2014, Colorado Convention Center, Denver (USA).

[8] K. A. Takeuchi, "Covariant Lyapunov vectors capture the collective dynamics of large chaotic systems", 'Dynamics Days Asia Pacific 08', July 22, 2014, IIT Madras and IMS, Chennai (India).

[9] K. A. Takeuchi, "Experimental evidence of KPZ growing interfaces and beyond", 'School on Non-linear Dynamics, Dynamical Transitions and Instabilities in Classical and Quantum Systems', Aug. 1, 2014, ICTP, Trieste (Italy).

[10] K. A. Takeuchi, "Weak ergodicity breaking in KPZ-class interfaces", 'Fluctuation and Correlation in Stochastic Systems', Oct. 15, 2014, Chuo Univ., Tokyo (Japan).

[11] K. A. Takeuchi, "Universal fluctuations of growing interfaces and characterization via sign renewals", 'Kyoto Winter School for Statistical Mechanics, Focus Meeting', Feb. 17, 2015, Maskawa Hall, Kyoto Univ., Kyoto (Japan).

[12] K. A. Takeuchi, "Universal transitions to turbulence: from simple fluid to liquid crystal, and quantum fluid", 'YKIS2015, New Frontiers in Non-equilibrium Statistical Physics 2015', Aug. 19, 2015, YITP, Kyoto Univ., Kyoto (Japan).

[13] K. A. Takeuchi, "Universal Fluctuations of Growing Interfaces", 'iCeMS International Symposium, Hierarchical Dynamics in Soft Materials and Biological Matter', Sep. 24, 2015, iCeMS, Kyoto Univ., Kyoto (Japan).

[14] K. A. Takeuchi, "Random-matrix distributions under microscope: evidence for universal interfacial fluctuations", 'RMT2015: Random matrix theory from fundamental mathematics to biological applications', Nov. 2, 2015, OIST, Kunigami (Japan).

[15] K. A. Takeuchi, "Time correlation properties of KPZ fluctuations: from experimental perspectives", 'KITP program, New approaches to non-equilibrium and random systems: KPZ integrability, universality, applications and experiments', Feb. 11, 2016, KITP, UCSB, Santa Barbara (USA).

[16] K. A. Takeuchi, "Growth with noise: experiments and theory", 'Nonequilibrium Statistical Physics & Active Matter Systems – School and Workshop', Aug. 8-10, 2016, Chinese Academy of Sciences, Beijing (China).

[17] K. A. Takeuchi, "ASEP as a surface growth model: universal fluctuation and its experimental test", 'Conference on Driven Stochastic Transport in Low-Dimensional Systems', Sep. 27, 2016, Institute for Research in fundamental Sciences (IPM), Tehran (Iran).

[18] K. A. Takeuchi, “Geometry-dependent interface fluctuations and their implications for chaos instability”, ‘Interdisciplinary Applications of Nonlinear Science’, Nov. 5, 2016, Kagoshima Univ., Kagoshima (Japan).

[19] D. Nishiguchi, “Long-range nematic order and anomalous fluctuations in suspension of swimming filamentous bacteria”, ‘Current and Future Perspectives in Active Matter’, Oct. 28, 2016, The University of Tokyo, Tokyo (Japan).

[20] K. A. Takeuchi, “Integrability and universality behind a random growth experiment”, ‘Frontiers in Mathematical Physics’, Jan. 9, 2017, Rikkyo Univ., Tokyo (Japan).

[21] K. A. Takeuchi, “Examples of absorbing-state transitions and universal hysteresis”, ‘International workshop on Glasses and Related Nonequilibrium Systems’, Mar. 22, 2017, Nakanoshima Center, Osaka Univ., Osaka (Japan).

[22] K. A. Takeuchi, “1D KPZ interfaces: theory and experiment”, ‘Fundamental Problems in Statistical Physics XIV’, July 21-22, 2017, Bruneck (Italy).

[23] K. A. Takeuchi, “The Tracy-Widom distribution: a possible ”central limit theorem” for certain correlated random problems”, ‘Japanese-American-German Frontiers of Science Symposium (JAGFoS) 2017’, Sep. 22, 2017, Steigenberger Hotel Bad Neuenahr, Bad Neuenahr (Germany).

[24] K. A. Takeuchi, “Experimental observations of statistical laws for growing interfaces & some connections to crystal facet fluctuations”, ‘New developments in step dynamics on crystal surfaces: from nanoscale to mesoscale’, Oct. 28, 2017, Osaka Elec.-Commun. Univ., Neyagawa (Japan).

[25] K. A. Takeuchi, “Flat Growth vs Circular Growth -implications for interfaces and beyond”, ‘The Berkeley Statistical Mechanics Meeting 2018’, Jan. 14, 2018, UC Berkeley, Berkeley (USA).

[26] K. A. Takeuchi, “Exploring Geometry Dependence of Universal Laws for Growing Interfaces”, ‘IBS CSLM-UNIST Soft Matter Conference’, Apr. 6, 2018, UNIST, Ulsan (South Korea).

[27] K. A. Takeuchi, “Current status of absorbing-state transitions and connections to reversible-irreversible transitions”, ‘Rheology of disordered particles - suspensions, glassy and granular materials’, June 28, 2018, YITP, Kyoto Univ., Kyoto (Japan).

[28] K. A. Takeuchi, “Liquid crystal turbulence as a probe to study non-equilibrium scaling laws and back”, ‘27th International Liquid Crystal Conference (ILCC2018)’, July 26, 2018, Kyoto International Conference Center, Kyoto (Japan).

[29] K. A. Takeuchi, “Universal scaling laws of growth processes and their implications for chaos instability”, ‘The 10th Dynamics Days Asia Pacific (DDAP10)’, Nov. 2, 2018, Huaqiao Univ., Xiamen (China).

[30] K. A. Takeuchi, “Revisiting circular vs flat interfaces and application of variational principle”, ‘MECO44: 44th Conference of the Middle European Cooperation, Key Challenges in Statistical Physics’, May 3, 2019, Kloster Seeon, Seeon (Germany).

[31] K. A. Takeuchi, “Disclination turbulence - from defect dynamics to macroscopic scaling laws -”, ‘2019 Gordon Conference on Liquid Crystals, Soft Order and Topology Motives in Biomedicine, Nanoscience, Cosmology, Living Matter and Emergent Industries’, July 10, 2019, Colby-Sawyer College, New London, New Hampshire (USA).

8 Teaching Accomplishment

- Takeuchi was awarded an Education Prize for Young Teachers in School of Science, Tokyo Institute of Technology, in 2018, for an attempt to use an online quiz platform for encouraging students to review the lectures.
- Takeuchi's lectures are generally highly evaluated by students. As an example, for the lecture on classical mechanics Takeuchi delivered to 1st year students in Tokyo Insitute of Technology in 2018, the evaluation score on the satisfication level was 4.25, to be compared with the average score of 3.65 for the same course delivered by other professors.

9 Contribution to Academic Community

9.1 Editorial Activities

- Editorial Board Member of Scientific Reports, Nature Publishing Group, 2014−2017
- Committee Member for "new book reviews" section of BUTSURI, The Physical Society of Japan, 2016−2018.

9.2 Organization of Professional Societies

- Steering Committee Member of Division 11, The Physical Society of Japan, 2016−2017

9.3 Organization and Advisory of Conferences

Kazumasa A. Takeuchi

- organizer, 'YITP Workshop 2012, Physics of Nonequilibrium Systems -Toward the Understanding of its Universal Aspects-', Aug. 1-4, 2012, Kyoto (Japan).
- organizer, '5th YSM-SPIP, Satellite Meeting of STATPHYS25, Frontier of Statistical Physics and Information Processing -Perspectives from Nonequilibrium Behaviors', July 11-14, 2013, Kyoto (Japan).
- organizing committee chair, 'YITP workshop, Interface fluctuations and KPZ universality class - unifying mathematical, theoretical, and experimental approaches', Aug. 20-23, 2014, Kyoto (Japan).
- organizer, 'Encountering between Quantum Turbulence and Classical Turbulence', Jan. 5-7, 2016, Kashiwa (Japan).
- scientific advisor, 'KITP program, New approaches to non-equilibrium and random systems: KPZ integrability, universality, applications and experiments', Jan. 11 - Mar. 11, 2016, Santa Barbara (USA).

- international advisory committee member, ‘STATPHYS26’, July 18-22, 2016, Lyon (France).
- organizer, ‘Physical and mathematical approaches to interacting particle systems -In honor of 70th birthday of Herbert Spohn-’, Jan. 11-12, 2017, Tokyo (Japan).
- organizing committee chair, ‘International Conference on Advances in Physics of Emergent orders in Fluctuations’, Nov. 12-15, 2018, Tokyo (Japan).

Daiki Nishiguchi

- organizer, ‘Paris Biological Physics Community Day 2018’, 2018, Paris, France.
- organizer, ‘The 59th Condensed Matter Physics Summer School’, 2014, Shizuoka, Japan.
- organizer, ‘The 58th Condensed Matter Physics Summer School’, 2013, Shiga, Japan.

10 Outreach

Kazumasa A. Takeuchi

- K. A. Takeuchi, Career guidance talk at Komagome High School, “What am I working on? / What is researchers?”, Nov. 20, 2013, Komagome High School, Tokyo (Japan).
- K. A. Takeuchi, Saturday Lecture at Ichikawa High School / Junior High School, “Laws of nature emerging from probability - what statistical physics aims for -”, Nov. 1, 2014, Ichikawa High School / Junior High School, Ichikawa (Japan).
- Lab visit by Ichikawa High School students, May 12, 2017.

Daiki Nishiguchi

- パリ日本人研究者会・講演，2019 年 6 月 21 日，パスツール研究所，パリ，フランス.
- パリ日本人若手物理学研究者の会・講演，2018 年 12 月 2 日，パリ国際大学都市日本館，パリ，フランス.
- 国際物理オリンピック日本代表候補者春合宿・OP 研究紹介，2013 年 3 月 24 日，八王子セミナーハウス，東京.
- パリ日本人研究者会・講演，2017 年 10 月 27 日，パスツール研究所，パリ，フランス.
- 東京大学 第 67 回駒場祭企画「10 分で伝えます！東大研究最前線」講演，2016 年 11 月 25-27 日，東京大学.
- 東京大学 理学部オープンキャンパス 学生による小柴ホール講演会，2016 年 8 月 4 日，東京大学.
- 東京大学 理学部オープンキャンパス 佐野研究室講演会「物理学とは何だろうか」・講演，2016 年 8 月 3 日，東京大学.

- 東京大学 第89回五月祭企画「10分で伝えます！東大研究最前線」・企画責任者および講演，2016年5月14-15日，東京大学.

- Google Science Jam 東京アワードツアー・講演，2016年3月25日，東京大学.

- 東京大学 第66回駒場祭企画「10分で伝えます！東大研究最前線」・企画責任者および講演，2015年11月21-23日，東京大学.

- 物理チャレンジ・オリンピック日本委員会ジュニアチャレンジにて小学生を対象に実験教室を実施，2015年8月6日，新潟市立和納小学校.

- 東京大学 第88回五月祭企画「院生サイエンスバー」・企画責任者および講演，2015年5月16-17日，東京大学.

- 国際物理オリンピック日本代表候補者春合宿・OPによる研究紹介・講演，2015年3月28日，八王子セミナーハウス，東京.

- 社会福祉法人聖愛学舎 西国立保育園で地域の小学生を対象とした実験教室を実施，2014年10月18日.

- 国際物理オリンピック日本代表候補者春合宿・OP研究紹介・講演，2014年3月26日，八王子セミナーハウス，東京.

- 東京大学 理学部オープンキャンパス 学生による小柴ホール講演会，2013年8月7日，東京大学.

- 国際物理オリンピック日本代表候補者春合宿・OP研究紹介，2013年3月24日，八王子セミナーハウス，東京.

- 文京区立汐見小学校にて実験教室を開催，2012年9月8日.

11 Committee Service

11.1 External Committees

- Editorial Board Member of Scientific Reports, Nature Publishing Group, 2014−2017

- Committee Member for "new book reviews" section of BUTSURI, The Physical Society of Japan, 2016−2018.

- Steering Committee Member of Division 11, The Physical Society of Japan, 2016−2017

11.2 University Committees

東京工業大学 理学院物理学系 ネットワーク委員 2015年 –2018年
東京工業大学 学術国際情報センター運営委員 2015年 –2017年
東京工業大学 理学院物理学系 1年生助言教員 2016年 –2017年

東京工業大学 理学院 ホームカミングデー委員 2016 年 –2017 年
東京工業大学 理学院物理学系 2 年生助言教員 2017 年 –2018 年
東京工業大学 理学院物理学系 3 年生助言教員 2018 年
東京工業大学 理学院物理学系 オープンキャンパス委員 2018 年
理学系研究科物理学専攻 記録係 2018 年 –
理学系研究科物理学専攻 年次報告係 2019 年 –2020 年
理学系研究科物理学専攻 教務（ガイダンス）係 2019 年 –
理学系研究科物理学専攻 駒場対策係 2019 年 –
卓越大学院プログラム「変革を駆動する先端物理・数学プログラム」プログラム担当者 2019 年 –

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	0	
Doctor Course	2	Brazil, France
Foreign researchers hosted	1	Iran
Students sent abroad	3	Brazil, France
Researchers sent abroad	0	
Foreign visitors	13	Canada, France, Germany, Israel, Mexico, USA

Junji Yumoto、湯本 潤司

1 Education and Professional Experiences

Education

1979	B.S. (Electrical Engineering)	Keio University
1981	MSc. (Electrical Engineering)	Keio University
1984	Ph.D. (Electrical Engineering)	Keio University

Professional Appointments

1984−2006		NTT Basic Research Laboratories
2006−2009	Director	NTT Basic Research Laboratries
2009−2011	Senior Vice President	NTT Electronics Co.
2011−2014	President	NTT Electronics America, Inc.

2 Research Highlights

Since I joined the Department of Physics in 2015, I have been doing research on laser ablation and laser material processing of wide bandgap dielectric materials and composite materials like carbon fiber reinforced plastics (CFRPs). I have completed experimental setups using femtosecond laser systems and developed techniques for observation and analysis of material deformation caused by laser irradiation.
The phenomena of laser ablation and laser material processing can be explained by the physics of open nonlinear systems which are far from equilibrium. Such systems are very complicated and there are many obstacles to the complete understanding of the physics. Adding to the difficulties, these phenomena span many orders of magnitude in timescales and laser intensity ranges: femtosecond to microsecond in time, and 10^8 to $10^{16} W/cm^2$ in laser intensity. These wide ranges for timescales and laser intensities increase the complexity of the physics and different types of physics are often necessary to explain the observed behaviors. The breaking threshold of the materials is very sensitive to experimental conditions. For example, there are more than 20 papers on the laser ablation threshold of sapphire, but each paper reports a different value for the ablation threshold, and consistent understanding has not been reached. In order to deal with these obstacles, we are now constructing a large database for laser material processing. "Big" data from this database is expected to enable us to create physical models for the laser material processing of various materials. Our final goal for this database is to provide suitable recipes for key laser parameters (wavelength, pulse width, repetition rate, etc.) required for processing each material. We are also working on accelerating "big" data collection by varying the conditions for laser material processing. As mentioned previously, the breaking test for the sample with carefully controlled experimental conditions, is too time consuming. In order to deal with this challenge, with collaboration from The National Institute of Advanced Industrial Science and Technology (AIST), we have developed a fiber laser with the pulse duration tunable between 400fs to 400ps, keeping the pulse-fluence constant. This laser system improves the data acquisition time by

about 2 orders of magnitude. We have also developed a CMOS image sensor to observe the laser beam profile with 1.13 m spatial resolution. This high-resolution image sensor enables precise measurement of the beam profile. Comparison between the profile of a laser light and the depth profile of a crater on a sample created by the laser pulse, gives about 100,000 data points of the ablation threshold in just a single measurement. These advanced laser and measurement and data acquisition systems are contributing to improving the quality and quantity of the "big" data and it is our expectation that this "big" data will contribute to a deeper understanding of laser material processing.

3 Selected Papers

- Takuya Ikemachi, Yasushi Shinohara, Takeshi Sato, Junji Yumoto, Makoto Kuwata-Gonokami, Phys. Rev. A **95** 043416/1-8 (2017)
  Trajectory analysis of high-order-harmonic generation from periodic crystals.

- Davide Bossini, Kuniaki Konishi, Shingo Toyoda, Taka-hisa Arima, Junji Yumoto, Makoto Kuwata-Gonokami, Nature Physics **14** 370-374 (2018)
  Femtosecond activation of magnetoelectricity.

- Takuya Ikemachi, Yasushi Shinohara, TakeshiSato, Junji Yumoto, Makoto Kuwata-Gonokami, and Kenichi L. Ishikawa, Phys. Rev. A **98** 0234150/1-8 (2018)
  Time-dependent Hartree-Fock study of electron-hole interaction effects on high-order harmonic generation from periodic crys-tals.

- Haruyuki Sakurai, Chao He, Kuniaki Konishi, Hiroharu Tamaru, Junji Yumoto, Makoto Kuwata-Gonokami, and Arnold Gillner, J. Appl. Phys. **125** (17) 173109/1-9 (2019)
  Effect of damage incubation in the laser grooving of sapphire.

- Haruyuki Sakurai, Natsuki Nemoto, Kuniaki Konishi, Ryota Takaku, Yuki Sakurai, Nobuhiko Katayama, Tomotake Matsumura, Junji Yumoto, and Makoto Kuwata-Gonokami, OSA Continuum **2** (9) 2764-2772 (2019)
  Terahertz broadband anti-reflection moth-eye structures fabricated by femtosecond laser processing.

4 Honors, Awards and Professional Society Memberships

· 2012 Fellow, Japanese Society of Applied Physics

5 Research Plan

In addition to the physics of laser material processing described above, we are planning to explore optical properties in the Extreme Ultra Violet (EUV) region using coherent EUV laser pulses generated by high harmonic generation (HHG). We are planning to make precise measurements of complex dielectric constants of semiconductors, metals and dielectrics in the EUV region. As of now, the database of The Center for X-Ray Optics (CXRO), at the Lawrence Berkeley National Laboratory, obtained using the synchrotron radiation facility, is available for typical materials. However, we need to evaluate the optical constants of samples which we make ourselves. In order to obtain these values, we are now fabricating a "table-top" measurement system for the EUV region using HHGs pumped by femtosecond laser pulses. This system is based on the principle of a Young's double slit experiment. In preliminary measurements, the consistency of our data measured by the double slit system is much better than those calculated by taking the ratio of composites, which are the values reported by CXRO. EUV lithography in semiconductor foundries using intense lights at a wavelength of 13.5nm has been finally fully deployed and semiconductor chips using 7nm process are already commercialized this year. Therefore, our measurement technique would also potentially contribute to the semiconductor manufacturing industry.

Finally, we are also applying HHG as a pump source for photoelectron spectroscopy. We have already successfully developed high energy resolution angle-resolved Time-of-Flight photoelectron spectroscopy (ARTOF). Our system has an energy resolution of 1.3meV which is the best reported value in ARTOF as far as we are aware. This instrument analyzes the kinetic energy and in-plane momenta px and py. of photoelectrons. The kinetic energy is estimated by measuring the flight of time related to the velocity of a photoelectron and the momenta are calculated from azimuths measured from the impact location of the photoelectrons hit on a 2D detector. The data acquisition time is about 2 orders of magnitude faster than angle resolved photoelectron spectrometers using a hemispherical analyzer. The combination of HHG and ARTOF with a high energy resolution is expected to achieve a superior dynamic range and signal-to-noise ratio, and provide important information on occupied and unoccupied electronic states.

6 Publications and Patents

< Refereed Original Papers >

[1] W.J. Otter, N.M. Ridler, H. Yasukochi, K. Soeda, K. Konishi, J. Yumoto, M. Kuwata-Gonokami, S. Lucyszyn, Electronics Letters **53** (7) 471-473 (2017)
"3D printed 1.1 THz waveguides".

[2] Takuya Ikemachi, Yasushi Shinohara, Takeshi Sato, Junji Yumoto, Makoto Kuwata-Gonokami,Phys. Rev. A **95** 043416/1-8 (2017)
"Trajectory analysis of high-order-harmonic generation from periodic crystals".

[3] A. A. Ushakov, M. Matoba, N. Nemoto, N. Kanda, K. Konishi, P. A. Chizhov, N. A. Panov, D. E. Shipilo, V. V. Bukin, M. Kuwata-Gonokami, J. Yumoto, O. G. Kosareva, S. V. Garnov and A. B. Savel'ev, JETP Lett. **106** (11) 506-708 (2017)
"Backward terahertz radiation from the two-color femtosecond laser filament".

[4] Davide Bossini, Kuniaki Konishi, Shingo Toyoda, Taka-hisa Arima, Junji Yumoto, Makoto Kuwata-Gonokami, Nature Physics **14** 370-374 (2018)
"Femtosecond activation of magnetoelectricity".

[5] Takuya Ikemachi, Yasushi Shinohara, TakeshiSato, Junji Yumoto, Makoto Kuwata-Gonokami, and Kenichi L. Ishikawa, Phys. Rev. A **98** 0234150/1-8 (2018)
"Time-dependent Hartree-Fock study of electron-hole interaction effects on high-order harmonic generation from periodic crys-tals".

[6] Haruyuki Sakurai, Chao He, Kuniaki Konishi, Hiroharu Tamaru, Junji Yumoto, Makoto Kuwata-Gonokami, and Arnold Gillner, J. Appl. Phys. **125** (17) 173109/1-9 (2019)
"Effect of damage incubation in the laser grooving of sapphire".

[7] Haruyuki Sakurai, Natsuki Nemoto, Kuniaki Konishi, Ryota Takaku, Yuki Sakurai, Nobuhiko Katayama, Tomotake Matsumura, Junji Yumoto, and Makoto Kuwata-Gonokami, OSA Continuum **2** (9) 2764-2772 (2019)
"Terahertz broadband anti-reflection moth-eye structures fabricated by femtosecond laser processing".

< Conference Proceedings >

[8] Haruyuki Sakurai, Yo Iida, Akira Mizutani, Kuniaki Konishi, Junji Yumoto, Makoto Kuwata-Gonokami, 2016 Conference on Lasers and Electro-Optics (CLEO), San Jose, CA, (Jun./05-10/2016)
"Wavelength Dependence of the Laser-Induced Damage Threshold of alpha-Al_2O_3".

[9] Ryo Imai, Kuniaki Konishi, Junji Yumoto, Makoto Kuwata-Gonokami, Conference on Frontiers in Ultrafast Optics - Biomedical, Scientific, and Industrial Applications XVII, San Francisco, CA, (Jan./29-Feb./02/2017)
"Fabrication of low loss waveguide using fundamental light of Yb-based femtosecond laser".

[10] Takuya Ikemachi, Yasushi Shinohara, Takeshi Sato, Junji Yumoto, Makoto Kuwata-Gonokami, Kenichi L. Ishikawa, Conference on Lasers and Electro-Optics (CLEO), San Jose, CA, (May/14-19/2017)
"Solid-State Three-Step Model for High-Harmonic Generation from Periodic Crystals"

[11] Haruyuki Sakurai, Chao He, C, Kuniaki Konishi, Hiroharu Tamaru, Junji Yumoto, Makoto Kuwata-Gonokami, Arnold Gillner, Conference on Lasers and Electro-Optics Europe / European Quantum Electronics Conference (CLEO/Europe-EQEC), Munich, GERMANY (Jun./25-29/2017)
"Linking Energy Density with Morphology in Laser Grooving of Sapphire"

[12] Kuniaki Konishi, Hiroyuki Yasukochi, Kentaro Soeda, Yuma Takano, Hiroaki Niwa, Jumji Yumoto, Makoto Kuwata-Gonokami, Conference on Lasers and Electro-Optics Europe / European Quantum Electronics Conference (CLEO/Europe-EQEC), Munich, GERMANY (Jun./25-29/2017)
"Thick THz Metamaterials fabricated by 3D printer for THz High-Pass Filter Application"

[13] Takuya Ikemachi, Sato Shinohara, Tasushi Shinohara, Takeshi Sato, Junji Yumoto, Makoto Kuwata-Gonokami, Kenichi L. Ishikawa, Conference on Lasers and Electro-Optics Europe / European Quantum Electronics Conference (CLEO/Europe-EQEC), Munich, GERMANY (Jun./25-29/2017)
”Extended Solid-State Three-Step Model for High-Harmonic Generation from Periodic Crystals”

[14] A. A. Ushakov, et al., 10th International Workshop on Strong Microwaves and Terahertz Waves - Sources and Applications, Nizhny Novgorod, RUSSIA, (Jul./17-22/2017)
”3D terahertz beam profiling from two color laser induced plasma with different focusing”

[15] Y. Nagashima, A. Iwata, K. Yoshioka, J. Omachi, J. Shimizu, S. Tsuji, J. Yumoto, M. Kuwata-Gonokami, 23rd World Congress of Neurology (WCN), Kyoto, JAPAN (Sep./16-21/2017)
”A new method to visualize abnormal lipid accumulation in tissues from Fabry disease patient using Raman spectroscopic marker of globotriaosylceramide”

[16] Y. Sekimoto,et al., Conference on Space Telescopes and Instrumentation - Optical, Infrared, and Millimeter Wave, Austin, TX (Jun./10-15/2018)
”Concept design of the LiteBIRD satellite for CMB B-mode polarization”

[17] Yuki Sakurai, et al., Conference on Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy IX, Austin, TX, (Jun./12-15/2018)
”Design and development of a polarization modulator unit based on a continuous rotating half-wave plate for LiteBIRD”

[18] P.A. Chizhov, A. A. Ushakov, V.A. Andreeva, N. A. Panov, D. E. Shipilo, M. Matoba, N. Nemoto, N, N. Kanda, K. Konishi, V. V. Bukin, M. Kuwata-Gonokami, J. Yumoto, O. G. Kosareva, S. V. Garnov, A. B. Saveliev, International Conference on Laser Optics (ICLO), St Petersburg, RUSSIA, (Jun./04-08/2018)
”Two-Color Plasma Terahertz Far-Field Angular Distribution Conversion By Focal Length Variation”

[19] Yu Nagashima, Atsushi Iwata, Kosuke Yoshioka, Junko Omachi, Jun Shimizu, Tatsushi Toda, Junji Yumoto, Makoto Kuwata-Gonokami, 19th International Congress of Neuropathology, Tokyo, JAPAN, (Sep./23-27/2018)
”Label-free visualization of abnormal lipid accumulation in tissues from Fabry disease patients using Raman spectroscopic marker of globotriaosylceramide

＜Review Papers＞

None

＜Books＞

None

＜Patent Applications＞

[20] 特願 2016-119965:「波長掃引光源」
豊田誠治、阪本 匡、長沼和則、湯本潤司

[21] 特願 2017-084033:「波長掃引光源」
豊田誠治、阪本 匡、長沼和則、湯本潤司

[22] 特願 2018-001390:「電気光学偏向器」
豊田誠治、阪本 匡、長沼和則、湯本潤司

[23] 特願 2018-244267:「レーザ加工におけるレーザ光強度への依存性の判定方法及びレーザ加工装置」
櫻井治之, 田丸博晴, 小西邦昭, 湯本潤司

[24] 特願 2019-150800:「真空紫外光の発生方法及びそれに用いる装置」
小西邦昭、湯本潤司、五神真、石田誠、赤井大輔

[25] US EFS ID: 344000108: ”Three-dimensional molding apparatus and manufacturing method”,
K Soeda, H. Yasukochi, H. Suzuki, J.Yumoto

7 Invited Presentations at International Conferences

[1] Junji Yumoto: "Coherent photon technology -Light matter interaction", The Second STEPS Symposium on Photon Science, St. Petersburg University, Russia (Mar./15/2016).

[2] Junji Yumoto: "Coherent photon technology-science, technology and innovation", LPM2016 - The 17th International Symposium on Laser Precision Microfabrication, Wyndham Grand Xi ' an South, Xi'an, China (May/26/2016.

[3] Junji Yumoto: "Exploring ultimate coherent photon technology for additive manufacturing and,laser material processing", ADD+it2016 (Additive Manufacturing and Innovative Technologies), Museum Arbeitswelt, Steyr, Austria (Sep./30/2016.

[4] Junji Yumoto: "Exploring Ultimate Coherent Technology for Medical Science and Bio-Science", Chitose International Forum on Photonics Science & Technology, Hokkaido (Nov./15/2016.

[5] Junji Yumoto: "High Aspect Ratio Laser Cut-ting of CFRP using Nanosecond UV Laser Pulses", Nanocarbon Photonics and Optoelectronics 2019, Savonlinna (Finland) (Aug./7-10/2018.

[6] Junji Yumoto: "Coherent Photon Technol-ogy - Light-Matter Interaction -", The Fourth STEPS Symposium on Photon Science, Tokyo (Mar./20-21/2019.

8 Teaching Accomplishment

9 Contribution to Academic Community

9.1 Editorial Activities

None

9.2 Organization of Professional Societies

None

9.3 Organization and Advisory of Conferences

None

10 Outreach

- 2014/2/21: 第一回 ICCPT シンポジウム
- 2015/8/21: 第二回 ICCPT シンポジウム
- 2017/12/13: 第三回 ICCPT（TACMI 合同）シンポジウム

11 Committee Service

11.1 External Committees

- 文部科学省量子科学技術員会専門委員 2015 年-
- 文部科学省未来技術予測調査委員 2018 年, 2019 年
- JST さきがけ「革新的光科学技術を駆使した最先端科学の創出」アドバイザー 2019 年-

11.2 University Committees

理学系研究学術運営委員会委員 2015 年
理学系研究科図書委員 2016 年
理学系研究科ハラスメント防止委員 2017 年, 2018 年
理学系研究科学術運営・教育委員会委員 2019 年

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	0	
Doctor Course	0	
Foreign researchers hosted	6	
Students sent abroad	2	USA
	2	Germany
	1	Canada
Researchers sent abroad	1	Italy
Foreign visitors	2	Russia
	5	Finland
	1	Germany

Astrophysics and Cosmology

Masaki Ando、安東 正樹

1 Education and Professional Experiences

Education

1994	B.S. (Physics)	Kyoto University
1996	MSc. (Physics)	The University of Tokyo
1999	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1999	JSPS Postdoctoral Fellow	The University of Tokyo
1999−2007	Research Assistant	The University of Tokyo
2007−2008	Assistant Professor	The University of Tokyo
2009−2012	Specific Associate Professor	Kyoto University
2012−2013	Associate Professor	National Astronomical Observatory of Japan
2013−	Associate Professor	The University of Tokyo

Visiting, Guest Appointments

2013−2019	Adjunct Associate Professor	National Astronomical Observatory of Japan

2 Research Highlights

I have been working in the reserch field of gravitaional-wave astrophysics for more than 20 year. After the first detection of gravitaional wave signal by the LIGO detectors in 2015, this field is in a harvest era of science. In these background, I have been mainly working in three directions: (1) Construction and operation of the large-scale gravitational wave antenna KAGRA, (2) Research for future space gravitational-wave antenna, mainly on B-DECIGO, and (3) Advanced laboratory-scale experimental reserch on low-frequency gravitational wave observatio]n and fundamental physics.

(1) Construction and operation of KAGRA

KAGRA is a 3-km scale gravitational wave antenna in Japan. This antenna is beeing constructed and operated by international collaboration with more than 300 collaborators. The projectstarted in 2010. Installation of main components has been completed at this moment. KAGRA will start observation run in 2019.

I have been working for this project from the very beginning, and summarized the conceptual design of the interferometer. Now I am contributiong to this project as a member of management team (Exective Office and Systems Engineering Office), and in charge of main inteferometer design and comissioning. I also contributed in the community support tasks, such as paper writing, management of author list, organization of collaborator meeting, and so on.

(2) Reserch on a space gravitaitonal wave antenna

The flagship project after the KAGRA project in Japan will be a space mission. I have been leading a mission named B-DECIGO, which has 100-km arm length. By using a Fabry-Perot cavity as the interferometer, B-DECIGO will have a sufficient sensitivity to observe about 100 events/year for mergers of binary neutron stars, and about 10^5 events/year for mergers of binary black holes. Our group has been woking on the design feasibility study of the mission, development of critical components, and study of science cases.

As a result, we published papers on the mission design, results of development, and science cases. In particular, we firstly pointed out the possibility and importance of the predicition of a gravitational wave event by a compact-star merger. This stimulated the theoretical research field to study new science possibilities in astrophsics of neutron stars and fundamental physics on gravity.

(3) Advanced laboratory-scale experimental reserch

I have been working on laboratory-scale advanced experiments with presision measurement techniques using laser interferometers. These experiments can be good reserch topics for graduate students: graduate students manages their own research subjects with high motivation, and grows up as independent reserchers.

We have developed a low-frequency gravitational wave antenna, named TOBA. We made observation runs with the world's-best sensitivity at 0.1-1 Hz frequency band. We set upper limits on stochastic back ground gravitational waves, low-frequency pulsars, mergers of intermediate black holes. As a sensitive gravity-gradiomeer, TOBA can be used for stufy of Newtonian noise in gravitational-wave antenna, early alert of large earthquake, and study of force noise in space gravitational-wave antenna.

Another topic is the test of quantum mechanics in a macroscopic scale. We are developing opt-mechanical systems, laser interferometers formed with mg-scale small mirrors. We mostly succeeded to directly observe the quantum radiation pressure fluctuation. This is an important mileston to reach standardquantum-limited measurement and test of quantum mechanics in a macroscopic scale. We are also developing a optical levitaiton system for this purpose.

3 Selected Papers

- KAGRA Collaboration, LIGO Scientific Collaboration and Virgo Collaboration: *"Prospects for Observing and Localizing Gravitational-Wave Transients with Advanced LIGO, Advanced Virgo and KAGRA"*, Living Reviews in Relativity **21**, 3 (2018).
  This is the first KAGRA paper published together with LIGO and VIRGO collaborations. I joined to the paper writing team represening the KAGRA project. 153 citations in one and half year.

- Y. Aso, Y. Michimura, et al.: *"Interferometer Design of the KAGRA Gravitational Wave Detector"*, Phys. Rev. D **88** 043007 (2013)

The paper has been cited 337 times. I have contributed to the original conceptual design of hte KAGRA interferometer.

- T. Nakamura, M. Ando, T. Kinugawa, et al.: *"Pre-DECIGO can get the smoking gun to decide the astrophysical or cosmological origin of GW150914-like binary black holes"*, Prog. Theor. Exp. Phys. **9** 093E01 (2016).
  This work has firstly shown the possibility to predict the merger event of compact binaries using a space gravitational-wave antenna Pre-DECIGO (now renamed to B-DECIGO).
- J. Harms, BJJ. Slagmolen, RX. Adhikari, MC. Miller, M. Evans, YB. Chen, H. Muller, M. Ando: *"Low-frequency terrestrial gravitational-wave detectors"*, Phys. Rev. D **88** 122003 (2013).
  After my first suggestion of the possibility of low-frequency gravitaional-wave observations in 2010 paper, this field collected interests in the international gravitationa-wave community. This paper is the first review paper of science cases and detectors for low-frequency gravitaitonal waves.
- A. Shoda, M. Ando, K. Ishidoshiro, K. Okada, W. Kokuyama, Y. Aso, K. Tsubono: *"Search for a stochastic gravitational-wave background using a pair of torsion-bar antennas"*, Phys. Rev. D **89** 027101 (2014).
  This paper describes search results for stochastic background gravitaitonal waves at low-frequency around 1 Hz. This is the original work of our group to make observation of gravitational wave at such a low frequency.

4 Honors, Awards and Professional Society Memberships

5 Research Plan

The goal of our group is to reveal the fundamental law dominating the universe. For that purpose, we are planning to work on gravitaiioal-wave astrophysics project as well as lboratory-scale experimental researches using presision measurement techniques.

(1) Large gravitational-wave observation projects

  - Observation runs using KAGRA
  - Studies for future space mission B-DECIGO
  - Theoretical and data-analysis studies

(2) Laboratory-scale fundamental reseches

  - Advanced techniques for future gravitationalwave antenna
  - Low-frequency gravitaional-wave observation
  - Applications of a sensitive gravity gradiometer
  - Test of macroscopic quantum mechanics
  - Test of relativity

6 Publications and Patents

< Refereed Original Papers >

[1] Koji Nagano, Tomohiro Fujita, Yuta Michimura, and Ippei Obata: *"Axion Dark Matter Search with Interferometric Gravitational Wave Detectors*", Phys. Rev. Lett. 123, 111301 (2019).

[2] Hiroki Takeda, Atsushi Nishizawa, Koji Nagano, et al.: *"Prospects for gravitational-wave polarization tests from compact binary merger"s with future ground-based detectors*, Phys. Rev. D, 100, 042001 (2019).

[3] Tomofumi Shimoda and Masaki Ando, *"Nonlinear vibration transfer in torsion pendulums"*, Classical and Quantum Gravity **36**, 12 (2019).

[4] Masaya Kimura, Nobuki Kame, Shingo Watada, Makiko Ohtani, Akito Araya, Yuichi Imanishi, Masaki Ando and Takashi Kunugi, *"Earthquake-induced prompt gravity signals identified in dense array data in Japan"*, Earth, Planets and Space **71**, 27 (2019).

[5] Nobuyuki Matsumoto, Seth B. Catao-Lopez, Masakazu Sugawara, Seiya Suzuki, Naofumi Abe, Kentaro Komori, Yuta Michimura, Yoichi Aso, and Keiichi Edamatsu: *"Demonstration of Displacement Sensing of a mg-Scale Pendulum for mm- and mg-Scale Gravity Measurements"*, Phys. Rev. Lett. 122, 071101 (2019).

[6] KAGRA collaboration, *"KAGRA: 2.5 Generation Interferometric Gravitational Wave Detector"*, Nature Astronomy **3**, 35 (2019).

[7] KAGRA Collaboration, *"Vibration isolation system with a compact damping system for power recycling mirrors of KAGRA"*, Class. Quantum Grav. **36**, 095015 (2019).

[8] Ippei Obata, Tomohiro Fujita, and Yuta Michimura: *"Optical Ring Cavity Search for Axion Dark Matter"*, Phys. Rev. Lett. 121, 161301 (2018)

[9] KAGRA Collaboration, LIGO Scientific Collaboration and Virgo Collaboration, *"Prospects for Observing and Localizing Gravitational-Wave Transients with Advanced LIGO, Advanced Virgo and KAGRA"*, Living Reviews in Relativity **21**, 3 (2018).

[10] Kentaro Komori, Yutaro Enomoto, Hiroki Takeda, Yuta Michimura, Kentaro Somiya, Masaki Ando, Stefan W. Ballmer, *"Direct approach for the fluctuation-dissipation theorem under nonequilibrium steady-state conditions"*, Physical Review **D 97** 10, 102001 (2018).

[11] Yuta Michimura, Kentaro Komori, Atsushi Nishizawa, et al., *"Particle swarm optimization of the sensitivity of a cryogenic gravitational wave detector"*, Physical Review **D 97** 12, 122003 (2018).

[12] Hiroki Takeda, Atsushi Nishizawa, Yuta Michimura, et al., *"Polarization test of gravitational waves from compact binary coalescences"*, Physical Review **D 98** 2, 022008 (2018).

[13] Tomofumi Shimoda, Naoki Aritomi, Ayaka Shoda, et al., *"Seismic cross-coupling noise in torsion pendulums"*, Physical Review **D 97** 10 104003 (2018).

[14] T. Akutsu, M. Ando, S. Araki, et al. (KAGRA Collaboration), *"Construction of KAGRA: an underground gravitational-wave observatory"*, Progress of Theoretical and Experimental Physics 2018, 013F01 (2018).

[15] Yuta Michimura, Tomofumi Shimoda, Takahiro Miyamoto, et al., *"Mirror actuation design for the interferometer control of the KAGRA gravitational wave telescope"*, Classical and Quantum Gravity 34, 225001 (2017).

[16] Yuta Michimura, Yuya Kuwahara, Takafumi Ushiba, Nobuyuki Matsumoto, M. Ando, *"Optical levitation of a mirror for reaching the standard quantum limit"*, Optics Express 25, 13799 (2017).

[17] Ayaka Shoda, Yuya Kuwahara, Masaki Ando, et al.: *"Ground-based low-frequency gravitational-wave detector with multiple outputs"*, Phys. Rev. D, 95, 082004 (2017).

[18] Kazunari Eda, Ayaka Shoda, Yuya Kuwahara, Yousuke Itoh and Masaki Ando: *"All-sky coherent search for continuous gravitational waves in 6-7 Hz band with a torsion-bar antenna"*, Prog. Theor. Exp. Phys. **1** 011F01 (2016).

[19] T. Nakamura, M. Ando, T. Kinugawa, et al.: *"Pre-DECIGO can get the smoking gun to decide the astrophysical or cosmological origin of GW150914-like binary black holes"*, Prog. Theor. Exp. Phys. **9** 093E01 (2016).

[20] Y. Kuwahara, A. Shoda, K. Eda, and M. Ando: *"Search for a stochastic gravitational wave background at 1-5 Hz with a torsion-bar antenna"*, Phys. Rev. D **94** 92003 (2016).

[21] K. Okutomi, T. Akutsu, M. Ando, et al.: *"Residual Gas Noise in the Test-mass Module for DECIGO Pathfinder*", Journal of Physics Conference Series **610** 012040 (2015).

[22] K. Eda, A. Shoda, Y. Itoh, M. Ando: *"Improving parameter estimation accuracy with torsion-bar Antennas*", Phys. Rev. D **90** 064039 (2014).

[23] M. Adier, F. Aguilar, T. Akutsu, M.A. Arain, M. Ando *"et al.:*" *"Progress and challenges in advanced ground-based gravitational-wave detectors*", General Relativity and Gravitation **46** 1749 (2014).

[24] A. Shoda, M. Ando, K. Ishidoshiro, K. Okada, W. Kokuyama, Y. Aso, K. Tsubono: *"Search for a stochastic gravitational-wave background using a pair of torsion-bar antennas*", Phys. Rev. D **89** 027101 (2014).

[25] K. Nakamura, M. Ando: *"Torsion-bar antenna in the proper reference frame with rotation*", Phys. Rev. D **89** 064008 (2014).

[26] M. Ando: *"DECIGO PATHFINDER"*, International Journal of Modern Physics D **22** 1341002 (2013).

[27] Y. Aso, Y. Michimura, et al.: *"Interferometer Design of the KAGRA Gravitational Wave Detector*, " Phys. Rev. D **88** 043007 (2013).

[28] J. Harms, BJJ. Slagmolen, RX. Adhikari, MC. Miller, M. Evans, YB. Chen, H. Muller, M. Ando: *"Low-frequency terrestrial gravitational-wave detectors"*, Phys. Rev. D **88** 122003 (2013).

[29] Yuta Michimura, Nobuyuki Matsumoto, Noriaki Ohmae, Wataru Kokuyama, Yoichi Aso, Masaki Ando, Kimio Tsubono: *"New Limit on Lorentz Violation Using a Double-Pass Optical Ring Cavity"*, Phys. Rev. Lett. **110** 200401 (2013).

[30] Yuta Michimura, Matthew Mewes, Nobuyuki Matsumoto, Yoichi Aso, Masaki Ando: *"Optical cavity limits on higher order Lorentz violation"*, Phys. Rev. D **88** 111101(R) (2013).

[31] A. Shoda, M. Ando, K. Okada, K. Ishidoshiro, W. Kokuyama, Y. Aso, and K. Tsubono: *" Search for a stochastic gravitational-wave background with torsion-bar antennas"*, J. Phys. Conf. Ser. **363** 012017 (2012).

