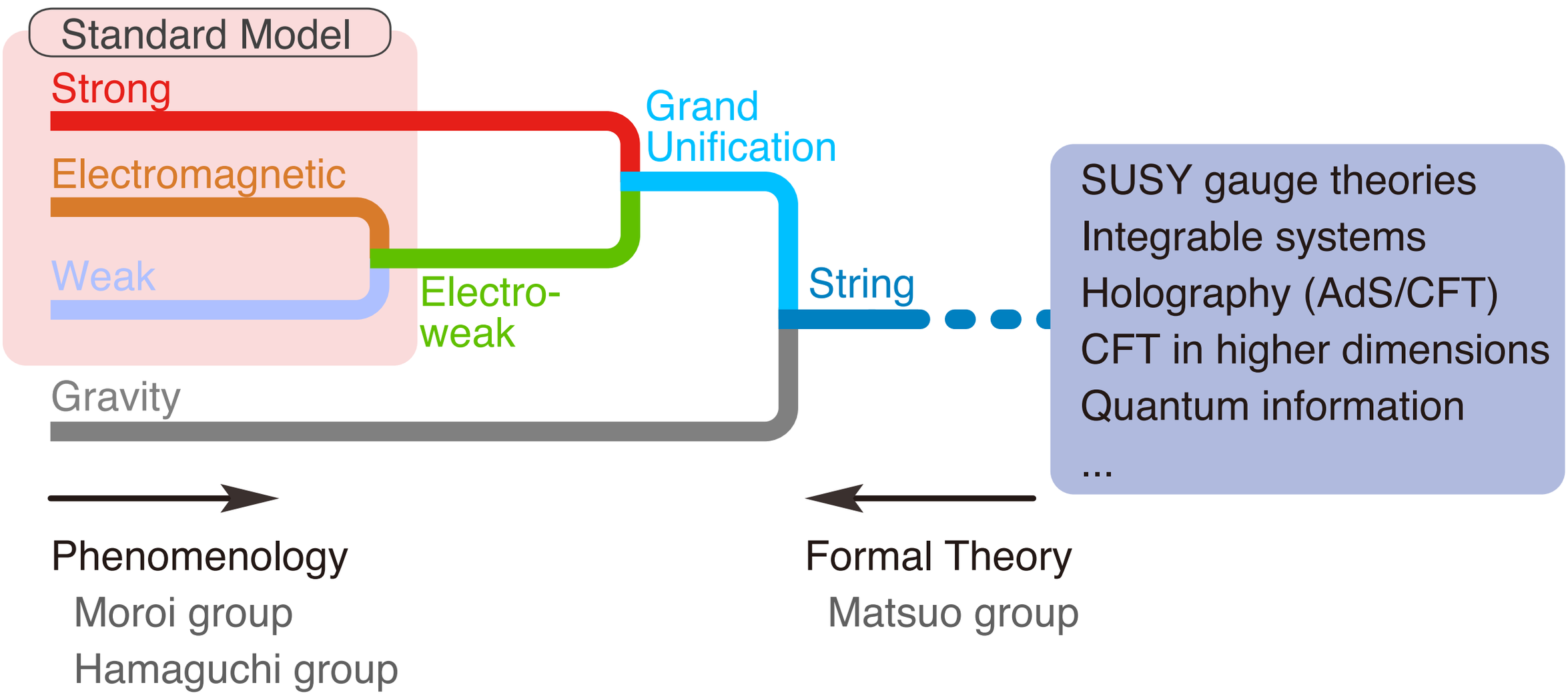
THEORETICAL PARTICLE PHYSICS

Theoretical Particle Physics: Overview

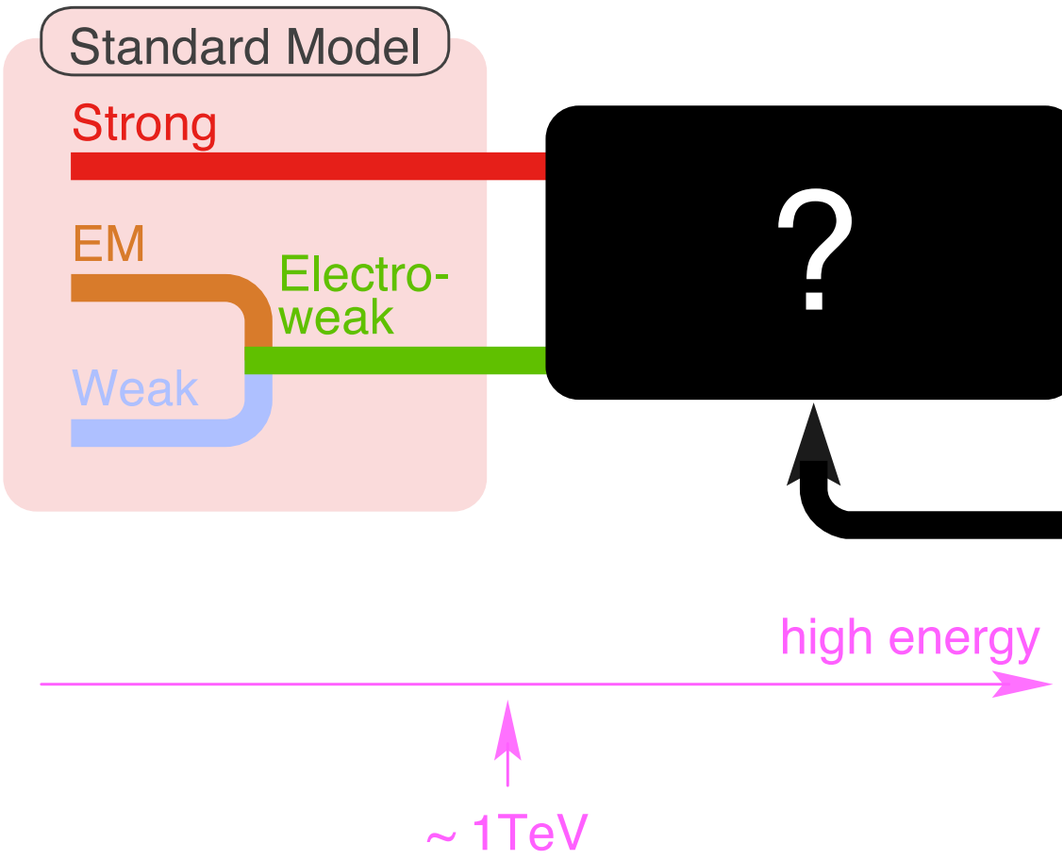


Theoretical Particle Physics: Overview

- 3 senior faculties
  - ⇒ Hamaguchi group (+ Nagata)
  - ⇒ Matsuo group (+ Nishioka)
  - ⇒ Moroi group (+ Nakayama)
- 3 groups are jointly organized
  - ⇒ Group meeting on Monday (with lunch talk)
  - ⇒ Theory group seminar (by outside speakers)
  - ⇒ Student seminars (with Kashiwa group)

TAKEO MOROI

