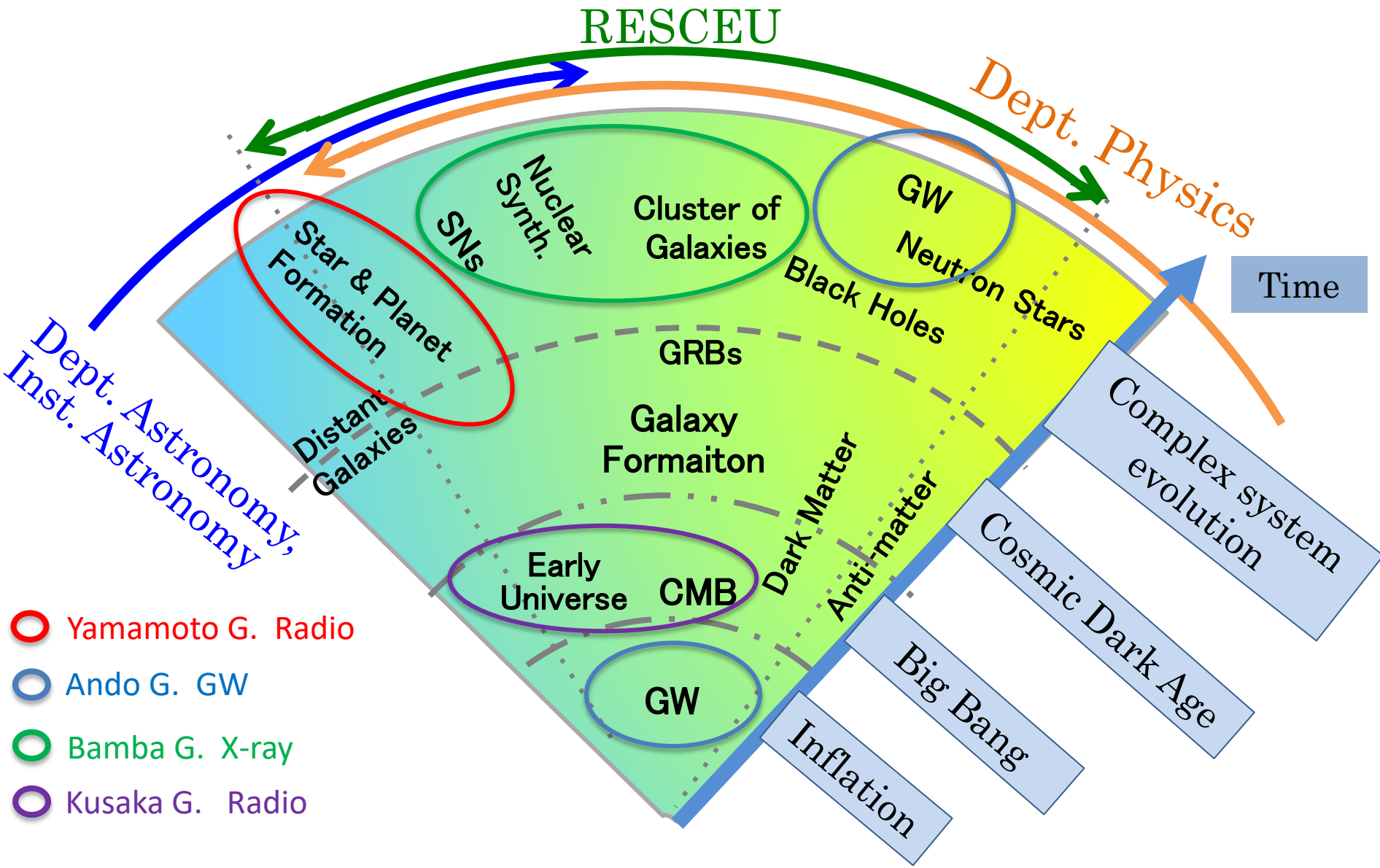
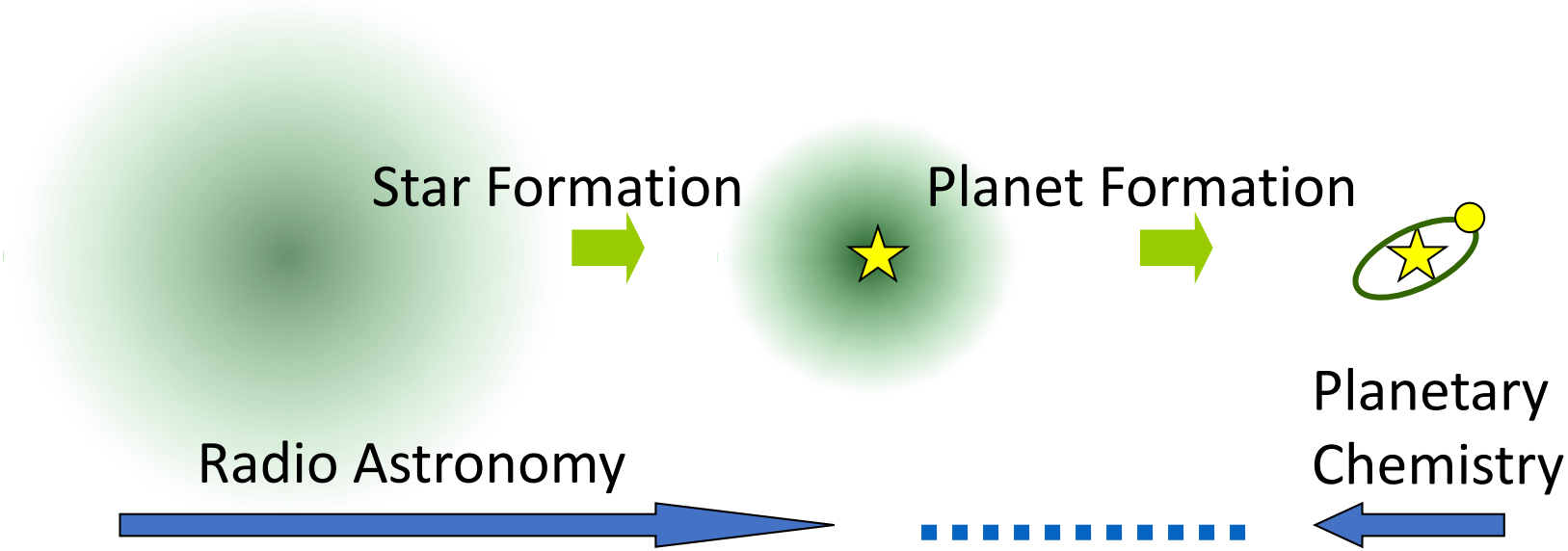
Astrophysics Groups (Experiment)