＜ Review Papers ＞

[32] 安東正樹: "重力波望遠鏡の極限光計測技術", フォトニクスニュース (応用物理学会・フォトニクス分科会会誌) **3** 1 (2017).

[33] 安東正樹: "重力波望遠鏡を用いた地震速報", 日本物理学会誌 **71** 636 (2016).

[34] 安東正樹: "重力波の初観測と重力波天文学の幕開け", 理科年表 (丸善出版, 2016).

[35] S. ドワイヤー, 安東正樹 (訳): "量子雑音のスクイージング", パリティ (丸善出版) 2015 年 8 月号.

[36] 安東正樹: "重力波天文学が拓く宇宙", 国立天文台ニュース 2014 年 2 月号 (2014).

[37] 瀬戸直樹，八木絢外，安東正樹: "宇宙レーザー干渉計が切り拓く重力波天文学", 日本物理学会誌 **68** 38 (2013).

[38] マーカス・アスペルマイヤー, ピエール・メスター, キース・シュワブ, 安東正樹 (訳): "量子オプトメカニクス", パリティ (丸善出版) 2013 年 5 月号.

＜ **Books** ＞

[39] Masaki Ando: Advanced Interferometric Gravitational-wave Detectors: "Essentials of Gravitational Wave Detectors, Chapter 6", ed: David Reitze, and Peter Saulson, World Scientific Pub. Co. Inc. (2019).

[40] ピエール ビネトリュイ, 安東正樹 監訳, 岡田好恵 訳: "重力波でみえる宇宙のはじまり", 講談社ブルーバックス (2017).

[41] 安東正樹: "重力波とはなにか", 講談社ブルーバックス (2016).

7 Invited Presentations at International Conferences

[1] Masaki Ando: "Gravity-Gradient-Based Early Earthquake Alert", UK-Japan Quantum Sensing and Metrology Research Workshop (Sept. 10th, 2019, The British Embassy, Tokyo).

[2] Masaki Ando: "Science and Technology of B-DECIGO and DECIGO", Summer School on Gravitaiotnal Waves (July 16-17, 2019, Sun Yat-sen University, China).

[3] Masaki Ando: "Gravitational-wave observation" The 15th International Symposium on Origin of Matter and Evolution of Galaxies (July 4th, 2019, YITP, Kyoto).

[4] Masaki Ando: "B-DECIGO and DECIGO", The 6th KAGRA International Workshop (June 23, 2019, WIPM, Wuhan, China).

[5] Masaki Ando: "Recent results of gravitational wave", Higgs Couplings 2018 (Nov. 28, 2018, KFC Hall and Rooms, Ryogoku, Tokyo).

[6] Masaki Ando: "DECIGO : Gravitational-Wave Observation from Space", Fifteenth Marcel Grossmann Meeting (July 1-7, 2018, University of Rome, Italy).

[7] Masaki Ando, T. Shimoda, S. Takano, C. P. Ooi, H. Takeda, N. Aritomi, A. Shoda, Y. Michimura: "TOBA: Torsion-Bar Gravitational-Wave Antenna", Fifteenth Marcel Grossmann Meeting (July 1-7, 2018, University of Rome, Italy).

[8] Masaki Ando: "KAGRA and B-DECIGO", YKIS2018a Symposium (Feb. 19th, 2018, Kyoto University).

[9] Masaki Ando: "Observation of Gravitational Waves", Japan-France Workshop "Neutron Star Mergers and Galactic Chemical Evolution" (Oct. 20th, 2017, NAOJ).

[10] Masaki Ando: "Science and Design of DECIGO and B-DECIGO", ISGW2017: International Symposium on Gravitational Waves (May 26th, 2017, Beijing, China).

[11] Masaki Ando: "Science and Design of DECIGO and B-DECIGO", The 2nd ASTROD International Workshop (May 22nd, 2017, National Tsing Hua Univ., Taiwan).

[12] Masaki Ando: "Science and Design of DECIGO and B-DECIGO", The 3rd KAGRA International Workshop (May 21st, 2017, Academia Sinica, Taiwan).

[13] Masaki Ando: *"TOBA: Low-frequency Gravitational Wave Antenna"*, GWADW2017 (May 10th, 2017, Hamilton Island, Australia).

[14] Masaki Ando: *"Observation of Gravitational Waves"*, Physics in LHC and the Early Universe (Jan. 10th, 2017, The University of Tokyo, Tokyo).

[15] Masaki Ando: *"KAGRA : a Cryogenic Interferometric Gravitational-Wave Antenna"*, Gravitational Wave Astronomy with Present and Future Detectors (Aug. 22nd, 2016, Yangpyeong, Korea).

[16] Masaki Ando: *"Space Gravitational-Wave Antenna: DECIGO and Pre-DECIGO"*, GWPAW2016 (June 15th, 2016, Cape Cod, Massachusetts, USA).

[17] Masaki Ando: *"KAGRA : a Gravitational-Wave Antenna in Japan"*, Korean Physical Society Spring Meeting (April 21st 2016, Daejon Convention Center, Daejon, Korea).

[18] Masaki Ando: *"The GW Research in Japan - Current Status of KAGRA -"*, ELiTES 4th General Meeting (December 3rd 2015, Delegation of the European Union to Japan, Tokyo).

[19] Masaki Ando: *"Space Gravitational-Wave Antenna: DECIGO and Pre-DECIGO"*, GWPAW2015 (June 19th, 2015, INTEX-Osaka, Osaka).

[20] M. Ando, A.Shoda, K. Yamamoto, Y. Aso, R. Takahashi: *"Lessons learned and the next steps of Torsion-Bar Antenna experiments"*, GWADW2015 (May 19th, 2015, Alaska, USA).

[21] Masaki Ando: *"Recent News from KAGRA"*, PAC37, The 37th Program Advisory Committee Meeting (January 28th, 2015, Hanford, USA).

[22] Masaki Ando: *"DECIGO: Space Gravitational-wave Antenna"*, RESCEU APCosPA Summer School on Cosmology and Particle Astrophysics (August 3rd, 2014, Matsumoto).

[23] Masaki Ando: *"DECIGO and DECIGO Pathfinder"*, 10th International LISA Symposium (May 19th, 2014, Florida, USA).

[24] Masaki Ando: *"Observation of Gravitational Waves"*, Multi-Messengers from Core-Collapse Supernovae (December 2nd, 2013, Fukuoka Univ.)

[25] Masaki Ando: *"Gravitational-Wave Telescopes"*, 6th OECD Meeting of the Astroparticle Physics International Forum (Oct. 29, 2013 Toyama)

[26] Masaki Ando: *"KAGRA, Large-scale Cryogenic Gravitational-Wave Telescope"*, Workshop on Scientific Project Management (Oct. 16, 2013, Fukuracia Tokyo Station, Tokyo)

[27] Masaki Ando: *"KAGRA and Gravitational-Wave Experiments"*, APPC12, The 12th Asia Pacific Physics Conference (July 17, 2013, Makuhari Messe, Chiba, Japan)

[28] Masaki Ando: *" Recent News from KAGRA"*, PAC34, The 34th Program Advisory Committee Meeting (June 4th 2013, Hanford, USA)

[29] M. Ando: *"Space Gravitational-wave observatory: DECIGO"*, The Fifth International ASTROD Symposium (July 12, 2012, Raman Research Institute, India).

[30] M. Ando: *"TOBA: Torsion-Bar Antenna"*, GWADW2012 (May 17, 2012, Hawaii, USA).

[31] M. Ando: *"News from KAGRA"*, The 32th Program Advisory Committee Meeting (May 3rd 2012, Caltech, USA).

[32] M. Ando: *"Gravitational Wave Experiment"*, Asian Winter School on Strings, Particles, and Cosmology (January 17, 2012, Kusatsu, Gunma).

8 Teaching Accomplishment

< Awards of Supervised Students >

- 有冨尚紀: 日本物理学会 宇宙線・宇宙物理領域 学生優秀発表賞 (2019 年 9 月).
- 宮崎祐樹: 日本物理学会 宇宙線・宇宙物理領域 学生優秀発表賞 (2019 年 9 月).
- 有冨尚紀: KAGRA F2F 会議 ポスター賞 (2019 年 8 月 24 日).
- 榎本雄太郎: 日本物理学会 宇宙線・宇宙物理領域 学生優秀発表賞 (2019 年 3 月).
- 長野晃士: KAGRA F2F 会議 ポスター賞 (2018 年 4 月 21 日).
- Yuta Michimura: Tests of Lorentz Invariance with an Optical Ring Cavity, Springer Thesis Prize (2016).
- 榎本雄太郎: 東京大学 理学系研究科 研究奨励賞・修士課程 (2016 年度).
- 道村唯太: 第 10 回 日本物理学会 若手奨励賞 (宇宙線・宇宙物理領域) (2015 年).
- 佐藤遼太郎: 東京大学 理学部 学修奨励賞 (2015 年度).
- Nobuyuki Matsumoto: Classical Pendulum Feels Quantum Back-Action, Springer Theses Prize (2015).
- 榎本雄太郎: 東京大学 理学部 学修奨励賞 (2014 年度).
- 正田亜八香 ほか: 大学院生出張授業プロジェクト (BAP), 東京大学 総長賞・課外活動 (2013 年度).
- 松本伸之: 東京大学 理学系研究科 研究奨励賞・博士課程 (2013 年度).
- 小森健太郎: 東京大学 理学部 学修奨励賞 (2013 年度).
- 石徹白晃治: 第 6 回 日本物理学会 若手奨励賞 (宇宙線・宇宙物理領域) (2012 年).

9 Contribution to Academic Community

9.1 Editorial Activities

- Editorial board member of a journal: Classical and Quantum Gravity (2017-).
- Chief editor of a PR magazine of Shcool of Science: the RIGAKUBU News (FY2018-).
- Editorial board member of a PR magazine of School of Science: the RIGAKUBU News (FY2014-).

9.2 Organization of Professional Societies

- Japanese Gravitational-Wave Community (JGWC), Steering Committee member (Sept. 2017- Aug. 2019).
- Japan Physical Society (JPS) Regional Steering Committee (FY2017-2018).
- Japanese Gravitational-Wave Community (JGWC), Chairperson of the Steering Committee (Sept. 2013- Aug. 2015).
- Cosmic-Ray Researcher Community (CRC), Steering Committee member (FY2012).

9.3 Organization and Advisory of Conferences

- Scientific Organizing Committee: 5th KAGRA International Workshop (Feb 14-16, 2019, Perugia, Italy).
- Session Organizer: Fifteenth Marcel Grossmann Meeting (MG15) (July 1-7, 2018, University of Rome, Italy).
- Scientific Organizing Committee: Gravity and Cosmology 2018 (February 5 - March 2, 2018, Yukawa Institute for Theoretical Physics (YITP), Kyoto).
- Scientific Organizing Committee: IAU Symposium on Gravitational Astrophysics: Early Results from search for Gravitational Wave and electromagnetic counterparts, (Oct. 9-11. 2017, Baton Rouge, LA, USA).
- Scientific Organizing Committee: 3rd KAGRA International Workshop (May 21-22, 2017, Academia Sinica, Taipei).
- Program Convener: GWADW 2015 (May 17-22, 2015, Girdwood, Alaska).

10 Outreach

＜**Media Appearance and Supervisions**＞

- 書籍 監修: 「宇宙の歴史と宇宙観測」 (技術評論社), 2019 年 2 月.
- プラネタリウム プログラム監修: 大阪市立科学館プラネタリウム, 2018 年.
- 雑誌 記事監修: 「日経サイエンス」(日経サイエンス社), 2018 年 11 月.
- 雑誌 記事監修: 「天文ガイド」(誠文堂新光社), 2017 年 11 月号, 12 月号.
- Web 記事 掲載:「講談社ブルーバックス」(講談社) 2016 年 10 月.
- 雑誌 記事監修・掲載: 「子供の科学」 (誠文堂新光社), 2016 年 5 月号.
- TV 番組 ビデオ出演 「クローズアップ現代＋」 (NHK) 2016 年 6 月 29 日 放送.

- TV 番組 出演: 「視点・論点」 (NHK), 2016 年 2 月 22 日 放送.
- 新聞 記事掲載: 連載記事「駆ける」, 読売新聞 2016 年 2 月 18 日 夕刊.
- 雑誌 記事掲載: 「ついに初観測! 重力波とはなにか」, 本 10 月号 p.38 (講談社, 2016).
- Web 記事掲載: 「日本最先端の研究者に聞いた 「ほかでは読めない重力波」」, 講談社 BOOK 倶楽部 (Web コラム), http://bluebacks.kodansha.co.jp/news/2016/2/16.html (2016).
- 新聞 記事・コメント掲載 (読売新聞, 産経新聞) 2016 年 2 月.
- 新聞 取材協力 (読売新聞, 毎日新聞, 産経新聞, 朝日新聞, 時事通信) 2016 年 2 月.

＜ **Outreach Events** ＞

- 講演会企画・実行委員長: 「一般相対性理論誕生 100 年記念市民講演会」 (2015 年 2 月-2016 年). [全国 14 の会場でシリーズ開催. 延べ 3,000 名程度の聴衆が参加.]
- 理学部オープンキャンパス 研究室公開 (2013-2019 年度).

＜ **Public Lectures** ＞

- 安東正樹: 重力波で宇宙を聴く, 日本物理学会 科学セミナー (2019 年 8 月 25 日, 早稲田大学, 東京).
- 安東正樹: 重力波で探る宇宙, 日本物理学会 市民科学講演会 (2019 年 3 月 16 日, 九州大学, 福岡).
- 安東正樹: 重力波で探る宇宙, NHK 文化センター講演会 (2019 年 2 月 23 日, 町田, 神奈川).
- 安東正樹: 重力波とブラックホール, 川口市立科学館 プラネタリウム (2019 年 2 月 17 日, 川口市立科学館, 埼玉).
- 安東正樹: 時空のさざ波 〜 重力波で探る宇宙, 第 26 回 自然科学研究機構シンポジウム (2018 年 12 月 8 日, 東京国際交流館, 東京).
- 安東正樹: 「重力波」観測の衝撃, NHK 文化センター横浜ランドマーク教室 (2018 年 11 月 11 日, 文化センター横浜, 神奈川).
- 安東正樹: アインシュタインの最後の宿題 重力波で探る宇宙: 山形県高等学校教育研究会 (2018 年 10 月 24 日, 河北町総合交流センター, 山形).
- 安東正樹: 重力波で探る宇宙, 第 7 回 福島医師会 市民文化講演会 (2018 年 10 月 6 日, 福島市保健福祉センター, 福島).
- 安東正樹: 重力波で探る宇宙のはじまり (2018 年 1 月 27 日, 朝日カルチャーセンター湘南).
- 安東正樹: 重力波で探る宇宙, 順天高校 グローバルウィーク (2017 年 11 月 8 日, 順天高校).

- 安東正樹: 重力波天文学で探る宇宙 (2017 年 11 月 4 日, 朝日カルチャーセンター横浜).
- 安東正樹: ブラックホール合体の重力波観測 (2017 年 9 月 9 日, 朝日カルチャーセンター新宿).
- 安東正樹: 重力波・ブラックホール・宇宙のはじまり, 東京大学オープンキャンパス 2017 (2017 年 8 月 2, 3 日, 東京大学).
- 安東正樹: 重力波でさぐる宇宙の大爆発, 第 125 回 東京大学 公開講座 (2017 年 6 月 3 日, 東京大学 安田講堂).
- 安東正樹: 重力波検出に挑む KAGRA, 朝日カルチャーセンター講演 (2017 年 4 月 22 日, ルミネ湘南, 藤沢).
- 安東正樹: 重力波で探るブラックホールと宇宙-アインシュタインの相対論と新しい天文学- , 富山県教育フォーラム (2016 年 12 月 10 日, 富山国際会議場, 富山).
- 安東正樹: 重力波で知る宇宙の不思議, サイエンスアゴラ 2016「限界に挑戦する光科学」(2016 年 11 月 6 日, 日本科学未来館, お台場).
- 安東正樹: 重力波で宇宙を探る-アインシュタインの相対論と新しい天文学- , 高尾記念市民公開講座 (2016 年 10 月 30 日, ワテラスコモン ホール, 神田淡路町, 東京).
- 安東正樹: 重力波の観測, 順天高校 見学・講演会 (2016 年 9 月 20 日, 東京大学).
- 安東正樹: 重力波でみるブラックホールと宇宙, いわて銀河フェスタ 2016 (2016 年 8 月 20 日, 国立天文台水沢, 岩手).
- 安東正樹: 重力波とブラックホール，そして宇宙, 2016 年七夕公開講演会 「七夕の夜は宇宙を見上げて」(2016 年 8 月 7 日, 法政大学 小金井キャンパス).
- 安東正樹: 重力波でさぐる宇宙, 朝日カルチャーセンター講演 (2016 年 7 月 23 日, ルミネ横浜, 横浜).
- 安東正樹: アインシュタイン“ 最後の宿題 ”が解けた！〜重力波天文学の夜明け〜, NHK クローズアップ現代+, ビデオ出演 (2016 年 6 月 29 日).
- 安東正樹: 重力波でさぐる宇宙, 第 28 回 東京大学理学部 公開講演会 (2016 年 4 月 24 日, 東京大学 安田講堂).
- 安東正樹: 重力波が切り拓く新たな天文学, NHK 視点・論点 (2016 年 2 月 22 日).
- 安東正樹: 重力波で見る宇宙 - 重力波の観測 -, 東京大学 駒場祭公開講座 (2015 年 11 月 21 日, 東京大学 駒場キャンパス).
- 安東正樹: アインシュタインの宿題 — 重力波 —, 一般相対性理論誕生 100 年記念市民講演会 (2015 年 10 月 3 日, 弘前大学).
- 安東正樹: アインシュタインの相対論と重力波天文学, 高校生のための夏休み講座 2015 (2015 年 8 月 18 日, 東京大学).

- <u>安東正樹</u>: 重力波望遠鏡でさぐる宇宙の姿, 物理学教室オープンラボ (2015 年 5 月 29 日, 小柴ホール, 東京大学).
- <u>安東正樹</u>: アインシュタインの宿題と重力波で探る宇宙, 一般相対性理論白寿記念シンポジウム (2014 年 9 月 27 日, 慶応大学)
- <u>安東正樹</u>: 重力波望遠鏡で探る宇宙, リクルート 受験サプリ Web 講義 (2014 年 4 月).
- <u>安東正樹</u>: 重力波でさぐる宇宙, 第 3 回 自然科学研究機構 機構長プレス懇談会 (2014 年 4 月 11 日, 虎ノ門 SQUARE, 東京).
- <u>安東正樹</u>: 重力波検出に挑む KAGRA, 朝日カルチャーセンター講演 (2013 年 11 月 16 日, ルミネ横浜, 横浜).
- <u>安東正樹</u>: 重力波望遠鏡「かぐら」 で切りひらく新しい天文学, 駿台天文講座 (2013 年 10 月 19 日, 駿台学園, 東京).
- <u>安東正樹</u>: 重力波望遠鏡「かぐら」 で探る宇宙, ビッグバン宇宙国際研究センター 講演会, オープンキャンパス 2013 (2013 年 8 月 8 日, 東京大学).
- <u>安東正樹</u>: 低周波数重力波の探査, 第 13 回 RESCEU サマースクール 「宇宙における時空・物質・構造の進化」 (2013 年 7 月 26 日, 蔵王, 山形).
- <u>安東正樹</u>: 重力波望遠鏡でさぐる宇宙の姿, 平成 26 年度 物理学教室ガイダンス・オープンラボ (2013 年 5 月 30 日, 東京大学).
- <u>安東正樹</u>: 重力波で解き明かす宇宙の謎, 平成 25 年度 物理学科進学ガイダンス講演会 「物理学の新たな地平」 (2013 年 5 月 27 日, 東京大学駒場キャンパス).
- <u>安東正樹</u>: 重力波望遠鏡 KAGRA が拓く宇宙の地平線, 2013 年 総研大特別公開講演 (2013 年 5 月 25 日, 国立天文台, 三鷹).
- <u>安東正樹</u>: 重力波天文学, 国立天文台・総合研究大学院大学 スプリングスクール (2013 年 3 月 25-28 日, 国立天文台).
- <u>安東正樹</u>: 金環日食, 出前授業 (2012 年 5 月 10 日, 高田中学校, 亀岡, 京都).

11 Committee Service

11.1 External Committees

- VIRGO (European Gravitational-Wave Observatory) STAC (Scientific and Technology Advisory Committee) Committee member (2013-2019).
- European Space Agency (ESA) GOAT (Gravitational-wave Advisory Team) (2014-2016).
- Gravitational-Wave International Committee (GWIC), 3G planning committee member (2018-2019).

- National Astronomical Observatory Japan (NAOJ), Advanced Technology Committee (先端技術専門委員会) (FY2016-2017).
- JAXA/ISAS Space Science Committee (宇宙理学委員会) Member (FY2011-2014).

11.2 University Committees

理学系研究科 広報委員会 委員 (2014 年度-).
オープンキャンパス係 (2015 年度).
大学院 物理学専攻 A8 サブコース主任 (2015, 2016 年度).
物理教室 留学担当 (2015 年度-).
物理教室 学生実験係 (2015 年度-).

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	3	USA, Australia, India
Master Course	2	Singapore
Doctor Course	2	Italy, USA, Singapore
Foreign researchers hosted	2	Italy, USA
Students sent abroad	19	USA, Italy, France, Germany, UK, Australia, China
Researchers sent abroad	7	USA, Italy, France, Australia, Korea
Foreign visitors	15	USA, Italy, France, Australia, UK, China, Korea

Aya Bamba、馬場 彩

1 Education and Professional Experiences

Education

1999	B.S. (Physics)	Kyoto University
2001	M.D. (Physics)	Kyoto University
2004	Ph.D. (Physics)	Kyoto University

Professional Appointments

2001−2004	Research Fellowship for Young Scientists (DC1)	Kyoto University
2004−2008	Special Postdoctoral Researcher	RIKEN
2008−2010	Research Fellowship for Young Scientists (SPD)	ISAS/JAXA
2010−2011	Shoroedinger Fellow	Dublin Institute for Advanced Studies
2011−2016	Associate Professor	Aoyama Gakuin University
2016−	Associate Professor	The University of Tokyo

2 Research Highlights

The universe is apparently cold, empty, quiet, and stable world. However, recent astrophysics reveal us that there are full of hot, energetic, and explosive phenomena. Our group study of such energetci universe with X-ray and gamma-ray observations.

The most exciting (and tragic) event for us was the launch of the fifth Japan-US X-ray observatory, Hitomi. Hitomi has micro-calorimeter (soft X-ray spectrometer, SXS), which has energy resolution of 4.5 eV with imaging capability by X-ray CCD (soft X-ray imager, SXI) in 0.3–12 keV, addition to the hard X-ray capability of 10–600 keV with hard X-ray imager (HXI) and soft gamma-ray detector (SGD). Bamba worked on this mission as one of the leads of Galactic diffuse objects. After the successful launch on 2016 Feb. 17, Hitomi observed several targets and achieved more than 10 papers including two Nature publishments. One of the highlight is the measurement of Turbulence of gas in the Perseus cluster to be ~ 200 km s^{-1}, which is much smaller than expected. Another highlight is the measurement of abundance pattern of the Perseus cluster, which is exactly same to that in our solar system. This means the recipe of stars is universal in our universe. Our group also contribute to mesure the anisotropic expansion of the X-ray brightest and most energetic supernovaremnant N132D.

We also utilize other X-ray satellite dataset, Chandra, XMM-Newton, Suzaku, NuSTAR to understand thermal and nonthermal properties of supernova remnants, neutron stars, and black holes. One of the high lights is on cosmic ray escape from the acceleration sites. After 100 years from the discovery of cosmic rays, it is believed that they are mainly accelrated on shocks of supernova remnants quite efficiently. However, the efficient acceleration creates induced magnetic field and the escape from the acceleration sites becomes quite difficult for charged particles. We introduced the method to measure the time scale of particle escape; most of SNRs with GeV gamma-rays, which is old SNRs particles already escaped, have rapid-cooling plasma. Its relaxing time scale can be measured with X-ray spectroscopy. Our idea is that we can use the relaxing time scale as the stop-watch of shock-cloud interaction and we can measure the time scale of escape. Another achievement is the measurements of SNR expansion asymmetry using Doppler maps of SNRs. We have made the Doppler map of SN 1604, called "Kepler's remnant", and found red-shifted iron ejecta on the center, implying that the expansion of Kepler is significantly asymmetric.

3 Selected Papers

- Hitomi collaboration, Bamba, A., Nakazawa, K. et al. The Quiet Intracluster Medium in the Core of the Perseus Cluster ", Nature, 535, 117–121 (2016)
  Result from first-light of Hitomi. Cited 187 times.

- Hitomi Collaboration, A. Bamba, K. Nakazawa, et al., "Solar abundance ratios of the iron-peak elements in the Perseus cluster", Nature, 551, 478 (2017)
  First precise measuerment of abundance outside of our Galaxy, cited 27 times.

- T. Enoto, Y. Wada, Y. Furuta, K. Nakazawa, T. Yuasa, K. Okuda, K. Makishima, M. Sato, Y. Sato, T. Nakano, D. Umemoto, H. Tsuchiya, ""Photonuclear reactions triggered by lightning discharge", Nature, Volume 551, Issue 7681, pp. 481-484 (2017)
  Thiw work was selected as "Top Ten Breakthrough of the Year (2017)" in "Physics World". Cited 27 times.

- H, Suzuki, A. Bamba, K. Nakazawa, Y. Furuta, M. Sawada, R. Yamazaki, K. Koyama, "Discovery of recombining plasma from the faintest GeV SNR HB 21 and a possible scenario of the cosmic ray escaping from SNR shocks ", PASJ, 70, 75 (2018)
  Launching idea on connection between cosmic ray escape and rapid-cooling plasma in supernova remnant. Cited 4 times.

- T. Kasuga, T. Sato, K. Mori, H. Yamaguchi, A. Bamba, " Asymmetric Expansion of the Fe ejecta in Kepler ' s Supernova Remnant ", PASJ, 70, 55 (2018)
  First measurement of asymmetric expansion of type Ia supernova remnant. Cited 3 times.

4 Honors, Awards and Professional Society Memberships

第 27 回科学技術分野の文部科学大臣表彰 若手科学者賞, 文部科学省、2015 年 4 月

5 Research Plan

After the crisis happend on Hitomi, we quickly planned the recover mission now called XRISM. Unfortunately, we cannot onboard HXI and SGD, and concentrate on soft X-rays with SXS (renamed to resolve) and SXI (renamed to Xtend). I lead science case study of Galactic diffuse source (supernova remnants, pulsar wind nebulae, interstellar medium, Galactic center, planetary targets such as Jupiter an comets). We are also in charge of developing tools for analysing very bright objects. We aim to launch XRISM on the Japanese fiscal year 2021.

We also develop FORCE mission (Focusing On the Relativistic universe and Cosmic Evolution), planned to launch aroun 2030. This is Japan-US small satellite mission aiming hard X-ray imaging of energetic phenomena, such as black holes, supernova remnants, clusters of galaxies, and so on. Our group has the responsibility on the lead of supernova remnant science, detector simulation, and constructing response matrics.

X-ray polarimetory is a kind of new dimension to get various information of high energy astrophsical objects, such as physical and electro-magnetic geometory. However, we still have very limited missions and results. We just started development of X-ray polarimetory mission using CubeSat standard. Fine pixel (2.5μm) CMOS sensors and coded aperture are the main development targets. Until now, we confirmed that CMOS sensors have enough X-ray energy resolution in the room temperature (good for very small satellites) and have resolution to detect polarimetory in the 10–30 keV band. Designing satellite and scheduling launching plan will be the task in these 5 years.

Such detailed data set now needs very careful analysis system. Just fitting with χ^2 test with simple models does not work in many cases. Thus we are developping Monte Carlo simulation code to understand photon transportation in complex geometry. The code is named MONACO. We will also include general relativistic effects and polarization which is inevitable to understand correctly the time-space vicinity of black holes.

Of course we keep our activities on study of high energy astrophysics phenomena such as black holes, neutron stars, supernova remnants, and so on, with past and present telescope data set.

6 Publications and Patents

< Refereed Original Papers >

[1] R. Nakamura, A. Bamba, T. Dotani, M. Ishida, R. Yamazaki, K. Kohri, " Evolution of Synchrotron X-rays in Supernova Remnants ", ApJ, 746, 134-138 (2012)

[2] T. Kishishita, A. Bamba, Y. Uchiyama, Y. Tanaka, T. Takahashi, " X-RAY INVESTIGATION OF THE DIFFUSE EMISSION AROUND PLAUSIBLE -RAY EMITTING PULSAR WIND NEBULAE IN KOOKABURRA REGION ", ApJ, 750, 162, 8pp. (2012)

[3] S. Yamada, H. Uchiyama, T. Dotani, M. Tsujimoto, S. Katsuda, K. Makishima, H. Takahashi, H. Noda, S. Torii, S. Sakurai, T. Enoto, T. Yuasa, S. Koyama, A. Bamba, " Data-oriented Diagnostics of Pileup Effects on the Suzaku XIS ", PASJ, 64, 53 (2012)

[4] A. Bamba, G. Puehlhofer, F. Acero, D. Klochkov, W. Tian, R. Yamazaki, Z. Li, D. Horns, K. Kosak, N. Komin " Suzaku Observations of the Non-thermal Supernova Remnant HESS J1731 − 347 " ApJ, 756, 149, 11pp. (2012)

[5] M. Lemoine-Goumard, M. Renaud, J. Vink, G. E. Allen, A. Bamba, F. Giordano, Y. Uchiyama, " Constraints on cosmic-ray efficiency in the supernova remnant RCW 86 using multi-wavelength observations ", A&A, 545, A28 (9pp.) (2012)

[6] Y. Terada, M.S. Tashiro, A. Bamba, R. Yamazaki, H. Seta, T. Kouzu, S. Koyama " Search for Diffuse X-rays from a Bow Shock Region of a Runaway Star, BD+433654, with Suzaku " PASJ, 64,138 (2012)

[7] K. Maeda, Y. Terada, D. Kasen, F.K. Ropke, A. Bamba, R. Diehl, K. Nomoto, M. Kromer, I.R. Seitenzahl, H. Yamaguchi, T. Tamagawa, W. Hillebrandt, " PROSPECT OF STUDYING HARD X- AND GAMMA-RAYS FROM TYPE IA SUPERNOVAE ", ApJ, 760, 54, 9pp. (2012)

[8] Y. Hanabata, M. Sawada, H. Katagiri, A. Bamba, Y. Fukazawa "X-Ray Observations of the Supernova Remnant W51C and Its Environment with Suzaku ", PASJ, 65, 42 (2013)

[9] B.S. Acharya, A. Bamba, et al. " Introducing the CTA concept ", Astroparticle Physics, 43, 3-18 (2013)

[10] F. Acero, A. Bamba, S. Casanova, E. de Cea, E. de Ona Wilhelmi, S. Gabici, Y. Gallant, D. Hadasch, A. Marcowith, G. Pedaletti, O. Reimer, M. Renaud, D. F. Torres, F. Volpe, for the CTA collaboration, "Gamma-ray signatures of cosmic ray acceleration, propagation, and confinement in the era of CTA ", Astroparticle Physics, 43, 276-286 (2013)

[11] T. Fujinaga, K. Mori, A. Bamba, S. Kimura, T. Dotani, M. Ozaki, K. Matsuta, G. Puehlhofer, H. Uchiyama, J.S. Hiraga, H. Matsumoto, Y. Terada, " An X-ray counterpart of HESS J1427-608 with Suzaku ", PASJ, 65, 61 (2013) 84. A. Harayama, Y. Terada, M. Ishida, T. Hayashi, A. Bamba, M.S. Tashiro, "Search for Non-Thermal Emission from an Isolated Magnetic White Dwarf EUVE J0317-855 with Suzaku ", PASJ, 65, 73, (6 pages) (2013)

[12] T. Kouzu, M.S. Tashiro, Y. Terada, S. Yamada, A. Bamba, T. Enoto, K. Mori, Y. Fukazawa, K. Makishima, " Spectral Variation of the Hard X-ray Emission from the Crab Nebula with the Suzaku Hard X-ray Detector ", PASJ, 65, 74, (11 pages) (2013) 86. E.A. Helder, J. Vink, A. Bamba, J.A.M. Bleeker, D.N. Burrows, P. Ghavamian, R. Yamazaki, "Proper Motion of Halpha filaments in Supernova Remnant RCW86 ", MNRAS, 435, 910-916 (2013)

[13] R. Yamazaki, Y. Ohira, M. Sawada, A. Bamba, " Synchrotron X-ray diagnostics of cutoff shape of nonthermal electron spectrum at young supernova remnants ", RAA, 14, 165-178 (2014)

[14] S. Yamauchi, A. Bamba, K. Koyama " X-Ray Emission from the Galactic Supernova Remnant G12.0-0.1 ", PASJ, 66, 20 (8pages) (2014)

[15] K. Someya, A. Bamba, M. Ishida, "Progenitor Type Identification of the Supernova Remnant N103B in the Large Magellanic Cloud by Suzaku and Chandra ", PASJ, 66, 26 (16 pages) (2014)

[16] K. Maeda, S. Katsuda, A. Bamba, Y. Terada, Y. Fukazawa "Long-Lasting X-Ray Emission from Type IIb Supernova SN2011dh and Mass-Loss History of The Yellow Supergiant Progenitor", ApJ, 785, 95 (12 pages) (2014)

[17] E. Rivers, A. Markowitz, R. Rothchild, A. Bamba, Y. Fukazawa, T. Okajima, J. Reeves, Y. Terashima, Y. Ueda, "Tracking the Complex Absorption in NGC2110 with Two Suzaku Observations", ApJ, 786, 126 (8 pages) (2014)

[18] Y.T. Tanaka, L. Stawarz, J. Finke, C.C. Cheung, C.D. Dermer, J. Kataoka, A. Bamba, G. Dubus, M. De Naurois, S. Wagner, Y. Fukazawa, D.J. Thompson, "Extreme TeV Blazer Candidate HESS J1943+213 Studied at High Energies with Suzaku and Fermi-LAT", ApJ, 787, 155 (10 pages) (2014)

[19] S. Broersen, A. Chiotellis, J. Vink, A. Bamba "Many sides of RCW86; a type Ia supernova remnant evolving in its progenitor's wind bubble", MNRAS, 441, 3040-3054 (2014)

[20] R. Nakamura, A. Bamba, M. Sawada, M. Ishida, R. Yamazaki, K. Tatematsu, K. Kohri, G. Puehlhofer, S. Wagner, "The X-ray Spectroscopy of the Mixed Morphology Supernova Remnant W28 with XMM-Newton", PASJ, 66, 6210 (10 pages) (2014)

[21] J. Shimoda, T. Inoue, Y. Ohira, R. Yamazaki, A. Bamba, J. Vink "On cosmic-ray production efficiency at supernova remnant shocks propagating into realistic diffuse interstellar medium", ApJ, 803, 98 (2015)

[22] T. Yasuda, W.B. Iwakiri, M.S. Tashiro, Y. Terada, T. Kouzu, T. Enoto, Y. E. Nakagawa. A. Bamba, Y. Urata, K. Yamaoka, M. Ohno, S. Shibata, K. Makishima, and The Suzaku-WAM team, "Sub-MeV Band Observation of a Hard Short Burst from AXP 1E 1547.0 − 5408 with the Suzaku Wide-band All-sky Monitor", PASJ, 67, 41 (12 pages) (2015)

[23] M. Izawa, T. Dotani, T. Fujinaga, A. Bamba, M. Ozaki, J.S. Hiraga "Suzaku observations of the old pulsar wind nebula candidate HESS J1356 − 645", PASJ, 67, 43 (8 pages) (2015)

[24] A. Bamba, Y. Terada, J. Hewitt, R. Petre, L. Angelini, S. Safi-Harb, P. Zhou, F. Bocchino, M., Sawada, "Discovery of X-ray Emission from the Galactic Supernova Remnant G32.8-0.1 with Suzaku", ApJ, 818, 63 (2016)

[25] Y. Terada, K. Maeda, Y. Fukazawa, A. Bamba, Y. Ueda, S. Katsuda, T. Enoto, T.Tak ahashi, T. Tamagawa, F. K. R¨ opke, A. Summa, R. Diehl, "Measurements of the Soft Gamma-ray Emission from SN2014J with Suzaku", ApJ, 823, 43 (2016)

[26] K. Hotokezaka, S. Wanajo, M. Tanaka, A. Bamba, Y. Terada, and T. Piran, "Gamma-r ay line emission from neutron star merger ejecta and its effects on the heating rate", MNRAS, 459, 35-43 (2016)

[27] A. Bamba, M. Sawada, Y. Nakano, Y. Terada, J. Hewitt, R. Petre, L. Angelini, "Ne w Identification of the Mixed-Morphology Supernova Remnant G298.6 − 0.0 with Suzak u", PASJ, 68, S5 (2016)

[28] S. Yamauchi, M. Sumita, A. Bamba "Suzaku observations of two diffuse hard X-ray sources G22.0+0.0 and G23.5+0.1", PASJ, 68, S6 (2016)

[29] S. Takeda, A. Bamba, Y. Terada, M.S. Tashiro, S. Katsuda, R. Yamazaki, Y. Ohira, W.B. Iwakiri, "Suzaku observations of the hard X-ray spectrum of Vela Jr.", PASJ, 68, S10 (2016)

[30] Hitomi collaboration, Bamba, A., Nakazawa, K. et al. "The Quiet Intracluster Medium in the Core of the Perseus Cluster", Nature, 535, 117–121 (2016)

[31] S. Katsuda, K. Maeda, A. Bamba, Y. Terada, Y. Fukazawa, K. Kawabata, M. Ohno, Y. Sugawara, Y. Tsuboi, "Soft and Hard X-Ray Components from Type IIn Supernovae: Evidence for Asphericity in the Circumstellar Medium", ApJ, 832, 194 (2016)

[32] S. Shibata, E. Watanabe, Y. Yatsu, T. Enoto, A. Bamba, "X-ray and Rotational Luminosity Correlation and Magnetic Heating of the Radio Pulsars", ApJ, 833, 59 (2016)

[33] Y. Tsubone, M. Sawada, A. Bamba, S. Katsuda, J. Vink, "A Systematic Study of the Thermal and Nonthermal Emission in the Supernova Remnant RCW 86 with Suzaku", ApJ, 835, 34 (2017)

[34] M. Miceli, A. Bamba, S. Orlando, F. Bocchino, P. Zhou, S. Safi-Harb, Y. Chen, " XMM-Newton observation of the supernova remnant Kes 78 (G32.8-0.1): Evidence for shock-cloud interaction ", A&A, 599, 45 (2017)

[35] T. Sato, Y. Maeda, A. Bamba, S. Katsuda, Y. Ohira, R. Yamazaki, K. Masai, H. Matsumoto, M. Sawada, Y. Terada, J. P. Hughes, M. Ishida, " Muti-year X-Ray Variations of Iron-K and Continuum Emissions in the Young Supernova Remant Cassiopeia A ", ApJ, 836, 225 (2017)

[36] Hitomi Collaboration, Bamba, A., Nakazawa, K. et al., " Hitomi Constraints on the 3.5 keV Line in Perseus ", ApJL, 837, L15 (2017)

[37] M. Ohno, et al. (incl, K. Nakazawa), "Development and verification of signal processing system of avalanche photo diode for the active shields onboard ASTRO-H ", *NUCL. INSTRUM. METHODS PHYS. RES. A* **831**, 410–414 (2016)

[38] G. Sato, et al. (incl K Nakazawa), "The Si/CdTe semiconductor camera of the ASTRO-H Hard X-ray Imager (HXI)" *NUCL. INSTRUM. METHODS PHYS. RES. A* **831**, 235–241 (2016)

[39] Kobayashi, S. B., Nakazawa, K., & Makishima, K.: "*Suzaku* Observations of Spectra Variations of the Ultra-Luminous X-ray Source Holmberg IX X-1 ", PASJ, 69, 4 (2017)

[40] Inoue, Y., Lee, S., Tanaka, Y. T., & Kobayashi, S. B. : "High energy gamma rays from nebulae associated with extragalactic microquasars and ultra-luminous X-ray sources ", ELSEVIER, 90, 14 (2017)

[41] Ono, K., Makishima, K., Sakurai, S., Zhang, Z., Yamaoka, K., Nakazawa, K.: "A Hard-to-Soft State Transition of Aquila X-1 Observed with Suzaku", PASJ, in press (2017)

[42] Miyake, K., Noda, H., Yamada, S., Makishima, K., & Nakazawa, K.: "The new primary X-ray component confirmed in the Seyfert I galaxy IC 4329A ", PASJ, 68, S28 (2016)

[43] Mori, H., Maeda, Y., Ueda, Y., Nakazawa, K., Tawara, Y., "Suzaku and Chandra observations of CIZA J1700.8-3144, a cluster of galaxies in the Zone of Avoidance", PASJ, 69, 3 (2017)

[44] Noda, H., Minezaki, T., Watanabe, M., Kokubo, M., Kawaguchi, K., Itoh, R., Morihana, K., Saito, Y., Nakao, H., Imai, M., Moritani, Y., Takaki, K., Kawabata, M., Nakaoka, T., Uemura, M., Kawabata, K., Yoshida, M., Arai, A., Takagi, Y., Morokuma, T., Doi, M., Itoh, Y., Yamada, S., Nakazawa, K., Fukazawa, Y., Makishima, K., "X-Ray and Optical Correlation of Type I Seyfert NGC 3516 Studied with Suzaku and Japanese Ground-based Telescopes", ApJ, 828, 78, (2016)

[45] Gu, L., Wen, Z., Gandhi, P., Inada, N., Kawaharada, M., Kodama, T., Konami, S., Nakazawa, K., Xu, H., Makishima, K., "Galaxy Infall by Interacting with Its Environment: A Comprehensive Study of 340 Galaxy Clusters", ApJ, 826, 72 (2016).