Main interest: physics beyond the standard model (BSM)



My Research Interest

Physics beyond the standard model (BSM)

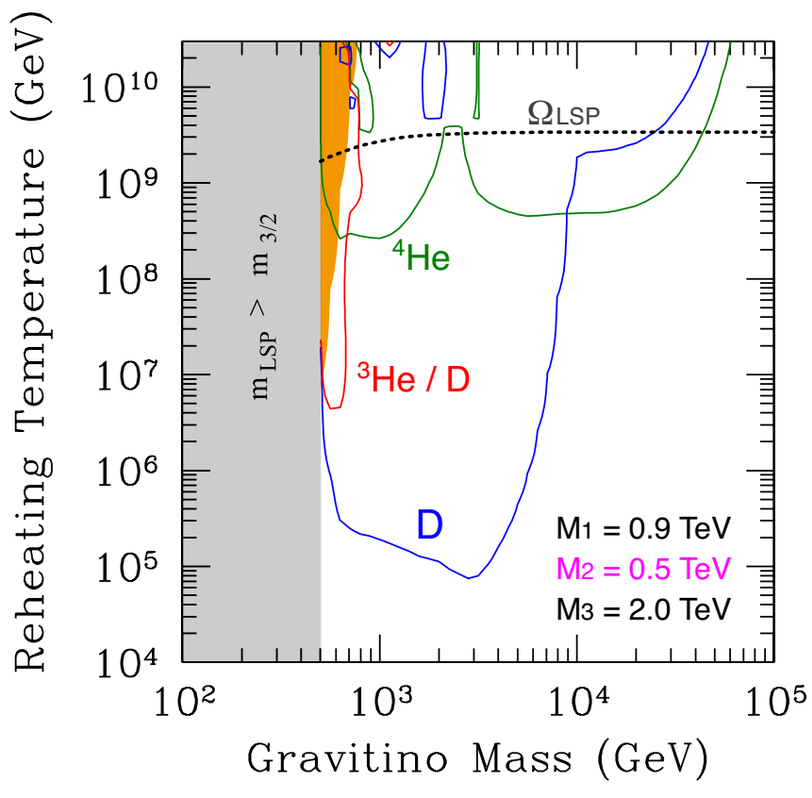
Supersymmetry (?)
Grand Unified Theory (?)
Origin of the neutrino mass (and flavors)
Solution to the strong-CP problem (axion ?)
Field theory related to BSM (and SM)
...

Particle cosmology (early universe)

Dark matter
Origin of the baryon asymmetry of the universe
Inflation and the origin of the density fluctuations
...