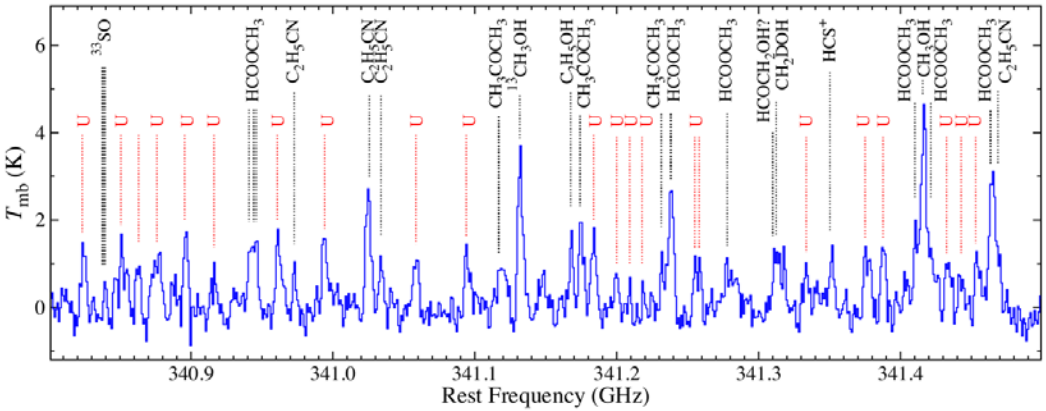
Yamamoto Group

Satoshi Yamamoto and Yoko Oya

Chemical Evolution from Interstellar Clouds to Planets



Molecular Cloud **Protostar** **Star and Planets**



Recent Discoveries

- Chemical Diversity in Solar-type Protostars

  Hot Corino vs WCCC object

  (Saturated Molecules vs Unsaturated Molecules)

  Sakai & Yamamoto, Chem. Rev. 113, 8981, (2013)

Before ALMA >1000 au

- Chemical Diversity in Disk Forming Region

  Chemical Heritage to Planetary Systems

  e.g., Oya et al, Astrophys. J., 824, 88 (2016)