[46] Ohmori, N., Yamaoka, K., Ohno, M., et al. (incl. K. Nakazawa), "Suzaku Wide-band All-sky Monitor measurements of duration distributions of gamma-ray bursts", PASJ, 68, S30 (2016)

[47] Nakazawa, K., Kato, Y., Gu, L., Kawaharada, M., Takizawa, M., Fujita, Y., Makishima, K., "Suzaku observation of a high-entropy cluster Abell 548W" , PASJ, 68, S21 (2016)

[48] Ono, K., Sakurai, S., Zhang, Z., Nakazawa, K., Makishima, K., "A Suzaku observation of the low-mass X-ray binary GS 1826-238 in the hard state", PASJ, 68, S14 (2016)

[49] Zhang, Z., Sakurai, S., Makishima, K., Nakazawa, K., Ono, K., Yamada, S., Xu, H., "Suzaku Observation of the High-inclination Binary EXO 0748-676 in the Hard State", ApJ, 823, 131, (2016)

[50] Makishima, K., Enoto, T., Murakami, H., Furuta, Y., Nakano, T., Sasano, M., Nakazawa, K., "Evidence for a 36 ks phase modulation in the hard X-ray pulses from the magnetar 1E 1547.0-5408", PASJ, 68, S12 (2016)

[51] F. Acero, A. Bamba, et al., "Prospects for Cherenkov Telescope Array Observatio ns of the Young Supernova Remnant RX J1713.7−3946", ApJ, 840, 74 (2017)

[52] Hitomi Collaboration, A. Bamba, K. Nakazawa, et al., “Solar abundance ratios of the iron-peak elements in the Perseus cluster”, Nature, 551, 478 (2017)

[53] V. Doroshenko, V, G. Puehlhofer, A. Bamba, F. Acero, W.W. Tian, D. Klochkov, A. Santangelo, “XMM-Newton observations of the non-thermal supernova remnant HESS J1731-347 (G353.6-0.7)”, A&A, 608, 23 (2017)

[54] T. Sato, S. Katsuda, M. Morii, A. Bamba, J.P.Hughes, Y. Maeda, M. Ishida, F. Fra schetti, “X-Ray Measurements of the Particle Acceleration Properties at Inward Shocks in Cassiopeia A”, ApJ, 863, 46 (2017)

[55] T. Tanaka, H. Uchida, H. Nakajima, H. Tsunemi, K. Hayashida, T.G. Tsuru, T. Dota ni, R. Nagino, S. Inoue, S. Katada, R. Washino, M. Ozaki, H. Tomida, C. Natsukar i, S. Ueda, M. Iwai, K. Mori, M. Yamauchi, I. Hatsukade, Y. Nishioka, E. Isoda, M. Nobukawa, J.S. Hiraga, T. Kohmura, H. Murakami, K.K. Nobukawa, A. Bamba, J.P. Doty, “Soft X-ray Imager aboard Hitomi (ASTRO-H)”, JATIS, 4, id. 011211 (2018)

[56] A. Bamba, Y. Ohira, R. Yamazaki, M. Sawada, Y. Terada, K. Koyama, E.D. Miller, H. Yamaguchi, S. Katsuda, M. Nobukawa, K.K. Nobukawa, “The Transition from Youn g to Middle-aged Supernova Remnants: Thermal and Nonthermal Aspects of SNR N132D ”, ApJ, 854, 71 (2018)

[57] Hitomi Collaboration, A. Bamba, K. Nakazawa et al., “Atmospheric gas dynamics i n the Perseus cluster observed with Hitomi”, PASJ, 70, 9 (2018)

[58] Hitomi Collaboration, A. Bamba, K. Nakazawa et al., “Measurements of resonant scattering in the Perseus Cluster core with Hitomi SX S”, PASJ, 70, 10 (2018)

[59] Hitomi Collaboration, A. Bamba, K. Nakazawa et al., “Temperature structure in the Perseus cluster core observed with Hitomi”, PASJ, 70, 11 (2018)

[60] Hitomi Collaboration, A. Bamba, K. Nakazawa et al., “Atomic data and spectral modeling constraints from high-resolution X-ray observations of the Perseus cluster with Hitomi”, PASJ, 70, 12 (2018)

[61] Hitomi Collaboration, A. Bamba, K. Nakazawa et al., “Hitomi observation of radio galaxy NGC 1275: The first X-ray microcalorimeter spectroscopy of Fe-K α line emission from an active galactic nucleus”, PASJ, 70, 13 (2018)

[62] Hitomi Collaboration, A. Bamba, K. Nakazawa et al., “Search for thermal X-ray features from the Crab nebula with the Hitomi soft X-ray spectrometer”, PASJ, 70, 14 (2018)

[63] Hitomi Collaboration, A. Bamba, K. Nakazawa et al., “Hitomi X-ray studies of giant radio pulses from the Crab pulsar”, PASJ, 70, 15 (2018)

[64] Hitomi Collaboration, A. Bamba, K. Nakazawa et al., “Hitomi observations of the LMC SNR N 132 D: Highly redshifted X-ray emission from iron ejecta”, PASJ, 70, 16 (2018)

[65] Hitomi Collaboration, A. Bamba, K. Nakazawa et al., “Glimpse of the highly obscured HMXB IGR J16318-4848 with Hitomi”, PASJ, 70, 17 (2018)

[66] H. Nakajima, Y. Maeda, H. Uchida, T. Tanaka, H. Tsunemi, K. Hayashida, T.G. Tsuru, T. Dotani, R. Nagino, S. Inoue, M. Ozaki, H. Tomida, C. Natsukari, S. Ueda, K. Mori, M. Yamauchi, I. Hatsukade, Y. Nishioka, M. Sakata, T. Beppu, D. Honda, M. Nobukawa, J.S. Hiraga, T. Kohmura, H. Murakami, K.K. Nobukawa, A. Bamba, J.P. Doty, R. Iizuka, T. Sato, S. Kurashima, N. Nakaniwa, R. Asai, M. Ishida, H. Mori, Y. Soong, T. Okajima, P. Serlemitsos, Y. Tawara, I. Mitsuishi, K. Ishibashi, K. Tamura, T. Hayashi, A. Furuzawa, S. Sugita, T. Miyazawa, H. Awaki, E.D. Miller, H. Yamaguchi, “In-orbit performance of the soft X-ray imaging system aboard Hitomi (ASTRO-H)”, PASJ, 70, 21 (2018)

[67] K. Miyaoka, et al. (incl. K. Nakazawa), “ Multiwavelength study of X-ray luminous clusters in the Hyper Suprime-Cam Subaru Strategic Program S16A field ” , PASJ, Volume 70, Issue SP1, id.S22 (2017)

[68] M. Itahana, K. Takizawa, H. Akamatsu, R.J. van Weeren, H. Kawahara, Y. Fukazawa, J.S. Kaastra, K. Nakazawa, T. Ohashi, N. Ota, H.J.A. Röttgering, J. Vink, F. Zandanel, "Suzaku and Chandra observations of the galaxy cluster RXC J1053.7+5453 with a radio relic", PASJ, Volume 69, Issue 6, id.88 (2017)

[69] K. Yamaoka et al., "Suzaku Wide-band All-sky Monitor (WAM) observations of GRBs and SGRs", PASJ, Volume 69, Issue 3, id.R2 (2017)

[70] K. Ono, K. Makishima, S. Sakurai, Z. Zhang, K. Yamaoka, K. Nakazawa, "A hard-to-soft state transition of Aquila X-1 observed with Suzaku", PASJ, Volume 69, Issue 2, id.23 (2917)

[71] H. Akamatsu, M. Mizuno, N. Ota, Y.Y. Zhang, R.J. van Weeren, H. Kawahara, Y. Fukazawa, J.S. Kaastra, M. Kawaharada, K. Nakazawa, T. Ohashi, H.J. Röttgering. M. Takizawa, J. Vink, F. Zandanel, "Suzaku observations of the merging galaxy cluster Abell 2255: The northeast radio relic", Astronomy & Astrophysics, Volume 600, id.A100, 12 pp. (2017)

[72] K. Nakazawa et al. "The hard X-ray imager (HXI) onboard ASTRO-H", K. Nakazawa et al., JATIS, 4, 021410 (2018)

[73] K. Hagino et al. "In-orbit performance and calibration of the hard x-ray imager onboard Hitomi (ASTRO-H)", JATIS, 4, 021409 (2018)

[74] H. Tajima et al. "Design and performance of Soft Gamma-ray Detector onboard the Hitomi (ASTRO-H) satellite", JATIS, 4, 021411 (2018)

[75] T. Enoto, Y. Wada, Y. Furuta, K. Nakazawa, T. Yuasa, K. Okuda, K. Makishima, M. Sato, Y. Sato, T. Nakano, D. Umemoto, H. Tsuchiya, ""Photonuclear reactions triggered by lightning discharge", Nature, Volume 551, Issue 7681, pp. 481-484 (2017)

[76] Y. Wada, T. Yuasa, K. Nakazawa, K. Makishima, T. Hayashi, M.Ishida, " An estimation of the white dwarf mass in the Dwarf Nova GK Persei with NuSTAR observations of two states ", MNRAS, 474,1564-1571 (2017)

[77] H.E.S.S. Collaboration, A. Bamba, et al., " A search for new supernova remnant shells in the Galactic plane with H.E.S.S. ", A&A, 612, 8 (2018)

[78] Hitomi Collaboration, A. Bamba, H. Odaka, et al., " Hitomi X-ray Observation of the Pulsar Wind Nebula G21.5 − 0.9 ". PASJ, 70, 38 (2018)

[79] K. Nakazawa, H. Odaka, et al., " Hard x-ray imager onboard Hitomi (ASTRO-H) ", Journal of Astronomical Telescopes, Instruments, and Systems, 4, 021410 (2018)

[80] H. Tajima, H. Odaka, et al., " Design and performance of Soft Gamma-ray Detector onboard the Hitomi (ASTRO-H) satellite ", Journal of Astronomical Telescopes, Instruments, and Systems, 4, 021411 (2018)

[81] R. Tomaru, C. Done, H. Odaka, S. Watanabe, T. Takahashi, " Monte Carlo simulations of the detailed iron absorption line profiles from thermal winds in X-ray binaries ", Monthly Notices of the Royal Astronomical Society, 476, 1776 (2018)

[82] H. Odaka, M. Asai, K. Hagino, T. Koi, G, Madejski, T. Mizuno, M. Ohno, S. Saito, T. Sato, D. Wright, et al. "Modeling of proton-induced radioactivation background in hard X-ray telescopes: Geant4-based simulation and its demonstration by Hitomi's measurement in a low Earth orbit", Nuclear Instruments and Methods in Physics Research A, 891, 92 (2018)

[83] Mizumoto, M., Done, C., Hagino, K., Ebisawa, K., Tsujimoto, M., Odaka, H., " X-ray short-time lags in the Fe-K energy band produced by scattering clouds in active galactic nuclei ", Monthly Notices of the Royal Astronomical Society, 478, 971 (2018)

[84] M. Hikitani, M. Ohno, Y. Fukazawa, T. Kawaguchi, H. Odaka, H., " Compton Shoulder Diagnostics in Active Galactic Nuclei for Probing the Metallicity of the Obscuring Compton-thick Tori ", The Astrophysical Journal, 867, 80 (2018)

[85] M. Kubota, H. Odaka, T. Tamagawa, T., Nakano, "Discovery of Redshifted He-like Iron Absorption Line from Luminous Accreting Neutron Star SMC X-1", The Astrophysical Journal Letters, 868 L26 (2018)

[86] M. Mizumoto, K. Ebisawa, M. Tsujimoto, C. Done, K. Hagino, H. Odaka, "X-ray reverberation lags of the Fe-K line due to AGN disc winds", Monthly Notices of the Royal Astronomical Society, 482, 5316 (2019)

[87] H. Suzuki, A. Bamba, K. Nakazawa, Y. Furuta, M. Sawada, R. Yamazaki, K. Koyama, "Discovery of recombining plasma from the faintest GeV supernova remnant HB 21 and a possible scenario for cosmic rays escaping from supernova remnant shocks", PASJ, 70, 75 (2018)

[88] M. Kuriki, H. Sano, N. Kuno, M. Seta, Y. Yamane, S. Yoshiike, K. Okawa, D. Tsutsumi, Y. Hattori, M. Khono, S. Fujita, A. Nishimura, A. Ohama, M. Matsuo, Y. Tsuda, K. Torii, T. Minamidani, T. Umemoto, G. Rowell, A. Bamba, K. Tachihara, Y. Fukui, "DISCOVERY OF MOLECULAR AND ATOMIC CLOUDS ASSOCIATED WITH THE GAMMA-RAY SUPERNOVA REMNANT KESTEVEN 79", ApJ, 864, 161 (2018)

[89] T. Kasuga, T. Sato, K. Mori, H. Yamaguchi, A. Bamba, "Asymmetric Expansion of the Fe ejecta in Kepler's Supernova Remnant", PASJ (2018)

[90] Hitomi Collaboration, A. Bamba, H. Odaka, et al., "Detection of polarized gamma-ray emission from the Crab nebula with Hitomi Soft Gamma-ray Detector", PASJ, 70, 113 (2018)

[91] T. Tanaka, H. Yamaguchi, D.R. Wik, H. Uchida, Y. Uchiyama, F.A. Aharonian, A. Bamba, F. Castro, A.R. Foster, R. Petre, J. Rho, R.K. Smith, B.J. Williams, "NuSTAR Observations of the Supernova Remnant W49B: II. Nonthermal Aspect", ApJL, 866, L26 (2018)

[92] H. Yamaguchi, T. Tanaka, D.R. Wik, J. Rho, A.R. Foster, A. Bamba, R. Petre, B.J. Williams, H. Uchida, R.K. Smith, D. Castro, "NUSTAR OBSERVATIONS OF THE SUPERNOVA REMNANT W49B: I. THERMAL ASPECT", ApJL, 868, :35 (2018)

[93] A. Simionescu, S. Nakashima, H. Yamaguchi, K. Matsushita, F. Mernier, N. Werner, T. Tamura, K. Nomoto, J. de Plaa, A. Bamba, E. Bulbul, Y. Ezoe, A. C. Fabian, Y. Fukazawa, L. Gu, Y. Ichinohe, M. N. Ishigaki, J. S. Kaastra, C. Kilbourne, T. Kitayama, S.-C. Leung, M. Leutenegger, M. Loewenstein, Y. Maeda, E. D. Miller, R. F. Mushotzky, H. Noda, C. Pinto, F. S. Porter, S. Safi-Harb, K. Sato, T. Takahashi, S. Ueda, S. Zha, "Constraints on the Chemical Enrichment History of the Perseus Cluster of Galaxies from High-Resolution X-ray Spectroscopy", MNRAS, 483, 1701-1721 (2019)

[94] M. Sawada, K. Tachibana, H. Uchida, Y. Ito, H. Matsumura, A. Bamba, T. G. Tsuru, T. Tanaka, "Still stratified ejecta in the late Sedov phase: A deep Suzaku observation of the Galactic Ia supernova remnant G306.3-0.9", PASJ, 71, (2019)

[95] Y. Wada, G. S. Bowers, T. Enoto, M. Kamogawa, Y. Nakamura, T. Morimoto, D. M. Smith, Y. Furuta, K. Nakazawa, T. Yuasa, A. Matsuki, M. Kubo, T. Tamagawa, K. Makishima, H. Tsuchiya, "Termination of Electron Acceleration in Thundercloud by Intracloud/Intercloud Discharge", Geophysical Research Letters, 45, 5700-5707 (2018)

[96] E. Watanabe, S. Shibata, T. Sakamoto, A. Bamba, "A high-magnetic-field radio pulsar survey with Swift/XRT", MNRAS, 486, 5323-5334 (2019)

[97] H. Watanabe, A. Bamba, S. Shibata, E. Watanabe, "XMM-Newton Spectrum of the magnetar CXOU J171405.7-381031", PASJ, 71, 84 (2019)

[98] T. Tamba, A. Bamba, H. Odaka, T. Enoto, "Temporal and spectral X-ray properties of magnetar SGR 1900+14 derived from observations with NuSTAR and XMM-Newton", PASJ, in press (arxiv:1906.04406)

＜ Conference Proceedings ＞

[99] A. Sezer, R. Yamazaki, X. Cui, A. Bamba, Y. Ohira, “Searching for the time variation in supernova remnant RX J1713.7−3946”, Proceeding of “Supernova Remnants: An Odyssey in Space after Stellar Death”, 30 (2016)

[100] A. Sezer, K. Auchettl, K., R. Yamazaki, A. Bamba, “Searching for evidence of non-thermal X-ray emission from supernova remnant W49B”, Proceeding of “Supernova Remnants: An Odyssey in Space after Stellar Death” 31 (2016)

[101] J. Shimoda, T. Inoue, Y. Ohira, R. Yamazaki, A. Bamba, J. Vink, “Importance of Richtmyer-Meshkov Instability on Measurements of Cosmic-Ray Acceleration Efficiency at Supernova Remnants”, Proceeding of “Supernova Remnants: An Odyssey in Space after Stellar Death” 103 (2016)

[102] M. Miceli, A. Bamba, S. Orlando, F. Bocchino, “Investigating the galactic Supernova Remnant Kes 78 with XMM-Newton”, Proceeding of “Supernova Remnants: An Odyssey in Space after Stellar Death” 142 (2016)

[103] M. Miceli, A. Bamba, S. Orlando, F. Bocchino, “Investigating the galactic Supernova Remnant Kes 78 with XMM-Newton”, Proceeding of “XMM-Newton: The Next Decade” 54 (2016)

[104] Hitomi collaboration, Bamba, A., Nakazawa, K., et al., “The ASTRO-H (Hitomi) x-ray astronomy satellite”, Proceedings of the SPIE, 9905, 99050U (2016)

[105] Nakazawa, K., Sato, G., Kokubun, M., et al., “The hard x-ray imager (HXI) onboard ASTRO-H”, Proceedings of the SPIE, 9905, 990511, (2016)

[106] Watanabe, S., Tajima, H., Fukazawa, et al. (incl. K. Nakazawa), “The soft gamma-ray detector (SGD) onboard ASTRO-H”, Proceedings of the SPIE, 9905, 990513 (2016)

[107] Tatischeff, V., Tavani, M., von Ballmoos, P., Hanlon, L., Oberlack, U., et al. (incl. K. Nakazawa) “The e-ASTROGAM gamma-ray space mission”, Proceedings of the SPIE, 9905, 99052N (2016)

[108] Mori, K., Tsuru, T. G., Nakazawa, K., Ueda, Y., Okajima, T., Murakami, H., Awaki, H., Matsumoto, H., Fukazawa, Y., Tsunemi, H., Takahashi, T., Zhang, W. W., “A broadband x-ray imaging spectroscopy with high-angular resolution: the FORCE mission”, Proceedings of the SPIE, 9905, 99051 (2016)

[109] Miyake, K., Saito, S., Nakano, T., Hagino, K., Kobayashi, B., S., Okuda, K., Mimura, Sato, G., Watanabe, S., Kokubun, M., Nakazawa, K., Takeda, S., Tajima, H., Fukazawa, Y., & Takahashi, T.: “Effects on hard x-ray response of a double-sided Si strip detector caused by interstrip surface charge”, Proceedings of the SPIE, 9968, 99680D (2016)

[110] H. Tsunemi, K. Hayashida, T.G. Tsuru, T. Dotani, H. Nakajima, N. Anabuki, R. Nagino, T. Tanaka, H. Uchida, M. Ozaki, C. Natsukari, H. Tomida, S. Ueda, M. Iwai, M. Nobukawa, J.S. Hiraga, T. Kohmura, H. Murakami, K. Mori,, M. Yamauchi, I. Hatsukade, Y. Nishioka, A. Bamba, K.K. Nobukawa, J. Doty, “Soft x-ray imager (SXI) onboard ASTRO-H”, Proceedings of the SPIE, 9905, 990510 (2016)

[111] Y. Terada, K. Maeda, Y. Fukazawa, A. Bamba, Y. Ueda, S. Katsuda, T. Enoto, T. Takahashi, T. Tamagawa, F.K. Röpke, A. Summa, R. Diehl, “Soft Gamma-ray Observation of SN2014J with Suzaku”, Proceedings of the 14th International Symposium on Nuclei in the Cosmos (NIC2016), 010306 (2016)

[112] Miyake, K., Noda, H., Yamada, S., Makishima, K., & Nakazawa, K.: “The new primary X-ray spectral component of IC4329A confirmed with *Suzaku* and *NuSTAR*”, 7 years of MAXI, in press, (2016)

[113] Ono, K., Makishima, K., Sakurai, S., Zhang, Z., Yamaoka, K., Nakazawa, K.: “Unveiling the spectral transition of Aql X-1 from the hard to soft state”, 7 years of MAXI, in press, (2016)

[114] Wada, Y., Yuasa, T., Nakazawa, K., Makishima, K., Hayashi T., & Ishida, M.: “NuSTAR observations of the Dwarf Nova GK Persei in 2015: comparison between outburst and quiescent phases”, “20th European White Dwarf Workshop” conference proceedings, Astronomical Society of the Pacific Conference Series, in press (2016)

[115] T. Enoto, Y. Wada, Y. Furuta, K. Nakazawa, T. Yuasa, K. Okuda, K. Makishima, M. Sato, Y. Sato, T. Nakano, D. Umemoto, H. Tsuchiya, M. Kamogawa, G. Bowers, D. Smith, T. Morimoto, Y. Nakamura, D. Wang, "Multi-point measurement campaigns of gamma rays from thunderclouds and lightning in Japan", Proceedings of XVI International Conference on Atmospheric Electricity (2018)

[116] Y. Wada, T. Enoto, Y. Furuta, K. Nakazawa, T. Yuasa, T. Matsumoto, D. Umemoto, K. Makishima, H. Tsuchiya, and the GROWTH collaboration, "Mapping Observation Project of High-Energy Phenomena during Winter Thunderstorms in Japan", Proceedings of International Symposium TEPA 2018 Thunderstorms and Elementary Particle Acceleration, A. Alikhanyan National Laboratory, 85-92 (2019)

7 Invited Presentations at International Conferences

[1] A. Bamba, "Recent Progress of X-ray Observations of Nonthermal Emission from Supernova Remnants and Pulsar Wind Nebulae", "Suzaku-MAXI 2014 - Expanding the Frontiers of the X-ray Universe", Ehime, Japan, (2014)

[2] A. Bamba, " Observational Results on Galactic Cosmic-Ray Acceleration ", " Cosmic Ray Origin - beyond the standard models - " , San Vito di Cadore, Italy (2014)

[3] A. Bamba, "Multiwavelength studies of gamma-ray supernova remnants", "Fifth International Fermi Symposium". Nagoya, Japan (2014)

[4] A. Bamba, "Non-thermal Phenomena in Shocks", "Japanese-Dutch Bilateral Workshop: Spectroscopy of Cosmic Plasma in the Era of ASTRO-H", Kanagawa, Japan (2015)

[5] A. Bamba, " X-ray properties of young SNRs with GeV/TeV gamma-rays ", " SNR Workshop ", Nagoya, Japan (2015)

[6] A. Bamba, " What can we learn on cosmic ray acceleration with ASTRO-H ? ", " Central Engines in the High Energy Universe ", KEK, Japan (2015)

[7] A. Bamba, " Particle Acceleration and Environments of Supernova Remnants ", " Workshop on Supernovae and Their Remnants - The Elegant Last Dance of Stars - ", ISAS, Japan (2015)

[8] A. Bamba, " X-ray observations of supernova remnants - environment study of acceleration sites - ", " Cosmic Ray Origin - beyond the standard models - ", 19–23 September 2016, San Vito di Cadore, Italy

[9] Kobayashi, S. B., "Ultra Luminous X-ray sources: one of the most curious objects in the universe", "Ultra Luminous X-ray sources workshop", 6–7 March 2017, ISAS, Kanagawa, Japan

[10] K. Nakazawa, "Filling the gap between MeV and GeV – eASTROGAM and CAST –", "The extreme Universe viewed in very-high-energy gamma rays 2016", December 15–16, 2016, in Kashiwa, Japan

[11] K. Nakazawa, "In orbit performance of Hitomi X-ray observatory and beyond", "INTEGRAL work shop 2016", 10–14 October, 2016, Amsterdam, Netherland

[12] Y. Kato, "CIZA J1358.9-4750: an early-phase merger clusters of galaxies exhibiting a twin shocks", "the workshop on the early-phase merging clusters", February 8 2017, SRON, Netherlands

[13] A. Bamba, " Recent Progress on Supernova Remnants - Progenitors, Evolution, Cosmic-ray Acceleration ", " X-ray Universe 2017 ". Roma, Italy, 2017, Jun.

[14] A. Bamba, " X-ray Observations of Supernova Remnants ", " Asia-Pacific Regional IAU Meeting ", Taipei, Taiwan, 2017, Jul.

[15] A. Bamba, " Recent Progress on Supernova Remnants - Present achievements and Future - " , " SNR workshop 2017 ", Nagoya University, Japan, 2017, Sep.28-29

[16] T. Enoto, Y. Wada, Y. Furuta, K. Nakazawa, T. Yuasa, K. Okuda, K. Makishima, M. Sato, Y. Sato, T. Nakano, D. Umemoto, H. Tsuchiya, “ Photonuclear reactions triggered by lightning discharges in a Japanese winter thunderstorm ” , ”EGU General Assembly”, Vienna, Austria, 7-12 April 2018

[17] Y. Wada, T. Yuasa, K. Nakazawa, K. Makishima, T. Hayashi, M. Ishida, ”X-ray estimates of white dwarf masses in magnetic cataclysmic variables”, ”15th Marcel Grossmann Meeting”, Rome, Italy, 1-7 July 2018

[18] H. Tsuchiya, T. Enoto, Y. Wada, Y. Furuta, K. Nakazawa, T. Yuasa, T. Matsumoto, D. Umemoto, K. Makishima, “ Recent status of the GROWTH experiment ” , Tsuruga, Japan, 4-6 September, 2018

[19] Y. Wada, T. Enoto, Y. Furuta, K. Nakazawa, T. Yuasa, T. Matsumoto, D. Umemoto, K. Makishima, H. Tsuchiya, and the GROWTH collaboration, ”Recent Updates from Mapping Observation of High-energy phenomena In Japanese Winter Thunderstorms”, ”Thunderstorms and Elementary Particle Acceleration (TEPA) 2018”, Aragatsotn District, Armenia, 17-20 September 2018

[20] A. Bamba, “X-ray studies of SNRs and relevant sources in Large Magellanic Clouds”, “SNR workshop 2018 ” , Nagoya University, Japan, 2018, Oct.9-10

[21] A. Bamba, “ Constraining the energetic particle content of Supernova Remnants through X-ray observations ” , “ Particle Acceleration and Transport: from the Sun to Extragalactic Sources ” , Universit della Callabria, Rende, Italy, 2018, Nov.12-16

[22] H. Odaka, ”Monte Carlo Simulations using Geant4 for Hitomi and Suzaku ” , ”New eyes on X-ray astrophysical objects with Japanese and Chinese observatories”, ISAS/JAXA, Sagamihara, Japan, November 19-21

[23] A. Bamba, “ Observational study of Nonthermal phenomena on SNR shocks ” , “ Supernova Remnants II: An Odyssey in Space after Stellar death ” , Crete, Greece, 2019, Jun. 3-8

[24] A. Bamba, “ Recent progress on X-ray study of supernova remnants as remnants of supernovae ” , “ X-ray Astronomy 2019 ” , Bologna, Italy, 2019 Sep. 8-13

8 Teaching Accomplishment

1 student got PhD thesis, and 4 students got MhD thesis. 3 were selected as selected students of Program for Leading Graduate Schools, 2 were selected as JSPS research fellowship for young scientists (DC), 1 got budget in JSPS verseas program for young researchers, and 1 got budget in Graduate Research Abroad in Science Program (GRASP). The following shows the prize list students got.

- 和田有希: 「雷活動に由来するガンマ線の観測プロジェクト：多地点観測の進展と大気電場・電波との協同観測」、日本物理学会 第 74 会年次大会 宇宙線・宇宙物理領域 学生優秀発表賞
- 和田有希: 「冬季雷における高エネルギー現象の観測プロジェクトの進展」、日本地球惑星科学連合 2019 年大会 学生優秀発表賞 (大気水圏科学セクション)

9 Contribution to Academic Community

9.1 Editorial Activities

- 馬場 彩「最も美しい宇宙 50」、別冊 Newton、p148-155、2013 年 12 月
- 馬場 彩「「すざく」でみた TeV ガンマ線未同定天体」、天文月報、2015 年 12 月号、809-814、日本天文学会

9.2 Organization of Professional Societies

- 日本天文月報編集委員 (2013 年 1 月- 2017 年 5 月)
- 日本天文学会代議員 (2013 年 1 月-)
- 日本天文学会男女共同参画委員 (2015 年 4 月-2017 年 5 月)
- 日本天文学会男女共同参画委員長 (2017 年 6 月 -)
- 日本天文学会コンプライアンス委員 (2017 年 7 月 -)
- 高エネルギー宇宙物理連絡会運営委員 (2018 年 4 月 -)
- 日本天文学会副会長 (2019 年 6 月 -)
- 日本天文学会ダイバーシティ理事 (2019 年 6 月 -)
- 日本天文学会研究奨励賞選考委員会 (2019 年 6 月 -)
- 日本天文学会天文遺産選考委員会 (2019 年 6 月 -)

9.3 Organization and Advisory of Conferences

- 日本天文学会春季年会企画セッション「超新星残骸」世話人 (2017 年 3 月)
- 「中性子星勉強会」SOC (2016 年 9 月、蔵王)
- 「すざく」衛星第 8 回観測提案審査員 (2013 年 1 月)
- 「すざく」衛星第 9 回観測提案審査員 (2014 年 1 月)
- 「すざく」衛星第 10 回観測提案審査員 (2015 年 1 月)
- すばる望遠鏡第 S16A 期観測提案審査員 (2015 年 10 月)
- Nobeyama 45m 電場望遠鏡観測提案審査員 (2018-2019 年度)

10 Outreach

- 「高エネルギー天文学: あなたのみたことのない知らない宇宙」、「Rikejo heart 青学」、青山学院大学 (2013 年 6 月)
- 「分光宇宙アルバム 17: X 線で探る超新星残骸内部のレアメタル」国立天文台 web 配信 (2014 年 2 月)
- 「高エネルギー天文学: あなたのみたことのない知らない宇宙」、「Rikejo heart 青学」、青山学院大学 (2014 年 6 月)
- 「目に見えない光・X 線でみる超新星残骸」、「クリスマスレクチャーズ 2014 in 東京」、昭和女子大学 (2014 年 12 月)
- 「目に見えない光・X 線で見た激動の宇宙」、「いろいろな「ひかり」で見る宇宙」、朝日カルチャーセンター横浜 (2015 年 5 月)
- 「高エネルギー天文学: あなたのみたことのない知らない宇宙」、「Rikejo heart 青学」、青山学院大学 (2015 年 6 月)
- 「とある研究者の半生と一日」、「理工系職員が語る私の生活」、宇宙科学研究所 (2015 年 7 月)
- 女子中高生夏の学校 2015　講師、国立女性教育会館 (2015 年 8 月)
- 「熱く激しい宇宙を観る - 高エネルギー宇宙物理学への招待 -」、国立科学博物館天文学普及講演会 (2016 年 6 月)
- 女子中高生夏の学校 2016　講師、国立女性教育会館 (2016 年 8 月)
- ビデオレター、"Athena Community joins the 11th of February "`http://www.phys.s.u-tokyo.ac.jp/?p=`
年 2 月)
- 「人工衛星打ち上げ動画紹介」、藤島高校訪問、東京大学 (2017 年 3 月)

- 「偶然からノーベル賞へ: X 線天文学」、「ノーベル賞と最新宇宙研究」、朝日カルチャーセンター横浜 (2017 年 12 月)
- 女子中高生夏の学校 2018　講師、国立女性教育会館 (2018 年 8 月)
- 「X 線で観る熱く激しい宇宙 - 星の爆発とその残骸 -」、2019 年度日本物理学会科学セミナー「宇宙を観る、聴く、計算する — マルチメッセンジャー天文学の幕開け —」、早稲田大学 (2019 年 8 月 24-25 日)
- 「X 線で観る熱く激しい宇宙」、サイエンスカフェオリオン講師、八王子市 (2019 年 10 月 27 日)

11 Committee Service

- 女子中高生夏の学校実行委員 (2017 年 4 月 -)
- 宇宙科学研究所広報委員 (2019 年 7 月 - 2021 年 3 月)

11.1 External Committees

- Steering Committee of International Astronomical Union, Division D High Energy Phenomena and Fundamental Physics (2018 年 8 月 -)
- Organizing Committee Member of Executive Committee WG Women in Astronomy, International Astronomical Union (2018 年 10 月 -)
- IAU Symposium “ Supernova Environmental Impacts ”, SOC 2012 年 1 月 (India)
- IAU Joint Discussion “ Joint Discussion on the Highest-Energy Gamma-Ray Universe observed with Cherenkov Telescope Arrays ”, SOC 2012 年 8 月 (Beijing, China)
- International Conference “ COSPAR 2014 X-Ray Spectroscopy of Large-scale Plasmas ”, SOC, 2014 年 8 月 (Russia)
- “Japanese-Dutch Bilateral Workshop: Spectroscopy of Cosmic Plasma in the Era of ASTRO-H ”, LOC, 2015 May (Tokyo, Japan)
- “Cosmic Ray Origin Beyond the Standard Models 2”, SOC, 2016 Sep (San Vito de Cadore, Itary)
- IAU symposium 331 “ SN 1987A, 30 years later ”, SOC, 2017 Feb. (La Reunion, Island, France)
- “New eyes on X-ray astrophysical objects with Japanese and Chinese observatories”, SOC, 2018 Nov. (ISAS/JAXA, Japan)
- Summer school ”Cosmic Explosions 2019”, SOC, 2019 May (Corsica, France)

- “Astrophysics of hot plasma ,in extended X-ray sources”, SOC, 2019 June 12-14 (Madrid, Spain)
- “International workshop on High Resolution X-ray Spectroscopy”, SOC, 2019 July 15-18 (Winchester, UK)
- IAU symposium “”Astronomy for Equity, Diversity and Inclusion – a roadmap to action within the framework of IAU 100”, LOC, 2019 Nov. (NAOJ, Japan)

11.2 University Committees

理学系研究科男女共同参画委員会 5 号委員　2016 年 –

12 Internationalization Statistics

外国人受け入れ・派遣状況

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	0	
Doctor Course	0	
Foreign researchers hosted	0	
	0	
Students sent abroad	3	France, USA, Netherland
Researchers sent abroad	0	
Foreign visitors	3	USA, Germany

Akito Kusaka、日下 暁人

1 Education and Professional Experiences

Education

2002	B.S. (Physics)	The University of Tokyo
2004	MSc. (Physics)	The University of Tokyo
2007	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

2007−2011	KICP Fellow	The University of Chicago
2011−2014	Dicke Fellow	Princeton University
2014−2017	Divisional Fellow	Lawrence Berkeley National Laboratory
2017−	Associate Professor	The University of Tokyo
2017−	Senior Scientist	Lawrence Berkeley National Laboratory
2017−	Visiting Researcher	University of California, Berkeley

2 Research Highlights

Cosmic Microwave Background (CMB) is the light from the very beginning of the universe, more than 10 billion years ago. We investigate how this hot and dense early universe began in the first place, and what governs the evolution of the universe, through the observation of CMB. Through this research, we aim to approach fundamental aspects of both astrophysics and elementary particle physics.

We conduct our research through a few observational projects in different stages of development. The Polarbear experiment and its successor, Simons Array, are the experiments on-going in Atacama plateau in northern Chile. In addition to this, we have initiated Simons Observatory experiment as a successor of Simons Array and Atacama Cosmology Telescope (ACT) projects. Simons Observatory is under development and construction, with its first light anticipated early in 2020s.

2.1 Polarbear and Simons Array

Polarbear is designed to explore both inflationary signature and the gravitational lensing effects in the CMB polarization, and started its observation in 2012. Recent highlight includes an improved measurement of so-called B-mode pattern in the polarization spectrum [13], detection of the correlation between the galaxy distribution from the Herschel satellite and gravitational lensing signature seen in the CMB polarization. We have also detection of the correlation in the gravitational lensing maps from the Polarbear's CMB polarization and from the so-called cosmic shear from Subaru Hyper Suprime Cam (HSC) [16]. This represents the first cross-correlation measurement between HSC cosmic shear and CMB lensing.

The Simons Array experiment is the successor to the POLARBEAR experiment, consisting of three telescopes and approximately 20 times more detectors than POLARBEAR. The first telescope of Simons Array, also known as POLARBEAR2-a, has celebrated its first light at the end of 2018. We are developing analysis pipeline optimized for an HPC (High-Performance Computation) environment in order to handle the large data volume from Simons Array.

2.2 Simons Observatory

Simons Observatory is the largest ground-based CMB experiment established in 2016. Our group plays an important role in this collaboration as well. The Simons Observatory consists of two types of telescopes. One, called large aperture telescope, employs a 6 m aperture diameter high-throughput reflective telescope focusing on the measurements of the evolution of the universe. Another, called small aperture telescopes, employs a high-throughput 42 cm aperture refractive optics and is dedicated for inflationary science. We have been working on the instrumental design [30] as well as establishing the science case [18].

Working with other Japanese collaborators, our research is focused on the small aperture telescope. We established the optics design and fabricated optics tube, which houses the cryogenic refractive optics and will be cooled down to 1 K cryogenic temperature to suppress noise due to thermal radiation. In addition, a cryogenic continuously rotating half-wave plate system using superconducting mag-lev bearings is under development for the small aperture telescope. This system has the largest aperture size built to date, and our technology is among the most advanced in this area.

2.3 Technology development

Superconducting detectors are among the core technologies in modern CMB experiments. They find applications also in other areas, such as dark matter searches and the searchers for neutrinoless double beta decays. We develop these superconducting devices as well as the evaluation technique for these detectors and multiplexed readout systems. As for the device fabrication, our research focuses is on Microwave Kinetic Inductance Detectors (MKIDs). We are developing MKIDs using external foundries, in particular those equipped with MEMS technologies, as well as those capable of fabricating large 8" wafers, which is advantageous for future mass-fabrication. Also, as described above, we are the leading expert in the development of the continuously rotating half-wave plate system. We developed the world largest superconducting mag-lev bearing with a 55 cm inner diameter, in collaboration with Kavli IPMU. This is a breakthrough in adopting this technique for the Simons Observatory telescopes.

3 Selected Papers

- QUIET Collaboration: D. Araujo, *et al.*, "Second season QUIET observations: Measurements of the cosmic microwave background polarization power spectrum at 95 GHz," Astrophys. J., **760** (2), 145 (2012)

This paper is the results from the QUIET experiments constraining B-modes. Cited 98 times.

- A. Kusaka, *et al.*, “Modulation of cosmic microwave background polarization with a warm rapidly rotating half-wave plate on the Atacama B-Mode Search instrument,” Rev. Sci. Instrum. 85 (2), 024501 (2014).
  This paper is the first demonstration of the ability to remove atmospheric contamination at these levels from a ground-based platform using a rapidly-rotating half-wave plate. Cited 54 times.

- A. Kusaka *et al.*, “Results from the Atacama B-mode Search (ABS) Experiment,” JCAP **09**(2018)005.
  This paper is the science results from the ABS experiment, demonstrating the CMB polarization power spectrum measurement using continuously rotating half-wave plate, for the first time as a ground-based experiment.

- D. Barron, Y. Chinone, A. Kusaka, *et al.*, “Optimization study for the experimental configuration of CMB-S4,” JCAP **02**(2018)009.
  An optimization study of the experimental configuration of the future CMB experiment, called CMB-S4.

- T. Namikawa, *et al.*, “Evidence for the Cross-correlation between Cosmic Microwave Background Polarization Lensing from POLARBEAR and Cosmic Shear from Subaru Hyper Suprime-Cam,” Astrophys. J., **882**:62 (2019).
  This represents the first cross-correlation measurement between Subaru Hyper Suprime Cam cosmic shear and CMB lensing.

4 Honors, Awards and Professional Society Memberships

5 Research Plan

In the next several years, we will deepen our insight toward the beginning, dark content, and the evolution of the universe by advancing the experimental projects observing CMB.

5.1 Simons Array

The Simons Array will complete the deployment of all three telescopes, and start observation with its full capability. The second telescope will deploy the first version of the cryogenic half-wave plate technology that we developed, and serve as the first demonstration. We will focus our analysis effort on the inflationary science and mapping the mass in the universe through gravitational lensing. For both, the treatment of so-called foregrounds, radio emission from inside our galaxy as well as extra galactic sources, will be crucial. We will develop the methodology and software to mitigate the effect, and put new constraints on the inflationary energy scale, or the tensor-to-scalar ratio r, as well as the sum of the neutrino mass. We will also exploit the dataset combining it with external data, such as those from the Subaru telescope.

5.2 Simons Observatory

We will continue the construction of the Simons Observatory instrument, making indispensable contribution to the small aperture telescopes. We plan to start early observation in 2021, and will start to acquire science-grade data in late 2022. Involvement of graduate students will be crucial element in this research activity. The graduate students will take part in all areas of research, including construction of instrument, calibration, and data analysis. We expect early results to be published mid-2020s. This will include significantly improved constraint on inflation, neutrino mass measurements, evolution of the universe and constraint on dark energy through survey of galaxy clusters, and constraint on relativistic species beyond the standard model.

5.3 Technology development

We will enhance maturity of the MKIDs fabrication, and bring it to the quality that can be adopted experimental projects. This includes not only the matured design and fabrication of the superconducting detector element, but also application specific components such as photon or phonon couplings. The goal is to propose experimental project such as those for radio astronomy, including CMB observation, or dark matter search, using the developed technology. Another key technology we develop, the cryogenic half-wave plate, will be in demonstration stage. By acquiring data from both Simons Array and Simons Observatory systems, we will not only demonstrate the supremacy of the technology but also collect lessons learned, and reflect them to further improve the technology.

6 Publications and Patents

< Refereed Original Papers >

[1] QUIET Collaboration: D. Araujo, *et al.*, "Second season QUIET observations: Measurements of the cosmic microwave background polarization power spectrum at 95 GHz," Astrophys. J., **760** (2), 145 (2012)

[2] QUIET Collaboration: C. Bischoff, *et al.*, "The Q/U imaging experiment instrument," Astrophys. J., **768** (1), 9 (2013).

[3] A. Kusaka, E. J. Wollack, and T. R. Stevenson, "Angular and polarization response of multimode sensors with resistive-grid absorbers," J. Opt. Soc. Am. A 31 (7), 1557-1576 (2014).

[4] A. Kusaka, *et al.*, "Modulation of cosmic microwave background polarization with a warm rapidly rotating half-wave plate on the Atacama B-Mode Search instrument," Rev. Sci. Instrum. 85 (2), 024501 (2014).

[5] A. J. Bevan, *et al.*, "The Physics of the B Factories," The European Physical Journal C, **74**:3026 (2014).

[6] QUIET Collaboration: K. Huffenberger, *et al.*, "The Q/U Imaging Experiment: Polarization Measurements of Radio Sources at 43 and 95 GHz," Astrophys. J., **806**:112(2015).

[7] K. N. Abazajian, *et al.*, "Inflation physics from the cosmic microwave background and large scale structure," Astropart. Phys. **63**, 15 (2015), p5565.

[8] POLARBEAR Collaboration: P. A. R. Ade, *et al.*, "POLARBEAR Constraints on Cosmic Birefringence and Primordial Magnetic Fields," Phys. Rev. D**92**, 123509 (2015).

[9] QUIET Collaboration: T. M. Ruud, *et al.*, "The Q/U Imaging ExperimenT: Polarization Measurements of the Galactic Plane at 43 and 95 GHz," Astrophys. J. **811**:89 (2015).

[10] ABS Collaboration: T. Essinger-Hileman, A. Kusaka, *et al.*, "Systematic effects from an ambient-temperature, continuously-rotating half-wave plate," Rev. Sci. Instrum. **87**, 094503 (2016)

[11] D. Poletti *et al.*, "Making maps of cosmic microwave background polarization for B-mode studies: the POLARBEAR example," A&A **600**, A60 (2017)

[12] S. Takakura *et al.*, "Performance of a continuously rotating half-wave plate on the POLARBEAR telescope," JCAP **05**(2017)008.

[13] The POLARBEAR Collaboration, P. A. R. Ade *et al.*, "A Measurement of the Cosmic Microwave Background B-mode Polarization Power Spectrum at Subdegree Scales from Two Years of POLARBEAR Data," Astrophys. J., **848**:121 (2017).

[14] D. Barron, Y. Chinone, A. Kusaka *et al.*, "Optimization study for the experimental configuration of CMB-S4," JCAP **02**(2018)009.

[15] A. Kusaka *et al.*, "Results from the Atacama B-mode Search (ABS) Experiment," JCAP **09**(2018)005.

[16] T. Namikawa, *et al.*, "Evidence for the Cross-correlation between Cosmic Microwave Background Polarization Lensing from POLARBEAR and Cosmic Shear from Subaru Hyper Suprime-Cam," Astrophys. J., **882**:62 (2019).