With ALMA <100 au

- Drastic Chemical Change in Disk Formation

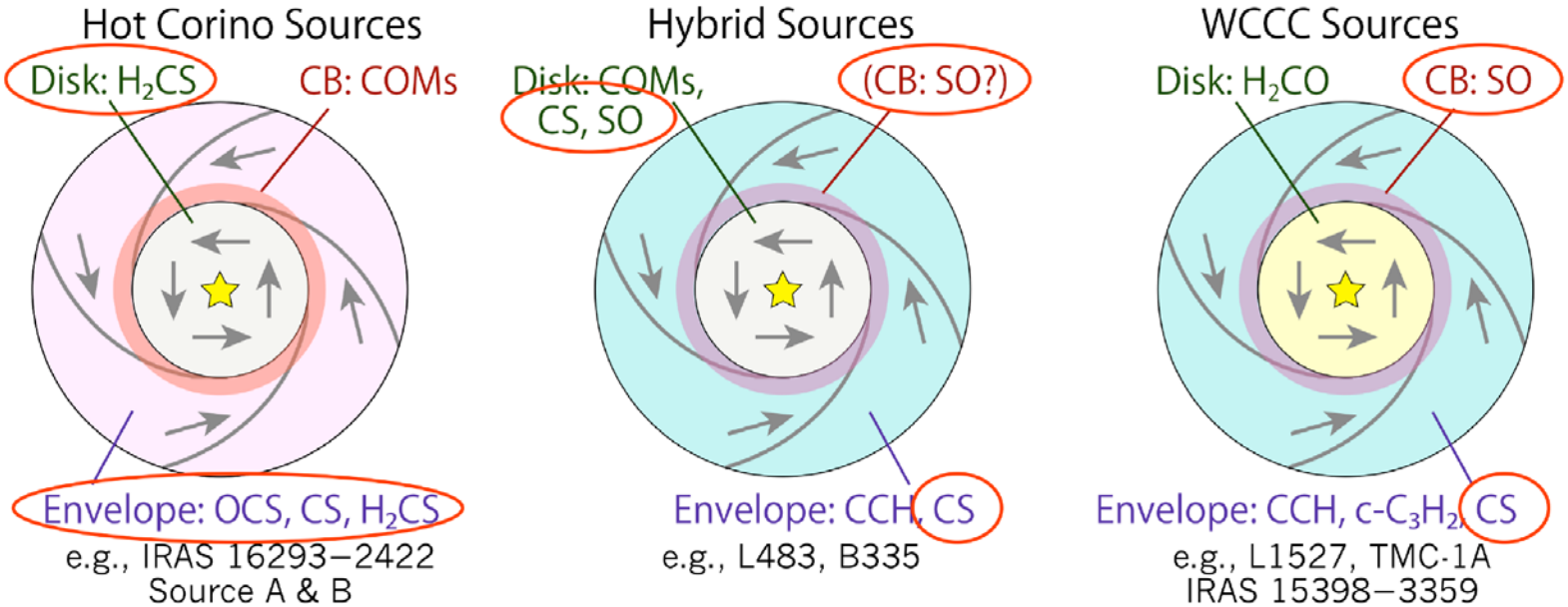
  Discontinuous Change at the Centrifugal Barrier of the Infalling Rotating Gas

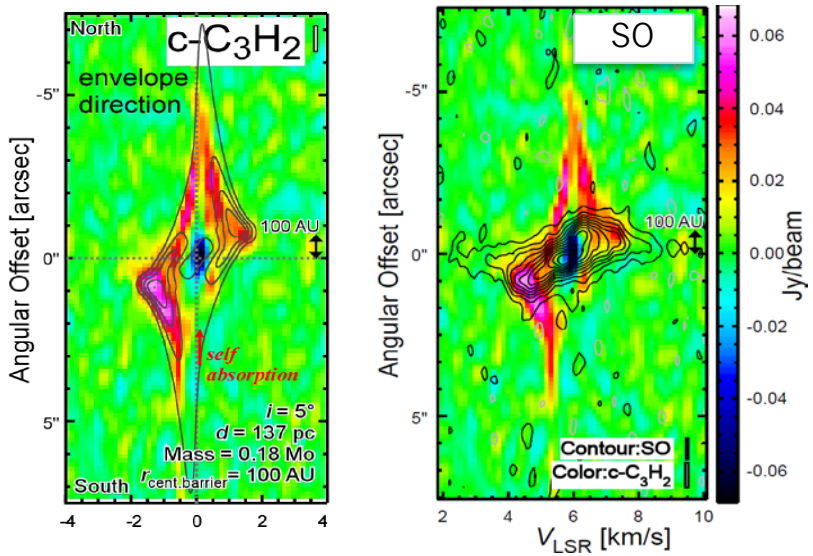
  e.g., Sakai et al, Nature 204, 517 (2014)

With ALMA <100 au

A New Picture of Chemical Evolution in Disk Forming Regions

Chemical Diversity in Disk Forming Regions





Physical structures are the same, while chemical structures are systematically different.

e.g., Sakai et al. 2014, Nature, 507, 78;
Oya et al. 2016, ApJ, 824, 88;
Oya et al.2017, ApJ, 837, 184;
Imai et al. 2019, ApJL, 873, L21