[17] S. Takakura, *et al.*, "Measurements of Tropospheric Ice Clouds with a Ground-based CMB Polarization Experiment, POLARBEAR," Astrophys. J., **870**:102 (2019).

[18] Simons Observatory Collaboration, "The Simons Observatory: Science goals and forecasts," JCAP **1902** (2019) 056.

< Conference Proceedings >

[19] O. Tajima, *et al.*, "Novel calibration system with sparse wires for CMB polarization receivers," Journal of Low Temperature Physics 167 (5-6), 936-942 (2012).

[20] A. Kusaka, *et al.*, "MuSE: a novel experiment for CMB polarization measurement using highly multimoded bolometers," Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy VI, 8452, 1L (2012).

[21] S. M. Simon, *et al.*, "In situ time constant and optical efficiency measurements of TRUCE pixels in the Atacama B-mode search," Journal of Low Temperature Physics 176 (5-6), 712-718 (2014).

[22] S. M. Simon, *et al.*, "Characterization of the Atacama B-mode Search," Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy VII, 9153, Y (2014)

[23] ABS Collaboration: S. M. Simon, *et al.*, "Characterizing Atacama B-mode Search Detectors with a Half-Wave Plate," Journal of Low Temperature Physics, 10.1007/s10909-015-1370-2 (2015)

[24] POLARBEAR Collaboration: A. Suzuki, *et al.*, "The POLARBEAR-2 and the Simons Array Experiment," Journal of Low Temperature Physics, 10.1007/s10909-015-1425-4 (2015)

[25] POLARBEAR Collaboration: K. Hattori, *et al.*, "Development of readout electronics for POLARBEAR-2 Cosmic Microwave Background experiment," Journal of Low Temperature Physics, 10.1007/s10909-015-1448-x (2015)

[26] Y. Inoue *et al.*, "POLARBEAR-2: an instrument for CMB polarization measurements," Proc. SPIE 9914, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy VIII, 99141I (2016).

[27] T. Elleflot, *et al.*, "Detector and Readout Assembly and Characterization for the Simons Array," J. Low. Temp. Phys. 193 (5-6), 1094-1102 (2018)

[28] B. Westbrook, *et al.*, "The polarbear-2 and simons array focal plane fabrication status," J. Low. Temp. Phys. 1-13 (2018)

[29] P. A. Gallardo, *et al.*, "Systematic uncertainties in the Simons Observatory: optical effects and sensitivity considerations," Proc. SPIE, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation, 107083Y (2018)

[30] N. Galitzki, *et al.*, "The Simons Observatory: instrument overview," Proc. SPIE, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation, 1070804 (2018)

[31] M. Salatino, *et al.*, "Studies of systematic uncertainties for Simons Observatory: polarization modulator related effects," Proc. SPIE, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation, 107083Y (2018)

[32] J. R. Stevens, *et al.*, "Designs for next generation CMB survey strategies from Chile," Proc. SPIE, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation, 1070841 (2018)

[33] F. T. Matsuda, S. Takakura, *et al.*, "Cross-polarization systematics due to Mizuguchi-Dragone condition breaking by a continuously rotating half-wave plate at prime focus in the Huan Tran telescope," Proc. SPIE, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation, 1070849 (2018)

[34] K. T. Crowley, *et al.*, "Studies of systematic uncertainties for Simons Observatory: detector array effects," Proc. SPIE, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation, 107083Z (2018)

[35] S. A. Bryan, *et al.*, "Development of calibration strategies for the Simons Observatory," Proc. SPIE, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation, 1070840 (2018)

[36] Y Sakurai, *et al.*, "Design and development of a polarization modulator unit based on a continuous rotating half-wave plate for LiteBIRD," Proc. SPIE, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation, 107080E (2018)

[37] C. A. Hill, *et al.*, "BoloCalc: a sensitivity calculator for the design of Simons Observatory," Proc. SPIE, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation, 1070842 (2018)

[38] C. A. Hill, A. Kusaka, P. Barton *et al.*, “A Large-Diameter Cryogenic Rotation Stage for Half-Wave Plate Polarization Modulation on the POLARBEAR-2 Experiment,” J. Low. Temp. Phys. (2018). https://doi.org/10.1007/s10909-018-1980-6

[39] T. Hasebe, *et al.*, “Concept Study of Optical Configurations for High-Frequency Telescope for LiteBIRD,” J. Low. Temp. Phys. (2018). https://doi.org/10.1007/s10909-018-1915-2

[40] A. Suzuki, *et al.*, “The LiteBIRD Satellite Mission: Sub-Kelvin Instrument,” J. Low. Temp. Phys. (2018). https://doi.org/10.1007/s10909-018-1947-7

[41] A. Suzuki *et al.*, “Commercialization of Micro-fabrication of Antenna-Coupled Transition Edge Sensor Bolometer Detectors for Studies of the Cosmic Microwave Background,” J. Low. Temp. Phys. (2018). https://doi.org/10.1007/s10909-018-1903-6

[42] F. Faramarzi *et al.*, “Lithographed Superconducting Resonator Development for Next-Generation Frequency Multiplexing Readout of Transition-Edge Sensors,” J. Low. Temp. Phys. (2018). https://doi.org/10.1007/s10909-018-1889-0

7 Invited Presentations at International Conferences

[1] A. Kusaka, (Jun. 2013), “MuSE: The Multimoded Survey Experiment,” CMB2013, Okinawa, Japan

[2] A. Kusaka, (Jun. 2013), “The Atacama B mode Search Status and Prospect,” CMB2013, Okinawa, Japan

[3] A. Kusaka, (Dec. 2015), “Polarization Modulator,” B-mode From Space, Kashiwa, Japan

[4] A. Kusaka, (Jun. 2016), “Cosmic Microwave Background past and future,” 28th Rencontres de Blois, Blois, France

[5] A. Kusaka, (Jun. 2016), “Tau measurements by future CMB missions,” Neutrinos and Light Particles in Cosmology, Berkeley, U.S.A.

[6] A. Kusaka, (Apr. 2019), “Non-Accelerator Experiments / Astro-Particle Physics / Cosmology / Dark Matter,” The 40th Anniversary Symposium of the US-Japan Science and Technology Cooperation Program in High Energy Physics, the University of Hawaii, U.S.

8 Teaching Accomplishment

9 Contribution to Academic Community

9.1 Editorial Activities

9.2 Organization of Professional Societies

9.3 Organization and Advisory of Conferences

10 Outreach

11 Committee Service

11.1 External Committees

Member of Governing Board of the CMB-S4 Collaboration, 2018−
Member of Executive Board of the Simons Observatory Collaboration, 2016−
Member of Management Board of the POLARBEAR/Simons Array Collaboration, 2014−
Member of CMB-S4 Concept Definition Taskforce, 2016−2017

11.2 University Committees

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	1	U.S.A.
Master Course	0	
Doctor Course	0	
Foreign researchers hosted	0	
Students sent abroad	0	
Researchers sent abroad	0	
Foreign visitors	3	U.S.A.

Yasushi Suto、須藤 靖

1 Education and Professional Experiences

Education

1981	B.S. (Physics)	The University of Tokyo
1983	MSc. (Physics)	The University of Tokyo
1986	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1986-1988	Miller Research Fellow	University of California at Berkeley
1988-1990	Assistant Professor	Ibaraki University
1990	Associate Professor	Research Institute for Theoretical Physics Hiroshima University
1990-1993	Associate Professor	Yukawa Institute for Theoretical Physics Kyoto University
1993-2006	Associate Professor	The University of Tokyo
2006-present	Professor	The University of Tokyo

Sept.2013 - Nov. 2013 Global Scholar (visiting professor) Princeton University

2 Research Highlights

Determination of three-dimensional spin-orbit angle of exoplanets

Observed exoplanets exhibit a broad distribution of the angle between the stellar spin and planetary angular momenta. The spin-orbit angle is supposed to be a unqiue probe of the origin and evolution of exoplanetary systems. Conventionally, however, its sky-projected component alone is observable through the Rossiter–McLaughlin effect. By combining the stellar inclination estimated from asteroseismology, we were able to determine the three-dimensional spin-orbit angle of two transiting exoplanets for the first time. In particular, we found that the real spin-orbit angle of HAT-P7b is around 120°, in contrast to its projected angle of 180°, implying that the misalignment can be acounted for from the Kozai effect, for instance.

The highest angular-resolution SZ imaging

For the last two decades, we have been working on the high-resolution multi-band imaging of a massive galaxy cluster RX J1347.5-1145 at $z = 0.45$. We achieved the highest angular-resolution record of the Sunyaev-Zel'dovich map using ALMA, revealing the detailed thermodynamical structure of the cluster.

Search for exo-rings

We proposed a methodology to search for a signature of a ring around exoplanets. We refined the methodology, and applied it to transiting planet candidates from the Kepler survey. We found one preliminary candidate, and put constraints on the occurence rate of exorings for the first time. Since there is no confirmed detection of an exoplanet with ring, our candidate and/or constraints are important for futute exo-ring search projects.

Hyper-Suprime Cam survey with Subaru telescope

Hyper-Suprime cam is a wide-field imaging camera installed at the prime focus of the Subaru telescope. We started intensive 300 nights survey with HSC in March 2014. We released two public datasets so far, which resulted in numerous papers over a variety of astronomical and cosmological research fields. I am one of the founders of this project, and contributed to the fund raising, collaboration with Princeton group, and collaboration policy making processes. I am currently working as the chair of the HSC excutive board that is responsible for all the decision making concerning the project.

3 Selected Papers

- Othman Benomar, Kento Masuda, Hiromoto Shibahashi, and Yasushi Suto "Determination of three-dimensional spin–orbit angle with joint analysis of asteroseismology, transit lightcurve, and the Rossiter–McLaughlin effect: cases for HAT-P-7 and Kepler-25", Publication of Astronomical Society of Japan, 66, 94 (2019).
  the first measurement of the true spin-orbit angles for exoplanets combining the Rossiter–McLaughlin effect and asteroseismology.

- T. Kitayama, S. Ueda, S. Takakuwa, T. Tsutsumi, E. Komatsu, T. Akahori, D. Iono, T. Izumi, R. Kawabe, K. Kohno, H. Matsuo, N. Ota, Y. Suto, M. Takizawa, and K. Yoshikawa "The Sunyaev-Zel'dovich Effect at Five Arc-seconds: RX J1347.5-1145 Imaged by ALMA", Publication of Astronomical Society of Japan, 68, 88 (2016).
  The highest angular-resolution image of the Sunyaev-Zel'dovich Effect with ALMA, selected as the press release at ALMA and Max Planck Instutute for Astrophysics.

- Masataka Aizawa, Sho Uehara, Kento Masuda, Hajime Kawahara, and Yasushi Suto "Towards detection of exoplanetary rings via transit photometry: methodology and a possible candidate", The Astronomical Journal, 153, 193 (2017).
  The first systematic search for exo-rings, selected as a highlight paper at the American Astronomical Society webpage.

- Hiroaki Aihara et al. (HSC collaboration) "First Data Release of the Hyper Suprime-Cam Subaru Strategic Program", Publication of Astronomical Society of Japan, 70, S8 (2018).
  This is the first data release of the cosmological survey, HSC. I am one of the founders of this international project, and currently served as the chair of the executive board.

- Shoya Kamiaka, Othman Benomar, Yasushi Suto, Fei Dai, Kento Masuda, and Joshua N. Winn "The misaligned orbit of the Earth-sized planet Kepler-408b", The Astronomical Journal, 157, 137(2019).
  Discovery of a spin-orbit misalignment for the smallest sub-Earth sized planet.

4 Honors, Awards and Professional Society Memberships

N/A

5 Research Plan

Orbital evolution of exoplanetary systems and origin of their diversity

The diversity of the observed exoplanetary systems is an important clue to their initial conditions and subsequent dynamical evolution. The presence of close-in giant gaseous planets, eccentric planets, mialigned planets implies that a substantial fraction of systems should have experienced significant orbital evolution. Detailed physical processes that are responsible for those diverse architecture, however, remain to be understood. We approach this problem in two different ways. The first is smoothed paricle hydrodynamic simulations of turbulent giant molecular gas clouds to the formaton of protostars and protoplanetary disks. Using the sink particle technique, we identify the spin of protostar and compute the evolution of the spin-orbit angles. The other is to simulate the planet-disk interaction by adopting the observed protoplanetary disks as the initial conditions. By doing so, we can skip various uncertainties of the initial conditions that are difficult to be predicted from theoreical models. After the disk gas component evaporates, the system consists of small-number of protoplanets, and their chaotic orbital evolution may account for the diversity of the observed spin-orbit architecture.

GCM simulation of earth-like planets for future remote-sensing

Direct-imaging of earth-like planets is a quite challenging but indispensable technique to revolutionize our understanding of planets in the near future. Their photometric and spectroscopic data are affected very sensitively by the presence of clouds. We apply the Global Climate Model (GCM) simulation to compute the cloud distribution under various atmospeheric and surface conditions, and explore the detecton method of the surface components and eventually the bio-signature that may characterize another habitable world.

Asteroseismology

Asteroseismology unveils the internal structure of stars from their pulsation signals. In the context of exoplanets, it significantly improves the parameter estimation of planets through precise measurements of their host star properties. In particular, asteroseismology is a unique methodology to probe the spin-orbit architecture of the transiting planetary systems through the determination of the stellar inclination angle. We select approximately 100 stars with and without transiting planets, which exhibit detectable pulsation signals in the Kepler data. Then we apply the hierarchical Bayesian method to extact rotation periods and inclinations of those stars in an unbiased fashion, and reconstruct the statistical distribution of the spin-orbit angles from asteroseismology.

6 Publications and Patents

Refereed Original Papers

[1] den Herder et al.;2012;0; "ORIGIN: Metal Creation and Evolution from the Cosmic Dawn"; Experimental Astronomy;34;519–549;

[2] Kenkichi Yamada, Tetsu Kitayama, Shigehisa Takakuwa, Daisuke Iono, Takahiro Tsutsumi, Kotaro Kohno, Motokazu Takizawa, Kohji Yoshikawa, Takuya Akahori, Eiichiro Komatsu, Yasushi Suto, Hiroshi Matsuo, and Ryohei Kawabe;2012;0; "Imaging Simulations of the Sunyaev-Zel'dovich Effect for ALMA";Publication of Astronomical Society of Japan;64;102;

[3] Teruyuki Hirano, Roberto Sabchis-Ojeda, Yoichi Takeda, Norio Narita, Joshua N. Winn, Atsushi Taruya, and Yasushi Suto; 2012;0;"Measurement of Stellar Inclinations for Kepler Planet Candidates"; The Astrophysical Journal;756;66;

[4] Masahiro Takada, Richard Ellis, Hiroaki Aihara, Nobuo Arimoto, Kevin Bundy, Masashi Chiba, Judith Cohen, Olivier Dore, Jenny E. Greene, James Gunn, Timothy Heckman, Chris Hirata, Paul Ho, Jean-Paul Kneib, Olivier Le Fevre, Hitoshi Murayama, Tohru Nagao, Masami Ouchi, Michael Seiffert, John Silverman, Laerte Sodre Jr, David Spergel, Michael A. Strauss, Hajime Sugai, Yasushi Suto, Hideki Takami, Rosemary Wyse, the PFS Team; 2012;0; "Extragalactic Science and Cosmology with the Subaru Prime Focus Spectrograph (PFS)"; Publication of Astronomical Society of Japan;66;R1;

[5] Teruyuki Hirano, Norio Narita, Bun'ei Sato, Yasuhiro H. Takahashi, Kento Masuda, Yoichi Takeda, Wako Aoki, Motohide Tamura, and Yasushi Suto; 2012;0;"Planet-Planet Eclipse and the Rossiter-McLaughlin Effect of a Multiple Transiting System: Joint Analysis of the Subaru Spectroscopy and the Kepler Photometry"; The Astrophysical Journal;759;L36;

[6] Yuka Fujii, Edwin L. Turner, and Yasushi Suto; 2013;0;"Variability of Water and Oxygen Absorption Lines in the Disk-Integrated Spectra of the Earth and Earth-like Exoplanets"; The Astrophysical Journal;765;76;

[7] Daichi Suto,Hajime Kawahara, Tetsu Kitayama, Shin Sasaki, Yasushi Suto, and Renyue Cen;2013;0; "Validity of Hydrostatic Equilibrium in Galaxy Clusters from Cosmological Hydrodynamical Simulations";The Astrophysical Journal;767;79;

[8] Toshiya Kashiwagi, Kazuhiro Yahata, and Yasushi Suto;2013;0; "Detection of Far Infrared emission from Galaxies and Quasars in the Galactic extinction map";Publication of Astronomical Society of Japan;65;43;

[9] Kento Masuda, Teruyuki Hirano, Atsushi Taruya, Mikiko Nagasawa, and Yasushi Suto;2013;0; "Characterization of KOI-94 system with transiting timing variation analysis: implication for the planet-planet eclipse"; The Astrophysical Journal;778;185;

[10] Yuxin Xue, Yasushi Suto, Atsushi Taruya, Teruyuki Hirano, Yuka Fujii, and Kento Masuda;2014;0; "Tidal evolution of the spin-orbit angle in exoplanetary systems"; The Astrophysical Journal;784;66;

[11] Othman Benomar, Kento Masuda, Hiromoto Shibahashi, and Yasushi Suto;2014;0; "Determination of three-dimensional spin–orbit angle with joint analysis of asteroseismology, transit lightcurve, and the Rossiter–McLaughlin effect: cases for HAT-P-7 and Kepler-25";Publication of Astronomical Society of Japan;66;94(1-21);

[12] Toshiya Kashiwagi, Yasushi Suto, Atsushi Taruya, Issha Kayo, Takahiro Nishimichi, and Kazuhiro Yahata;2014;0; "Modeling the anomaly of surface number densities of galaxies on the Galactic extinction map due to their FIR emission contamination"; The Astrophysical Journal;799;132;

[13] S. Colombi, T. Sousbie, S. Peirani, G. Plum & Y. Suto;2015;0; "Vlasov versus N-body: the Hénon sphere"; Monthly Notices of Royal Astronomical Society;450;3724;

[14] Toshiya Kashiwagi and Yasushi Suto;2015;0; "Constraining spatial extent and temperature of dust around galaxies from far-infrared image stacking analysis"; Monthly Notices of Royal Astronomical Society;451;4162;

[15] Shoya Kamiaka, Kento Masuda, Yuxin Xue, Yasushi Suto, Tsubasa Nishioka, Risa Murakami, Koichiro Inayama, Madoka Saitoh, Michisuke Tanaka, and Atsunori Yonehara;2015;0; "Revisiting a gravity-darkened and precessing planetary system PTFO 8-8695: spin-orbit non-synchronous case"; Publication of Astronomical Society of Japan;67;94(1–10);

[16] Daichi Suto, Tetsu Kitayama, Ken Osato, Shin Sasaki, and Yasushi Suto;2016;0; "Confrontation of Top-Hat Spherical Collapse Against Dark Halos from Cosmological N-Body Simulations"; Publication of Astronomical Society of Japan;68;14(1-17);

[17] Taizo Okabe, Toshiya Kashiwagi, Yasushi Suto, Shuji Matsuura, Yasuo Doi, Satoshi Takita, and Takafumi Ootsubo;2016;0; "Image Stacking Analysis of SDSS Galaxies with AKARI Far-Infrared Surveyor Maps at 60μm, 90μm, and 140μm"; Publication of Astronomical Society of Japan;68;17(1-15);

[18] Kento Masuda and Yasushi Suto;2016;0; "Transiting planets as a precision clock to constrain the time-variaton of the gravitational constant"; Publication of Astronomical Society of Japan;68;L5(1-5);

[19] Yuxin Xue and Yasushi Suto;2016;0; "Difficulty in Formation of Counter-orbiting Hot Jupiters from Near-coplanar Hierarchical Triple Systems: A Sub-stellar Perturber"; The Astrophysical Journal;820;55(17pp);

[20] Naoyuki Tamura et al.;2016;0; "Prime Focus Spectrograph (PFS) for the Subaru telescope: overview, recent progress, and future perspectives"; Proceedings of the SPIE;9908;99081M (17pp) (arXiv:1608.01075);

[21] T. Kitayama, S. Ueda, S. Takakuwa, T. Tsutsumi, E. Komatsu, T. Akahori, D. Iono, T. Izumi, R. Kawabe, K. Kohno, H. Matsuo, N. Ota, Y. Suto, M. Takizawa, and K. Yoshikawa;2016;0; "The Sunyaev-Zel'dovich Effect at Five Arc-seconds: RXJ1347.5-1145 Imaged by ALMA"; Publication of Astronomical Society of Japan;68;88(1-19);

[22] Daichi Suto, Tetsu Kitayama, Takahiro Nishimichi, Shin Sasaki, and Yasushi Suto;2016;0; "Evolution and Statistics of Non-Sphericity of Dark Matter Halos from Cosmological N-Body Simulation"; Publication of Astronomical Society of Japan;68;97(1-20);

[23] Daichi Suto, Sébastien Peirani, Yohan Dubois, Tetsu Kitayama, Takahiro Nishimichi, Shin Sasaki, and Yasushi Suto;2017;0; "Projected Axis Ratios of Galaxy Clusters in the Horizon-AGN Simulations: Impact of Baryon Physics, and Comparison with Observations"; Publication of Astronomical Society of Japan;69;14(1-15);

[24] Yuxin Xue, Kento Masuda, and Yasushi Suto;2017;0; "Possible Outcomes of Coplanar High-eccentricity Migration: Hot Jupiters, Close-in Super-Earths, and Counter-orbiting Planets"; The Astrophysical Journal;835;204(1-21);

[25] Masataka Aizawa, Sho Uehara, Kento Masuda, Hajime Kawahara, and Yasushi Suto;2017;0; "Towards detection of exoplanetary rings via transit photometry: methodology and a possible candidate"; The Astronomical Journal;153;193(1-23);

[26] Hiroaki Aihara et al. (HSC collaboration);2018;0; "The Hyper Suprime-Cam SSP Survey: Overview and Survey Design"; Publication of Astronomical Society of Japan;70;S4;

[27] Hiroaki Aihara et al. (HSC collaboration);2018;0; "First Data Release of the Hyper Suprime-Cam Subaru Strategic Program"; Publication of Astronomical Society of Japan;70;S8;

[28] Masataka Aizawa, Kento Masuda, Hajime Kawahara, and Yasushi Suto;2018;0; "Systematic Search for Rings around *Kepler* Planets: Statistical Constraints on Ring Size and Occurrence Rate"; The Astronomical Journal;155;206(1-18);

[29] Taizo Okabe, Takahiro Nishimichi, Masamune Oguri, Sébastien Peirani, Tetsu Kitayama, Shin Sasaki, and Yasushi Suto;2018;0; "Projected alignment of non-sphericities of stellar, gas and dark matter distribution in galaxy clusters: analysis of the Horizon-AGN simulation"; Monthly Notices of Royal Astronomical Society;478;1141–1160;

[30] Shoya Kamiaka, Othman Benomar, and Yasushi Suto;2018;0; "Reliability of stellar inclination estimated from asteroseismology: analytical criteria, mock simulations and Kepler data analysis"; Monthly Notices of Royal Astronomical Society;479;391–405;

[31] Shutaro Ueda, Tetsu Kitayama, Masamune Oguri, Takuya Akahori, Daisuke Iono, Takumi Izumi, Ryohei Kawabe, Eiichiro Komatsu, Kotaro Kohno, Hiroshi Matsuo, Naomi Ota, Yasushi Suto, Shigehisa Takakuwa, Motokazu Takizawa, Takahiro Tsutsumi, and Kohji Yoshikawa; 2018;0; "A cool core disturbed: Observational evidence for coexistence of sub-sonic sloshing gas and stripped shock-heated gas around the core of RX J1347.5-1145"; The Astrophysical Journal;866;48(13pp);

[32] Shoya Kamiaka, Othman Benomar, Yasushi Suto, Fei Dai, Kento Masuda, and Joshua N. Winn;2019;0; "The misaligned orbit of the Earth-sized planet Kepler-408b"; The Astronomical Journal;157;137(13pp);

[33] Yasushi Suto;2019;0; "How to Search for Possible Bio-signatures on Earth-Like Planets: Beyond a Pale Blue Dot"; a refereed contribution in *Astrobiology - from the Origins of Life to the Search for Extraterrestrial Intelligence* (Springer Nature, 2019);pp.441 − 450;;

[34] Yasushi Suto, Shoya Kamiaka, and Othman Benomar;2019;0; "Asteroseismic determination of the stellar rotation period of the *Kepler* transiting planetary systems and its implications for the spin-orbit architecture"; The Astronomical Journal;157;172(15pp);

[35] Hiroaki Aihara et al. (HSC collaboration);2019;0; "Second Data Release of the Hyper Suprime-Cam Subaru Strategic Program"; Publication of Astronomical Society of Japan;71;;

[36] Taizo Okabe, Takahiro Nishimichi, Masamune Oguri, Sébastien Peirani, Tetsu Kitayama, Shin Sasaki, Yasushi Suto, Christophe Pichon, and Yohan Dubois;2019;0; "Cosmological evolution of orientations of cluster-sized dark matter haloes and their central galaxies in the Horizon-AGN simulation"; Monthly Notices of Royal Astronomical Society;480;;

和文解説

[1] "右下がりの時代をいきのびる"、パリティ **27**(2012) 5 月号, pp.52–55.
[2] "ハッブルかルメートルか: 宇宙膨張発見史をめぐる謎"、日本物理学会誌 **67** (2012) 5 月号 pp.311–316.
[3] "注文の多い雑文 その二十三:科学者の品格"、東京大学出版会 UP **488**(2013)6 月号, pp.24–31.
[4] "解き尽くせないから面白い　宇宙原理と人間原理"、MOKU **260**(2013)11 月号, pp.62–71.
[5] "もうひとつの地球から眺める我が地球"、HUMAN **5**(2013)12 月号, pp.123–130.
[6] "考える冬：世界は法則に支配されている（のだろうか？）"、考える人 **47**(2013) 冬号, pp.288–289.
[7] "天文学は invaluable"、MOKU **262**(2014)1 月号, pp.34–37.
[8] "宇宙の加速膨張：宇宙定数か、ダークエネルギーか"、日本物理学会誌 **69**(2014)7 月号, pp.442–443.
[9] "一般相対論ミニマム"、日本物理学会誌 **70**(2015)2 月号, pp.87–94.
[10] 物理科学、この 30 年："宇宙論"、パリティ **30**(2015)5 月号, pp.6–8.
[11] 巻頭エッセイ　文藝春秋　"宇宙の加速膨張と高知家"、2016 年 2 月号, pp.88–89.
[12] "もうひとつの地球での生命の探し方"、アドスリー　BioPhilia 2016 年 10 月号　「アストロバイオロジー」.
[13] "「わかる」という意味"、窮理社　窮理　第 5 号 (2017), pp.2–10.
[14] "「これからの高校理科教育のありかた」をめぐって"、学術の動向 **22**(2017)1 月号, 特集 2　序文 p.41
[15] "線引きの議論に没入する前に"、岩波 科学 **87**(2017)2 月号, 巻頭エッセイ p.93.
[16] "物理学とテンソル - 一般相対論を例として"、数理科学 **647**(2017) pp.45–52.
[17] "「学術のために」という視点"、学術の動向 **22**(2017)5 月号 pp.24–29
[18] シリーズ：安全保障と天文学 (1) "安全保障に関する日本学術会議声明ー若手天文学研究者に向けてー"、日本天文学会誌 天文月報 **110**(2017) pp.728–735.
[19] "「宇宙」の外に「宇宙」はあるか"、講談社　本 2019 年 2 月号, pp.46–47.
[20] "宇宙生物学と学術会議越しに見た海部先生"、日本天文学会誌 天文月報 **112**(2019) pp.574–575.
[21] "2019 年ノーベル物理学賞：宇宙の構造進化と太陽系外惑星"、現代化学 **585** (2019) 12 月号.

上記を含み、2012 年以降現在までに、135 編の和文解説及び雑文を出版。

和文著書 (単著のみ)

[1] “三日月とクロワッサン”、毎日新聞社 (2012 年 2 月刊行、217 ページ)
[2] “主役はダーク”、毎日新聞社 (2013 年 3 月刊行、293 ページ)
[3] “宇宙人の見る地球”、毎日新聞社 (2014 年 5 月刊行、180 ページ)
[4] “情けは宇宙のためならず”、毎日新聞出版社 (2018 年 6 月刊行、243 ページ)
[5] “この空のかなた”、亜紀書房 (2018 年 7 月刊行、182 ページ)
[6] “不自然な宇宙”、講談社ブルーバックス (2019 年 1 月刊行、240 ページ)
[7] “解析力学・量子論 (第 2 版)”、 東京大学出版会 (2019 年 5 月刊行、308 ページ)
[8] “一般相対論入門（改訂版）”、日本評論社 (2019 年 9 月刊行、218 ページ)

7 Invited Presentations at International Conferences

[1] The 5th KIAS workshop on Cosmology and Structure Formation, Korean Institute for Advanced Study, Seoul, November 1, 2012 “Detection of Far Infrared Emission from SDSS Galaxies in the SFD Galactic Extinction Map”

[2] The 5th KIAS workshop on Cosmology and Structure Formation, Korean Institute for Advanced Study, Seoul, November 2, 2012 “Summary talk”

[3] SPICA Science Conference “From exoplanets to distant galaxies: SPICA’s new window on the coold universe”, The University of Tokyo, June 18, 2013 “Opening talk: message from Science Council of Japan”

[4] The 10th Sino-Germany Workshop on Galaxy Formation and Cosmology, Xi’an, China, May 22, 2014 “Anomaly in the SFD extinction map and discovery of FIR emission of SDSS galaxies and quasars by stacking image analysis”

[5] The 6th KIAS workshop on Cosmology and Structure Formation, Korean Institute for Advanced Study, Seoul, November 5, 2014, “Spatial extent of dust from stacking image analysis of SDSS galaxies over IRAS and AKARI maps”

[6] The 6th KIAS workshop on Cosmology and Structure Formation, Korean Institute for Advanced Study, Seoul, November 6, 2014, “Workshop summary: from after dark to beyond dark”

[7] Kyoto YITP-IAP workshop “Vlasov-Poisson: towards numerical methods without particles”, Yukawa Institute, Kyoto University, June 2, 2015, “Beyond the spherical dust collapse model”

[8] The 2015 Kyoto Prize Workshop in Basic Sciences “Formation mechanism of planetary systems and the quest for earth-twins”, Kyoto International Center, November 12, 2015 “Beyond a pale blue dot”

[9] The 7th KIAS workshop on Cosmology and Structure Formation, Korean Institute for Advanced Study, Seoul, November 1, 2016, “Impact of baryon physics on non-sphericity of galaxy clusters”

[10] The 2016 Inter-Academy Seoul Science Forum “Physics for Earth and Space”, The Plaza Hotel, Seoul, November 3, 2016, “Colors of a Second Earth: A Future Path Towards Astrobiology From Space”

[11] International conference at Centre International de Rencontres Mathematiques “Collisionless Boltzmann (Vlasov) Equaton and Modeling of Self-Gravitating Systems and Plasmas”, Marseille, France, November 1, 2017 “Non-sphericity of collisionless gravitating systems in the universe”

[12] NAOJ workshop “Asteroseismology and its impact on other branches of astronomy”, The University of Tokyo, March 20, 2018, “Reliability of the asteroseismic measurement of the stellar obliquity”

[13] The 8th KIAS workshop on Cosmology and Structure Formation, Korean Institute for Advanced Study, Seoul, November 6, 2018, “GCM simulation of a second earth: cloud pattern and the obliquity determination from future direct imaging”

[14] JSPS Planet2/RESCEU Symposium “From Protoplanetary Disks through Planetary System Achitecture to Planetary Atmospehers and Habitability”, Okinawa, Japan, October 18, 2019, “Spin-orbit architecture of planetary systems”

8 Teaching Accomplishment

指導した学生の受賞

- 2013 年 3 月 21 日 松原隆彦: 第 17 回（2012 年度）日本天文学会林忠四郎賞
  “統計的摂動解析理論に基づく観測的宇宙論の開拓”
- 2013 年 3 月 25 日 平野照幸: 平成 24 年度東京大学大学院理学系研究科　研究奨励賞（博士課程）
  “惑星移動機構解明に向けたトランジット惑星系の軌道傾斜角測定”
- 2013 年 3 月 25 日 荒川尚輝: 平成 24 年度東京大学大学院理学系研究科　研究奨励賞（学部 4 年）
  “すばる望遠鏡を用いた大光度近赤外銀河撮像による銀河合体と活動銀河核構造の探求”
- 2014 年 2 月 4 日 平野照幸: 第 30 回（2013 年度）井上研究奨励賞
  “惑星移動機構解明に向けたトランジット惑星系の軌道傾斜角測定”
- 2014 年 2 月 4 日 成田憲保: 第 6 回（2013 年度）井上リサーチアウォード
  “スーパーアースとは何か?: その組成と形成過程の解明”
- 2014 年 3 月 20 日 成田憲保: 第 25 回（2013 年度）日本天文学会研究奨励賞
  “トランジット法による系外惑星の成り立ちの研究”
- 2014 年 3 月 24 日 増田賢人: 平成 25 年度東京大学大学院理学系研究科　研究奨励賞（修士課程）
  “トランジット時刻変動を用いた超低密度惑星の発見”
- 2016 年 2 月 4 日 藤井友香: 第 32 回（2015 年度）井上研究奨励賞
  “惑星光による系外地球型惑星の表層環境の推定：将来の直接撮像観測にむけて”
- 2017 年 3 月 8 日 増田賢人: 第 7 回日本学術振興会育志賞
  “高精度測光観測によるトランジット系外惑星系の探究”
- 2017 年 3 月 24 日 増田賢人: 平成 28 年度東京大学大学院理学系研究科　研究奨励賞（博士課程）
  “高精度測光観測によるトランジット系外惑星系の探究”
- 2018 年 2 月 2 日 増田賢人: 第 34 回（2017 年度）井上研究奨励賞
  “高精度測光観測によるトランジット系外惑星系の探究”
- 2019 年 3 月 16 日 大栗真宗: 第 23 回（2018 年度）日本天文学会林忠四郎賞
  “重力レンズ天文学への基礎的貢献”

9 Contribution to Academic Community

9.1 Editorial Activities

N/A

9.2 Organization of Professional Societies

- 2010 年 1 月 — 2013 年 12 月 日本天文学会評議員
- 2011 年 10 月 — 2014 年 9 月 第 22 期日本学術会議会員
- 2011 年 10 月 — 2014 年 9 月 第 22 期日本学術会議 物理学委員会 幹事
- 2011 年 10 月 — 2014 年 9 月 第 22 期日本学術会議科学力増進分科会 委員長
- 2011 年 10 月 — 2014 年 9 月 第 22 期日本学術会議 天文学・宇宙物理学分科会副委員長
- 2014 年 10 月 — 2017 年 9 月 第 23 期日本学術会議会員
- 2014 年 10 月 — 2017 年 9 月 第 23 期日本学術会議 物理学委員会 幹事
- 2014 年 10 月 — 2017 年 9 月 第 23 期日本学術会議広報・科学力増進分科会 副委員長
- 2014 年 10 月 — 2017 年 9 月 第 23 期日本学術会議 天文学・宇宙物理学分科会副委員長
- 2013 年 4 月 — 2017 年 9 月 第 23 期日本学術会議　高校理科教育検討小委員会 委員長
- 2008 年 1 月 — 2017 年 9 月 日本アストロバイオロジーネットワーク　世話人
- 2017 年 10 月 — 2020 年 9 月 第 24 期日本学術会議連携会員
- 2017 年 4 月 — 2020 年 3 月 日本天文学会代議員

9.3 Organization and Advisory of Conferences

- October 29 - Noember 2, 2012 SOC
  The 5th KIAS International workshop "Cosmology and Structure Formation", Seoul, Korea
- November 3 -6, 2014 SOC
  The 6th KIAS International workshop "Cosmology and Structure Formation", Seoul, Korea
- May 19-22, 2014 SOC
  The 10th Sino-Germany workshop "Galaxy formation and cosmology", Xien, China
- June 1-3, 2015 SOC
  Kyoto YITP-IAP wokrshop "The Vlasov equation", Kyoto, Japan
- November 1-3, 2016 SOC
  The 7th KIAS International workshop "Cosmology and Structure Formation", Seoul, Korea
- February 20-23, 2017 SOC
  JSPS Planet2 symposium "Origin and diversity of planetary systems from the miscroscope to the telescope", Nice, France
- November 28-30, 2017 SOC chair
  JSPS Planet2/RESCEU symposium "Plnet Formation Around Snow Line", Tokyo, Japan

- October 14-18, 2019　SOC
  JSPS Planet2/RESCEU symposium “From Protoplanetary Disks through Planetary System Achitecture
  to Planetary Atmospehers and Habitability”, Okinawa, Japan

10 Outreach

一般講演

	2012	2013	2014	2015	2016	2017	2018	2019
中学・高校での講演	2	2	2	2	2	1	1	1
市民講演会など	4	5	3	3	3	6	6	4

マスメディア

- 2010 年 11 月 — 現在 朝日新聞　論座　筆者
- 2012 年 12 月 — 2014 年 12 月 読売新聞　読書委員
- 2014 年 7 月 — 2016 年 9 月 毎日新聞社　週刊エコノミスト　毎月連載宇宙物理解説記事執筆
- 2016 年 4 月 — 2019 年 3 月 高知新聞　毎月連載天文学解説記事執筆

11 Committee Service

11.1 External Committees

- 2013 年　3 月 東京工業大学　地球惑星科学専攻　外部評価委員
- 2014 年 11 月 — 2015 年 11 月 稲盛財団第 31 回京都賞基礎科学部門専門委員会　委員
- 2015 年　3 月 神戸大学　地球惑星科学専攻　外部評価委員
- 2015 年　4 月 — 2016 年 9 月 独立行政法人　科学技術振興機構　サイエンスアゴラ推進委員会　委員
- 2018 年 11 月 — 2019 年 11 月 稲盛財団第 35 回京都賞基礎科学部門 審査委員
- 2014 年 4 月 — 現在 仁科財団　運営諮問委員会 委員
- January 2012 — August 2018 Subaru HSC collaboration executive board
- September 2018 — present Subaru HSC collaboration executive board, Chair

11.2 Universit Committees

Apri 2015 — March 2021 Director of Research Center for the Early Universe (RESCEU), Graduat School of Science, the University of Tokyo

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	3	UK, USA
Master Course	3	China
Doctor Course	2	China
Foreign researchers hosted	3	France
Students sent abroad	11	USA, France, UAE
Researchers sent abroad	1	USA
Foreign visitors	30	USA, Germany, France, UAE, UK, Italy, China, Korea

Satoshi Yamamoto、山本 智

1 Education and Professional Experiences

Education

1980	B.S. (Chemistry)	The University of Tokyo
1982	MSc. (Chemistry)	The University of Tokyo
1985	Ph.D. (Chemistry)	The University of Tokyo

Professional Appointments

1985−1993	Assistant Professor	Nagoya University
1993−2004	Associate Professor	The University of Tokyo
2004−	Professor	The University of Tokyo

2 Research Highlights

We are mainly investigating physical and chemical evolution of Solar-type protostars through molecular line observations with state-of-the-art radio telescopes including ALMA (Atacama Large Millimeter/submillimeter Array). Scientific highlights of our group are summarized below:

(1) Discovery of Chemical Diversity in Low-mass Protostellar Sources

Before the advent of the ALMA era, we found a source-to-source difference of chemical composition around the protostar at a few 1000 au scale. Two distinct cases are hot corino chemistry sources rich in *saturated* organic molecules (CH_3OH, CH_3OCH_3 etc.) and warm-carbon-chain-chemistry (WCCC) sources rich in *unsaturated* organic molecules (C_4H_2, c-C_3H_2 etc.) In addition, our survey observations revealed the sources having the hybrid character. Such chemical diversity most likely originates from an environmental effect for each protostellar source, for instance, the duration time of the starless core phase before the onset of star formation.

(2) Discovery of a Drastic Chemical Change in Disk Forming Regions

Our ALMA observations at a high angular resolution at a 50 au scale revealed a basic structure of the disk forming region, that is a rotationally supported disk surrounded by an infalling-rotating envelope. We identified the centrifugal barrier of the infalling gas, which stands for an approximate transition zone from the envelope to the disk. The centrifugal barrier corresponds the perihelion of the ballistic infalling motion and a half of the centrifugal radius. If the dynamic pressure of the infalling gas overwhelms the gas pressure (and magnetic pressure), the gas continues to fall to the centrifugal barrier and causes a weak accretion shock. Such a shock drastically changes the chemical composition there, as found in our ALMA observations toward various sources. This result, in turn, indicates that particular physical parts can be highlighted by particular molecular lines just as ‘molecular marker’. Chemical diagnostics is thus found to be useful for disentangle complex physical structures of the disk forming regions.

(3)Discovery of Chemical Diversity in Disk Forming Regions

Through our ALMA observations of several representative protostellar sources, we found that the above chemical diversity at a few 1000 au scale is inherited to the disk forming region at a 50 au scale (a planetary system scale). In the WCCC sources, saturated organic molecules are generally deficient even in the vicinity of the protostar, while in hot corino source, unsaturated organic molecules are deficient. This means that the initial condition for the chemical evolution of the disk toward a planetary system can be different from source to source. This finding provides us with an important implication on the material origin of our solar system.

3 Selected Papers

- Nami Sakai, Takeshi Sakai, Tomoya Hirota, Yoshimasa Watanabe, Cecilia Ceccarelli, Claudine Kahane, Sandrine Bottinelli, Emmanuel Caux, Karine Demyk, Charlotte Vastel, Audrey Coutens, Vianney Taquet, Nagayoshi Ohashi, Shigehisa Takakuwa, His-Wei Yen, Yuri Aikawa, and Satoshi Yamamoto, "Change in the Chemical Composition of Infalling Gas Forming a Disk around a Protostar", *Nature*, **507**, 78-80 (2014)
  This work has been cited 102 times.

- Nami Sakai and Satoshi Yamamoto, "Warm Carbon-Chain Chemistry", *Chem. Rev.*, **113**, 8981-9015 (2013).
  The review summarized the work on chemical diversity.

- Satoshi Yamamoto, "Introduction to Astrochemistry: Chemical Evolution from Interstellar Clouds to Star and Planet Formation", Springer (2017).
  This is an introductory textbook for astrochemistry.

- Yoko Oya, Nami Sakai, Ana Lopez-Sepulcre, Yoshimasa Watanabe, Cecilia Ceccarelli, Bertrand Lefloch, Cecile Favre, and Satoshi Yamamoto, "Infalling-Rotating Motion and Associated Chemical Change in the Envelope of IRAS 16293-2422 Source A Studied with ALMA", *Astrophys. J.*, **824**, 88 (19 pages) (2016).
  This paper reported the first observation of the kinematic and chemical structures of the famous hot corino source.

- Yuki Okoda, Yoko Oya, Nami Sakai, Yoshimasa Watanabe, Jes K. Jorgensen, Ewine F. van Dishoeck, and Satoshi Yamamoto, "The Co-evolution of Disks and Stars in Embedded Stages: The Case of the Very-low-mass Protostar IRAS 15398-3359", *Astrophys. J.*, **864**, L25 (7 pages) (2018).
  This paper was picked up by BBC “100 Women in 2018”.

4 Honors, Awards and Professional Society Memberships

1991 Japan Astronomical Society Prize for Young Researchers
1993 Japan IBM Prize
2014 Hayashi Chushiro Prize of Japan Astronomical Society

5 Research Plan

For the next few years, we are going to extend our work on physical and chemical evolution of disk forming regions around Solar-type protostars toward its full understanding. Major directions are as follows:

(1) Detailed Structure of the Transition Zone from the Envelope to the Disk
As mentioned in Research Highlights, we identified the centrifugal barrier of the infalling-rotating gas as an approximate transition zone from the envelope to the disk. This transition zone is worth studying in more detail, because it is an important place for transferring or discarding the angular momentum for the growth of the protostar and the protostellar disk. Our preliminary results show that it has a complex vertical structure which suggest its link to molecular outflows. In addition, stability of the transition zone is likely related to the episodic accretion onto the protostar, which is now a hot issue for star formation studies. With these in mind, we will conduct sensitive molecular line observations at the highest angular resolution (0.02”-0.03”) achievable with ALMA to resolve the detailed structure at a few au scale.

(2) Detailed Study of Chemical Diversity of the Disk Forming Regions
So far, we have investigated physical and chemical structures of about 10 Solar-type protostars and have revealed the chemical diversity at a 50 au scale. However, these observations were carried out at different angular resolution by using different molecular lines for each source. For this reason, fair comparison of the chemical composition among the observed sources was difficult. In order to overcome this situation, we are now conducting the ALMA large program FAUST (Fifty AU Study of the chemistry in the disk/envelope system of Solar-like protostars), in which we observe 13 protostellar sources by using the same molecular lines at the same linear resolution with the same brightness sensitivity. This observation provides us with a complete dataset for studying chemical diversity and its origin in detail. Observations and analyses of this program are in progress.

(3) Application of Machine Learning to the Observed Molecular Line Data
With ALMA, a huge number of molecular lines are usually detected for one source. Hence, an obtained data cube (image for many velocity channels) is difficult to be inspected by eye. In order to extract the physical and chemical characteristics of the source from such a huge dataset without any preconception, we are now applying the principal component analysis to the data as one of the machine learning procedures. Indeed, we have successfully disentangled physical and chemical components for a few sources by this method. We will extend this direction for the full and efficient use of the ALMA data.

6 Publications and Patents

< Refereed Original Papers >

[1] Shoichi Shiba, Yoshihisa Irimajiri, Tetsuya Yamakura, Hiroyuki Maezawa, Norihiko Sekine, Iwao Hosako, and Satoshi Yamamoto, "3.1-THz Heterodyne Receiver Using an NbTiN Hot-Electron Bolometer Mixer and a Quantum Cascade Laser", *IEEE Trans. Terahertz Sci. Technol.*, **2**, 22-27 (2012).

[2] Yoshimasa Watanabe, Nami Sakai, Johan E. Lindberg, Jes K. Jorgensen, Suzanne E. Bisschop, and Satoshi Yamamoto, "An Unbiased Spectral Line Survey toward R CrA IRS7B in the 345 GHz Window with ASTE", *Astrophys. J.*, **745**, 126 (23 pages) (2012).

[3] Nami Sakai, Cecilia Ceccarelli, Sandrine Bottinelli, Takeshi Sakai, and Satoshi Yamamoto, "Distribution of CH_3OH in NGC1333IRAS4B", *Astrophys.J.*, **754**, 70 (8 pages) (2012).

[4] Nami Sakai, Yancy L. Shirley, Takeshi Sakai, Tomoya Hirota, Yoshimasa Watanabe, and Satoshi Yamamoto, "Tentative Detection of Deuterated Methane toward the Low-Mass Protostar IRAS 04368+2557 in L1527", *Astrophys. J*, **758** L4 (4 pages) (2012).

[5] Nami Sakai, Hiroyuki Maezawa, Takeshi Sakai, Karl M. Menten, and Satoshi Yamamoto, "CH Radio Emission from Heiles Cloud 2 as a Tracer of Molecular Cloud Evolution", *Astron. Astrophys.*, **546**, A103 (8 pages) (2012).

[6] Takahiro Yamaguchi, Shuro Takano, Yoshimasa Watanabe, Nami Sakai, Takeshi Sakai, Sheng-Yuan Liu, Yu-Nung Su, Naomi Hirano, Shigehisa Takakuwa, Yuri Aikawa, Hideko Nomura, and Satoshi Yamamoto, "The 3 mm Spectral Line Survey toward the Lynds 1157 B1 Shocked Region. I. Data", *Publ. Astron. Soc. Japan*, **64**, 105 (45 pages) (2012).

[7] Takeshi Sakai, Nami Sakai, Jonathan B. Foster, Patricio Sanhueza, James M. Jackson, Marc Kassis, Kenji Furuya, Yuri Aikawa, Tomoya Hirota, and Satoshi Yamamoto, "ALMA Observations of the IRDC Clump G34.43+00.24 MM3: Hot Core and Molecular Outflows", *Astrophys. J.*, **775**, L31 (6 pages) (2013).

[8] Nami Sakai, Shuro Takano, Takeshi Sakai, Shoichi Shiba, Yoshihiro Sumiyoshi, Yasuki Endo, and Satoshi Yamamoto, "Anomalous ^{13}C Isotope Abundances in C_3S and C_4H Observed toward the Cold Interstellar Cloud, Taurus Molecular Cloud-1", *J. Phys. Chem. A*, **117**, 9831-9839 (2013).

[9] Jes K. Jorgensen, Ruud Visser, Nami Sakai, Edwin A. Bergin, Christian Brinch, Daniel Harsono, Johan E. Lindberg, Ewine F. van Dishoeck, Satoshi Yamamoto, Suzanne E. Bisschop, Magnus V. Persson, "A Recent Accretion Burst in the Low-mass Protostar IRAS 15398-3359: ALMA Imaging of Its Related Chemistry", *Astrophys. J.*, **779**, 22 (6 pages) (2013).

[10] Ken'ichi Tatematsu, Satoshi Ohashi, Tomofumi Umemoto, Jeong-Eun Lee, Tomoya Hirota, Satoshi Yamamoto, Minho Choi, Ryo Kandori, and Norikazu Mizuno, Norikazu, "Chemical Variation in Molecular Cloud Cores in the Orion A Cloud. II", *Publ. Astron. Soc. Japan*, **66**, 16 (2014).

[11] Nami Sakai, Takeshi Sakai, Tomoya Hirota, Yoshimasa Watanabe, Cecilia Ceccarelli, Claudine Kahane, Sandrine Bottinelli, Emmanuel Caux, Karine Demyk, Charlotte Vastel, Audrey Coutens, Vianney Taquet, Nagayoshi Ohashi, Shigehisa Takakuwa, His-Wei Yen, Yuri Aikawa, and Satoshi Yamamoto, "Change in the Chemical Composition of Infalling Gas Forming a Disk around a Protostar", *Nature*, **507**, 78-80 (2014).

[12] F. Fontani, T. Sakai, K. Furuya, N. Sakai, Y. Aikawa, and S. Yamamoto, "DNC/HNC and N_2D^+/N_2H^+ Ratios in High-mass Star-forming Cores", *Mon. Not. R. Astron. Soc.*, **440**, 448-456 (2014).

[13] Johan E. Lindberg, Jes K. Jorgensen, Christian Brinch, Troels Haugbolle, Edwin A. Bergin, Daniel Harsono, Magnus V. Persson, Ruud Visser, Satoshi Yamamoto, "ALMA Observations of the Kinematics and Chemistry of Disc Formation", *Astron. Astrophys.*, **566**, A74 (10 pages) (2014).

[14] Yoshimasa Watanabe, Nami Sakai, Kazuo Sorai, and Satoshi Yamamoto, "Spectral Line Survey toward Spiral Arm of M51 in the 3 mm and 2 mm Bands", *Astrophys. J.*, **788**, 4 (20 pages) (2014).

[15] Nami Sakai, Yoko Oya, Takeshi Sakai, Yoshimasa Watanabe, Tomoya Hirota, Cecilia, Ceccarelli, Claudine Kahane, Ana Lopez-Sepulcre, Bertrand Lefloch, Charlotte Vastel, Sandrine Bottinelli, Emmanuel Caux, Audrey Coutens, Yuri Aikawa, Shigehisa Takakuwa, Nagayoshi Ohashi, His-Wei Yen, and Satoshi Yamamoto, "A Chemical View of Protostellar Disk Formation in L1527", *Astrophys. J.*, **791**, L38 (5 pages) (2014).

[16] Takahiro Yanagida, Takeshi Sakai, Tomoya Hirota, Nami Sakai, Jonathan B. Foster, Patricio Sanhueza, James M. Jackson, Kenji Furuya, Yuri Aikawa, and Satoshi Yamamoto, "ALMA Observations of the IRDC Clump G34.43+00.24 MM3: 278 GHz Class I Methanol Masers", *Astrophys. J.*, **794**, L10 (6 pages) (2014).

[17] Yoko Oya, Nami Sakai, Takeshi Sakai, Yoshimasa Watanabe, Tomoya Hirota, Johan, E. Lindberg, Suzanne E. Bisschop, Jes K. Jorgensen, Ewine, F. van Dishoeck, and Satoshi Yamamoto, "A Substellar-Mass Protostar and Its Outflow of IRAS15398-3359 Revealed by Subarcsecond Resolution Observations of H_2CO and CCH", *Astrophys. J.*, **795**, 152 (9 pages) (2014).

[18] Tatsuya Soma, Nami Sakai, Yoshimasa Watanabe, and Satoshi Yamamoto, "Methanol in the Starless Core, Taurus Molecular Cloud-1", *Astrophys. J.*, **802**, 74 (9 pages) (2015).

[19] Tatsuya Shiino, Ryuta Furuya, Tatsuya Soma, Yoshimasa Watanabe, Y., Takeshi Sakai, Ling Jiang, Hiroyuki Maezawa, Tetsuya Yamakura, Nami Sakai, and Satoshi Yamamoto, "Low-Noise 1.5 THz Waveguide-Type Hot-Electron Bolometer Mixers Using Relatively Thick NbTiN Superconducting Film", *Japan. J. Appl. Phys.*, **54**, 033101 (5 pages) (2015).

[20] Takeshi Sakai, Nami Sakai, Kenji Furuya, Yuri Aikawa, Tomoya Hirota, Jonathan B. Foster, Patricio Sanhueza, James M. Jackson, and Satoshi Yamamoto, "ALMA Observations of the IRDC Clump G34.43+00.24 MM3: DNC/HNC Ratio", *Astrophys. J.*, **803**, 70 (9 pages) (2015).

[21] Kento Yoshida, Nami Sakai, Tomoya Tokudome, Ana Lopez-Sepulcre, Yoshimasa Watanabe, Shuro Takano, Bertrand Lefloch, Cecilia Ceccarelli, Rafael Bachiller, Emmanuel Caux, Charlotte Vastel, and Satoshi Yamamoto, "Abundance Anomaly of the ^{13}C Isotopic Species of c-C_3H_2 in the Low-mass Star Formation Region L1527", *Astrophys. J.*, **807**, 66 (9 pages) (2015).

[22] Yoshimasa Watanabe, Nami Sakai, Ana Lopez-Sepulcre, Ryuta Furuya, Takeshi Sakai, Tomoya Hirota, Sheng-Yuan Liu, Yu-Nung Su, and Satoshi Yamamoto, "Spectral Line Survey toward the Young Massive Protostar NGC 2264 CMM3 in the 4 mm, 3 mm, and 0.8 mm Bands", *Astrophys. J.*, **809**, 162 (48 pages) (2015).

[23] Yoko Oya, Nami Sakai, Bertrand Lefloch, Ana Lopez-Sepulcre, Yoshimasa Watanabe, Cecilia Ceccarelli, and Satoshi Yamamoto, "Geometric and Kinematic Structure of the Outflow/Envelope System of L1527 Revealed by Subarcsecond-resolution Observation of CS", *Astrophys. J.*, **812**, 59 (12 pages) (2015).

[24] J.E. Lindberg, J.K. Jorgensen, Y. Watanabe, S.E. Bisschop, N. Sakai, S. Yamamoto, "Probing the Effects of External Irradiation on Low-mass Protostars through Unbiased Line Surveys", *Astron. Astrophys.*, **584**, A28 (84 pages) (2015).

[25] Yuji Ebisawa, Hiroshi Inokuma, Nami Sakai, Karl M. Menten, Hiroyuki Maezawa, and Satoshi Yamamoto, "OH 18 cm Transition as a Thermometer for Molecular Clouds", *Astrophys. J.*, **815**, 13 (9 pages) (2015).

[26] Yoshito Shimajiri, Takeshi Sakai, Yoshimi Kitamura, Takashi Tsukagoshi, Masao Saito, Fumitaka Nakamura, Munetake Momose, Shigehisa Takakuwa, Takahiro Yamaguchi, Nami Sakai, Satoshi Yamamoto and Ryohei Kawabe, "Spectral-line Survey at Millimeter and Submillimeter Wavelengths toward an Outflow-shocked Region, OMC 2-FIR 4", *Astrophys. J. Suppl.*, **221**, 31 (31 pages) (2015).

[27] Kotomi Taniguchi, Hiroyuki Ozeki, Masao Saito, Nami Sakai, Fumitaka Nakamura, Seiji Kameno, Shuro Takano, and Satoshi Yamamoto, "Implication of Formation Mechanisms of HC_5N in TMC-1 as Studied by ^{13}C Isotopic Fractionation", *Astrophys. J.*, **817**, 147 (7 pages) (2016).

[28] Yuri Nishimura, Takashi Shimonishi, Yoshimasa Watanabe, Nami Sakai, Yuri Aikawa, Akiko Kawamura, and Satoshi Yamamoto, "Spectral Line Survey toward Molecular Clouds in the Large Magellanic Cloud", *Astrophys. J.*, **818**, 161 (17 pages) (2016).

[29] Yoshimasa Watanabe, Nami Sakai, Kazuo Sorai, Junko Ueda, and Satoshi Yamamoto, "Molecular Distribution in the Spiral Arm of M51", *Astrphys. J.*, **819**, 144 (11 pages) (2016).

[30] Nami Sakai, Yoko Oya, Ana Lopez-Sepulcre, Yoshimasa Watanabe, Takeshi Sakai, Tomoya Hirota, Yuri Aikawa, Cecilia Ceccarelli, Bertrand Lefloch, Emmanuel Caux, Charlotte Vastel, Claudine Kahane, and Satoshi Yamamoto, "Subarcsecond Analysis of the Infalling-Rotating Envelope around the Class I Protostar IRAS 04365+2535", *Astrophysical Journal*, **820**, L34 (6 pages) (2016).

[31] Ana Lopez-Sepulcre, Yoshimasa Watanabe, Nami Sakai, Ryuta Furuya, Osamu Saruwatari, and Satoshi Yamamoto, "The Role of SiO as a Tracer of Past Star-formation Events: The Case of the High-mass Protocluster NGC 2264-C", *Astrophys. J.*, **822**, 85 (14 pages) (2016).

[32] Yoko Oya, Nami Sakai, Ana Lopez-Sepulcre, Yoshimasa Watanabe, Cecilia Ceccarelli, Bertrand Lefloch, Cecile Favre, and Satoshi Yamamoto, "Infalling-Rotating Motion and Associated Chemical Change in the Envelope of IRAS 16293-2422 Source A Studied with ALMA", *Astrophys. J.*, **824**, 88 (19 pages) (2016).

[33] Yuri Nishimura, Takashi Shimonishi, Yoshimasa Watanabe, Nami Sakai, Yuri Aikawa, Akiko Kawamura, and Satoshi Yamamoto, "Spectral Line Survey toward a Molecular Cloud in IC10", *Astrophys. J.*, **829**, 94 (8 pages) (2016).

[34] Muneaki Imai, Nami Sakai, Yoko Oya, Ana Lopez-Sepulcre, Yoshimasa Watanabe, Cecilia Ceccarelli, Bertrand Lefloch, Emmanuel Caux, Charlotte Vastel, Claudine Kahane, Takeshi Sakai, Tomoya Hirota, Yuri Aikawa, and Satoshi Yamamoto, "Discovery of a Hot Corino in the Bok Globule B335", *Astrophys. J.*, **830**, L37 (7 pages) (2016).

[35] Mitsunori Araki, Shuro Takano, Nami Sakai, Satoshi Yamamoto, Takahiro Oyama, Nobuhiko Kuze, and Koichi Tsukiyama, "Precise Observations of the $^{12}C/^{13}C$ Ratios of HC_3N in the Low-mass Star-forming Region L1527", *Astrophys. J.*, **833**, 291 (9 pages) (2016).

[36] Yoko Oya, Nami Sakai, Yoshimasa Watanabe, Aya E. Higuchi, Tomoya Hirota, Ana Lopez-Sepulcre, Takeshi Sakai, Yuri Aikawa, Cecilia Ceccarelli, Bertrand Lefloch, Emmanuel Caux, Charlotte Vastel, Claudine Kahane, and Satoshi Yamamoto, "L483: Warm Carbon-chain Chemistry Source Harboring Hot Corino Activity", *Astrophys. J.*, **837**, 174, (15 pages) (2017).

[37] Aya E. Higuchi, Aki Sato, Takashi Tsukagoshi, Nami Sakai, Kazunari Iwasaki, Munetake Momose, Hiroshi Kobayashi, Daisuke Ishihara, Sakae Watanabe, Hidehiro Kaneda, and Satoshi Yamamoto, "Detection of Submillimeter-wave [C I] Emission in Gaseous Debris Disks of 49 Ceti and β Pictoris", *Astrophys. J.*, **839**, L14 (6 pages) (2017).

[38] Nami Sakai, Yoko Oya, Aya E. Higuchi, Yuri Aikawa, Tomoyuki Hanawa, Cecilia Ceccarelli, Bertrand Lefloch, Ana Lopez-Sepulcre, Yoshimasa Watanabe, Takeshi Sakai, Tomoya Hirota, Emmanuel Caux, Charlotte Vastel, Claudine Kahane, and Satoshi Yamamoto, "Vertical Structure of the Transition Zone from Infalling Rotating Envelope to Disc in the Class 0 Protostar, IRAS 04368+2557", *Mon. Not. R. Astron. Soc.*, **467**, L76-L80 (2017).

[39] Yoshimasa Watanabe, Yuri Nishimura, Nanase Harada, Nami Sakai, Takashi Shimonishi, Yuri Aikawa, Akiko Kawamura, and Satoshi Yamamoto, "Molecular-cloud-scale Chemical Composition. I. A Mapping Spectral Line Survey toward W51 in the 3 mm Band", *Astrophys. J.*, **845**, 116 (30 pages) (2017).

[40] Mitsunori Araki, Shuro Takano, Nami Sakai, Satoshi Yamamoto, Takahiro Oyama, Nobuhiko Kuze, and Koichi Tsukiyama, "Long Carbon Chains in the Warm Carbon-chain-chemistry Source L1527: First Detection of C7H in Molecular Clouds", *Astrophys. J.*, **847**, 51 (7 pages) (2017).

[41] A. Lopez-Sepulcre, N. Sakai, R. Neri, M. Imai, Y. Oya, C. Ceccarelli, A.E. Higuchi, Y. Aikawa, S. Bottinelli, E. Caux, T. Hirota, C. Kahane, B. Lefloch, C. Vastel, Y. Watanabe, and S. Yamamoto, "Complex Organics in IRAS 4A Revisited with ALMA and PdBI: Striking Contrast between Two Neighbouring Protostellar Cores", *Astron. Astrophys.*, **606**, A121 (12 pages) (2017).

[42] Yoshimasa Watanabe, Nami Sakai, Ana Lopez-Sepulcre, Takeshi Sakai, Tomoya Hirota, Sheng-Yuan Liu, Yu-Nung Su, and Satoshi Yamamoto, "Discovery of Striking Difference of Molecular-emission-line Richness in the Potential Proto-binary System NGC 2264 CMM3", *Astrophys. J.*, **847**, 108 (8 pages) (2017).

[43] Yuri Nishimura, Yoshimasa Watanabe, Nanase Harada, Takashi Shimonishi, Nami Sakai, Yuri Aikawa, Akiko Kawamura, and Satoshi Yamamoto, "Molecular-cloud-scale Chemical Composition. II. Mapping Spectral Line Survey toward W3(OH) in the 3 mm Band", *Astrophys. J.*, **848**, 17 (18 pages) (2017).

[44] Yoko Oya, Kana Moriwaki, Shunsuke Onishi, Nami Sakai, Ana Lopez-Sepulcre, Cecile Favre, Yoshimasa Watanabe, Cecilia Ceccarelli, Bertrand Lefloch, and Satoshi Yamamoto, "Chemical and Physical Picture of IRAS 16293-2422 Source B at a Sub-arcsecond Scale Studied with ALMA", *Astrophys. J.*, **854**, 96 (19 pages) (2018).

[45] Tatsuya Soma, Nami Sakai, Yoshimasa Watanabe, and Satoshi Yamamoto, "Complex Organic Molecules in Taurus Molecular Cloud-1", *Astrophys. J.*, **854**, 116 (11 pages) (2018).

[46] Takeshi Sakai, Takahiro Yanagida, Kenji Furuya, Yuri Aikawa, Patricio Sanhueza, Nami Sakai, Tomoya Hirota, James M. Jackson, and Satoshi Yamamoto, "ALMA Observations of the IRDC Clump G34.43+00.24 MM3: Complex Organic and Deuterated Molecules", *Astrophys. J.*, **857**, 35 (11 pages) (2018).

[47] Elizabeth Artur de la Villarmois, Lars E. Kristensen, Jes K. Jorgensen, Edwin A. Bergin, Christian Brinch, Soren Frimann, Daniel Harsono, Nami Sakai, and Satoshi Yamamoto, "Chemistry of a Newly Detected Circumbinary Disk in Ophiuchus", *Astron. Astrophys.*, **614**, A26 (18 pages) (2018).

[48] Aya E. Higuchi, Nami Sakai, Yoshimasa Watanabe, Ana Lopez-Sepulcre, Kento Yoshida, Yoko Oya, Muneaki Imai, Yichen Zhang, Cecilia Ceccarelli, Bertrand Lefloch, Claudio Codella, Rafael Bachiller, Tomoya Hirota, Takeshi Sakai, and Satoshi Yamamoto, "Chemical Survey toward Young Stellar Objects in the Perseus Molecular Cloud Complex", *Astrophys. J. Suppl.*, **236**, 52 (25 pages) (2018).

[49] K. Furuya, Y. Watanabe, T. Sakai, Y. Aikawa, and S. Yamamoto, "Depletion of ^{15}N in the Center of L1544: Early Transition from Atomic to Molecular Nitrogen?", *Astron. Astrophys.*, **615**, L16 (5 pages) (2018).

[50] Takashi Shimonishi, Yoshimasa Watanabe, Yuri Nishimura, Yuri Aikawa, Satoshi Yamamoto, Takashi Onaka, Nami Sakai, and Akiko Kawamura, "A Multiline Study of a High-mass Young Stellar Object in the Small Magellanic Cloud with ALMA: The Detection of Methanol Gas at 0.2 Solar Metallicity", *Astrophys. J.*, **862**, 102 (14 pages) (2018).

[51] Yoko Oya, Nami Sakai, Yoshimasa Watanabe, Ana Lopez-Sepulcre, Cecilia Ceccarelli, Bertrand Lefloch, and Satoshi Yamamoto, "Sub-arcsecond Kinematic Structure of the Outflow in the Vicinity of the Protostar in L483", *Astrophys. J.*, **863**, 72 (14 pages) (2018).

[52] Yichen Zhang, Aya E. Higuchi, Nami Sakai, Yoko Oya, Ana Lopez-Sepulcre, Muneaki Imai, Takeshi Sakai, Yoshimasa Watanabe, Cecilia Ceccarelli, Bertrand Lefloch, and Satoshi Yamamoto, "Rotation in the NGC 1333 IRAS 4C Outflow", *Astrophys. J.*, **864**, 76 (11 pages) (2018).

[53] Yuki Okoda, Yoko Oya, Nami Sakai, Yoshimasa Watanabe, Jes K. Jorgensen, Ewine F. van Dishoeck, and Satoshi Yamamoto, "The Co-evolution of Disks and Stars in Embedded Stages: The Case of the Very-low-mass Protostar IRAS 15398-3359", *Astrophys. J.*, **864**, L25 (7 pages) (2018).

[54] Muneaki Imai, Nami Sakai, Ana Lopez-Sepulcre, Aya E. Higuchi, Yichen Zhang, Yoko Oya, Yoshimasa Watanabe, Takeshi Sakai, Cecilia Ceccarelli, Bertrand Lefloch, and Satoshi Yamamoto, "Deuterium Fractionation Survey Toward Protostellar Sources in the Perseus Molecular Cloud: HNC Case", *Astrophys. J.*, **869**, 51 (26 pages) (2018).

[55] Yuji Ebisawa, Nami Sakai, Karl M. Menten, and Satoshi Yamamoto, "The Effect of Far-infrared Radiation on the Hyperfine Anomaly of the OH 18 cm Transition", *Astrophys. J.*, **871**, 89 (28 pages) (2019).

[56] Nami Sakai, Tomoyuki Hanawa, Yichen Zhang, Aya E. Higuchi, Satoshi Ohashi, Yoko Oya, and Satoshi Yamamoto, "A warped disk around an infant protostar", *Nature*, **565**, 206-208 (2019).

[57] Kento Yoshida, Nami Sakai, Yuri Nishimura, Tomoya Tokudome, Yoshimasa Watanabe, Takeshi Sakai, Shuro Takano, and Satoshi Yamamoto, "An unbiased spectral line survey observation toward the low-mass star-forming region L1527", *Publ. Astron. Soc. Japan*, in press.

[58] Nanase Harada, Yuri Nishimura, Yoshimasa Watanabe, Satoshi Yamamoto, Yuri Aikawa, Nami Sakai, and Takashi Shimonishi, "Molecular-cloud-scale Chemical Composition. III. Constraints of Average Physical Properties through Chemical Models", *Astrophys. J.*, **871**, 238 (25 pages) (2019).

[59] Muneaki Imai, Yoko Oya, Nami Sakai, Ana Lopez-Sepulcre, Yoshimasa Watanabe, and Satoshi Yamamoto, "Unveiling a Few Astronomical Unit Scale Rotation Structure around the Protostar in B335", *Astrophys. J.*, **873**, L21 (7 pages) (2019).

[60] Shogo Tachibana, Takafumi Kamizuka, Tomoya Hirota, Nami Sakai, Yoko Oya, Aki Takigawa, and Satoshi Yamamoto, "Spatial Distribution of AlO in a High-mass Protostar Candidate Orion Source I", *Astrophys. J.*, **875**, L29 (4 pages) (2019).

[61] Yoshimasa Watanabe, Yuri Nishimura, Kazuo Sorai, Nami Sakai, Nario Kuno, and Satoshi Yamamoto, "A 3 mm Spectral Line Survey toward the Barred Spiral Galaxy NGC 3627", *Astrophys. J. Suppl.*, **242**, 26 (21 pages) (2019).

[62] Yuri Nishimura, Yoshimasa Watanabe, Nanase Harada, Kotaro Kohno, and Satoshi Yamamoto, "Molecular Gas Density Measured with H_2CO and CS toward a Spiral Arm of M51", *Astrophys. J.*, **879**, 65 (10 pages) (2019).

< Review Papers >

[63] Nami Sakai and Satoshi Yamamoto, "Warm Carbon-Chain Chemistry", *Chem. Rev.*, **113**, 8981-9015 (2013).

< Books >

[64] Satoshi Yamamoto, "Introduction to Astrochemistry: Chemical Evolution from Interstellar Clouds to Star and Planet Formation", Springer (2017).

7 Invited Presentations at International Conferences

[1] Satoshi Yamamoto, Nami Sakai, and Yoshimasa Watanabe, "Chemical Diagnostics of the Early Phase of Star Formation", Early Phase of Star Formation 2012, (Lindberg Castle, Germany, 2012).

[2] Satoshi Yamamoto, Nami Sakai, and Yoshimasa Watanabe, "Chemical Diversity in Low-Mass Star Forming Regions", Astrochemistry in the ALMA Era, (Copenhagen, Denmark, 2013).

[3] Satoshi Yamamoto and Nami Sakai, "Carbon-Chain Molecules in Astrophysics", Symposium on Advanced Molecular Spectroscopy, (Tokyo, 2015).

[4] Satoshi Yamamoto, "Chemical Tracers of Dynamics in Low-mass Protostellar Objects", IAU Symposium 332 Astrochemistry VII, (Puerto Varas, Chile, 2017).

[5] Satoshi Yamamoto, Yoko Oya, and Nami Sakai, "Chemical Evolution and Its Diversity in Disk Forming Regions", 703. WE-Heraeus-Seminar: Chemical Evolution of Cosmic Matter, (Bad Honnef, Germany).

8 Teaching Accomplishment

- Yoko Oya: 東京大学総長賞 (2018)
- Yoko Oya: 井上研究奨励賞（2018）
- Yuki Okoda: BBC が選ぶ今年の女性 100 人 (2018)
- Yuki Okoda: Forbes Asia: 30 歳以下 30 人 (科学、健康部門)(2019)

9 Contribution to Academic Community

- Supervisory Board, H2020 EC MARIE SK?ODOWSKA-CURIE ACTION ‘ Astrochemical Origin ’ (2018-)

9.1 Editorial Activities

- Editor, Molecular Astrophysics (Elsevier)

9.2 Organization and Advisory of Conferences

- SOC of IAU Symposium 332 Astrochemistry VII (2017)
- SOC of Early Phase of Star Formation 2018

10 Outreach

11 Committee Service

11.1 External Committees

日本学術振興会　学術システム研究センター　主任研究員　2012 年—2018 年
文部科学省　科学技術・学術審議会　学術分科会　臨時委員　2017 年—

11.2 University Committees

理学系研究科副研究科長　2016 年 –2018 年
理学系研究科物理学専攻長　2018 年 –

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	0	
Doctor Course	0	
Foreign researchers hosted	1	France
Students sent abroad	5	USA, France, Germany
Researchers sent abroad	0	
Foreign visitors	3	USA, France, Denmark

Naoki Yoshida、吉田 直紀

1 Education and Professional Experiences

Education

1996	B.S. (Aerospace Engineering)	The University of Tokyo
1998	MSc. (Aerospace Engineering)	The University of Tokyo
1998	Tekn. Lic. (Applied Math)	Royal Institute of Technology of Sweden
2002	Ph.D. (Astronomy)	Ludwig-Maximilians-Universität München

Professional Appointments

2004−2008	Assistant Professor	Department of Physics, Nagoya University
2008−2012	Project Associate Professor	Kavli IPMU (WPI), The University of Tokyo
2012−	Professor	Department of Physics, The University of Tokyo

2 Research Highlights

Theoretical Astrophysics group has been exploring a variety of research topics including observational cosmology and time-domain astronomy. Recent research highlights are mostly studies by our PhD students: (1) We developed a novel theoretical model for rapid transients originating from thermonuclear explosions of white dwarf stars around massive blackholes, (2) We identified a viable formation model of massive blackholes via runaway stellar collisions in dense star clusters, (3) We derived the metallicity dependence of the lifetimes of proto-planetary disks via photo-evaporation processes, (4) We proposed a theoretical model and observational tests of super-luminous supernovae powered by young neutron stars, and (5) We proposed and measured the spatial cross-correlation of the extra-galactic γ-ray background with the large-scale matter distribution to probe and constrain the particle nature of dark matter.

Our members actively make proposals for observations of distant galaxies and galaxy clusters using large optical and radio telescopes, and also use data from Subaru Hyper-Suprime-Cam (HSC) galaxy imaging survey together with other cosmological observations such as cosmic microwave background anisotropies by Planck satellite. Since 2014, I have been also leading astrophysics/cosmology researches utilizing modern machine learning and deep learning. Working together with computer scientists, math and statistics experts, we analyze big astronomical imaging data from Subaru-HSC survey. Our novel machine learning method enables us to detect thousands of distant supernovae over fifty nights. Our newly developed statistical method based on sparsity prior modelling allows us to reconstruct the large-scale matter distribution in the universe through analysis of weak gravitational lensing. We have explored modern techniques based on generative adversarial networks for noise reduction and for information extraction from large astronomical images. I list in the next section our notable scientific results that have been published as refereed papers.

3 Selected Papers

- ”Supersonic gas streams enhance the formation of massive blackholes in the early universe”, Hirano, S, Hosokawa, T., Yoshida, N., Kuiper, R, *Science*, 357, 1375 (2017)
  This work proposes a novel formation mechanism of massive blackholes from cosmological initial conditions.

- ”Single-epoch supernova classification with deep convolutional neural networks”, Kimura, A., Takahashi, I., Tanaka, M., Yasuda, N., Ueda, N., Yoshida, N., Proceedings of the 37th IEEE International Conference on Distributed Computing (2017)
  This paper presents a fast and efficient method of supernova classification by deep learning.

- ”Cross correlation of cosmic shear and extragalactic gamma-ray background: Constraints on the dark matter annihilation cross section”,
  Shirasaki, M., Horiuchi, S., Yoshida, N., Physical Review D., 90, 3502 (2014)
  This presents the first measurement of the cosmic mass density and the gamma-ray emission cross-correlation, to place constraints on the particle nature of dark matter.

- ”One Hundred First Stars: Protostellar Evolution and the Final Masses”,
  Hirano, S., Hosokawa, T., Yoshida, N., Umeda, H., Omukai, K., Chiaki, G., Yorke, H., The Astrophysical Journal, 781, 60
  This paper, together with a companion paper, showed the mass distribution of the first generation of stars in the universe, for the first time, and has been cited 400 times.

4 Honors, Awards and Professional Society Memberships

2017 Japan Academy Medal
2017 Japan Society of Promotion of Science Prize
2015 Georgia Institute of Technology CRA Distinguished Lecture

5 Research Plan

Our group pursues a number of topics in theoretical astrophysics from black hole formation to time domain astronomy, from evolution of proto-planetary disks to the particle nature of dark matter. The goal is to understand the formation and evolution of astronomical objects in the cosmological context. We primarily use super-computer simulations, but often analyze observational data from wide-field sky surveys. We plan to use the next-generation Fugaku computer, a national flagship supercomputer, to perform numerical simulations of cosmic structure formation, formation of stars and blackholes, and of high-energy astrophysical phenomena such as supernovae and tidal disruption of stars. We use novel numerical techniques such as direct integration of the Boltzmann equation in six-dimensional phase space. A specific science goal is to perform fine calculations of the distribution of cosmic relic neutrinos and to study the effect on the dark matter/galaxy distribution in the universe. By comparing the results from such fully nonlinear calculations with observations, one can constrain or infer the total mass of neutrinos, We also utilize modern statistical methods and machine learning/AI to analyze data from future galaxy surveys and cosmic microwave background observations. Of particular interest is the so-called intensity mapping observations, both in infrared and submillimeter wave bands. An intensity map contains an enormously rich but mixed information on the distribution of matter, gas, stars and galaxies. We plan to use machine-learning/deep-learning to analyze the complex data to be obtained from NASA's SPHEREx satellite.

6 Publications and Patents

< Refereed Original Papers >

[1] "Spiral arm instability - III. Fragmentation of primordial protostellar discs"
Inoue, S., Yoshida, N., 2019, Monthly Notices of the Royal Astronomical Society (MN) Letters, 490, 154

[2] "Clumpy galaxies in cosmological simulations: the effect of ISM model"
Inoue, S., Yoshida, N., 2019, MN, 488, 4400

[3] "Correlation between the 21cm signal and [OIII] line emitters during the early cosmic reionisation"
Moriwaki, K., Yoshida, N., Eide, M., Ciardi, B., 2019, MN, 489, 2471

[4] "Spectral Energy Distribution of the First Galaxies: Contribution from Pre-Main-Sequence Stars"
Mitani, H., Yoshida, N., Hosokawa, T., Omukai, K., 2019, MN Letters, 488, 64

[5] "The Hyper Suprime-Cam SSP Transient Survey in COSMOS: Overview" Yasuda, N., et al., 2019, Publication of the Astronomical Society of Japan (PASJ), 71, 74

[6] "Denoising of Weak Lensing Maps with Deep Learning"
Shirasaki, M., Yoshida, N., Ikeda, S., 2019, Phys. Rev. D. (PRD) 100, 3527

[7] "Dark Quest I. Fast and Accurate Emulation of Halo Clustering Statistics and its Application to Galaxy Clustering"
Nishimichi, T.. et al., 2019, The Astrophysical Journal (ApJ), 884, 29

[8] "Detection of the Far-Infrared [OIII] and Dust Emission in a Galaxy at Redshift 8.312"
Tamura, Y. et al., 2019, ApJ, 874, 27

[9] "Formation of Carbon-Enhanced Metal-Poor Stars as a Consequence of Inhomogeneous Metal Mixing"
Hartwig, T., Yoshida, N., 2019, ApJ, 870, 3

[10] "Photoevaporation of Molecular Gas Clumps Illuminated by External Massive Stars"
Nakatani, R., Yoshida, N., 2019, ApJ, 883, 127

[11] "Growth of Intermediate-Mass Black Holes by Tidal Disruption Events in the First Star Clusters"
Sakurai, Y., Fujii, M., Yoshida, N., 2019, MN, 484, 4665

[12] "Spiral Arm Instability II: Magnetic Destabilization"
Inoue, S., Yoshida, N., 2019, MN, 485, 3024

[13] "Fingerprint of the First Stars: Multi-Enriched Extremely Metal-Poor Stars in the TOPoS Survey"
Hartwig, T., Ishigaki, M., Yoshida, N., Klessen, R., 2019, MN, 482, 1204

[14] "Radiation Hydrodynamics Simulations of Photoevaporation of Protoplanetary Disks II: Metallicity Dependence of UV and X-ray Photoevaporation"
Nakatani, R., Hosokawa, T., Nomura, H., Yoshida, N., Kuiper, R., 2018, ApJ, 865, 75

[15] "The Distribution and Physical Properties of [OIII] Emitters in a Cosmological Hydrodynamics Simulation"
Moriwaki, K., Yoshida, N., Shimizu, I., Harikane, Y., Matsuda, Y., Hashimoto, T. et al., 2018, MN Letters, 481, 84

[16] "The Onset of Star Formation 250 Million Years After the Big Bang"
Hashimoto, T. et al., 2018, Nature, 557, 392

[17] "The Cross-Correlation of Extragalactic γ-Rays with Matter Density Distributions from Weak Gravitational Lensing",
Shirasaki, M., Macias, O., Horiuchi, S., Yoshida, N., 2018, PRD, 97, 123015

[18] "Descendants of the First Stars: The Distinct Chemical Signature of Second Generation Stars"
Hartwig T., Yoshida, N., et al., 2018, MN, 478, 1795

[19] "Tidal Disruption of a White Dwarf by a Blackhole: The Diversity of Nucleosynthesis, Explosion Energy, and the Fate of Debris Streams"
Kawana, K., Tanikawa, A., Yoshida, N., 2018, MN, 477, 3449

[20] "Radiation Hydrodynamics Simulations of Photoevaporation of Protoplanetary Disks by Ultra-Violet Radiation: Metallicity Dependence"
Nakatani, R., Hosokawa, T., Nomura, H., Yoshida, N., 2018, ApJ, 857, 57

[21] "Formation of the First Star Clusters and Massive Star Binaries by Fragmentation of Filamentary Primordial Gas Clouds"
Hirano, S., Yoshida, N., Sakurai, Y., Fujii, M., 2018, ApJ, 855, 17

[22] "Radiation Hydrodynamics Simulations of the Formation of Direct-Collapse Supermassive Stellar Systems"
Chon, S., Hosokawa, T., Yoshida, N., 2018, MN, 475, 4104

[23] "Investigating Cluster Astrophysics and Cosmology with Cross-Correlation of the Sunyaev-Zeldovich Effect and Weak Lensing"
Osato, K., Flender, S., Nagai, D., Shirasaki, M., Yoshida, N., 2018, MN, 475, 532

[24] "Supersonic Gas Streams Enhance the Formation of Massive Blackholes in the Early Universe"
Hirano, S., Hosokawa, T., Yoshida, N., R. Kuiper, 2017, Science, 357, 1375

[25] "Spiral Arm Instability: Giant Clump Formation via Fragmentation of a Galactic Spiral Arm"
Inoue, S., Yoshida, N., 2018, MN, 474, 3466

[26] "Formation of Intermediate-Mass Black Holes through Runaway Collisions in the First Star Clusters"
Sakurai, Y., Fujii, M., Yoshida, N., Hirano, S., 2017, MN, 472, 1677

[27] "Multi-Dimensional Vlasov-Poisson Simulations with High-Order Monotonicity and Positivity Preserving Schemes"
Tanaka, S., Yoshikawa, K., Minoshima, T., Yoshida, N., 2017, ApJ, 849, 76

[28] "Probing the Shape and Internal Structure of Dark Matter Halos with the Halo-Shear-Shear Three-Point Correlation"
Shirasaki, M., Yoshida, N., 2018, MN, 475, 1665

[29] "Effects of electrically charged dark matter on cosmic microwave background anisotropies"
Kamada, A., Takahashi, T., Kohri, K., Yoshida, N., 2017, PRD, 95, 023502

[30] "Large-Scale Clustering as a Probe of the Origin and the Host Environment of Fast Radio Bursts"
Shirasaki, M., Kashiyama, K., Yoshida, N., 2017, PRD, 95, 3012

[31] "ALMA Deep Field in SSA22: Blindly Detected CO Emitters and [CII] Emitter Candidates"
Hayatsu, N., Matsuda, Y., Umehata, H., Yoshida, N., Smail, I., Swinbank, A., et al., 2017, PASJ, 69, 45

[32] "The final fates of accreting supermassive stars"
Umeda, H., Hosokawa, T., Omukai, K., Yoshida, N., 2016, 830, ApJ, L34

[33] "Cosmological Simulations of Early Blackhole Formation: Halo Mergers, Tidal Disruption, and the Conditions for Direct Collapse"
Chon, S., Hirano, S., Hosokawa, T., Yoshida, N., 2016, ApJ, 832, 134

[34] "Machine-learning Selection of Optical Transients in Subaru/Hyper Suprime-Cam"
Morii, M., et al. 2016, PASJ, 68, 104

[35] "Cosmological Constraints on Dark Matter Annihilation and Decay: Cross-Correlation of the Extragalactic γ-Ray Background and Cosmic Shear",
Shirasaki, M., Macias, O., Horiuchi, S., Shirai, S., Yoshida, N., 2016, PRD, 94, 3522

[36] "Detection of an oxygen emission line from a high redshift galaxy in the reionization epoch"
Inoue, A. K., Tamura, Y., Matsuo, H., Mawatari, K., Shimizu, I., Shibuya, T., Ota, K., Yoshida, N. et al., 2016, Science, 352, 1559

[37] "The Hydrodynamic Feedback of Cosmic Reionization on Small-Scale Structures and Its Impact on Photon Consumption during the Epoch of Reionization"
Park, H., Shapiro, P., Choi, J., Yoshida, N., Hirano, S., Ahn, K., 2016, ApJ, 831, 86

[38] "Matter Power Spectrum in Hidden Neutrino Interacting Dark Matter Models: A Closer Look at the Collision Term"
Binder, T., Covi, L., Kamada, A., Murayama, H., Takahashi, T., Yoshida, N., 2016, JCAP, 11, 043

[39] "Cosmological Constraint on the Mass of Light Gravitino from CMB Lensing and Cosmic Shear"
Osato, K., Sekiguchi, T., Shirasaki, M., Kamada, A., Yoshida, N., 2016, JCAP, 06, 004