Progress in X-ray Astrophysics Aya Bamba

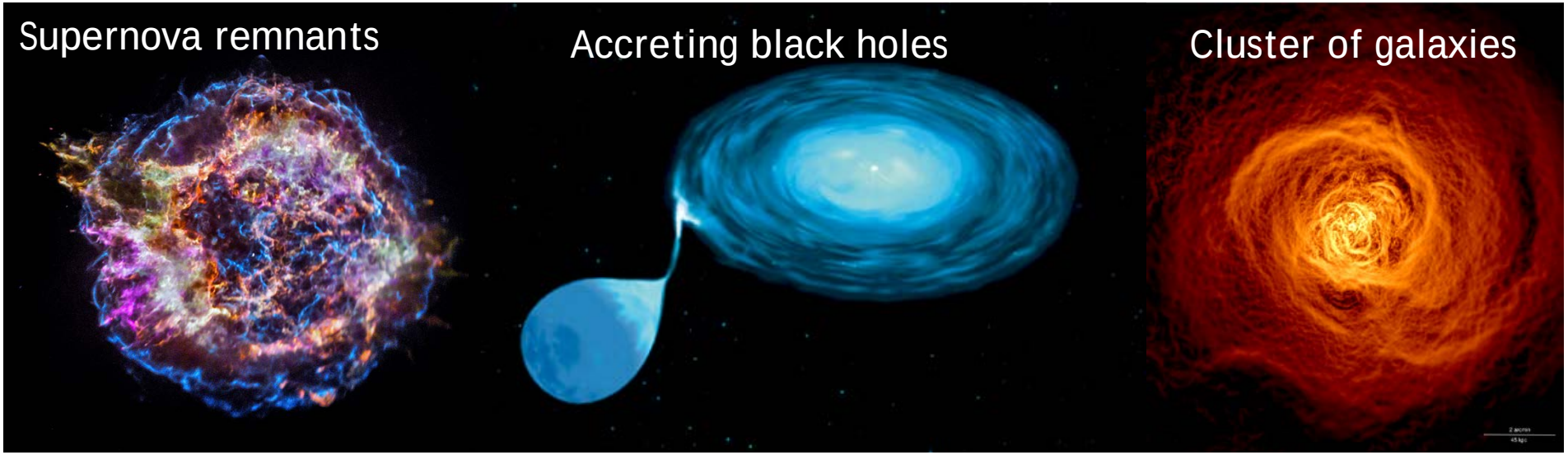
X-ray astronomy:

- Good at exporeing hot and energetic phenomena in the Universe

  hot: 1- 100 MK

  energetic: ~TeV particles with photon/B/…

- Achievable only with space missions due to absorption by air

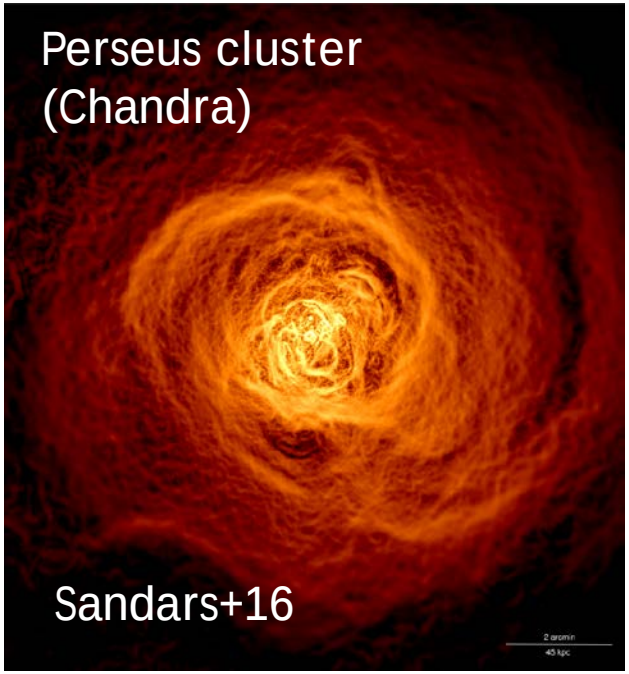


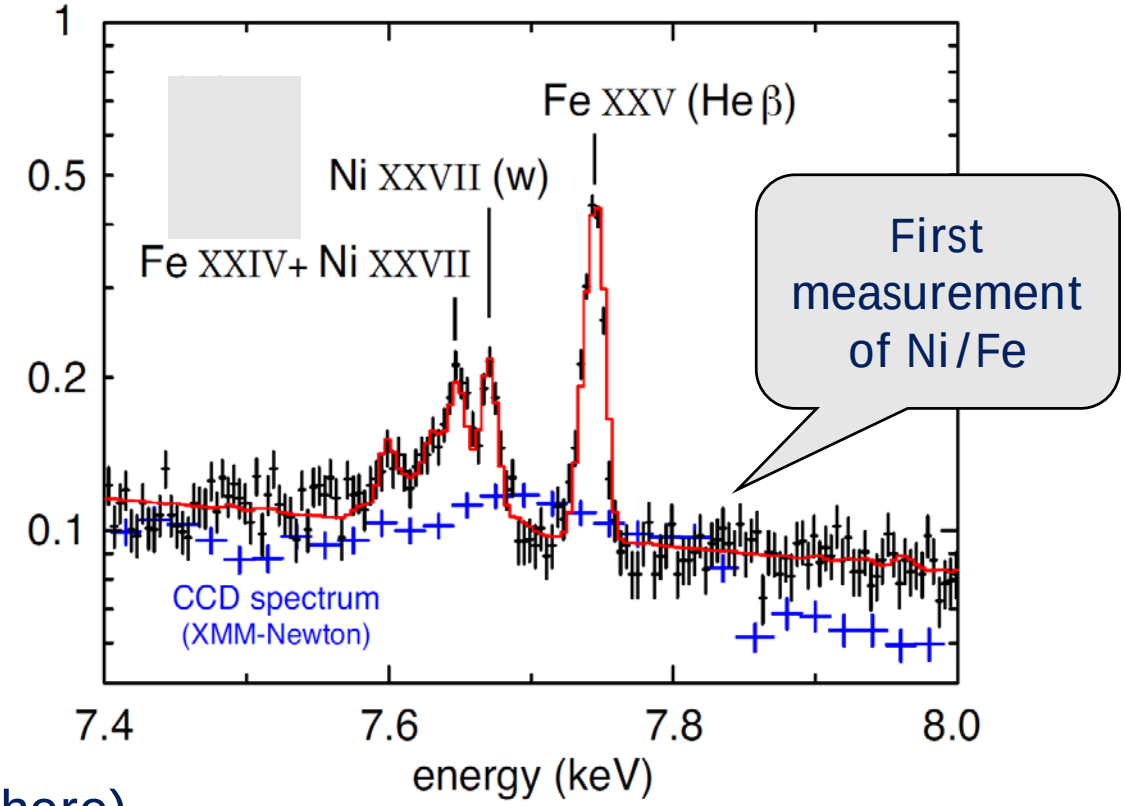
Hitomi mission

JP-US lead X-ray mission launched on 2016.Feb.17

Advantage: State-of-Art energy resolution of ~5 eV @ 6 keV

- weak line search
- Doppler shift (~200 km/s @ 6 keV)
- plasma diagnostics ...





Operation stopped Mar. 26

(5 days before I came here)

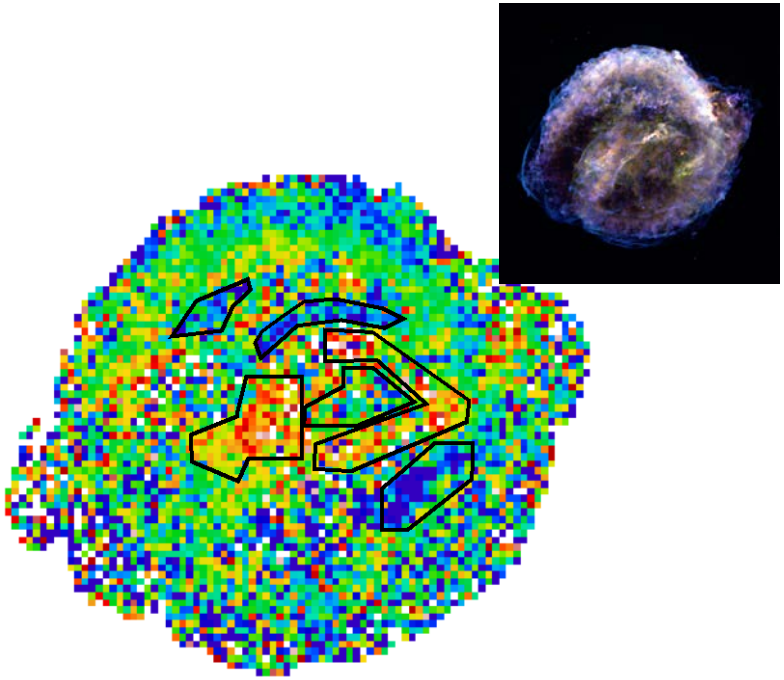
11 papers including 2 nature one

(2 of them are written in our labo.)

Other achievements and Future plan:

1. Study with existing data

example:
Expantion measurement of
Kepler's SN remnant (SN1604)



First measurement of
asymmetric expansion
with Doppler shift of Fe lines
-> impact for chemical evolution

86 papers, 1 press release

2. XRISM mission

re-try of Hitomi
planned on 2022 winter
lead of Gal. diffuse science
data performance study

3. Future missions

CubeSat plan: Cipher
Aiming first hard X-ray
polarimetry imaging

Winner of satellite design contest
(2019)

東京大学 大学院 理学系研究科・理学部
SCHOOL OF SCIENCE, THE UNIVERSITY OF TOKYO
Dept. of Physics

あんどう　けんきゅうしつ

Ando Group

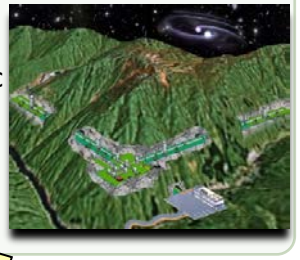
Gravitational-Wave Astrophysics: Reveal the fundamental law of the universe by observation of gravitational wave. Fundamental physics using precise measurement techniques.

Large-scale Projects.

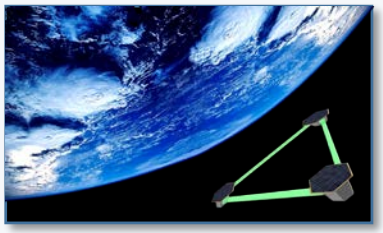
New astrophysics using gravitational waves.
Observation of extreme-state in the universe

KAGRA (かぐら)

Large-scale cryogenic GW antennae at Kamioka, Gifu.
Start obs. in 2020.