[40] "The Subaru FMOS galaxy redshift survey (FastSound). IV: New constraint on gravity theory from redshift space distortions at z=1.4",
Okumura, T., et al., 2016, PASJ, 68, 38

[41] "Supermassive Star Formation via Episodic Accretion",
Sakurai, Y., Vorobyov, E., Hosokawa, T., Yoshida, N., Omukai, K., Yorke, H. W., 2016, MN, 459, 1137

[42] "Gravitational Collapse and the Thermal Evolution of Low-Metallicity Gas Clouds",
Chiaki, G., Hirano, S., Yoshida, N., 2016, MN, 463, 2781

[43] "Formation of Massive Primordial Stars: Intermittent UV Feedback with Episodic Mass Accretion",
Hosokawa, T., Hirano, S., Kuiper, R., Yorke, H. W., Omukai, K., Yoshida, N., 2016, ApJ, 824, 119

[44] "Nebular Line Emission from $z > 7$ Galaxies in Cosmological Simulations",
Shimizu, I., Inoue, A. K., Okamoto, T., Yoshida, N., 2016, MN, 461, 3563

[45] "Probing Cosmology with Weak Lensing Selected Clusters II",
Shirasaki, M., Hamana, T., Yoshida, N., 2016, PASJ, 68, 4

[46] "Formation of primordial supermassive stars by burst accretion",
Sakurai, Y., Hosokawa, T., Yoshida, N., Yorke, H. W., MN, 2015, 452, 755

[47] "Particle Splitting in Smoothed Particle Hydrodynamics Based on Voronoi Diagram",
Chiaki, G., Yoshida, N., MN, 2015, 451, 3955

[48] "Probing Cosmology with Weak Lensing Selected Clusters I",
Shirasaki, M., Hamana, T., Yoshida, N., MN, 2015, 453, 3043

[49] "Early Structure Formation from Density Fluctuations with a Blue-Tilted Power Spectrum",
Hirano, S., Zhu, N., Yoshida, N., Spergel, D. N, Yorke, H. W., 2015, ApJ, 814, 18

[50] "Impact of Baryonic Processes on Weak Lensing Cosmology"
Osato, K., Shiarasaki, M., Yoshida, N., ApJ, 2015, 806, 186

[51] "Primordial Star Formation Under the Influence of Far Ultra-Violet Radiation"
S. Hirano, T. Hosokawa, Yoshida, N., K. Omukai, H. W. Yorke., 2015, MN, 448, 568

[52] "Supernova dust formation and the grain growth in the early universe: The Critical Metallicity for Low-Mass Star Formation"
Chiaki, G., Nozawa, T., Yoshida, N., Marassi, S., Schneider, R., Omukai, K., Limongi, M., Chieffi, A., MN, 2015, 446, 2659

[53] "The Origin of the Most Iron-Poor Star"
Marrasi, S., Chiaki, G., Schneider, R., Nozawa, T., Omukai, K., Limongi, M., Chieffi, A., Yoshida, N., 2014 ApJ, 794, 100

[54] "Cross-Correlation of Cosmic Shear and the Extragalactic γ-Ray Background: Constraints on the Dark Matter Annihilation Cross-Section"
Shirasaki, M., Horiuchi, S., Yoshida, N., 2014, PRD, 90, 3502

[55] "Reproducing the Cosmic Evolution of Galaxy Population from $z = 4$ to 0"
Okamoto, T., Shimizu, I., Yoshida, N., 2014, PASJ, 66, 70

[56] “Weighing the Light Gravitino Mass with Weak Lensing Surveys”
Kamada, A., Shirasaki, M., Yoshida, N., 2014, JHEP, 162

[57] “On the Systematic Errors in Cosmological-Scale Gravity Tests using Redshift Space Distortion: Nonlinear Clustering and the Halo Bias”
Ishikawa, T., Totani, T., Nishimichi, T., Yoshida, N., Takahashi, R., Tonegawa, M., 2014, MN, 443, 3359

[58] “The Dark Ages of the Universe and Hydrogen Reionization”
Natarajan, A., Yoshida, N., 2014, PTEP, 06B112

[59] “Statistical and Systematic Errors in Measurement of Weak Lensing Minkowski Funtionals”
Shirasaki, M., Yoshida, N., 2014, ApJ, 786, 43

[60] “Physical Properties of UDF12 Galaxies”
Shimizu, I., Inoue, A. K., Yoshida, N., Okamoto, T., 2014, MN, 440, 731

[61] “Dust Grain Growth and the Formation of the Extremely Primitive Star SDSS J102915+172927”
Chiaki, G., Schneider, R., Nozawa, T., Omukai, K., Limongi, M., Yoshida, N., Chieffi, A., Bianchi, S., 2014, MN, 439, 3121

[62] “One Hundred First Stars: Protostellar Evolution and the Final Masses”
Hirano, S., Hosokawa, T., Yoshida, N., Yorke, H. W., Omukai, K., Chiaki, G., Umeda, H., 2014, ApJ, 781, 60

[63] “On de-Sitter Geometry in Cosmic Void Statistics”,
Gibbons, G. W., Werner, M. C., Yoshida, N., Chon, S., 2014, MN, 438, 1603

[64] “ALMA will determine the spectral redshifts of z> 8 Galaxies by OIII lines”
Inoue, A. K., Shimizu, I., Tamura, Y., Matsuo, H., Okamoto, T., Yoshida, N., 2014, ApJL, 780, L18

[65] “Formation of Primordial Supermassive Stars”
Hosokawa, T., Yorke, H. W., Omukai, K., Inayoshi, K, Yoshida, N., 2013, ApJ, 778, 178

[66] “Detectability of High-Redshift Superluminous Supernovae with Upcoming Optical and Near-Infrared Surveys II: Beyond z=6”
Tanaka, M., Moriya, T, Yoshida, N., 2013, MN, 435, 2483

[67] “Modeling Color-Dependent Galaxy Clustering in Cosmological Simulations”
Masaki, S., Lin, Y.-T., Yoshida, N., 2013, 436, 2286

[68] “Effect of Mask Regions on Weak Lensing Statistics”,
Shirasaki, M., Yoshida, N., Hamana, T., 2013, ApJ, 774, 111

[69] “Constraints on Warm Dark Matter Models from High-Redshift Long Gamma-Ray Bursts”
de Souza, R. S., Messinger, A., Ferrara, A., Yoshida, N., Haiman, Z., Perna, R., 2013, MN, 432, 3218

[70] “Structure of Dark Matter Halos in Warm Dark Matter Models and in Models with Long-Lived Charged Massive Particles”
Kamada, A., Yoshida, N., Kohri, K., Takahashi, T., JCAP, 03, 0008

[71] “Growth of Dust Grains in a Low-Metallicity Gas”
Chiaki, G., Nozawa, T., Yoshida, N., 2013, ApJ, 765, 3

[72] “The Nature of Dark Matter from High-Redshift HI 21cm Signal”
Valdes, M., Evoli, C., Messinger, A., Ferrara, A., Yoshida, N., 2013, MN, 429, 1705

[73] “Radiative Cooling Implementations in Simulations of Primordial Star Formation”,
Hirano, S., Yoshida, N., 2013, ApJ, 763, 52

[74] “Simulations of Early Baryonic Structure Formation with Stream Velocity II”
Naoz, S., Yoshida, N., Gnedin, N., 2013, ApJ, 763. 27

[75] “Direct Integration of the Collisionless Boltzmann Equation in Six-Dimensional Sphase Space”,
Yoshikawa, K., Yoshida, N., Umemura, M. 2013, ApJ, 762, 116

[76] “WIMP Dark Matter and First Stars”,
Smith, R. J., Iocco, F., Glover, S.C.O., Schleicher, D., Klessen, R., Greif, T. H., Hirano, S., Yoshida, N., 2012, ApJ, 761, 154

[77] “Protostellar Feedback and Final Mass of the Second-Generation Primordial Stars”
Hosokawa, T., Yoshida, N., Omukai, K., Yorke, H., 2012, ApJL, 760, 37

[78] “Formation of the First Stars in the Universe”,
Yoshida, N., Hosokawa, T., Omukai, K., 2012, Progress of Theoretical and Experimental Physics, 01A305

[79] “Low-mass Star Formation Triggered by Early Supernova Explosions”
Chiaki, G., Yoshida, N., Kitayama, T. 2012, ApJ, 762, 50

[80] “Light Curve Modeling of Superluminous Supernova 2006gy”,
Moriya, T.J., Blinnikov, S.I., Tominaga, N., Yoshida, N., Tanaka, M., Maeda, K., Nomoto, K., 2013, MN, 428, 1020

[81] “Sub-Millimetre Galaxies in Cosmological Hydrodynamic Simulations”
Shimizu, I., Yoshida, N., Okamoto, T. 2012, MN, 427, 2866

[82] “Probing Primordial Non-Gaussianity with Weak Lensing Minkowski Functionals”,
Shirasaki, M., Yoshida, N., Hamana, T., Nishimichi, T., 2012, ApJ, 760, 45

[83] “Formation and Evolution of Primordial Protostellar Systems”
Greif, T.H., Bromm, V., Clark, P.C., Glover, S.C.O., Smith, R.J., Klessen, R. S., Springel, V., Yoshida, N., 2012, MN, 424, 399

[84] “Distribution of Dust around Galaxies: An Analytic Model”
Masaki, S., Yoshida, N., 2012, MN, 423, L117

[85] “Detectability of High-Redshift Superluminous Supernovae with Upcoming Optical and Near-Infrared Surveys”
Tanaka, M., Moriya, T, Yoshida, N., Nomoto, K., 2012, MN, 422, 2675

[86] “Energy Deposition by WIMPs”
Evoli, C., Valdes, M, Ferrara, A., Yoshida, N., 2012, MN, 422, 420

[87] “Simulations of Early Baryonic Structure Formation with Stream Velocity I” Naoz, S., Yoshida, N., Gnedin, N., 2012, ApJ, 747, 128

[88] “Matter Distribution Around Galaxies”
Masaki, S., Fukugita, M., Yoshida, N., 2012, ApJ, 746, 38

[89] “The origin of multiple nuclei in ULIRGS”
Matsui, H., Saitoh, T. R., Makino, J., Daisaka, H., Kokubo, E., Okamoto, T., Tomisaka, K., Wada, K., Yoshida, N., 2012, ApJ, 746, 26

＜**Conference Proceedings**＞

[90] “Single-Epoch Supernova Classification with Deep Convolutional Neural Networks”, Kimura, A., Takahashi, I., Tanaka, M., Yasuda, N., Ueda, N., Yoshida, N., 2017, The 37th IEEE International Conference on Distributed Computing

＜**Review Papers**＞

[91] ”Formation of the First Generation of Stars and Blackholes in the Universe”,
Yoshida, N., 2019, Proceeding of Japan Academy Series B, 95, 17

[92] ”The Dark Ages of the Universe and hydrogen reionization”,
Natarajan, A., Yoshida, N., 2014, Progress of Theoretical and Experimental Physics, Volume 2014, Issue 6, id.06B11219

[93] ”Formation of the First Stars in the Universe”
Yoshida, N., Hosokawa, T., Omukai, K., 2012, Progress of Theoretical and Experimental Physics, Volume 2012, Issue 1, id.01A305

＜ **Books** ＞

[94] 地球一やさしい宇宙の話, 吉田 直紀 (小学館 2018.12)

[95] ムラムラする宇宙, 吉田 直紀 (学研 2014.10)

＜ **Patent Applications** ＞

7 Invited Presentations at International Conferences

[1] Naoki Yoshida: “ Cosmology and Fundamental Physics with AI ” ,
Information Search, Integration and Personalization 2019 (Crete, Greece, May 10, 2019)

[2] Naoki Yoshida: “ Formation of the First Galaxies and Blackholes ” ,
IGM 2018 (Kashiwa, Chiba, September 20, 2018)

[3] Naoki Yoshida: “ Formation of the First Galaxies and Blackholes ” ,
European Week of Astronomy and Astrophysics (Liverpool, UK, April 5, 2018)

[4] Naoki Yoshida: “ Formation of the First Galaxies and Blackholes ” ,
Rise and Shine (Strasbourg, France, June 19, 2018)

[5] Naoki Yoshida: “ Simulating Cosmic Structure Formation ” ,
SIAM Conference on Parallel Processing for Scientific Computing (PP18) (Tokyo, March 7, 2018) Keynote talk

[6] Naoki Yoshida: “ Cosmology with Big Astronomical Data ” ,
4th International Symposium on Big-Data Analytics in Science and Engineering (Aizu, Fukushima, February 4, 2019)

[7] Naoki Yoshida: “ Fragmentation of disks and filaments in the early universe ” ,
Disk Instability across Cosmic Scales (Sesto, Italy, July 19, 2017)

[8] Naoki Yoshida: “ Formation of primordial stars and blackholes ” ,
Star Formation in Different Environment (Quy Nhon, Vietnam, August 10, 2017)

[9] Naoki Yoshida: “ Cosmology and fundamental physics with big astronomical data ” ,
2017 IEEE International workshop on machine learning and signal processing (Tokyo, September 28, 2017) Keynote talk

[10] Naoki Yoshida: “ Formation of primordial stars and blackholes ” ,
IAU333 Peering towards Cosmic Dawn (Dubrovnik, Croatia, October 3, 2017)

[11] Naoki Yoshida: “ Multi-label classification of supernovae detected with Subaru HSC ” ,
3rd International Symposium on Big-data Analytics in Science and Engineering (Aizu, November 28, 2017)

[12] Naoki Yoshida: “ Formation of Astrophysical Blackholes ” ,
NCTS Annual Theory Meeting (Taiwan, December 7, 2017)

[13] Naoki Yoshida: “ Formation of Primordial Stars ” ,
Metals and Dust as Fuels of Star Formation (Santa Barbara, USA, June 28, 2016)

[14] Naoki Yoshida: “ Simulations of Cosmic Structure Formation ” ,
The 1st Computer Alliance Symposium (Tokyo, Japan, November 20, 2016)

[15] Naoki Yoshida: “Simulations of the formation of large-scale structure”,
Dark Side of the Universe (Kyoto, Japan, December 15, 2015)

[16] Naoki Yoshida: “Formation of the First Stars in the Universe”,
Quarks to Universe in Computational Science (Nara, Japan, November 8, 2015)

[17] Naoki Yoshida: “Statistical Computational Cosmology”,
Big Data Application Symposium (Tokyo, Japan, August 1, 2015)

[18] Naoki Yoshida: “From the First Stars to Massive Blackholes”,
First stars, galaxies, and black holes: now and then (Groningen, Netherland, June 18, 2015)

[19] Naoki Yoshida: “Formation of Early Blackholes”,
Olympian Symposium (Paralia, Greece, May 20, 2015)

[20] Naoki Yoshida: “Formation of Primordial Stars”,
South by High-Redshift (Austin, USA, April 1, 2015)

[21] Naoki Yoshida: “Subaru Hyper-Suprime Cam Survey and Big Data Cosmology”,
10th International Workshop on Databases in Networked Information Systems (Aizu, Japan, March 23, 2015)

[22] Naoki Yoshida: “Formation of Early Blackholes”,
Focus Week on Hyper Accretion (Kashiwa, Japan, April 9, 2014)

[23] Naoki Yoshida: “Formation of Primordial Stars”,
Physics of First Star and Galaxy Formation (Edinburgh, June 10, 2014)

[24] Naoki Yoshida: “Structure Formation in the Early Universe”,
Unsolved Problems in Astrophysics (Budapest, Hungary, July 3, 2014)

[25] Naoki Yoshida: “Direct Integration of the Collisionless Boltzmann Equation”;
Exascale Computing in Astrophysics (Ascona, Switzerland, September 2013)

[26] Naoki Yoshida: “Low-mass Stars, Massive Blackholes, and Luminous Supernovae in the Early Universe”;
Mind the Gap (Cambridge, UK, July 2013)

[27] Naoki Yoshida: “Cosmic Dawn: Conference Summary”;
Cosmic Dawn (Ringberg, Germany, June 2013)

[28] Naoki Yoshida: “Hunting for the First Supernovae”;
Cosmos Meeting 2013 (Kyoto, May 2013)

[29] Naoki Yoshida: “Physics of primordial star formation”;
The physics of star formation (Trieste, Italy, October 2012)

[30] Naoki Yoshida: “Star formation in a low-metallicity gas”;
The low-metallicity ISM (Goettingen, Germany, October 2012)

[31] Naoki Yoshida: “Three-body chemistry in the early universe”;
The 20th International IUPAP Conference on Few-Body Problems in Physics (Fukuoka, Japan, August 2013)

[32] Naoki Yoshida: “Primordial star formation”;
39th COSPAR General Assembly (Mysore, India, July 2012)

[33] Naoki Yoshida: “Hunting for the first stars”;
GRB in the era of rapid follow-up (Liverpool, UK, June 2012)

[34] Naoki Yoshida: “Physics of primordial star formation”;
The First Stars IV (Kyoto, Japan, May 2012)

8 Teaching Accomplishment

2016, Ken Osato, Dean's award
2014, Masato Shirasaki, Dean's award and selected as a Springer Thesis

9 Contribution to Academic Community

9.1 Editorial Activities

Editorial Board, Scientific Reports by Nature Publishing Group, 2011-present

9.2 Organization of Professional Societies

Chair, Theoretical Astronomy and Astrophysics Society (rironkon), 2012

9.3 Organization and Advisory of Conferences

SOC, The First Stars V; SOC, IAU Symposium Massive Stars 2020; SOC, The First Stars VI

10 Outreach

I have given a number of science talks to public in the past several years. On average, I give about 10 such talks per year, including those hosted by University of Tokyo and Kavli IPMU. Several times featured on TV and radio, mostly on science programs on NHK TV. I also visited domestic high schools and gave lectures.

11 Committee Service

11.1 External Committees

Asian Pacific Center for Theoretical Physics External Committee 2014-2015

11.2 University Committees

IT security committee member (東京大学 IT セキュリティ委員) 2013−2017
University-wide curriculum planning committee member (東京大学 カリキュラム改革部会) 2014

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	6	USA
Master Course	3	Canada, China
Doctor Course	3	Canada, China, Germany
Foreign researchers hosted	6	
Students sent abroad	30	USA, France, Germany, Israel, Italy
Researchers sent abroad	10	USA, France, Germany, Italy
Foreign visitors	34	Many countries

Biophysics

Higuchi Hideo、樋口 秀男

1 Education and Professional Experiences

Education

1981	B.S. (Physics)	Waseda University
1983	MSc. (Physics)	Waseda University
1988	Ph.D. (Physics)	Waseda University

Professional Appointments

1983−1992	Assistant Professor	The Jikeikai University School of medicine
1992−1997	Group reader	JST ERATO Yanagida Biomotoron project
1997−2004	Associate Professor	Tohoku University
2004−2008	Professor	Tohoku University
2008−present	Professor	The University of Tokyo

2 Research Highlights

Human and mammalian bodies have a structural hierarchy in order of bio-molecule, cell, organ and body. Therefore, to understand each hierarchy and relationship between hierarchy. we investigated the dynamic function of purified protein molecule by single molecule technology, the function of molecules or organelle in cell and the vesicle movement of neutrophil in mouse.

Single Molecules: Cytoplasmic dynein is a molecular motor moving toward the minus end of microtubules. The swing of the dynein linker is supposed to be cruicial to walking of dynein. However, there is no measurement of the displacement generated by the swing. We investigated the displacement of microtubules driven by the swing of single molecules of single-headed dynein by optical tweezers [Kinoshita et al. Scientific Rep 2018]. The displacement of swing by dynein was 8.3 nm which is close to tubulin spacing in microtubule, indicating that dynein is able to walk only by the swing of dynein lever.

Model for single molecules: We constructed the unified mathematical model for processive molecular motors, dynein, kinesin and myosin-V. Our model consists of three states, and the forward and backward steps are represented by the cycles of transitions visiting different pairs of states among the three states [Sasaki et al. Biophys. J. 2018]. Our model successfully describes the behavior of step ratio of forward to backward steps and the stepping time for all of the motors in a wide range of loads from large assisting loads to superstall loads.

Multiple molecules: To understand the molecular mechanism of muscle contraction, we measured forces generated by synthetic myofilaments, in which 17 myosin molecules interact with single actin filament [Kaya et al. Nature Comm. 2017]. We found the synchronization of myosin power stroke that helps generation of large force.

Vesicle transport in cells: The transports of vesicles in cells are driven by the motor proteins. To understand the trajectory form of the transport, we tracked the vesicles by labeling it with fluorescence quantum dots [Opt. Exp. 2018]. We found an acute rotational movement of an endocytic vesicle with a pitch of 1 micrometer along microtubules in cells. It is expected that vesicles encountered any obstacles and rotated to avoid it. We also found that the vesicle transport is an excellent indicator of cell activity. Vesicle movement in cells was decreased with increase in the cell damage induced by reactive oxygen species (ROS) of fluorescence dye [Sakuma et.al. Sci. Technol. Adv. Mater. 2016]. The motilities of kinesin and dynein were also reduced by the ROS. We evaluated quantitatively cell damage or cell activity by calculating the vesicle motility which reflects activity of the motor proteins.

Vesicle transport in mouse: Neutrophils play an essential role in the innate immune response. We developed a new non-invasive technique for the in vivo imaging of neutrophils labeled with quantum dots. The quantum dots were endocytosed into vesicles in the neutrophils, allowing us to track the vesicles at 80 frames/s with ~20 nm accuracy [Kikushima et al. Scientific Rep. 2013]. Intriguingly, the vesicles containing quantum dots were transported at higher speed than the in vitro velocity of a molecular motor such as kinesin or dynein.

3 Selected Papers

- K. Sasaki, M. Kaya, and H. Higuchi. A unified walking model for dimeric motor proteins Biophys. J.115, 1-12 (2018)
  This work proposes the unified working model that explained movement of many molecular motors.

- Motoshi Kaya, Yoshiaki Tani, Takumi Washio, Toshiaki Hisada and Hideo Higuchi. Coordinated force generation of skeletal myosins in myofilaments through motor coupling. Nature Communications 8,16036 (2017)
  The paper has been cited 22 times for two years. This work solved the mechanism of spontaneous oscillation of cardiomyocyte.

- Takumi Washio, Toshiaki Hisada, Seine A. Shintani and Hideo Higuchi. Analysis of spontaneous oscillations for a three state power stroke model. Physical Review E. 95, 022411(2017)
  This work solved the mechanism of spontaneous oscillation of cardiomyocyte.

- Kohsuke Gonda, Minoru Miyashita, Hideo Higuchi, Hiroshi Tada, Tomonobu M Watanabe, Mika Watanabe, Takanori Ishida, Noriaki Ohuchi. Predictive diagnosis of the risk of breast cancer recurrence after surgery by single-particle quantum dot imaging. Scientific Reports 5, 14322 (2015).
  In this paper, we developed a useful monoclonal antibody (Inventers of Patent, Gonda, Higuchi, Ohuchi, Takeda) that was sold commercially (Novus Biologicals).

- Kenji Kikushima, Sayaka Kita and Hideo Higuchi* A non-invasive imaging for the in vivo tracking of high-speed vesicle transport in mouse neutrophils. Scientific reports 3:1913 (2013)
  This is the first report of noninvasively imaging of vesicles in mice.

4 Honors, Awards and Professional Society Memberships

5 Research Plan

We plan to verify the unified model for motor proteins by experiment, extend the skeletal myosin work to cardiac one, investigate the beating mechanism of sperm flagella and verify the generality of vesicle fluctuation method for index of cell activity.

Experimental evidence for the unified model: The unified mathematical model for processive molecular motors predicted the behavior of step ratio of forward to backward steps and the stepping time for kinesin, dynein and myosin-V in a wide range of loads from large assisting loads to superstall loads. However, experimental data is limited in the range of load and some data had large errors. It is, therefore, crucial to clarify the step ratio and dwell time of motors under a wide range of load. We will measure stepping motion of single molecule of motors at high temporal resolution to obtain the data with small errors.

Cyclic force generation of cardiac myosin: Molecular structure of cardiac muscle is the similar to that of skeletal muscle, while cyclical contraction of cardiac muscle is clearly different from skeletal one. We will elucidate the molecular mechanism of how dynamics of cardiac myosin molecules contributes to heart function by measuring forces of synthetic β-cardiac myosin filaments using optical tweezers. In preliminary work, the stepping ratio of cardiac myosin is much lower than that of skeletal myosin and the peak forces generated by cardiac myofilaments were 2 times higher than those observed in skeletal myofilaments. We will reveal the function of cardiac myosin specialized for cyclical contraction.

Beating mechanism of sperm flagella: The beating of sperm flagella is generated by axonemal dynein with regulation. The knowledge of the beating mechanism is still very limited at molecular level. We plan to measure force generation of dynein attached on a doublet microtubule to understand the collective force generation of an ensemble of dynein in axoneme, bundle of doublet microtubules and single doublet microtubule. In the preliminary work, the force generated by dynein ensemble was ∼15 pN perm of double. The 15pN will be generated ∼3 dynein molecules as reported value of purified dynein. The dynein containing in doublet per onem is ∼100. These indicate that only 3% of dynein generates force. We will understand how such low population of dynein generates beating motion.

Generality of vesicle fluctuation method: We evaluated quantitatively cell damage or activity by calculating the vesicle motility or fluctuation for two kinds of cells. We do not know the vesicle fluctuation is general index for cell activity. We plan to verify generality of the vesicle fluctuation for general cells (cancer cells, frog cells and yeast) and damages (heat, pH, toxin and ROS).

6 Publications and Patents

< Refereed Original Papers >

[1] Kon T, Oyama T, Shimo-Kon R, Imamula K, Shima T, Sutoh K, and Kurisu G The 2.8 A crystal structure of the dynein motor domain, Nature, Epub ahead of print(2012)

[2] Jinha A., Ait-Haddou R., Kaya M. and Herzog W. Response to Letter to the Editor regarding Jinha et al. A task-specific validation of homogeneous non-linear optimization approaches Journal of Theoretical Biology 306, 145. (2012)

[3] Arslam Y. Z., Jinha A., Kaya M. and Herzog W. Prediction of muscle forces using static optimization for different contractile conditions. Journal of Mechanics in Medicine and Biology 13, 1350022-1-13. (2013)

[4] Yasuhiro Suzuki, Chandra Nath Roy, Warunya Promjunyaku, Hiroyasu Hatakeyama, Kohsuke Gonda, Junji Imamura, Biju Vasudevan Pillai, Noriaki Ohuchi, Makoto Kanzaki , Hideo Higuchi, and Mitsuo Kaku. Single quantum dot tracking reveals that an individual multivalent 2 HIV-1 Tat-protein transduction domain can activate machinery for 3 lateral transport and endocytosis. Mol. Cell Biol. 33: 3039-3049 (2013).

[5] Kaya. M. and H. Higuchi. Stiffness, working stroke and force of single myosins in skeletal muscle: Elucidation of these mechanical properties by non-linear elasticity. Cell and Mol. life Sci. 70: 4275-4292 (2013)

[6] Kikushima Kenji, Kita Sayaka and Higuchi Hideo. A non-invasive imaging for the in vivo tracking of high-speed vesicle transport in mouse neutrophils. Scientific Reports 3:doi:10.1038/srep01913 (2013).

[7] Ryoma Nakao, Kenji Kikushima, Hideo Higuchi, Nozomu Obana, Nobuhiko Nomura, Bai DongYing, Makoto Ohnishi, and Hidenobu Senpuku. Novel Approach for Purification and Selective Capture of Membrane Vesicles of Periodontopathic Bacteria, Porphyromonas gingivalis. PLos One. May9e95137 (2014)

[8] Ichimura T., T. Jin, H. Fujita, H. Higuchi and T.M. Watanabe. Nano-scale measurement of biomolecules by optical microscopy and semiconductor nanoparticles. Frontiers in Physiology. 00273 (2014)

[9] Kohsuke Gonda, Minoru Miyashita, Hideo Higuchi, Hiroshi Tada, Tomonobu M Watanabe, Mika Watanabe, Takanori Ishida, Noriaki Ohuchi. Predictive diagnosis of the risk of breast cancer recurrence after surgery by single-particle quantum dot imaging. Scientific Reports 5, 14322 (2015)

[10] Chikako Shingyoji, Izumi Nakano, Yuichi Inoue and Hideo Higuchi. Dynein arms are strain-sensitive direction-switching force generators. Cytoskeleton 72:388-401 (2015) doi: 10.1002/cm.21232.

[11] Naoaki Bekki and Seine A. Shintani "Simple Dispersion Equation Based on Lamb-Wave Model for Propagating Pulsive Waves in Human Heart Wall" J. Phys. Soc. Jpn. Publication Center for Pure and Applied Physics, 84, 124802-1-6 (2015)

[12] Naoaki Bekki, Seine A. Shintani, Shin'ichi Ishiwata and Hiroshi Kanai "A Model for Measured Traveling Waves at End-Diastole in Human Heart Wall by Ultrasonic Imaging Method" J. Phys. Soc. Jpn. Publication Center for Pure and Applied Physics, 85, 044802-1-6 (2016)

[13] Morito Sakuma, Sayaka Kita and Hideo Higuchi. Quantitative evaluation of malignant gliomas damage induced by photoactivation of IR700 dye. Science and Technology of Advanced Materials. 17, 473-482 (2016)

[14] Eug Kuan Moo, Daniel R Peterson, Timothy R Leonard, Motoshi Kaya, Walter Herzog. In vivo muscle force and muscle power during near-maximal frog jumps. PLoS One. Mar 10;12(3): e0173415 (2016)

[15] Katsuhiko Sato, Koutaro Nakagome, Seine A. Shintani, Fuyu Kobirumaki-Shimozawa, Norio Fukuda, Kazuya Suzuki, Jun Takagi, Yuta Shimamoto and Takeshi Itabashi., "Dynamic properties of bio-motile systems with a liquid-crystalline structure", Molecular Crystals and Liquid Crystals, 647,127-150(2016)

[16] Seiichi Tsukamoto, Teruyuki Fujii, Kotaro Oyama, Seine A. Shintani, Togo Shimozawa, Fuyu Kobirumaki-Shimozawa, Shin’ichi Ishiwata and Norio Fukuda, “Simultaneous imaging of local calcium and single sarcomere length in rat neonatal cardiomyocytes using yellow Cameleon-Nano140” J. Gen. Phys. 148, 341-355 (2016)

[17] Koutaro Nakagome, Katsuhiko Sato, Seine A. Shintani and Shin’ichi Ishiwata, “Model simulation of the SPOC wave in a bundle of striated myofibrils”, Biophysics and Physicobiology, 13, 217-226 (2016)

[18] Naoaki Bekki, Seine A. Shintani, Shin’ichi Ishiwata and Hiroshi Kanai, “A model for Measured Traveling Waves at End-Diastole in Human Heart Wall by Ultrasonic Imaing Method”, 85, 044802 (2016)

[19] Takumi Washio, Seine A. Shintani, Hideo Higuchi and Toshiaki Hisada. Analysis of spontaneous oscillations for a three state power stroke model. Physical Review E. 95, 022411 (2017).

[20] Togo Shimozawa, Erisa Hirokawa, Fuyu Kobirumaki-Shimozawa, Kotaro Oyama, Seine A. Shintani, Takako Terui, Yasuharu Kushida, Seiichi Tsukamoto, Teruyuki Fujii and Shin’ichi Ishiwata, “In vivo cardiac nano-imaging: A new technology for high-precision analyses of sarcomere dynamics in the heart”, Prog. Biophys. Mol. Bio. 124, 31-40 (2017)

[21] Motoshi Kaya, Yoshiaki Tani, Takumi Washio, Toshiaki Hisada and Hideo Higuchi*. Coordinated force generation of skeletal myosins in myofilaments through motor coupling. Nature Communications 8,16036 (2017)

[22] Takumi Washio, Toshiaki Hisada, Seine A. Shintani and Hideo Higuchi. Analysis of spontaneous oscillations for a three state power stroke model. Physical Review E. 95, 022411(2017).

[23] Eng Kuan Moo, Daniel R.Peterson, Timothy R. Leonard, Motoshi Kaya and Walter Herzog In vivo muscle force and muscle power during near-maximal frog jumps. PLoS One. Mar 10;12(3): e0173415 (2017)

[24] Seohyun Lee, Hyuno Kim, Hideo Higuchi. Focus Stabilization by Axial Position Feedback in Biomedical Imaging Microscopy IEEE Sensors Applications Symposium pp. 309-314 (2018)

[25] K. Sasaki, M. Kaya, and H. Higuchi. A unified walking model for dimeric motor proteins Biophys. J.115, 1-12 (2018)

[26] Yoshimi Kinoshita, Taketoshi Kambara,Kaori Nishikawa, Motoshi Kaya and Hideo Higuchi. Step Sizes and Rate Constants of Single-headed Cytoplasmic Dynein Measured with Optical Tweezers. Sci. Rep. 16333 (2018)

[27] Seohyun Lee, Hyuno Kim, Hideo Higuchi. Numerical method for vesicle movement analysis in a complex cytoskeleton network. Opt. Express 26, 16236-16239 (2018)

[28] Seohyun Lee, Hyuno Kim, Masatoshi Ishikawa, and Hideo Higuchi. 3D Nanoscale Tracking Data Analysis for Intracellular Organelle Movement using Machine Learning Approach. International conference on Artificial Intelligence in Information and Communication (IEEE -ICAIIC) (2019)

[29] Naohiko Shimada, Hirotaka Kinoshita, Takuma Umegae, Satomi Azumai, Nozomi Kume, Takuro Ochiai, Tomoka Takenaka, Wakako Sakamoto, Takayoshi Yamada, Tadaomi Furuta, Tsukuru Masuda, Minoru Sakurai, Hideo Higuchi, and Atsushi Maruyama. Cationic Copolymer-Chaperoned 2D3D Reversible Conversion of Lipid Membranes Advanced Materials190432,1-7(2019)

[30] Takumi Washio, Seine A. Shintani, Hideo Higuchi, Seiryo Sugiura and Toshiaki Hisada. Effect of myofibril passive elastic properties on the mechanical communication between motor proteins on adjacent sarcomeres. Scientific Reports 9:9355 (2019)

[31] Seohyun Lee, Hyuno Kim, Hideo Higuchi, and Masatoshi Ishikawa. Optical flow of vesicles: computer vision approach for endocytosis of Nano Particles in a living cell. SPIE Photonics West In press (2020)

＜**Books**＞

[32] Y Toyoshima and H. Higuchi " Motile and Enzymatic properties of native dynein molecules " in Handbook of Dynein. K. Hirose and LA Amos ed. (2012)

[33] Shima T, Sutoh K, and Kon T Chapter3, Functional Analysis of the Dynein Motor Domain, Handbook of Dynein, Pan Stanford Publishing (2012)

[34] 樋口秀男、権田幸祐 「量子ドットを用いたがん細胞の単一分子イメージング」 分担執筆 NTS 出版 バイオマテリアル (2012)

[35] 茅元司，樋口秀男 ビジュアルレビュー：筋肉の巧みな収縮メカニズム．感染. 疫 42-2，28-35. (2012)

[36] 樋口秀男、神原丈敏 「歩行型分子モーター、ダイニン」 パリティ (2013)

[37] 樋口秀男 「普遍生物学」生物物学会誌 巻頭言 55,285. (2015)

[38] 新谷正嶺、戸次直明、福田紀男、石渡信一、樋口秀男「心筋細胞に備わった昇温誘起の高速サルコメア振動」国士舘大学紀要 情報科学 第 37 号 (2015)

[39] 樋口秀男 「石渡牧場」早稲田応用物理会, 理会会報 27, (2016)

[40] 戸次直明、新谷正嶺「レイリーラム方程式の心室中隔壁への応用」国士舘大学紀要 情報科学 第 37 号 (2016)

[41] 新谷正嶺、戸次直明、樋口秀男、福田紀男、石渡信一「心筋細胞に備わった温度依存の高速自励振動特性」統計数理研究所共同研究リポート「動的生体情報の現状と展望」 21-27(2016)

[42] 茅 元司 第 11 章 少数の機能を知る（93-111 頁）「少数性生物学」永井健治・冨樫祐一編 日本評論社 (2016)

[43] 木下慶美「Opinion- 研究の現場から ～研究交流から共同研究への実現に向けた挑戦～」，羊土社『実験医学』34 (3) (2016)

[44] 新谷正嶺「第 3 回少数性生物学トレーニングコース 参加者の声」少数性生物学 NEWS LETTER Vol. 5 (2016)

[45] 新谷正嶺「温めた心筋細胞に備わった収縮リズムの周期安定化の仕組みについて」国士舘大学紀要 情報科学 第 38 号 (2017)

[46] 樋口秀男 「生物物理学と他の領域をゆらぐ」 東大理学部ニュース 48 （2017）

[47] 戸次直明、石井啓翔、城戸真弥、新谷正嶺、鷲尾巧「心臓壁に対する非線形波動モデルを目指して」国士舘大学紀要 情報科学 第 38 号 (2017)

[48] 樋口秀男 数理科学 「ファイマンラチェット-生体分子の運動の理解にむけて-」633, 34-39 （2018）

[49] H. Higuchi and C. Shingyoji. Measuring the Motile Properties of Single Dynein Molecules Chaper 5 In Handbook of dynein 2nd. Hirose and Amos ed. Pan Stanford Publishing (2019)

＜ **Patent Applications** ＞

[50] USA patetnt Kohsuke Gonda, Hideo Higuchi, Noriaki Ohuchi, Motohiro Takeda, Cancer cell migration and cancer cell invasion inhibitor. #8674079. March 3, 2014.