B-DECIGO (びーでさいご)



Space GW antenna with 100km length.
Original science by observation of early-inspirals of compact binaries.

DECIGO (でさいご)

Future plan observe the very early universe using primordial GW background.

Small-scale experiments.

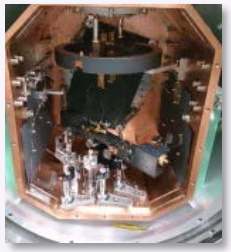
Emerging research for fundamental physics and future projects.

Optical Squeezing

Generation of frequency-dependent squeezing for improvement of GW antenna in operation.

Collab. with NAOJ GW group

TOBA (とーば)



Ground-based Low-frequency (~0.1Hz) GW antenna.

B-DECIGO development

Ground test prototype for B-DECIGO laser interferometer.

Quantum Opt-Mechanics

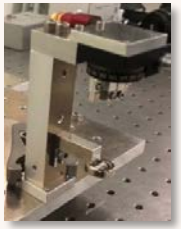
Test of quantum mechanics at macroscopic scale, to obtain prospects for modified quantum mechanics or unification with relativity.

mg-scale Opt-mechanics

Direct observation of quantum rad.-press. fluctuations.

Optical Levitation

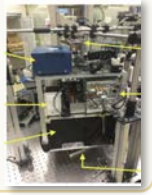
Fundamental research for optical levitation.



JST CREST : Collab. with, TITECH, French group.

Test of Relativity

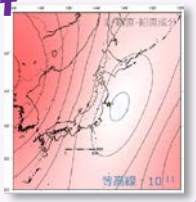
Test of Lorentz invariance by rotating a small laser interferometer.



Earthquake Early Alert

Detection of earthquakes using sensitive gravity gradiometer.

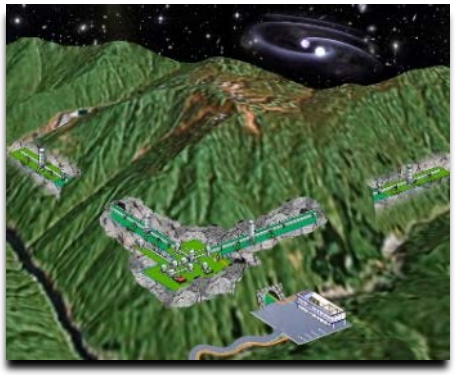
MEXT Q-LEAP program:
collab. with ERI, U-Tokyo



Other activities: Theoretical and data-analysis research on test of relativity using GW.
Experimental research for Axion. Test of modified quantum mechanics

Gravitational-Wave Astrophysics: Reveal the fundamental law of the universe by observation of gravitational wave. Fundamental physics using precise measurement techniques.

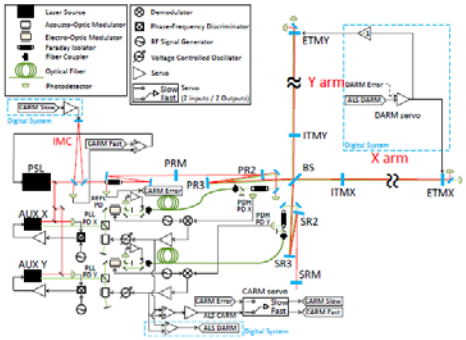
KAGRA (かぐら)



* Large-scale cryogenic GW antennae at Kamioka, Gifu.
* Planning to start observation run in 2020.

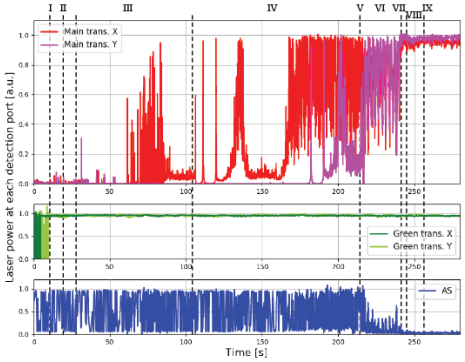
Ando group is playing a key role in KAGRA
(even before the project start in 2010).

* Top-level management (EO, SEO, Ando)
* Main interferometer subsystem (Michimura + Students)



Recent achievement in commissioning:
First operation of the full-scale KAGRA laser interferometer.

Lock acquisition is one of the largest factor of uncertainty in operation of complex laser interferometer. KAGRA was operated as FPMI configuration for the first time in 2019.
Achieved an important milestone



⇨ Ph.D Thesis by Y. Enomoto (FY2019)
'Interferometer Locking Scheme for Advanced Gravitational-Wave Detectors and Beyond'

東京大学 大学院 理学系研究科・理学部
Dept. of Physics

あんどう　けんきゅうしつ
Ando Group

Gravitational-Wave Astrophysics: Reveal the fundamental law of the universe by obser
physics using precise

Degree Theses since FY2012 and Recent Publications

9 Doctor and 13 Master theses in 8 years

・KAGRA for GW observation

- Doctor thesis: Y. Enomoto (FY2019).
- Hiroki Takeda+: Phys. Rev. D, 100, 042001 (2019).
- KAGRA collaboration, Nature Astronomy 3, 35 (2019).
- KAGRA Collaboration, Class. Quantum Grav. 36, 095015 (2019).
- KAGRA Collaboration, LIGO Scientific Collaboration and Virgo Collaboration, Living Reviews in Relativity 21, 3 (2018).
- Yuta Michimura+: Physical Review D, 97 12, 122003 (2018).
- Hiroki Takeda+: Physical Review D 98 2, 022008 (2018).
- T. Akutsu+: Progress of Theoretical and Experimental Physics 2018, 013F01 (2018).
- Y. Michimura+: Class. and Quantum Gravity 34, 225001 (2017).

・TOBA for Low-freq. Observation

- Doctor thesis: T. Shimoda (FY2019), A.Shoda (FY2014).
- Master Thesis: Y. Miyazaki (FY2019), S. Takano (FY2018), C.P. Ooi (FY2018), N. Aritomi (FY2016), T. Shimoda (FY2016).
- T. Shimoda+: Classical and Quantum Gravity 36, 12 (2019).
- Masaya Kimura+: Earth, Planets and Space 71, 27 (2019).
- Tomofumi Shimoda+: Physical Review D 97, 10 104003 (2018).
- Ayaka Shoda+: Phys. Rev. D 95, 082004 (2017).
- Kazunari Eda+: Prog. Theor. Exp. Phys. 1 011F01 (2016).
- Y. Kuwahara+: Phys. Rev. D 94, 92003 (2016).

・Space GW antenna for future mission

- Doctor thesis: K.Nagano (FY2019), W. Kokuyama (FY2012).
- T. Nakamura+: Prog. Theor. Exp. Phys. 9 093E01 (2016).
- K. Okutomi+: Journal of Physics Conference Series, 610 012040 (2015).

・Opt-Mechanics for Macroscopic QM

- Doctor Thesis: K. Komori (FY2018), N. Matsumoto (FY2013).
- Master Thesis: N. Kita (FY2019), S. Wada (FY2017). Y. Kuwahara (FY2015), K. Komori (FY2015).
- Nobuyuki Matsumoto+: Phys. Rev. Lett. 122, 071101 (2019).
- Kentaro Komori+: Physical Review, 97, 10, 102001 (2018).
- Yuta Michimura+: Optics Express 25, 13799 (2017).

・Experiments for Fundamental Physics

- Doctor thesis: Y. Michimura (FY2014), T. Ushiba (FY2015).
- Master Thesis: H. Takeda (FY2017). Y. Sakai (FY2017), T. Ushiba (FY2012), K. Shibata (FY2012).
- Koji Nagano+: Phys. Rev. Lett. 123, 111301 (2019).
- Ippei Obata+: Phys. Rev. Lett. 121, 161301 (2018).

Kusaka group

Observational Cosmology via Cosmic Microwave Background

Inflation

Primordial GW

Early Universe (Quantum) Fluctuations

Axion ?

Sterile ν ?

Dark Radiation

$\delta(\sum m_\nu) \sim 30\mathrm{meV}$

Hierarchy

Sum of Neutrino mass

Vacuum ?

Dark Energy

Reionization

Galaxy Evolution

400k yrs

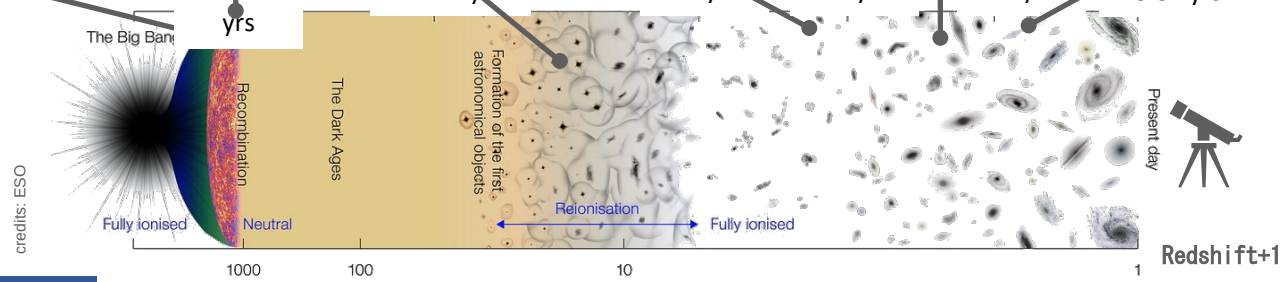
100M yrs

1B yrs

4B yrs

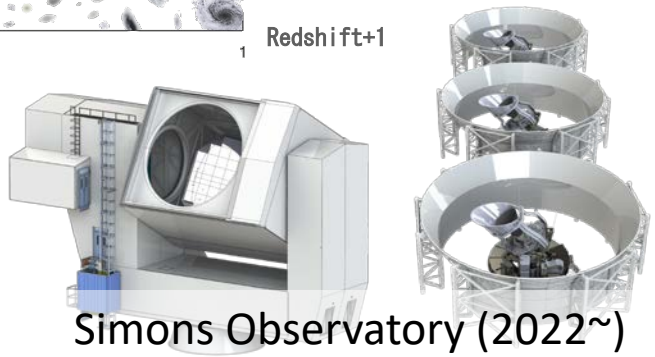
8B yrs

13.8B yrs



POLARBEAR

POLARBEAR2 / Simons Array (2018 ~ 2022)