7 Invited Presentations at International Conferences

[1] Motoshi Kaya (2012) Application of optical tweezers to understand molecular mechanism of muscle contractions. International Symposium on Nanomedicine, Nagoya University, Japan (Mar. 2012)

[2] Higuchi H. and M Kaya Single molecule biophysics in an in vivo and in vitro. Japan-Taiwan joint symposium. Kyoto, Japan (Feb. 2012)

[3] Kaya, M. Force generation mechanism of single skeletal myosin molecules in myofilaments. The 50th Annual Meeting of the Biophysical Society of Japan, Nagoya University, Japan (Sep.2012)

[4] Kikushima k. A non-invasive method for the in vivo tracking of high-speed vesicle transport in mouse neutrophils. 6th International Symposium of Nanomedicine Tottori (Nov.2012)

[5] Higuchi H., Kikushima K., and Kita S. Single molecule biophysics toward in vivo. The 4th Taiwan-Japan Symposium on Nanomedicine. Taipei,Taiwan (Jan.2013)

[6] Higuchi H., Kikushima K., and Kita S. Single molecule biophysics toward in vivo. 2nd Tokyo U-Korea U Joint Symposium. Soul, Korea (2013.3)

[7] Higuchi H and T. Nomura. " Understanding of hierarchy in muscle contraction. " The international Symposium on multi-scale muscle mechanics. Session Moderator. Yokohama, Japan (Mar.2013)

[8] Kaya, M. Molecular level on muscle contraction. The international Symposium on multi-scale muscle mechanics. Session Moderator. Yokohama, Japan (Mar.2013)

[9] Hideo Higuchi, Kenji Kikushima, Sayaka Kita: Noninvasive in vivo imaging of neutrophil and tumor in mouse auricles. Dynein 2013 International Workshop, Kobe , Japan (Nov.2013)

[10] Hideo Higuchi, Kenji Kikushima and Sayaka Kita " Noninvasive in vivo imaging of neutrophil and tumor in mouse auricles " Molecules view The International Symposium on Multi-Scale Muscle Mechanics. ,Kitakyusyu Fukuoka, Japan (Nov.2013)

[11] Hideo Higuchi, Kenji Kikushima and Sayaka Kita. Biophysics toward noninvasive imaging. International Symposium on Nanomedicine molecular Science,Nagoya, Japan (Jan.2014)

[12] Hideo Higuchi and Norio Fukuda. Symposium on Biophysics toward In Vivo work. Biophysical society of Japan,Kyoto, Japan (Oct.2013)

[13] Motoshi Kaya, Hideo Higuchi Mokecular properties and dynamics of single skeletal myosins designed for force generations in ensemble of myosin molecules.Biophysical society of Japan,Kyoto, Japan (Oct.2013)

[14] Kenji Kikushima,Sayaka Kita,Hideo Higuchi,A non-invasive technique for the in vivo tracking of high-speed versicle transport in mouse neutrophils Symposium on Biophysics toward In Vivo work.Biophysical society of Japan,Kyoto, Japan (Oct.2013)

[15] Motoshi Kaya,Intermolecular cooperativity of skeletal myosins in myofilaments. Gordon Research Conference (Muscle & Molecular Motors), Mount Snow Resort West Dover, VT USA (Jul.2014)

[16] Hideo Higuchi, Kenji Kikushima and Sayaka Kita Noninvasive in vivo imaging of neutrophil and tumor in mouse auricles. A3 Foresight Symposium on Nanomedicine,Sendai, Japan (Sep.2014)

[17] Hideo Higuchi, Kenji Kikushima and Sayaka Kita. Noninvasive in vivo imaging of neutrophil and tumor in mouse auricles. 8th Internal Symposium on Nanomedicine ,Matsushima, Japan (Dec.2014)

[18] Hideo Higuchi Noninvasive in-vivo imaging of neutrophil and tumor cells in mouse auricles. PacifiChem Hawai USA （Dec.2016）

[19] Hideo Higuchi「Toward Medical Biophysics」3rd international nanomedicine symposium. Univ Tokyo , Japan (Nov.2015)

[20] Motoshi Kaya. Molecular mechanism of efficient muscle contraction revealed by single molecule approach. 5th Asian and Pacific-Rim Symposium on Biophotonics (Pacifico Yokohama) , Japan (Apr.2015)

[21] Hideo Higuchi: Motility of motor proteins, myosin, kinesin and dynein. Cooperation in Physics Workshop: LMU-UT Univ Tokyo, Japan (Feb.2016)

[22] Seohyun Lee, Motoshi Kaya, Kohsuke Gonda, Hideo Higuchi. Trafficking of Endocytic Vesicles on Cytoskeleton in LiveCancer Cells. A3 Foresight 9th Meeting． Yokohama, Japan (Sep.2017)

[23] Yongtae Hwang, Hideo Higuchi. Motoshi Kaya. Property of Cardiac Myosin Assemble Measured by Optical Trapping. A3 Foresight 9th Meeting. Yokohama, Japan (Sep.2017)

[24] Yoshimi Kinoshita, Hideo Higuchi. Step sizes and rate constants of single-headed dynein measured by optical tweezers, International Workshop Dynein 2017, International Conference Center, Awaji Yumebutai, Japan （Oct.2017）

[25] Chikako Shingyoji, Hiroshi Yoke,Yasuhide Izawa, Izumi Nakano,Yuichi Inoue, Hideo Higuchi. Mechanical activity of dynein and its dynamical regulation underlying oscillatory movement of sperm flagella. International Workshop Dynein 2017, International Conference Center, Awaji Yumebutai, Japan （Oct.2017）

[26] Morihito Sakuma,Yuichi Kondo and Hideo Higuchi. Damage of cancer cells evaluated by intensity fluctuation of images under phase contrast microscope. 11th International Symposium on Nanomedicine. University of Tohoku, Japan (Dec.2017)

[27] S. Shintani, T. Washio, Y. Hwang, M, Kaya and H. Higuchi. Molecular mechanism of self-oscillatory contraction of cardiac muscle. Internatinal Symposium on Nanomedicine. Ube Yamaguchi, Japan (Dec.2018)

[28] Hideo Higuchi, Yuichi Kondo and Kazuo Sasaki. Unified walking model for processive motor proteins and its experimental evidences Joint symposium between UBI and MBI in NUS Natinal university of Singapore. Singapore (Apr.2018)

[29] Yongtae Hwang. Collective behaviors of cardiac myosin molecules for effective cardiac function. LMU-UT Joint Workshop on Statistical and Biological Physics,Germany (Oct.2018)

[30] Motoshi Kaya. Keynote lecture: Reverse stroke of cardiac myosin is essential for heart function: lessons from skeletal myosin. The 4th Rocky Mountain satellite Muscle Symposium. Canmore. Canada (Jul.2019)

[31] Motoshi Kaya. Function of cardiac myosin essential for heart contraction. 2nd East Asian Symposium On Single-Molecule Biological Sciences. Seoul. Korea (Jul.2019)

[32] Hideo Higuchi and Kazuo Sasaki Universal walking model for processive motor proteins. Joint Workshop between NanoLSI (Kanazawa University) and Universal biology institute (The University of Tokyo). Kanazawa. Japan (Sep.2019)

[33] Motoshi Kaya, Yongtae Hwang and Hideo Higuchi. Reverse stroke of cardiac myosin revealed by single molecule microscopy is essential for heart function. 2nd Joint Symposium between mechanobaiology institute and Universal biology institute. Tokyo. Japan (Sep.2019)

8 Teaching Accomplishment

- 菊島健児　「量子ドットを用いたマウス耳介内における白血球内小胞運動の非侵襲イメージング」ナノ学会　若手優秀発表賞 (2012. 6)
- 新谷正嶺：日本生物学会優秀ポスター賞、日本時間生物学会 (2016.11.12)
- 張致遠「超解像イメージ法を用いた骨格筋ミオシン分子動態の直接計測」、第 54 回日本生物物理学会年会学生賞、つくば、(2016.11.25 − 11.27)
- 近藤雄一　「広い負荷領域におけるキネシン 1 分子のステップ運動」ナノ学会　Young best presentation award　(2018.5.12)
- Hwang Yongtae　Collective behaviors of cardiac myosins for effective cardiac function. 第 56 回生物物理学会　発表奨励賞　(2018.9.15)
- 上道　雅仁　Traction Force of Neural Stem Cells under Collective Migration was Modeled using the Orientation Field of Cell Alignment　第 57 回生物物理学会年会　学生発表賞 (2019.9.27)

9 Contribution to Academic Community

- Vice president of the society of Nano Science and Technology (2016-present)
- Session chair of nanomedicine and nanobiology in the society of Nano Science and Technology (2009-2016)

9.1 Editorial Activities

9.2 Organization of Professional Societies

9.3 Organization and Advisory of Conferences

- Member of advisory committee of ISSPIC (International Symposium on Small Particles and Inorganic Clusters) 2013−2014
- Organizer of 3rd International symposium on Nanomedicine molecular Science.
- Organizer of 2nd joint symposium between Mechanobiology Institute (National University of Singapore) and Universal Biology Institute (Univ. Tokyo) 2019

10 Outreach

- 樋口秀男「細胞の謎をさぐる」東大理学部高校生のための夏休み講座 2013　東大（本郷）東京 (2013.7.25)　（対象　高校生・中学生）
- 喜多清 日本免疫学会主催「免疫ふしぎ未来 2013」協力員 日本科学未来館 (2013.8.11)
- 喜多清　小学校 5 年生への理科の講義（ガン研究の紹介と発生についてとキャリア教育も兼ねて）つくばみらい市立　小絹小学校 約 100 名 (2014.7.14)
- 樋口秀男　高校生に対する講義「傷を治す白血球と分子の活躍」 沼津西高校生約 90 名、東大 (2014.10.20)
- 樋口秀男　講義「傷を治す白血球と分子の活躍」 沼津西高校 1，2 年生　（東大）(2015.10.19)
- 喜多清　出前講義　「最先端 がん細胞のナノイメージングと生き物の誕生～研究の仕事～」茨城県つくばみらい市市立小絹小学校 5 年生 (2015.7.9)
- 樋口，齋藤，佐久間，茅，喜多．沼津西高生へ講義および実験の実演 (2016.10.17)
- 喜多清　出前授業「理科関係のお仕事（研究の仕事とは？）＆ 生き物の誕生」茨城県つくばみらい市市立小絹小学校 5 年生（2017.2.3）
- 樋口秀男，喜多清，Hwang Yongtae，Seohyun Lee．沼津西高校生に対する模擬講義「がんを知り，がんを治す」および実験の実演　（2017.10.16）
- 喜多清 : 茨城県つくばみらい市市立小絹小学校 5 年生対象の出前講義　研究の仕事とは」～最先端　がん細胞をナノサイズで観察する研究～（2017.7.4）
- 樋口秀男　東京大学　「生命現象の普遍性」理学部公開講演会　(東大)　(2018.3.28)
- 樋口秀男　講義「がんを知り，がんを治す」 沼津西高校生約 45 名　（東大）　(2018.10.15)
- 茅　元司　2019 年 第 3 回 KISTEC 理科実験室　「きん肉が動く仕組みをさぐろう！」　小学生 3 年生～中学 2 年生 37 名（かながわサイエンスパーク、溝の口）(2019.2.23)
- 茅元司　KISTEC 理科実験室「きん肉が動く仕組みをさぐろう！」小中学生対象（神奈川県立産業技術総合研究所）（2019.2.23）
- 樋口秀男　講義「がんを知り，がんを治す」 沼津西高校生　（東大）　(2019.10.25)

11 Committee Service

- 医療分野研究成果展開事業　審査委員 (2018)
- JST　さきがけ　審査委員長 (2018)
- JST　ICORP　事後審査委員長 (2015-2016)

11.1 External Committees

11.2 University Committees

President of Universal Biology Institute (Graduate School of Science)　2018 年 −present
理学系研究科キャンパス将来計画員会　委員
理学系研究科バイオサイエンス委員会　委員
理学系研究科男女共同参画委員会　委員

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	2	Korea
Doctor Course	2	Korea
Foreign researchers hosted	0	
Students sent abroad	2	USA, Germany
Researchers sent abroad	2	USA, Switzerland
Foreign visitors	9	Germany, USA, Singapole, France

Akinao Nose、能瀬 聡直

1 Education and Professional Experiences

Education

1984	B.S. (Science)	Kyoto University
1986	MSc. (Biophysics)	Kyoto University
1989	Ph.D. (Biophysics)	Kyoto University

Professional Appointments

1989−1989	Postdoctoral Researcher	Kyoto University
1989−1993	Postdoctoral Researcher	University of California at Berkeley, U.S.A.
1993−1998	Research Associate	National Institute for Basic Biology
1998−2007	Associate Professor	The University of Tokyo
2007−	Professor	The University of Tokyo

2 Research Highlights

We are interested in the mechanisms of how the neural circuits develop and function to generate specific behavior, by using the nervous system of the fruit fly Drosophila as a model. In this organism, the relative simplicity and highly sophisticated genetic techniques allow one to identify and manipulate specific neurons. To dissect the circuit logic, we use a variety of genetic and biophysical techniques. For example, we use calcium imaging to record the activity of specific population of neurons. By using optogenetics, we manipulate the activity of specific neurons with light at high resolution. Connectomics (reconstruction from 3D electron microscopy images) allows determination of neuronal wiring diagrams at the cellular and synaptic level. Recent research highlights are summarized below.

(1) Circuit mechanisms for motor pattern generation: Animals move by adaptively coordinating the sequential activation of muscles. We aim to reveal novel circuit mechanisms for the propagation of muscle contraction, using the peristaltic locomotion of Drosophila larvae as a model. One circuit motif we identified was a feed-forward circuit, which consists of an intersegmental chain of synaptically connected neurons, alternating excitatory (a27h) and inhibitory (GDL), necessary for wave propagation and active in phase with the wave (Fushiki et al., eLife, 2016). Another circuit motif was a feed-back motif that mediates phase-coupled delay in motor activation. The central component of the circuit is a pair of higher-order premotor excitatory interneurons (Ifb-fwd) present in each abdominal neuromere that intersegmentally provides feedback to the adjacent neuromere during motor propagation (Kohsaka et al., Nat. Comm., 2019).

(2) Circuit mechanisms for action selection: How animals adaptively respond to sensory stimuli by choosing an ethologically relevant behavior is a fundamental question in neuroscience. We

investigate this problem by using the body-location specific tactile responses in Drosophila larvae. Larvae escape by backward locomotion when touched on the head, while they crawl forward when touched on the tail. We identify a class of segmentally repeated second-order somatosensory interneurons, that we named Wave, whose activation in anterior and posterior segments elicit backward and forward locomotion, respectively. Anterior and posterior Wave neurons extend their dendrites in opposite directions to receive somatosensory inputs from the head and tail, respectively. Downstream of anterior Wave neurons, we identify premotor circuits including the neuron A03a5, which together with Wave, is necessary for the backward locomotion touch response. Thus, Wave neurons match their receptive field to appropriate motor programs by participating in different circuits in different segments (Takagi et al., Neuron, 2017).

3 Selected Papers

- Kohsaka H, Takasu E, Morimoto T and *Nose A. A Group of Segmental Premotor Interneurons Regulates the Speed of Axial Locomotion in Drosophila Larvae, ***Current Biology*** **24**, 2643-2651 (2014).
  (Journal Impact Factor 9.1, Citation 32)

- Fushiki, A., Zwart M.F., Kohsaka, H., Fetter, R.D., *Cardona, A., *Nose, A. A circuit mechanism for the propagation of waves of muscle contraction in Drosophila. ***eLife*** **10**, 7554/eLife.13253 (2016).
  (Journal Impact Factor 7.6, Citation 48, Introduced by an "INSIGHT" article of the journal)

- Takagi S, Cocanougher BT, Niki S, Miyamoto D, Kohsaka H, Kazama H, Fetter RD, Truman JW, Zlatic M, Cardona A, *Nose A. Divergent Connectivity of Homologous Command-like Neurons Mediates Segment-Specific Touch Responses in Drosophila. ***Neuron*** **96**(6):1373-1387 (2017).
  (Journal Impact Factor 14.4, Citation 10)

- Matsunaga T, Kohsaka H, *Nose A. Gap junction-mediated signaling from motor neurons regulates motor generation in the central circuits of larval Drosophila. ***J Neurosci.*** **37**: 2045-2060 (2017).
  (Journal Impact Factor 6.0, Citation 12, selected as a "featured article" in the issue of the journal)

- Kohsaka H, Zwart M, Fushiki A, Fetter R, Truman J, Cardona A, *Nose A. Regulation of forward and backward locomotion through intersegmental feedback circuits in Drosophila larvae. ***Nat. Commun.*** **10**(1):2654. (2019).
  (Journal Impact Factor 11.9, Citation 0)

4 Honors, Awards and Professional Society Memberships

Member: The Biophysical Society of Japan
Member: Society for Neuroscience
Member: The Japan Neuroscience Society
Member: Japanese Society of Developmental Biologists
Member: The Molecular Biology Society of Japan

5 Research Plan

We focus on the ”small-scale neurocircuity” in the larvae of fruitfly and try to understand the logic of brain information processing. We try to identify neural circuits that function as units of brain information processing and analyze their structural and functional connectivity by cellular imaging, optogenetics, connectomics and mathematical modeling. We use machine learning and other computational methods to analyze the dynamics of population activity of neurons. We also study how neural circuits form during development via activity-dependent processes such as the sensory feedback.

6 Publications and Patents

＜Refereed Original Papers＞

[1] Fukui A, Inaki M, Tonoe G, Hamatani H, Homma M, Morimoto T, Aburatani H and *Nose A. ”Lola regulates glutamate receptor expression at the Drosophila neuromuscular junction”. Biology Open 1, 362-375 (2012).

[2] Matsunaga T, Fushiki A, Nose A, *Kohsaka H. ”Optogenetic Perturbation of Neural Activity with Laser Illumination in Semi-intact Drosophila Larvae in Motion”. J Vis Exp. 2013 Jul 4;(77), e50513 (2013).

[3] Fushiki A, Kohsaka H, *Nose A. ”Role of sensory experience in functional development of Drosophila motor circuits”. PLoS One. 2013 Apr 19;8(4), e62199 (2013).

[4] Okusawa S, Kohsaka H, *Nose A. ”Serotonin and downstream leucokinin neurons modulate larval turning behavior in Drosophila”. J Neurosci. 34, 2544-2558 (2014).

[5] Kohsaka H, Takasu E, Morimoto T and *Nose A. ”A Group of Segmental Premotor Interneurons Regulates the Speed of Axial Locomotion in Drosophila Larvae”, Current Biology 24, 2643-2651 (2014).

[6] Itakura Y, Kohsaka H, Ohyama T, Zlatic M, *Pulver SR, *Nose A. ”Identification of Inhibitory Premotor Interneurons Activated at a Late Phase in a Motor Cycle during Drosophila Larval Locomotion”. PLoS One 3, e0136660 (2015)

[7] Fushiki, A., Zwart M.F., Kohsaka, H., Fetter, R.D., *Cardona, A., *Nose, A. ”A circuit mechanism for the propagation of waves of muscle contraction in Drosophila”. eLife 10, 7554/eLife.13253 (2016) doi: 10.7554/eLife.13253.

[8] Hasegawa E, Truman JW, *Nose A. ”Identification of excitatory premotor interneurons which regulate local muscle contraction during Drosophila larval locomotion”. Sci Rep. 2016; 6: 30806 (2016) doi: 10.1038/srep30806.

[9] Matsunaga T, Kohsaka H, *Nose A. ”Gap junction-mediated signaling from motor neurons regulates motor generation in the central circuits of larval Drosophila”. J Neurosci. 37: 2045-2060 (2017)

[10] Takagi S, Cocanougher BT, Niki S, Miyamoto D, Kohsaka H, Kazama H, Fetter RD, Truman JW, Zlatic M, Cardona A, *Nose A. ”Divergent Connectivity of Homologous Command-like Neurons Mediates Segment-Specific Touch Responses in Drosophila”. Neuron 96(6):1373-1387 (2017)

[11] Park J, Kondo S, Tanimoto H, Kohsaka H, *Nose A. ”Data-driven analysis of motor activity implicates 5-HT2A neurons in backward locomotion of larval Drosophila”. Sci Rep. 2018 Jul 9;8(1):10307 (2018)

[12] Yoon Y, Park J, Taniguchi A, Kohsaka H, Nakae K, Nonaka S, Ishii S, Nose A. ”System level analysis of motor-related neural activities in larval Drosophila”. J Neurogenet. 33, 179-189. (2019) doi: 10.1080/01677063.2019.1605365.

[13] *Kohsaka H, Zwart M, Fushiki A, Fetter R, Truman J, Cardona A, *Nose A. ”Regulation of forward and backward locomotion through intersegmental feedback circuits in Drosophila larvae”. Nat. Commun. 10(1):2654. (2019) doi: 10.1038/s41467-019-10695-y.

＜Review Papers＞

[14] Kohsaka H, Okusawa S, Itakura Y, Fushiki A and Nose A. ”Development of larval motor circuits in Drosophila”. Develop.Growth Differ. 54, 408-419 (2012).

[15] Nose A. ”Generation of neuromuscular specificity in Drosophila: novel mechanisms revealed by new technologies”. Front Mol Neurosci. 5, 62 (2012).

[16] 高坂洋史、能瀬聡直　”ショウジョウバエを用いたオプトジェネティクス研究”、in オプトジェネティクス、エヌ・ティー・エス、141-153 (2013). （著書、分担執筆、査読なし）

[17] 能瀬聡直 文部科学省科学研究費・新学術領域研究「メゾスコピック神経回路から探る脳の情報処理基盤」がめざすもの　生体の科学 64(1), 80-87 (2013).

[18] 能瀬聡直 ”ショウジョウバエ幼虫を用いて定型運動の制御機構を探る” 細胞工学 33, 249-254 (2014).

[19] Kohsaka, H. and Nose, A. ”Optogenetics in Drosophila. (a book chapter in ”Optogenetics ”)”, Springer Verlag (2015).

[20] 能瀬聡直、高坂洋史、伏木彬　”光によるショウジョウバエ中枢回路の機能解剖”　生体の科学 68(5):478-479 (2017).

[21] *Kohsaka H, Guertin PA, Nose A. ”Neural circuits underlying fly larval locomotion”. Current Pharm. Design. 23:1-12 (2017).

[22] 高木優、能瀬聡直　”ショウジョウバエ幼虫の行動制御回路”　月刊　臨床神経科学 36(8):903-906 (2018). 中外医学社

[23] Takagi S, Nose A ”Circuit architecture for somatotopic action selection in invertebrates”. Neurosci Res. 2019 Mar;140:37-42. doi: 10.1016/j.neures.2018.08.008. Epub 2018 Aug 18.

＜**Books**＞

[24] 高坂洋史、能瀬聡直：”ショウジョウバエを用いたオプトジェネティクス研究”、「オプトジェネティクス」、エヌ・ティー・エス、141-153 (2013).（分担執筆）

[25] Kohsaka, H. and Nose, A. ”Optogenetics in Drosophila. (a book chapter in ”Optogenetics”)”, Springer Verlag (2015).

7 Invited Presentations at International Conferences

[1] 能瀬聡直：”Optogenetic dissection of motor circuits that regulate larval locomotion in Drosophila”、新学術領域「メゾ神経回路」第 1 回公開国際シンポジウム、 2012.7.7、東京

[2] 能瀬聡直、高坂洋史、高木俊輔：”Optogenetic dissection of motor circuits in Drosophila larvae”、「第 35 回日本神経科学大会」シンポジウム、 2012.9.18、名古屋

[3] Nose, A. ：”Optogenetic dissection of motor circuits that regulate larval peristalsis in Drosophila”, ”Behavioral Neurogenetics of Drosophila Larva” meeting at Janelia Farm,2012.9.30～10.3, 米国

[4] Nose, A. :”Optogenetic dissection of the neural circuits that regulate rhythmic movement in Drosophila larvae”, Symposium on Sensory Systems and Neural Circuits, 2013.2.12, 東京

[5] Nose, A. :”Optogenetic dissection of the neural circuits that regulate rhythmic movement in Drosophila larvae”, The University of Tokyo - Korea University The 2nd Joint Workshop on Bio-Soft Matter, 2013.3.1, Seoul, Korea

[6] Nose, A. ：”Functional dissection of the central circuits that regulate larval locomotion, Behavioral Neurogenetics of larval Drosophila: Molecules”, Circuits, Computation and Robotics, 2014.3.10, Atami

[7] Nose, A. ：”Functional dissection of the central circuits that regulate Drosophila larval locomotion”, ESF-EMBO Flies, worms and robots: combining perspectives on minibrains and behaviours, 2014.11.11, Sant Feliu, Spain

[8] Nose, A.: ”Neuronal dynamics underlying motor decision making”, Cooperation in Physics Workshop: LMU-UT , 2016.2.29-3.1, Tokyo, Japan

[9] Nose, A., Kohsaka, H., Yoon, Y., Takagi, S., Hiramoto, A., Ohura, S. and Niki, S.: ”Circuit mechanisms that regulate motor pattern in larval Drosophila. Behavioral Neurogenetics of Drosophila Larva”, 2016 10.25 Janelia Farm Research Campus, USA.

[10] Nose, A. : "Genomic and connectomics analysis of the motor circuits in larval Drosophila", NSF Workshop: Comparative Principles of Brain Architecture and Functions 2016.11.18, Marriott Marquis San Diego Marina, USA

[11] Nose, A. : "Circuit mechanisms of action selection in Drosophila larvae, Systems biology of the brain "Reconstructing the connectome of the fruit fly larva" : CUSO Staromics PhD-program Workshop, 2017.9.11, University of Fribourg, Switzerland

[12] X. Zeng, T. Kawasaki, K. Inada, H. Kazama and A. Nose : Embryonic development of the motor circuits in Drosophila: emergence of coordinated neural activities and the role of sensory feedback", Behavioral Neurogenetics of Drosophila Larva, 2018.10.10, University of Edinburgh, UK

[13] Nose, A. : "Regulation of motor circuit development by proprioceptive feedback", 2019 ASIA-PACIFIC DRORSOPHILA NEUROBIOLOGY CONFERENCE, 2019.1.18, Institute of Molecular Biology, Academia Sinica, 台湾

[14] Nose, A. : "Functional connectomics of motor circuits in Drosophila larvae", Max Planck / HHMI Connectomics Conference Berlin 2019, 2019.4.16, Harnack-Haus of the Max Planck Society, Berlin

[15] Xiangsunze Zeng, Tappei Kawasaki, Kengo Inada, Hokto Kazama, Akinao Nose : "Embryonic development of the motor circuits in Drosophila: emergence of coordinated neural activities and the role of sensory feedback", NEURO2019, 2019.7.27, TOKI MESSE , Niigata

8 Teaching Accomplishment

Student awards:

- 2018, Suguru Takagi; 第 3 回時実利彦記念神経科学優秀博士研究賞
- 2016, Shoya Ohura; 第 39 回日本分子生物学会年会、優秀ポスター賞

9 Contribution to Academic Community

9.1 Editorial Activities

- N/A

9.2 Organization of Professional Societies

- 文部科学省科学研究費補助金　新学術領域研究　「メゾスコピック神経回路から探る脳の情報処理基盤」領域代表　2010−2015

9.3 Organization and Advisory of Conferences

- Co-organizer, International Symposium on “Neuronal circuits at the intersection of theory and experiment”, Tokyo, Japan, 2012
- Program Committee, The 35th Annual meeting of the Japan Neuroscience Society, Nagoya, Japan, 2012
- Local Organizing Committee, 16th International Conference on Retinal Proteins (ICRP), Nagahama, Japan, 2014
- Co-organizer, International Symposium on “Neuronal Circuits: Cutting edge approaches to the complexity”, Kyoto, Japan, 2013
- Co-organizer, Conference on “Behavioral Neurogenetics of larval Drosophila: Molecules, Circuits, Computation and Robotics”, Atami, Japan, 2014
- Co-organizer, Janelia Research Conference on “Behavioral Neurogenetics of Drosophila Larva”, Ashburn, USA, 2016
- Co-organizer, Conference on “Behavioral Neurogenetics of Drosophila Larva”, Edinburgh, UK, 2018
- Local Organizing Committee, 19th International Conference on Retinal Proteins (ICRP), Shima, Japan, 2020

10 Outreach

プレスリリース

- 「動物の動く速さをコントロールする。– 動物の運動速度を支える神経回路の解明 –」2014.10.16
- 「臨機応変」を配線する – 動物の行動選択を担う神経回路メカニズムの解明 –」2017.12.1
- 「前に行ったり、後ろに行ったり 〜 1 つの神経回路が異なる動きを効率よく生み出すしくみ 〜」 2019.6.17

11 Committee Service

11.1 External Committees

- 領域アドバイザー、戦略的創造研究推進事業（さきがけ）研究領域「脳神経回路の形成・動作と制御」、2009−2017 年
- 外部評価委員会、新潟大学脳研究所、2012 年
- 専門委員、日本学術振興会　科学研究費委員会（基盤・社会脳科学 A）、2012−2014 年
- 評価者、文部科学省　科学研究費補助金の評価（審査）、2012-2013 年
- 専門委員、文部科学省　科学研究費　新学術領域研究専門委員会（メゾ神経回路）、2012 年
- 英国 Welcome Trust Henry Dale Fellowship 審査委員
- 第 1 段審査担当委員、科学研究費補助金（基盤研究等）、脳科学、基盤・社会脳科学 2013−2014 年度
- 外部評価委員会、沖縄科学技術大学院大学、2014 年
- 運営会議委員、基礎生物学研究所、2015−2019 年
- 領域アドバイザー、JST 戦略的創造研究推進事業（さきがけ）　研究領域「生命機能メカニズム解明のための光操作技術」、2016−2020 年
- 書面審査員・書面評価員、日本学術振興会　特別研究員等審査会専門委員及び国際事業委員会、2016−2017 年
- 点検評価委員会、基礎生物学研究所、2017−2018 年
- 外部評価者、JST 戦略的創造研究推進事業（さきがけ）　研究領域「多細胞システムにおける細胞間相互作用とそのダイナミクス」、2019 年

11.2 University Committees

新領域創成科学研究科複雑理工学専攻・入試委員、2014 年度
新領域創成科学研究科・研究教育改善室長、2017−2018 年度

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	5	China, Korea
Doctor Course	5	China, Korea
Foreign researchers hosted	0	
Students sent abroad	5	USA
Researchers sent abroad	2	USA
Foreign visitors	5	USA

Yasushi Okada、岡田 康志

1 Education and Professional Experiences

Education

1993	B.S. (Medicine)	The University of Tokyo
2011	Ph.D. (Medicine)	The University of Tokyo

Professional Appointments

1994−1997	JSPS Research Fellow (DC1)	The University of Tokyo
1995−2011	Assistant Professor	The University of Tokyo
2011−	Team Leader	RIKEN
2016−	Professor	The University of Tokyo

Visiting, Guest Appointments

2012−	Guest Professor	Osaka University
2017−	Visiting Professor	Kobe University
2018−	VIsiting Professor	National Institutes of Natural Sciences

2 Research Highlights

We are trying to understand the dynamics of the protein molecules working in the living cells, especially motor proteins undergoing the intracellular transport. For that purpose, we have been working on the development of the imaging technologies as well as their biological applications.

2.1 Development of imaging technologies

2.1.1 Super-resolution microscope

For the development of the microscopes, we have been working on the super-resolution microscope for the observation of the fast dynamics in the living cells. Our original super-resolution microscope, the spinning-disk super-resolution microscope or SDSRM [19] has enabled us to observe dynamic processes of fine structures in living cells at 100 frames per sec per plane.

Special fluorescent dyes are required for the further improvement in the spatial resolution. We are, therefore, collaborating with chemists for the development of new fluorescent dyes suitable for the super-resolution live-cell imaging. For example, HMSiR is a self-blinking dye which is ideal for the single molecule localization microscopy [23, 5]. PREX710 is an extremely photostable near infrared dye, and is very suitable for the long-term in vivo imaging and single-molecule imaging [11]. MitoPB Yellow stains the inner membrane of mitochondria specifically and is very suitable for the super-resolution STED imaging. The inner membrane structure or cristae was clearly observed in living cells [2].

2.1.2 Improvement of single-molecule imaging optics for living cells

Total internal reflection fluorescence (TIRF) optics has been widely used for single-molecule imaging but it has several drawbacks. It illuminates the sample from one side. Thus, the generated evanescence field is highly polarized and only half of the fluorescent molecules are excited. Secondly, the excitation laser is focused to a single point on the back focal plane of the objective lens. Thus, the area of homogeneous illumination is limited and can be sensitive to the speckle pattern noise, which collectively results in a small field of view. Moreover, the power of the excitation laser cannot be increased, because the focused laser beam can damage the objective lens. We have developed a new illumination optics which we call as the ring-TIRF system. The excitation laser beam is shaped as an annular ring pattern on the back focal plane of the objective lens, so that the sample is illuminated homogeneously from all directions. Thus, a homogeneous large field of view without polarization bias is achieved. Furthermore, the introduction of a higher power laser enabled us to accelerate the frame rate of the single molecule imaging to 1000 frames/sec.

The ring-TIRF microscope was successfully applied for the live cell super-resolution imaging of the structure and the dynamics of the genome DNA in the nucleus [16], the dynamics of the transcription factors such as nanog, and the measurement of the protein-protein interaction kinetics in the cytoplasm of living cells.

2.2 Study of axonal transport

The axonal transport is one of the most sophisticated intracellular transport system. We have been working on this sytem for more than 20 years, but still many basic questions have remained unanswered. For example, it has not been clear how many molecules of motor protein are required to transport a single cargo vesicle in the axon. We have solved this question by applying the fluctuation theorem of non-equilibrium statistical physics [9].

We have also examined the navigation mechanisms in this transport system. A neuron typically has a single axon and more than dozens of dendrites, but the axonally transported cargos are transported into the axon. We have identified that the microtubules, the rail polymer for the transport, can take two different conformations. Binding of kinesin-1, the motor protein for the axonal transport, triggers the cooperative conformational changes in the microtubule, which serves as the road sign for the following kinesins [8].

3 Selected Papers

- S. Hayashi & Y. Okada, Molecular Biology of the Cell, 26: 1743-1751 (2015)
  This work was selected and highlighted as the cover for this issue. Commendation for Science and Technology was awarded to this work by MEXT.

- C. Wang et al., Proceedings of the National Academy of Science USA. 116: 15817-22 (2019)
  This works was highlighted in PNAS, Scientific American and other news media.

- K. Hayashi et al., Molecular Biology of the Cell, 29: 3017-3025 (2018)
  A successful combination of physics theory and biological experiments.

- S. Uno et al., Nature Chemistry 6: 681-689 (2014)
  This paper is cited 131 times.
- T. Shima et al., Journal of Cell Biology 217: 4164-4183 (2018)
  This paper got 2 recommendations in F1000Prime.

4 Honors, Awards and Professional Society Memberships

2017 Commendation for Science and Technology by MEXT.

5 Research Plan

5.1 Development of imaging technologies – Molecular resolution at sub-millisecond frame rates

Bridging the gap between the molecular and the cellular levels is one of the BDR missions. The current spatial resolution of our microscope is still much larger than molecules. Furthermore, the molecules in the cell are moving very rapidly, so that the imaging speed should be increased proportionally to the increased spatial resolution. We are, therefore, starting the development of several new microscopes. One is to track the trajectories of a single fluorescent molecule at 10,000 frames per second or more. This frame rate is required to measure the dynamics of protein molecules in the cytoplasm. Conventional single-molecule imaging could only observe the protein molecules bound to some fixed structures such as membranes or cytoskeleton. The development of photostable fluorescent dye is required to track the molecule for longer time at this frame rate, and we will continue the current collaboration with chemists.

The third key emerging technology for imaging is the computational image processing. Machine-learning or neural-network based image processing technologies would enable us to overcome the conventional limits of the optics or the fluorescent dyes/molecules. Through the STEPS program, we have started collaboration with computer scientists in Moscow Univ.

5.2 Study of axonal transport – Physics in the crowded environment of living cytoplasm

The results of the force estimation from the fluctuation theorem [9] indicated that more than 1000x stronger drag force is exerted on the axonally transported vesicles from the crowded cytoplasm than in vitro. However, the velocity is even faster in vivo than in vitro, though kinesin has been shown to slow down in the crowded solution in vitro. Our working hypothesis is that this apparent paradox might be resolved through the understanding of the crowded environment of the cytoplasm of living cells. The new microscope discussed in the previous section was primarily designed for this study. Here, the theoretical physics would play important roles. Our force measurement is dependent on the modern theory of non-equilibrium physics. The movement of the molecular motor can be theoretically analyzed by using the information thermodynamics. The characterization of the crowded environment of the cytoplasm and its interaction with kinesin would require new theory of non-equilibrium information thermodynamics. So we have started a new collaborative project along with theoretical physicists. The project has been approved by MEXT and supported by Grant-in-Aid for Scientific Research on Innovative Areas.

6 Publications and Patents

＜ Refereed Original Papers ＞

[1] Kaneshiro J *et al.* Biophys Physbiol. 16: 147-157, 2019.

[2] Wang C *et al.*, Proc Natl Acad Sci U S A. 116:15817-15822, 2019.

[3] Tanaka H *et al.*, J Cell Sci. 132: jcs224766, 2019.

[4] Kono K *et al.*, eLife 8: e45559, 2019. .

[5] Lu CH *et al.*, Commun Biol. 2:177, 2019.

[6] Li J *et al.*, Exp Cell Res. pii:S0014-4827: 30149-1, 2019.

[7] Hasegawa S *et al.*, Sci. Rep 9: 5099, 2019.

[8] Shima T *et al.*, J Cell Biol. 217:4164-4183, 2018.

[9] Hayashi K *et al.*, Mol Biol Cell. 29:3017-3025, 2018.

[10] Okamoto K *et al.*, Sci Rep. 8:11965, 2018.

[11] Gzrybowski M *et al.*, Angew. Chem. 57:10137-10141, 2018..

[12] Komatsu N *et al.*, Scientific Reports 8: 8984, 2018.

[13] Takeshima T *et al.*. Journal of Microscopy. 2018.

[14] Ueno A *et al.*, Cell Rep. 2018 Mar 27;22(13):3548-3561.

[15] Chiba K *et al.*, Mol Biol Cell, 28:3857-3869, 2017.

[16] Nozaki T *et al.*, Mol Cell. 67:282-293, 2017.

[17] Minegishi K *et al.*, Dev Cell. 40:439-452, 2017.

[18] Chinen T *et al.*, Nat Commun. 6:8722, 2015.

[19] Hayashi S & Okada Y. Mol. Biol. Cell., 26:1743-51, 2015.

[20] Takai A *et al.*, Proc. Natl. Acad. Sci. U S A. 112:4352-6. 2015.

[21] Ohyanagi T *et al.*, Chem. Commun., 51(80):14836-9. 2015.

[22] Okada Y & Nakagawa S. Methods Mol. Biol., 1262:21-35. 2015.

[23] Uno S *et al.*, Nat. Chem., 6: 681-689, 2014.

[24] Chiba K *et al.*,Mol Biol Cell, 25: 3569-3580, 2014.

[25] Hayashi K *et al.*, Euro Phys J, E 36: 136, 2013.

[26] Sato Y *et al.*, Sci Rep. 3:3436, 2013.

[27] Ota S *et al.*, Genes Cells, 18: 450-458, 2013.

[28] Hisano Y *et al.*, Biol Open, 2, 363-367, 2013.

[29] Sakuma T *et al.*, Genes Cells, 18: 315-326, 2013.

[30] Yajima H *et al.*, J Cell Biol 198: 315-322, 2012.

＜ Review Papers ＞

[31] 岡田康志、”超解像顕微鏡の原理と応用”、病理と臨床 37: 580-587, 2019.

[32] 岡田康志、”共焦点顕微鏡の光学系を用いた超解像顕微鏡法”、顕微鏡 52(2):62-66, 2017.

[33] 岡田康志、”超解像顕微鏡研究の最前線”、顕微鏡 52(2):61, 2017.

[34] 岡田康志、”超解像顕微鏡で観える生物現象”、医学の歩み 262(5): 573-579, 2017.

[35] 岡田康志、”超解像顕微鏡によるライブイメージング”、生体の科学、68(5): 378-379, 2017.

[36] 岡田康志、ライブイメージングのための高速超解像蛍光顕微鏡法”、O plus E、39(2): 174-178, 2017.

[37] 高井啓、岡田康志、3 色の高輝度発光タンパク質プローブの開発と応用”、Journal of Japanese Biochemical Society 88:669-673, 2016.

[38] 岡田康志、超解像蛍光顕微鏡法の現状と生体イメージングへの応用”、レーザー研究 44:643-647, 2016.

[39] 岡田康志、「超解像蛍光顕微鏡」、Clinical Neuroscience 34(6): 638-642, 2016.

[40] 岡田康志、”シャッター速度世界一の超解像蛍光顕微鏡”、OplusE 2015 年 8 月号.

[41] 岡田康志、藤田克昌、清末優子、”2014 年ノーベル化学賞：超解像蛍光顕微鏡法の開発”、実験医学 32:3074-3076, 2014.

[42] 岡田康志、”ノーベル化学賞：超解像蛍光顕微鏡法の開発”、パリティ 29:37-39, 2014.

[43] 岡田康志、”ゲノム編集革命”、現代化学 2014 年 8 月号 p 22-27.

[44] 岡田康志、”はじめての超解像イメージング”、実験医学 32:2623-2629, 2014.

[45] 岡田康志 、”超解像光学顕微鏡によるイメージング”、パリティ28:25-30, 2013.

[46] 川原敦雄、岡田康志、”TALEN による遺伝子改変ゼブラフィッシュの作成”、細胞工学 32:558-563, 2013.

[47] 岡田康志、”ライブイメージングのための超解像顕微鏡”、光技術コンタクト 51:4-12, 2013.

[48] 岡田康志、”ライブセルイメージングのための超解像蛍光顕微鏡法”、バイオイメージング 21: 100-101, 2012.

＜ **Books** ＞

[49] 岡田康志、”超解像・一分子イメージングによる分子動態の計測”、森泰生、尾藤晴彦編、「脳神経化学」、第 30 章、319- 329、化学同人、2018.

[50] 岡田康志 [編 · 著]「初めてでもできる！超解像イメージング」羊土社、2016.

＜ **Patent Applications** ＞

[51] 岡田康志、池田一穂　”DNA 結合タンパク質ドメインの改変による高活性 TALE タンパク質”、特願 2013-167144.

[52] 林久美子、岡田康志　”力測定方法、力測定装置、力測定システム、力測定プログラム及び記録媒体”、特願 2017-210698.

[53] 岡田康志、有吉哲郎　”蛍光発生核酸分子、及び標的ＲＮＡの蛍光標識方法”、特願 2018-226743.

[54] 岡田康志、稲生大輔　”ＤＮＡ結合タンパク質、及びゲノムＲＮＡ立体構造の標識方法”、特願 2019-074004.

7 Invited Presentations at International Conferences

[1] Okada Y. “Dissecting molecular mechanisms by optical microscopy in living cells and in vitro.” Cold Spring Harbor Conferences Asia, Cross-scale biological structure 2019..

[2] Okada Y. “Super-resolution live-cell imaging 2019: new optics, new dyes, and new algorithms.” The 46th Annual Meeting of Microscopical Society of Canada, 2019.

[3] Okada Y. “Mechanisms of axonal transport investigated by high-speed and high-resolution imaging.” 15th Annual German-Japanese Colloquium, 2019.

[4] Okada Y. “Live cell imaging technologies for single-cell analysis How can imaging meets genomics ” Human Genome Meeting 2018.

[5] Okada Y. “Development and application of high-speed super-resolution and single-molecule imaging for cell biology studies’ ’SPIE BioS、2018 .

[6] Okada Y. “Development and application of high-speed super-resolution and single-molecule microscopes for nanomedicine” International Symposium on Nanomedicine (ISNM2017), 2017.

[7] Okada Y. “Imaging technologies for single cell analysis” Human Cell Atlas Asia Meeting, 2017.

[8] Okada Y. “Current limitations in super-resolution fluorescence microscopy for biological specimens: how deep can we go from the cover glass?” Biomedical Imaging and Sensing Conference 2017 (BISC2017), 2017.

[9] Okada Y. “Regulation of the conformational polymorphism of microtubule and its physiological role in the regulation of kinesin-based intracellular transport ”, IGER International Symposium on “ Now in actin study: Motor protein research reaching a new stage ”, 2016.

[10] Okada Y. “Development and application of high-speed super-resolutoin microscope ” The 31st International Congress on High-Speed Imaging and Photonics, 2016.

[11] Okada Y. “Neuronal Biophysics ”, Discussion Leader, Gordon Research Conference, “ Single Molecule Approaches to Biology ”, 2016.

[12] Okada Y. “Development and application of spinning disk super-resolution microscope for the high spatio-temporal resolution imaging of dynamic cellular components in living cells ” The 43rd Annual Meeting of Microscopical Society of Canada, 2016.

[13] Okada Y. “Dissecting kinesin regulation through single molecule in cellulo measurements ” Janelia Conference, 2015.

[14] Okada Y. “Ultrafast superresolution fluorescence imaging with spinning disk confocal microscope optics ” 9th Asian Biophysics Association Symposium, 2015.

[15] Okada Y. “Atomic mechanism for the intracellular navigation of molecular motor, kinesin. ” Joint Weizmann-MBI Mechanobiology Conference, Singapore, 2013.

[16] Okada Y. “Structural basis for the polarized axonal transport by kinesin-1 ” The 4th Taiwan-Japan Symposium on Nanomedicine, 2013.

[17] Okada Y. “Structural basis for the polarized axonal transport by kinesin-1 ” UK-Japan Symposium for Mechanochemical Cell Biology, 2012.

[18] Okada Y. “From single molecule to in vivo imaging ” Leica Meets Science, 2012.

8 Teaching Accomplishment

- 2019 Early Carrier Award, the Biophysical Society of Japan Hideyuki Yaginuma.
- 2019 Young Scientist Award, Japanese Society for Cell Biology Hideyuki Yaginuma.
- 2018 Young Scientist Award, Japanese Society for Cell Biology Tetsuro Ariyoshi.
- 2015 Young Scientist Award, Japanese Society for Cell Biology Akira Takai.

9 Contribution to Academic Community

9.1 Editorial Activities

- Associate Editor, Cell Structure and Function 2014−

9.2 Organization of Professional Societies

- Representative of the Japanese Society of Microscopy 2017−
- Exective board member of Japan Society of Cell Biology 2016−

9.3 Organization and Advisory of Conferences

- Committee chair for Naito Conference 2021.
- President, the 73rd Annual Meeting of the Japan Society for Cell Biology 2021.
- Organizing committee member, the 57th Annual Meeting of the Biophysical Society of Japan 2019.
- Program committee member, Joint Annual Meeting of 71st JSCB and 19th PSSJ, 2019.
- Executive committee member, the 61st Symposium of the Japanese Society of Microscopy, 2018.
- Session organizer, Gordon Conference on "Single molecules approaches to biology" 2016.
- Organizer, QBiC International symposium 2016.
- Organizer, RIKEN Symposium, the 4th Molecular Motor Meeting, 2014.

10 Outreach

一般講演会：

- 「生物の普遍性を探る〜生きているってどういうこと？」、高校生のための東京大学オープンキャンパス、2019 年
- 「神経細胞の中のミクロの「宅配便」」、理研・生命システム研究センター一般公開「世界一おもろい授業」2016 年
- 「最先端イメージング技術で探る神経細胞の中の「宅配便」の仕組み」新適塾「脳はおもしろい」2016 年
- 「ライブイメージングのための高速超解像顕微鏡の開発と応用」、理研理事長懇談会、2015 年
- 「細胞の中の宅配便を光で見て、理解して、操作する」、東京大学物性研一般講演会、2015 年
- 「小さな分子モーターの大きな働き」理研神戸研一般公開講演会、2012 年

マスメディア：

- サイエンス ZERO「青色 LED だけじゃない！ノーベル賞特集」2014 年

Web メディア・動画：

- テルモ生命科学芸術財団　生命科学 DOKIDOKI 研究室　第 42 回「細胞内のモーター分子の動きをとことん見つめ生命の謎に迫る」
- YouTube 理研チャネル 60 秒でわかる？　「キネシンは、なぜ迷子にならない？」
- 理学系研究科 YouTube チャネル 研究室の扉「生きたミトコンドリアの内部構造を鮮明に見る」

11 Committee Service

11.1 External Committees

- Research Area Advisor, PREST “Quantum Bio”, JST 2017−2022

11.2 University Committees

理学系研究科技術委員会 委員　2018 年 –
Community office member of IRCN 2019−
卓越大学院運営委員 2019 年 –

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	6	USA, Denmark
Master Course	3	Germany, Russia
Doctor Course	1	UK
Foreign researchers hosted	6	Singapore, Finland
Students sent abroad	2	USA, Germany
Researchers sent abroad	0	
Foreign visitors	20	USA, Singapore, UK, France, Germany, Sweden, Taiwan

Chikara Furusawa、古澤 力

1 Education and Professional Experiences

Education

1995	B.S. (Physics)	Meiji University
1997	MSc. (Physics)	The University of Tokyo
2000	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

1999−2001	JSPS Research Fellow	The University of Tokyo
2001−2003	Special Postdoctoral Scientist	RIKEN
2003−2012	Associate Professor	Osaka University
2011−	Team Leader	RIKEN
2016−	Professor	The University of Tokyo

2 Research Highlights

Highlights of our research achievements are as follows:

(1) A dynamical system model of stem cell differentiation: One important issue in developmental biology is the understanding of differences between multipotent stem cells from differentiated cell types. We have performed computer simulations of the developmental process to screen for the gene regulatory networks that can generate cell-type diversity through stem cell differentiations. We found that those stem cells that both proliferate and always differentiate exhibit oscillatory expression dynamics, and that regulating the differentiation frequency of these stem cells causes a robust number distribution of cell types. These findings can explain the recently observed heterogeneity and dynamic equilibrium of the cellular states in stem cells (Furusawa and Kaneko, Science 2012; Suzuki, Furusawa and Kaneko, PLoS One 2012).