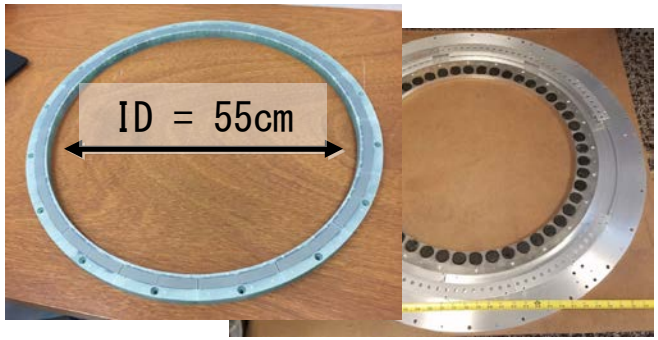


Simons Observatory (2022~)

Kusaka group
Observational Cosmology via Cosmic Microwave Background

Team:
2 faculties (Assoc. Prof., Assist. Prof.)
2 research faculties (Assist. Prof.)
2 first year grad students.
3 graduate students to start in Apr.
Rapidly growing since 2017

Cryogenic Half Wave Plate



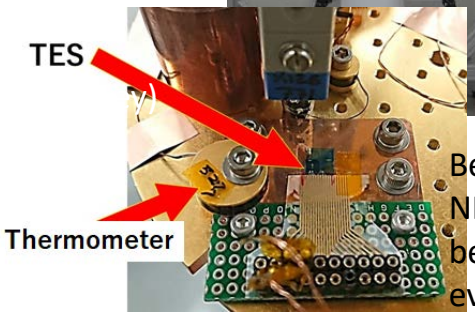
World largest ID, superconducting mag-lev bearing. Enabling technology for SO system, in collaboration w/ IPMU, Berkeley

Optics Tube for Simons Observatory

Core component of Japanese contribution to Simons Observatory, in collaboration with Kyoto, IPMU, Tohoku, KEK.

Superconducting Detector Development

Oxford DR testbed. Optical test setup under development.



Berkeley and NIST TESes being evaluated

TES, RF (GHz) readout using rf-SQUIDs, and MKIDs, development in collaboration with Princeton, Berkeley, NIST, Stanford, RIKEN.

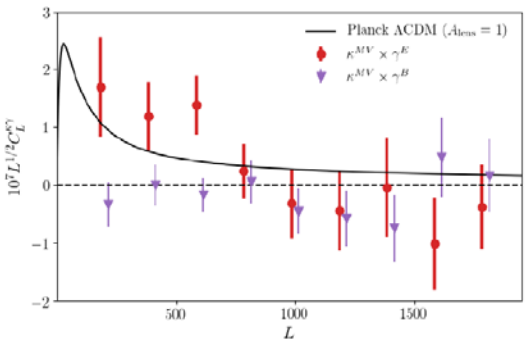
Kusaka group
Observational Cosmology via Cosmic Microwave Background

Data Analysis

Our team comprises leading players in developing analysis pipeline and running analyses of

- POLARBEAR
- Simons Array / POLARBEAR-2
- Simons Observatory

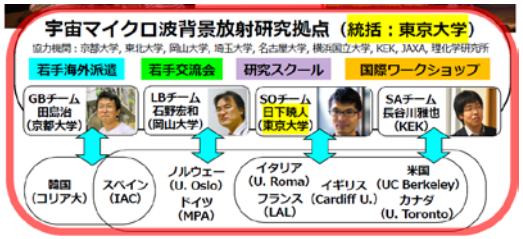
First evidence of correlated gravitational lensing measured by Subaru HyperSuprime Cam and CMB.



T. Namikawa, Y. Chinone, H. Miyatake, M. Oguri, R. Takahashi, A. Kusaka, N. Katayama, et al., *Astrophys. J.*, 882:62 (2019).

Serving for the Community

Superconducting detector mini-workshop. (Sep. 2019)
~20 attendees from Japanese CMB community. Lecturers invited from other fields as well.

High-Performance Computation Workshop. (Jan. 2020)
~40 attendees from Japanese CMB community. Experts invited from Berkeley (LBNL/NERSC) as lecturers.

Pending Proposal (Core2Core)
We are proposing to establish the "core" for the Japanese CMB community, here at UTokyo.