(2) Study on the emergence of low-dimensional dominant mode in evolutionary dynamics: A reduction in high-dimensional phenotypic states to a few degrees of freedom is essential to understand biological systems. In this study, we show evolutionary robustness causes such reduction which restricts possible phenotypic changes in response to a variety of environmental conditions. To examine if such dimension reduction is a result of evolution, we analyzed a cell model?with a huge number of components, that reproduces itself via a catalytic reaction network?and confirmed that common proportionality in the concentrations of all components is shaped through evolutionary processes. We found that the changes in concentration across all components in response to environmental and evolutionary changes are constrained to the changes along a small number of "dominant modes," within a huge-dimensional state space. From these observations, we propose a theory in which such constraints in phenotypic changes are achieved both by evolutionary robustness and plasticity and formulate this proposition in terms of dynamical systems (Furusawa and Kaneko, Phys Rev. E 2018; Kaneko and Furusawa, Annu. Rev. Biophys. 2018). Accordingly, broad experimental and numerical results on phenotypic changes caused by evolution and adaptation are coherently explained.

(3) Phenotype-genotype analysis of bacterial adaptive evolution: Technological advances enabled us to quantify the phenotypic and genetic changes in their adaptive evolution. Here, to analyze nature of phenotypic and genetic changes in microbial adaptive evolution, we performed laboratory evolution experiments of E. coli under addition of various antibiotics and obtained drug-resistant strains (Suzuki et al., Nature Comm. 2014). The results of phenotypic and genotypic analyses demonstrated that the resistance to antibiotics can be quantitatively predicted by expression levels of small number genes, which suggested that the expression changes were restricted to a low dimensional dynamics which is consistent with the phenomenological laws mentioned above. The existence of an epigenetic memory that has a much longer time-scale than their generation time and contributes to the adaptive phenotypic changes was also suggested (Horinouchi et al., BMC Evo. Biol. 2015).

3 Selected Papers

- C. Furusawa and K. Kaneko, Science **338**, 215 (2012)
  This paper has been cited 138 times.
- S. Suzuki et al., Nature Comm. **5**, 5792 (2014)
  This paper has been cited 133 times.
- C. Furusawa and K. Kaneko, Phys. Rev. Lett. **108**, 208103 (2012)
  This paper has been cited 38 times.
- T. Miyamoto et al., PLoS Comp. Biol. **11**(8), e1004476 (2015)
  The paper has been cited 32 times.
- S. Ohno et al., Bioinformatics **30**(7), 981-7 (2014)
  The paper has been cited 31 times.

4 Honors, Awards and Professional Society Memberships

2012, Chikara Furusawa, Fermentation and Metabolism Research Award, Japan Bioindustry Association.

2012, Chikara Furusawa, Outstanding Paper Award, The Biophysical Society of Japan.

5 Research Plan

Future research plans are as follow:

(1)High-throughput bacterial experimental evolution under various conditions: Our theoretical and computational analyzes suggested that a phenotype of replicating cells are restricted to relatively low-dimensional dynamics. To verify the theoretical predictions and to unveil universal laws of adaptive evolution, we are planning to perform a systematic experimental evolution of E. coli cells under hundreds of stress conditions. For this purpose, we have developed an automated system for experimental evolution. This system enables us to maintain thousands of independent culture series in a fully automated manner (Horinouchi et al., Jour. Lab Auto. 2014), which is the most high-throughput system for laboratory evolution at present. We will perform a genome-wide analysis of phenotypic and genotypic changes occurred during the adaptive evolution experiments. By integrating these high-dimensional data, we will analyze the structure and dimensionality of "possible phenotype/genotype space" in the high-dimensional state space of *E. coli*, by using appropriate machine learning methods. We expect that the comprehensive analysis of phenotype-genotype mapping during the adaptive evolutions will provide the nature of phenotypic and genotypic plasticity.

(2) Analysis of interplay between adaptive dynamics at different time-scales: The process of adaptive evolution is maintained by cellular dynamics of different time-scales. These include expression dynamics, epigenetic dynamics, and evolutionary dynamics with genomic alternations. For robust adaptive evolution, the appropriate interplay between the dynamics of different time-scales should be critical. In this study, by using the theoretical analysis computational model of replicating cells, we will analyze how such dynamics interplays between different time-scale maintains robustness and plasticity in biological systems, and how such dynamics can be represented by a small number of macroscopic variables. Furthermore, based on the high-dimensional data acquired of phenotypic and genetic changes in bacterial adaptive evolution mentioned above, we are planning to decode the macroscopic state variables representing plasticity and robustness. We expect the construction of a macroscopic state theory will provide an effective method for the prediction and control of adaptive evolution in biological systems.

(3) Understanding the plasticity and robustness of multicellular systems: Recently, high-dimensional quantifications of biological dynamics, such as single-cell RNA-Seq analysis of developmental process (e.g., Wagner et al., Science 2018) have become possible. Although such large-scale data have enough information to describe plasticity and robustness of complex cellular dynamics, methods for analyzing such high-dimensional data of biological dynamics are still in developmental stages. Here, by using such high-dimensional data of developmental dynamics, we will decode a small number of essential degrees of freedom representing stem cell differentiation dynamics. Furthermore, we will reconstruct an epigenetic landscape represented by the essential degrees of freedom, which controls the differentiation dynamics of stem cells, as proposed by Waddington. The landscape should dynamically change via cell-cell communications. Analyzing the dynamics of the landscape helps us understand how phenotypic plasticity (e.g., fluctuations and oscillations in the expression dynamics) and cell-cell communication coordinate robust developmental processes. Based on this understanding, we will develop a method that can control the cellular state by modifying the landscape using chemical or physical perturbations.

6 Publications and Patents

< Refereed Original Papers >

[1] C. Furusawa and K. Kaneko: A Dynamical-Systems View of Stem Cell Biology, Science **338**, 215 (2012).

[2] T. Hirasawa, J. Kim, T. Shirai, C. Furusawa, H. Shimizu: Molecular Mechanisms and Metabolic Engineering of Glutamate Overproduction in Corynebacterium glutamicum, Subcell. Biochem. **64**, 261-81 (2012).

[3] S. Ohno, C. Furusawa, H. Shimizu: In silico screening of triple reaction knockout Escherichia coli strains for over production of useful metabolites., J. Biosci. Bioeng. **115**(2), 221-8 (2012).

[4] C. Furusawa, K. Kaneko: Adaptation to optimal cell growth through self-organized criticality, Phys. Rev. Lett. **108**, 208103 (2012).

[5] Y Usui, T. Hirasawa, C. Furusawa, N. Yamamoto, H. Mori, and H. Shimizu: Investigating the effects of perturbations to pgi and eno gene expression on central carbon metabolism in Escherichia coli using 13C metabolic flux analysis, Microb. Cell Fact. **11**(1), 87 (2012).

[6] S. Chatsurachai, C. Furusawa and H. Shimizu: An in silico Platform for Heterologous Pathway Design to Produce Nonnative Metabolites, BMC Bioinformatics **13**(1), 93 (2012).

[7] S.A. Mahmud, T. Hirasawa, C. Furusawa, K. Yoshikawa, H. Shimizu: Understanding the mechanism of heat stress tolerance caused by high trehalose accumulation in Saccharomyces cerevisiae using DNA microarray, J Biosci Bioeng **113**(4), 526-8 (2012).

[8] Y. Ida, C. Furusawa, T. Hirasawa, H. Shimizu: Stable disruption of ethanol production by deletion of the genes encoding alcohol dehydrogenase isozymes in Saccharomyces cerevisiae, Jour. Biosci. Bioeng. **113**(2), 192-5 (2012).

[9] T. Hirasawa, M. Takekuni, K. Yoshikawa, A. Ookubo, C. Furusawa, H. Shimizu: Genome-wide identification of the targets for genetic manipulation to improve L-lactate production by Saccharomyces cerevisiae by using a single-gene deletion strain collection, Jour. Biotech. **168**(2), 185-93 (2013).

[10] C. Furusawa, K. Kaneko: Epigenetic feedback regulation accelerates adaptation and evolution, PLoS One **8**(5), e61251 (2013).

[11] S. Chatsurachai, C. Furusawa, H. Shimizu: ArtPathDesign - Rational heterologous pathway design system for the production of nonnative metabolites, Jour. Biosci. Bioeng. **116**(4), 524-7 (2013).

[12] K. Yoshikawa, T. Hirasawa, K. Ogawa, Y. Hidaka, T. Nakajima, C. Furusawa, H. Shimizu: Integrated transcriptomic and metabolomic analysis of the central metabolism of Synechocystis sp. PCC 6803 under different trophic conditions, Biotech. Jour. **8**(5), 571-80 (2013).

[13] Y. Ida, T. Hirasawa, C. Furusawa, H. Shimizu: Utilization of Saccharomyces cerevisiae recombinant strain incapable of both ethanol and glycerol biosynthesis for anaerobic bioproduction, J. Biosci. Bioeng. **97**(11), 4811-9 (2013).

[14] N. Ono, S. Suzuki, C. Furusawa, H. Shimizu, T. Yomo: Development of a physical model-based algorithm for the detection of single-nucleotide substitutions by using tiling microarrays, PLoS One **8**(1), e54571 (2013).

[15] C. Furusawa, T. Horinouchi, T. Hirasawa, H. Shimizu: Systems Metabolic Engineering: The Creation of Microbial Cell Factories by Rational Metabolic Design and Evolution, Adv. Biochem. Eng. Biotechnol. **131**, 1-23 (2013).

[16] N. Saito, S. Ishihara, K. Kaneko: The Baldwin effect under multi-peaked fitness landscapes: Phenotypic fluctuation accelerates evolutionary rate, Physical Review E, **87**, 052701 (2013).

[17] N. Saito, M. Kikuchi: Robustness Leads Close to the Edge of Chaos in Coupled Map Networks: toward the understanding of biological networks, New Journal of Physics, **15** 053037 (2013).

[18] Y. Matsumoto, Y. Murakami, S. Tsuru, B.W. Ying, T. Yomo: Growth rate-coordinated transcriptome reorganization in bacteria, BMC Genomics **14**(808), 1-10 (2013).

[19] S. Suzuki, T. Horinouchi, C. Furusawa: Prediction of antibiotic resistance by gene expression profiles, Nature Comm. **5**, 5792 (2014).

[20] K. Tokuyama, S. Ohno, K. Yoshikawa, T. Hirasawa, S. Tanaka, C. Furusawa, H. Shimizu: Increased 3-hydroxypropionic acid production from glycerol, by modification of central metabolism in Escherichia coli, Microb. Cell Fact **13**, 64 (2014).

[21] N. Okahashi, S. Kajihata, C. Furusawa, H. Shimizu: Reliable Metabolic Flux Estimation in Escherichia coli Central Carbon Metabolism Using Intracellular Free Amino Acids, Metabolite **4**(2), 408-20 (2014).

[22] T. Nakajima, S. Kajihata, K. Yoshikawa, F. Matsuda, C. Furusawa, T. Hirasawa, H. Shimizu: Integrated Metabolic Flux and Omics Analysis of Synechocystis sp. PCC 6803 under Mixotrophic and Photoheterotrophic Conditions, Plant Cell Physiol. **55**(9), 1605-12 (2014).

[23] S. Kajihata, C. Furusawa, F. Matsuda, H. Shimizu, OpenMebius: An Open Source Software for Isotopically Nonstationary (13)C-Based Metabolic Flux Analysis, Biomed. Res. Int. **2014**, 627014 (2014).

[24] Y. Yamauchi, T. Hirasawa, M. Nishii, C. Furusawa H. Shimizu: Enhanced acetic acid and succinic acid production under microaerobic conditions by Corynebacterium glutamicum harboring Escherichia coli transhydrogenase gene pntAB, Jour. Gen. Appl. Microbiol. **60**(3), 112-8 (2014).

[25] S. Ohno, H. Shimizu, C. Furusawa: FastPros: screening of reaction knockout strategies for metabolic engineering, Bioinformatics **30**(7), 981-7 (2014).

[26] T. Horinouchi, T. Minamoto, S. Suzuki, H. Shimizu, C. Furusawa: Development of an Automated Culture System for Laboratory Evolution, Jour. Lab. Automation **19**(5), 478-82 (2014).

[27] T. Hirasawa, Y. Ida, C. Furusawa, H. Shimizu: Potential of a Saccharomyces cerevisiae recombinant strain lacking ethanol and glycerol biosynthesis pathways in efficient anaerobic bioproduction, Bioengineered **5**(2), 123-8 (2014).

[28] N. Saito, S. Ishihara, K. Kabeko: Evolution of Genetic Redundancy : The Relevance of Complexity in Genotype-Phenotype Mapping, New Journal of Physics, **16**, 063013 (2014).

[29] B.W. Ying, S. Tsuru, S. Seno, H. Matsuda, T. Yomo: Gene expression scaled by distance to the genome replication site, Molecular BioSystems **10**(3), 375-9 (2014).

[30] Y. Akeno, B.W. Ying, S. Tsuru, T. Yomo: A reduced genome decreases the host carrying capacity for foreign DNA, Microbial Cell Factories **13**(49), 1-9 (2014).

[31] K. Nishimura, S. Tsuru, H. Suzuki, T. Yomo: Stochasticity in gene expression in a cell-sized compartment, ACS Synthetic Biology **4**(5), 566-76 (2014).

[32] Y. Ishizawa, B.W. Ying, S. Tsuru, T. Yomo: Nutrient-dependent growth defects and mutability of mutators in Escherichia coli, Genes to Cells **20**(1), 68-76 (2014).

[33] M. Yoshida, S. Tsuru, N. Hirata, S. Seno, H. Matsuda, B.W. Ying, T. Yomo: Directed evolution of cell size in Escherichia coli, BMC Evolutionary Biology **14**(257), 1-12 (2014).

[34] K. Yoshikawa, S. Aikawa, Y. Kojima, Y. Toya, C. Furusawa, A. Kondo, and H. Shimizu: Construction of a genome-scale metabolic model of Arthrospira platensis NIES-39 and metabolic design for cyanobacterial bioproduction, PLoS One **10**(12), e0144430 (2015).

[35] C. Furusawa and K. Kaneko: Global relationships in fluctuation and response in adaptive evolution, Jour. Roy. Soc. Interface **12**(109), 20150482 (2015).

[36] T. Horinouchi, S. Suzuki, T. Hirasawa, N. Ono, T. Yomo, H. Shimizu, and C. Furusawa: Phenotypic convergence in bacterial adaptive evolution to ethanol stress, BMC Evo. Biol. **15**, 180 (2015).

[37] B.W. Ying, Y. Matsumoto, K. Kitahara, S. Suzuki, N. Ono, C. Furusawa, T. Kishimoto, and T. Yomo: Bacterial transcriptome reorganization in thermal adaptive evolution, BMC genomics **16**(1), 802 (2015).

[38] T. Miyamoto, C. Furusawa, and K. Kaneko: Pluripotency, Differentiation, and Reprogramming: A Gene Expression Dynamics Model with Epigenetic Feedback Regulation, PLoS Comp. Biol. **11**(8), e1004476 (2015).

[39] K. Kaneko, C. Furusawa, T. Yomo: Universal Relationship in Gene-Expression Changes for Cells in Steady-Growth State, Physical Review X **5**, 011014 (2015).

[40] S. Suzuki, T. Horinouchi, C. Furusawa: Suppression of antibiotic resistance acquisition by combined use of antibiotics, Jour. Biosci. Bioeng. **120**(4), 467 (2015).

[41] K. Kajihata, F. Matsuda, M. Yoshimi, K. Hayakawa, C. Furusawa, A. Kanda, H. Shimizu: 13C-based metabolic flux analysis of Saccharomyces cerevisiae with a reduced Crabtree effect, Jour. Biosci. Bioeng. **120**(2), 140 (2015).

[42] Y. Murakami,Y. Matsumoto, S. Tsuru, B.W. Ying,T. Yomo: Global coordination in adaptation to gene rewiring, Nucleic Acids Research **42**(2), 1304-16 (2015).

[43] T. Kishimoto, B.W. Ying, S. Tsuru, L. Iijima, S. Suzuki, T. Hashimoto, A. Oyake, H. Kobayashi, Y. Someya, D. Narisawa, T. Yomo: Molecular Clock of Neutral Mutations in a Fitness-Increasing Evolutionary Process, PLoS Genetics **11**(7), 1-18 (2015).

[44] B.W. Ying, T. Honda, S. Tsuru, S. Seno, H. Matsuda, Y. Kazuta, T. Yomo: Evolutionary Consequence of a Trade-Off between Growth and Maintenance along with Ribosomal Damages, PLoS ONE **10**(8), 1-19 (2015).

[45] S. Tsuru, Y. Ishizawa, A. Shibai, Y. Takahashi, D. Motooka, S. Nakamura, T. Yomo: Genomic confirmation of nutrient-dependent mutability of mutators in Escherichia coli, Genes to Cells **20**(12), 972-81 (2015).

[46] R. Baumstark, S. Hanzelmann, S. Tsuru, Y. Schaerli, M. Francesconi, F.M. Mancuso, R. Castelo, M. Isalan: The propagation of perturbations in rewired bacterial gene networks, Nature Communications **6**(10105), 1-11 (2015).

[47] N. Saito, Y. Sughiyama and K. Kaneko: Motif Analysis for Small-Number Effects in Chemical Reaction Dynamics, Jour. Chem. Phys. **145**, 094111 (2016).

[48] C. Furusawa and T. Yamaguchi: Robust and Accurate Discrimination of Self/Non-Self Antigen Presentations by Regulatory T Cell Suppression, PLoS One **11**(9), e0163134 (2016).

[49] S. Suzuki, T. Horinouchi and C. Furusawa: Phenotypic changes associated with the fitness cost in antibiotic resistant Escherichia coli strains, Mol. Biosys **12**(2), 414-20 (2016).

[50] J. F. Yamagishi, N. Saito and K. Kaneko: Symbiotic Cell Differentiation and Cooperative Growth in Multicellular Aggregates, PLoS Comput. Biol. **12**(10), e1005042 (2016).

[51] N. Saito and K. Kaneko: Embedding dual function into molecular motors through collective motion, Scientific Reports **7**, 44288 (2017).

[52] H. Shimizu, C. Furusawa, T. Hirasawa, K. Yoshikawa, Y. Toya, T. Shirai and F. Matsuda: Omics-Integrated Approach for Metabolic State Analysis of Microbial Processes: Innovations and Future Directions, Appl. Bioeng. **5**, 213-236 (2017).

[53] S. Suzuki, T. Horinouchi and C. Furusawa: Expression profiling of antibiotic resistant bacteria obtained by laboratory evolution, Meth. Mol. Biol. **1520**, 263-279 (2017).

[54] H. Matsumoto, H. Kiryu, C. Furusawa, M. SH. Ko, S. BH. Ko, N. Gouda, T. Hayashi and I. Nikaido: SCODE: An efficient regulatory network inference algorithm from single-cell RNA-Seq during differentiation, Bioinformatics **33**(15), 2314-2321 (2017).

[55] S. Suzuki, T. Horinouchi and C. Furusawa: Acceleration and Suppression of Resistance Development by Antibiotic Combinations, BMC Genomics, **18**(1), 328 (2017).

[56] M. Yoshida, S. G. Reyes, S. Tsuda, T. Horinouchi, C. Furusawa and L. Cronin: Time-programmable drug dosing allows the manipulation, suppression and reversal of antibiotic drug resistance *in vitro*, Nature Comm. **8**, 15589 (2017).

[57] A. Germond, V. Kumar, T. Ichimura, J. Moreau, C. Furusawa, H. Fujita, T. M. Watanabe: Raman spectroscopy as a tool for ecology and evolution, Jour. Roy. Soc. Interface **14**(131) 20170174 (2017).

[58] T. Horinouchi, A. Sakai, H. Kotani, K Tanabe, C. Furusawa: Improvement of isopropanol tolerance of Escherichia coli using adaptive laboratory evolution and omics technologies, Jour. Biotech **255**, 47-56 (2017).

[59] T. Horinouchi, S. Suzuki, H. Kotani, K. Tanabe, N. Sakata, H. Shimizu, C. Furusawa: Prediction of Cross-resistance and Collateral Sensitivity by Gene Expression profiles and Genomic Mutations, Sci. Rep. **7**(1), 14009 (2017).

[60] T. S. Hatakeyama, C. Furusawa: Metabolic dynamics restricted by conserved carriers: Jamming and feedback, PLoS Comp. Biol. **13**(11), e1005847 (2017).

[61] A. Shibai, Y. Takahashi, Y. Ishizawa, D. Motooka, S. Nakamura, B. W. Ying, S. Tsuru: Mutation accumulation under UV radiation in Escherichia coli, Sci. Rep. **7**(1), 14531 (2017).

[62] S. Takano, B.J. Pawlowska, I. Gudelj, T. Yomo, S. Tsuru: Density-Dependent Recycling Promotes the Long-Term Survival of Bacterial Populations during Periods of Starvation, mBio **8**(1), 1-14 (2017).

[63] C. Furusawa, T. Horinouchi, T. Maeda: Toward prediction and control of antibiotic-resistance evolution, Curr. Opin. Biotechnol. **54**, 45-59 (2018).

[64] K. Kaneko and C. Furusawa: Macroscopic Theory for Evolving Biological Systems Akin to Thermodynamics, Annu. Rev. Biophys. **47**, 273-290 (2018).

[65] C. Furusawa and K. Kaneko: Formation of Dominant Mode by Evolution in Biological System, Phys. Rev. E **97**(4), 042410 (2018).

[66] K. Tokuyama, Y. Toya, T. Horinouchi, C. Furusawa, F. Matsuda, H. Shimizu: Application of adaptive laboratory evolution to overcome a flux limitation in an Escherichia coli production strain, Biotechnol. Bioeng. **115**(6), 1542-1551 (2018).

[67] T. Hirasawa, M. Saito, K. Yoshikawa, C. Furusawa, H. Shimizu: Integrated Analysis of the Transcriptome and Metabolome of Corynebacterium glutamicum during Penicillin-Induced Glutamic Acid Production, Biotechnol. Jour. **13**(5), e1700612 (2018).

[68] A. Germond, T. Ichimura, T. Horinouchi, H. Fujita, C. Furusawa, T. M. Watanabe: Raman spectral signature reflects transcriptomic features of antibiotic resistance in Escherichia coli, Comm. Biology **1**, 85 (2018).

[69] K. Okamoto, A. Germond, H. Fujita, C. Furusawa, Y. Okada, T. M. Watanabe: Single cell analysis reveals a biophysical aspect of collective cell-state transition in embryonic stem cell differentiation, Sci. Rep. **8**(1), 11965 (2018).

[70] T. Komori, A. Shibai, H. Saito, Y. Akeno, A. Germond, T. Horinouchi, C. Furusawa, S. Tsuru: Enhancement of K-strategy evolution in histidine utilization using a container with compartments, Genes Cells **23**(10), 893-903 (2018).

[71] A. Shibai, S. Tsuru, T. Yomo: Development of an Automated UV Irradiation Device for Microbial Cell Culture, SLAS Technol. **10**, 1-7 (2018).

[72] T. Maeda, T. Horinouchi, N. Sakata, A. Sakai, C. Furusawa: High-throughput identification of the sensitivities of an Escherichia coli ΔrecA mutant strain to various chemical compounds, Jour. Antibiot.**72**(7), 566 (2019).

[73] C. Furusawa, T. Horinouchi, T. Maeda: Toward prediction and control of antibiotic-resistance evolution, Curr. Opin. Biotech. **54**, 45-49 (2019).

[74] A. Shibai, T. Maeda, M. Kawada, H. Kotani, N. Sakata, C. Furusawa: Complete Genome Sequences of Three Star-Shaped Bacteria, Stella humosa, Stella vacuolata, and Stella Species ATCC 35155, Microbiol. Resour. Announc.**8**(32), e00719 (2019).

[75] T. Yamaguchi, S. Teraguchi, C. Furusawa, H Machiyama, T. M. Watanabe, H. Fujita, S. Sakaguchi, T. Yanagida: Theoretical modeling reveals that regulatory T cells increase T cell-interaction with antigen-presenting cells for stable immune-tolerance, Int. Immunol. in press.

[76] A. Shibai, K. Satoh, M. Kawada, H. Kotani, I. Narumi, C. Furusawa: Complete Genome Sequence of a Radioresistant Bacterial Strain, Deinococcus grandis ATCC 43672, Microbiol. Resour. Announc., in press.

＜ Review Papers ＞

[77] K. Yoshikawa, C. Furusawa, T. Hirasawa, and H. Shimizu: Design of Superior Cell Factories Based on Systems Wide Omics Analysis, Systems Metabolic Engineering p. 57-81 (edited by C. Wittmann and S. Y. Lee), Springer (2012).

[78] C. Furusawa, T. Horinouchi, T. Hirasawa, and H. Shimizu: Systems Metabolic Engineering: The Creation of Microbial Cell Factories by Rational Metabolic Design and Evolution, Adv. Biochem. Eng. Biotechnol. **131**, 1-23 (2013).

[79] 堀之内貴明, 古澤力: 適応進化はどのように起こるのか？～進化実験によるアプローチ～, 細胞工学 **33**(6), 666-669 (2014).

[80] 古澤力: 微生物の実験室進化, 生体の科学 **65**(5), 452-453 (2014).

[81] Y. Iba, N. Saito: A. Kitajima: Multicanonical MCMC for Sampling Rare Events, Annals of the Institute of Statistical Mathematics, **66**, issue3, (2014)

[82] 堀之内貴明, 鈴木真吾, 古澤力: 微生物の適応進化過程の理解とその応用, 生物工学会 **93**(9), 536-538 (2015).

[83] 古澤力, 鈴木真吾, 堀之内貴明: 大腸菌進化実験を用いた遺伝子発現量からの抗生物質耐性メカニズムの解析, バイオサイエンスとインダストリー **74**(2), 138-140 (2016).

[84] C. Furusawa: Analysis of Drug Resistance Using Experimental Evolution, Yakugaku Zasshi **137**(4), 373-376 (2017).

[85] T. Horinouchi, T. Maeda, C. Furusawa: Understanding and engineering alcohol-tolerant bacteria using OMICS technology, World Jour. Microb. Biotech. **34**(11), 157 (2018).

[86] 金子邦彦, 古澤力: 適応と進化におけるマクロ現象論–表現型変化の低次元拘束と揺らぎ-応答関係–, 日本物理学会誌 **74**(3), 137-145 (2019).

＜ Books ＞

[87] 古澤力: 進化学に残された謎：複数の形質が絡み合う進化プロセスはどのように可能か？, 進化の謎をゲノムで解く（長谷部光泰 編）, 学研メディカル秀潤社　(2015).

[88] 古澤力, 前田智也, 堀之内貴明: ラボ内での全自動進化実験システムの構築, 実験医学別冊「あなたのラボに AI ×ロボットがやってくる（夏目徹 編）, 羊土社 (2017).

[89] 古澤力: 進化実験の定量生物学, 定量生物学（小林徹也　編）, 化学同人 (2018).

＜ Patent Applications ＞

[90] R. Fujii, T. Shirai, T. Araki, K. Amano, Y. Matsumoto, T. Tateno, N. Takebayashi, T. Morishige, H. Takahashi, M. Wada, H. Shimizu, C. Furusawa, T. Hirasawa, T. Hidesaki, A. Endo, D. L. Jurgenlohmann, A. Madhavan, S. S. Chong: Microorganism having carbon dioxide fixation pathway introduced thereinto. Patent Application WO2013018734

[91] K. Amano, T. Shirai, H. Takahashi, J. Hirano, Y. Matsumoto, N. Takebayashi, M. Wada, H. Shimizu, C. Furusawa, T. Hirasawa: Isopropyl alcohol-producing bacterium having improved productivity by gntr destruction, United States Patent Application 201302808044

[92] Y. Matsumoto, J. Hirano, T. Morishige, T. Shirai, H. Takahashi, K. Amano, N. Takebayashi, M. Wada, H. Shimizu, C. Furusawa, T. Hirasawa: Highly Productive Isopropyl Alchol-Producing Bacterium, United States Patent Application 20130005008

[93] 白井智量, 古澤力, 堀之内貴明, 折下涼子, 阪田奈津枝, 田辺久美, 小谷葉月: メタクリル酸耐性微生物及びその製造方法, 特願 2016-230548

7 Invited Presentations at International Conferences

[1] Chikara Furusawa: Oscillatory protein expression dynamics generates robust and irreversible differentiation dynamics of stem cells, iCeMS Symposium on Theoretical and Computational Biology, Kyoto (2013).

[2] Chikara Furusawa: Oscillatory protein expression dynamics generates robust and irreversible differentiation dynamics of stem cells, 8th Asian Biophysics Association (ABA) Symposium, Jeju (2013).

[3] Chikara Furusawa: Oscillatory Protein Expression Dynamics Generates Robust and Irreversible Differentiation Dynamics of Stem Cells, The 4th Symposium on Systems and Synthetic Biology(TriSys), Hong-Kong (2013).

[4] Chikara Furusawa: Oscillatory protein expression dynamics generates robust and irreversible differentiation of stem cells, 3rd International Conference on Tissue Science & Regenerative Medicine, Valencia (2014).

[5] Chikara Furusawa: Creating stress tolerant bacterial cells by experimental evolution, 5th Asian Symposium on Innovative Bio-production and Biorefinery, Tainan (2014).

[6] Chikara Furusawa: Toward Understanding of Adaptive Evolution: Computational Analysis and Experimental Evolution, QBiC Symposium: High-dimensional data for the design principles of life, Osaka (2015).

[7] Chikara Furusawa: Phenotypic Convergence in Experimental Evolution of Antibiotic Resistant Bacteria, 2nd Symposium on Complex Biodynamics & Networks, Tsuruoka (2015).

[8] Chikara Furusawa: Toward Understanding of Adaptive Evolution: High-throughput Laboratory Evolution and Computational Analysis, International Symposium on Universal Biology, Tokyo (2016).

[9] Chikara Furusawa: Toward Understanding of Adaptive Evolution: Theoretical Analysis and Microbial Laboratory Evolution, 5th International Symposium of the Mathematics on Chromatin Live Dynamics, Hiroshima (2017).

[10] Chikara Furusawa: Phenotypic diversity and constraints in microbial adaptive evolution, Les Houches School "Evolution of Diversity", France (2018).

[11] Chikara Furusawa: High-throughput Laboratory Evolution of E. coli to Unveil Phenotypic Plasticity and Constraint, 1st Asia Evo., China (2018).

[12] Chikara Furusawa: High-throughput laboratory evolution of E. coli: toward understanding of phenotypic plasticity and constraint, Euro EvoDevo2018, Ireland (2018).

[13] Chikara Furusawa: High-throughput Laboratory Evolution of E. coli to Unveil Phenotypic Plasticity and Constraint, 46th Naito Conference, Sapporo (2018).

[14] Nen Saito: Self organization via membrane deformation and reaction diffusion: 3D modeling for macropinocytosis of ameboid cell, LMU-UT Joint Workshop ,Tokyo (2018).

8 Teaching Accomplishment

9 Contribution to Academic Community

9.1 Organization of Professional Societies

- 2011-, 古澤力, 分野別専門委員会, 日本生物物理学会

9.2 Organization and Advisory of Conferences

- 2012, Chikara Furusawa, Organizing committee, QBiC Symposium: High-dimensional data for the design principles of life
- 2016, Chikara Furusawa, Organizing committee, International Symposium on Universal Biology

10 Outreach

- 2012, 古澤力, 「生きているって何だろう？」, 平成２３年度西宮湯川記念こども課外教室, 西宮市立甲東小学校
- 2012, 古澤力, 細胞が語り合う『言葉』を理解する ～計算機シミュレーションによる生命システムの解析～, オープントラカレ講座（ヒッポファミリークラブ主催）
- 2013, 古澤力, 「生きているって何だろう？」, QBiC サイエンスカフェ（理化学研究所・神戸研究所一般公開）
- 2014, 古澤力, 生物らしさの理解へ向けて : ゆらぎと進化について, オープントラカレ講座（ヒッポファミリークラブ主催）

11 Committee Service

11.1 University Committees

理学系研究科物理学専攻サブコース主任, 2017 年 –

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	3	India, USA
Master Course	0	
Doctor Course	0	
Foreign researchers hosted	0	
Students sent abroad	1	France
Researchers sent abroad	0	
Foreign visitors	5	France, Germany, Denmark, UK

Sosuke Ito、伊藤 創祐

1 Education and Professional Experiences

Education

2010	B.S. (Physics)	The University of Tokyo
2012	MSc. (Physics)	The University of Tokyo
2015	Ph.D. (Physics)	The University of Tokyo

Professional Appointments

2012−2015	JSPS Research Fellowships for Young Scientists (DC1)	The University of Tokyo
2015−2017	JSPS Research Fellowships for Young Scientists (PD)	Tokyo Institute of Technology
2017−2018	Assistant Professor	Hokkaido University
2018−	PRSETO researcher	JST
2018−	Lecturer	The University of Tokyo

2 Research Highlights

We have mainly discussed connections between thermodynamics and information theory which are applicable to biochemical systems. Based on thermodynamics for stochastic processes (stochastic thermodynamics), we have newly found several relationships between thermodynamics and information theory for mesoscopic systems such as chemical reaction in biological cells and the Brownian particles. We here show research highlights of our recent results as follows.

We have generalized the second law of thermodynamics for autonomous information processing, which can solve the paradox of the Maxwell's demon. For example, we have used the Bayesian network to describe the complex information processing and generalized the second law of thermodynamics with information flow on this network [7]. In this generalization, information flow is quantified by the transfer entropy and the directed information which are well known measures of causal information flow. Then, our result gives a thermodynamic interpretation of the transfer entropy and the directed information.

We have also discussed an application of this generalized second law to the biochemical signal transduction of *E. coli* bacterium chemotaxis [5]. In this application, we focus on the information flow from the kinase activity (CheA) and the methylation level of the receptor in *E. coli* cell. As a result, we can quantitatively show that the generalized second law gives the informational bound of the robustness of the sensory adaptation.

We have additionally obtained several thermodynamic and informational results related to this generalized second law of thermodynamics with information flow. For example, the second law of thermodynamics has been generalized not only for the Bayesian network, but also for the Markov jump process [6]. We then have obtained the generalization of the Onsager reciprocal relationship for autonomous information processing with information flow for the Markov jump process [2]. We have also proposed informational and thermodynamic measure of causality based on the generalization of the second law of thermodynamics, that is called as the backward transfer entropy [3].

Recently, we have consider another type of relationship between thermodynamics and information theory based on geometry. To consider a differential geometric theory of information well known as information geometry, we have tried to construct information geometric theory of thermodynamics which are applicable to biochemical systems. For example, we have obtained a classical thermodynamic generalization of the uncertainty relationship between energy and speed (the quantum speed limit) [1]. This uncertainty relationship is applicable to the biochemical reaction such as the enzyme reaction.

3 Selected Papers

- S. Ito and T. Sagawa, Physical Review Letters, 111, 180603 (2013)
  This paper has been cited 123 times in Google scholar.
- S. Ito and T. Sagawa, Nature communications, 6, 7498 (2015)
  The paper has been cited 80 times in Google scholar. This work has been highlighted in natureasia.com as a featured paper.
- N. Shiraishi, S. Ito, K. Kawaguchi, T. Sagawa, New Journal of Physics 17, 045012 (2015)
  The paper is an invited paper. The paper has been cited 40 times in Google scholar.
- S. Ito, Scientific reports 6, 36831 (2016)
  The paper has been cited 18 times in Google scholar.
- S. Ito, Physical Review Letters, 121, 030605 (2018)
  The paper has been cited 12 times in Google scholar.

4 Honors, Awards and Professional Society Memberships

2015 The Research Award for Ph. D. Students of Faculty of Science, The University of Tokyo
2015 11th Early Career Award in Biophysics in Japan
2017 11th Young Scientist Award of the Physical Society of Japan

5 Research Plan

In a near future, we would like to develop a fundamental theory of thermodynamics with information geometry as a general framework to understand a thermodynamic aspect of information processing in living systems. To clarify the deep connection between information geometry and thermodynamics, we can consider biological systems in information geometry, which is used in the fields of the artificial intelligence, the machine learning, and neural networks. We would like to understand the design principle of living systems as a machine of information transmission driven by thermodynamic resources.

To develop it, we will reconsider several laws of thermodynamics and recent results of thermodynamics with information, from a view point of information geometry at first. To reconsider it, we have obtained several relationships between thermodynamics and information geometry. For example, we will reconsider the thermodynamic theory of stability well known as the Glansdorff-Prigogine criterion for stability from a view point of information geometry. This theory is the old theory in 1970s, but it can be generalized in a modern form based on our theory of information geometry and thermodynamics.

Moreover, we would like to make a fundamental theory of the phase transition, dynamical system of chemical reaction, and chaos based on thermodynamics of information geometry. This fundamental theory would help to understand biological systems, which is constructed by dynamical system of chemical reactions. We would like to reconsider informational aspects of the well known phenomena from a view point of information geometry.

We also would like to make a statistical method to measure informational and thermodynamic quantities from biological experimental data, e. g., the statistics of trajectories of time series such as the FRET signal and the motion of colloidal particles. For example, we would like to make a method to measure several informational and thermodynamic quantities such as the mutual information, the transfer entropy, the integrated information, the entropy production, the partial entropy production, dynamic information flow, thermodynamic efficiency, the Fisher information and efficiencies of thermodynamic uncertainty relationships.

Based on the above plan, we would like to ask a fundamental question, i.e., how biological system can reduce thermodynamic cost and maintain an efficient system. The answer of this question would reveal the universality of living things.

6 Publications and Patents

< Refereed Original Papers >

[1] S. Ito, Phys. Rev. Lett. 121, 030605 (2018)

[2] S. Yamamoto, S. Ito, N. Shiraishi and T. Sagawa, Phys. Rev. E 94, 052121 (2016)

[3] S. Ito, Sci. Rep. 6, 36831 (2016)

[4] N. Matsumoto, K. Komori, S. Ito, Y. Michimura and Y. Aso, Phys. Rev. A 94, 033822 (2016)

[5] S. Ito and T. Sagawa, Nat. Commun. 6, 7498 (2015)

[6] N. Shiraishi, S. Ito, K. Kawaguchi and T. Sagawa, New J. Phys. 17, 045012 (2015)

[7] S. Ito and T. Sagawa, Phys. Rev. Lett. 111, 180603 (2013)

[8] K. Ashida, K. Hotta and K. Oka, iScience 19, 191 (2019)

[9] K. Ashida, T. Kato, K. Hotta and K. Oka, Neuroscience letters 706 68 (2019)

[10] K. Ashida and K. Oka, Biochemical and biophysical research communications 508, 690 (2019)

[11] T. Yoshimizu, H. Shidara, K. Ashida, K. Hotta and K. Oka, The Journal of experimental biology 221, 182790 (2018)

< Conference Proceedings >

< Review Papers >

[12] S. Ito, BUSSEI KENKYU DENSHIBAN, 6(4), 064232 (2017)

[13] S. Ito and T. Sagawa, NIHON BUTSURI GAKKAISHI, 72, 9 (2017).

[14] S. Ito, SEIBUTSU BUTSURI, 56, 232 (2016).

< Books >

[15] S. Ito, "Information Thermodynamics on Causal Networks and its Application to Biochemical Signal Transduction", Springer, 2016. (ISBN: 978-981-10-1664-6)

[16] S. Ito and T. Sagawa, "Information flow and entropy production on Bayesian networks" As a chapter of M. Dehmer, F. Emmert-Streib, Z. Chen, X. Li, Y. Shi (Eds.), "Mathematical Foundations and Applications of Graph Entropy", Wiley, 2016. (ISBN: 978-3-527-33909-9)

< Patent Applications >

7 Invited Presentations at International Conferences

[1] S. Ito, "Thermodynamics of information geometry", Data analysis and machine learning in dynamical systems, Tokyo, Japan, May. 27-29, 2019.

[2] S. Ito, "Stochastic thermodynamics of information", Frontiers of complex systems science: soft matters, statistical physics, and big data, Taipei, Taiwan, Jan. 22-23, 2018.

[3] S. Ito, "Thermodynamics of information on biochemical signaling networks", Deciphering complex energy landscape and kinetic network from single molecules to cells: a new challenge to make theories meet experiments, Dijon, France, Sep. 3-8, 2017.

[4] S. Ito, "Information flow and entropy production on Bayesian networks", Data Science Challenges: a Complex Systems Perspective, Torino, Italy, Oct. 14-17, 2015.

[5] S. Ito, "Maxwell's demon in biochemical signal transduction with feedback loop: the role of information flow in biological communication", Conference on Sensing, Information and Decision at the Cellular Level, Trieste, Italy, Jul. 14-17, 2015.

[6] S. Ito, "Maxwell ' s demon in biochemical signal transduction with feedback loop", Focus Meeting of the Kyoto Winter School for Statistical Mechanics, Kyoto, Japan, Feb. 16-17, 2015.

[7] S. Ito, "Information thermodynamics reveals the robustness of biochemical signal transduction", Bridging the gap between matter and life -Discussion with Prof. Albert Libchaber-, Tokyo, Japan, Jun. 6, 2014.

[8] S. Ito, "Information Thermodynamics on Causal Networks", Frontier of Statistical Physics and Information Processing -Perspectives from Nonequilibrium Behaviors-, Kyoto, Japan, Jul. 11-14, 2013.

8 Teaching Accomplishment

9 Contribution to Academic Community

9.1 Editorial Activities

9.2 Organization of Professional Societies

9.3 Organization and Advisory of Conferences

10 Outreach

- 2013 年 8 月 8 日　東京大学理学部オープンキャンパス 2013 講演会「情報と物理　ギャンブルの情報理論から最新の熱力学まで 」
- 2015 年 6 月 30 日　プレスリリース: 大腸菌に潜む「マクスウェルのデーモン」の働きを解明―情報と熱力学の融合による生体情報処理の解析への第一歩―
- 2015 年 7 月 15 日　拓く研究人-81- 「日本学術振興会特別研究員 伊藤創祐氏」 日刊工業新聞
- 2015 年 9 月 20 日　第 2 回ぶつりがく徒のつどい 「確率的な熱力学と「情報」」
- 2018 年 3 月 2 日 企業での一般公開セミナー: “Stochastic thermodynamics of information”, ARAYA Seminar, ARAYA Inc.
- 2018 年 7 月 19 日　プレスリリース: 情報の幾何学から熱力学的な不確定性原理を発見 生体内の“ ゆらぐ化学反応 ”による情報伝達の普遍的な理解へ
- 2018 年 7 月 30-31 日　夢・化学 21 北海道大学化学系への二日体験入学「サイコロから学ぶ化学反応-化学反応の熱力学理論-」
- 2019 年 8 月 8 日　東京大学理学部オープンキャンパス 2019 「生物の普遍性を探る」

11 Committee Service

11.1 External Committees

11.2 University Committees

12 Internationalization Statistics

	Number	Country
Foreign students advised		
Bachelor Course	0	
Master Course	0	
Doctor Course	0	
Foreign researchers hosted	0	
Students sent abroad	0	
Researchers sent abroad	0	
Foreign visitors	1	Germany