Selected Work 1: Big-bang nucleosynthesis & new physics

- Decay of exotic particles after big-bang nucleosynthesis (BBN) may change the abundances of light elements (D, He, …)
- We studied BBN constraints on long-lived new particles, taking into account exotic dissociation (and other) processes

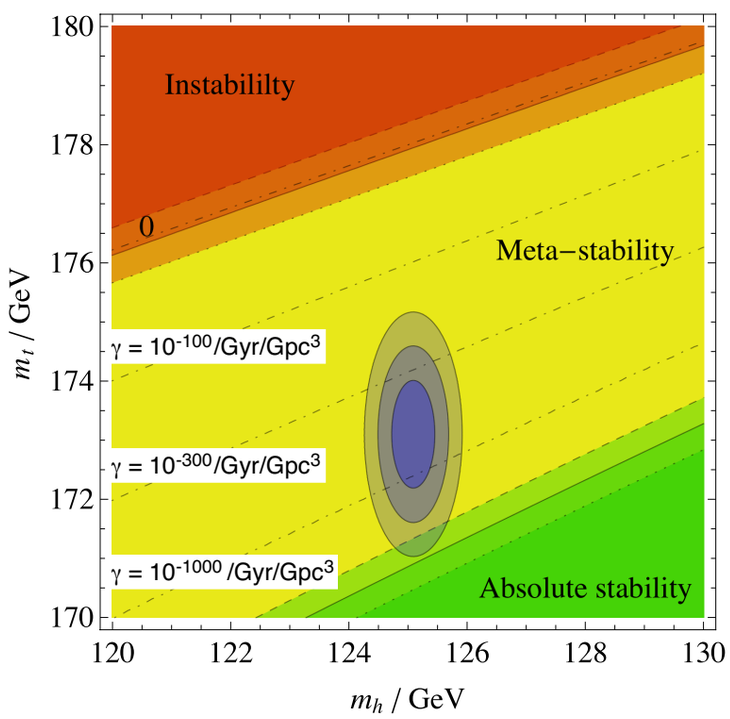


[Kawasaki, Kohri, TM, Takaesu ('17)]

- We derived an upper bound on the reheating temperature to avoid the overproduction of gravitino in supersymmetric model
- Our collaboration has been updating the analysis from 1995

Selected Work 2: Decay of electroweak vacuum

- I am studying the stability of the electroweak vacuum
- We performed a full 1-loop calculation of the decay rate of the standard-model vacuum, which was not done before



[Chigusa, TM, Shoji ('17 & '18)]

- The lifetime is shorter than the present cosmic age if the top-quark mass is a few % heavier
- Our paper has been referred in Particle Data Book

Outlook

- I will keep on working on physics beyond the SM

  ⇒ Model building

  ⇒ New experimental ideas to find new physics

  ⇒ Application to cosmology

- Some directions for a next few years

  ⇒ Dark-matter search: new ideas

  ⇒ Implications of future experiments (ILC, FCC, ⋯)

  ⇒ ⋯ and things which look interesting

KOICHI HAMAGUCHI

Koichi Hamaguchi @External Review, Feb. 13, 2020

I am working on:

Particle Physics beyond the Standard Model (BSM).

- Dark Matter,
- Matter > Antimatter in the Universe (baryogenesis),
- Inflation,
- Supersymmetry,
- collider phenomenology,
- ……

Research highlights written in the document:

- BSM and Neutron Star,
- BSM and muon g-2,
- ``Flaxion" model to solve the puzzles in the SM.

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- **Neutron Star and Axion**
  Hamaguchi, Nagata, Yanagi, Zheng

PHYSICAL REVIEW D **98,** 103015 (2018)

Limit on the axion decay constant from the cooling neutron star in Cassiopeia A

Koichi Hamaguchi,[1,2,*] Natsumi Nagata,[1,†] Keisuke Yanagi,[1,‡] and Jiaming Zheng[1,§]
[1]*Department of Physics, University of Tokyo, Tokyo 113–0033, Japan*
[2]*Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU), University of Tokyo, Kashiwa 277–8583, Japan*

(Received 22 June 2018; published 16 November 2018)

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Physics Letters B 795 (2019) 484–489
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www.elsevier.com/locate/physletb

Dark matter heating vs. rotochemical heating in old neutron stars

Koichi Hamaguchi [a,b], Natsumi Nagata [a], Keisuke Yanagi [a,*]
[a] *Department of Physics, University of Tokyo, Tokyo 113–0033, Japan*
[b] *Kavli IPMU (WPI), UTIAS, The University of Tokyo, Kashiwa, Chiba 277–8583, Japan*

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Cooling Theory Faced with Old Warm Neutron Stars: Role of Non-Equilibrium Processes with Proton and Neutron Gaps

Keisuke Yanagi, Natsumi Nagata, Koichi Hamaguchi

Monthly Notices of the Royal Astronomical Society, staa076, https://doi.org/10.1093/mnras/staa076
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-> one of the strongest bound so far.

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2019 Review of Particle Physics.
Warning: production version with current encodings in progress

Invisible A^0 (Axion) Limits from Nucleon Coupling

INSPIRE search

Limits are for the axion mass in eV.

VALUE (eV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limit					
< 65	95	1 AKHMATOV		[illegible]	Solar axion
< 6.6	90	2 ARMENGAUD		[illegible]DE3	Solar axion
< 0.085	90	3 BEZNOGOV		ASTR	Neutron star cooling
< 12.7	95	4 GAVRILYUK	2018	CNTR	Solar axion
< 0.01		5 HAMAGUCHI	2018	ASTR	Neutron star cooling
		6 ABEL	2017		Neutron EDM
< 93	90	7 ABGRALL	2017	HPGE	Solar axion

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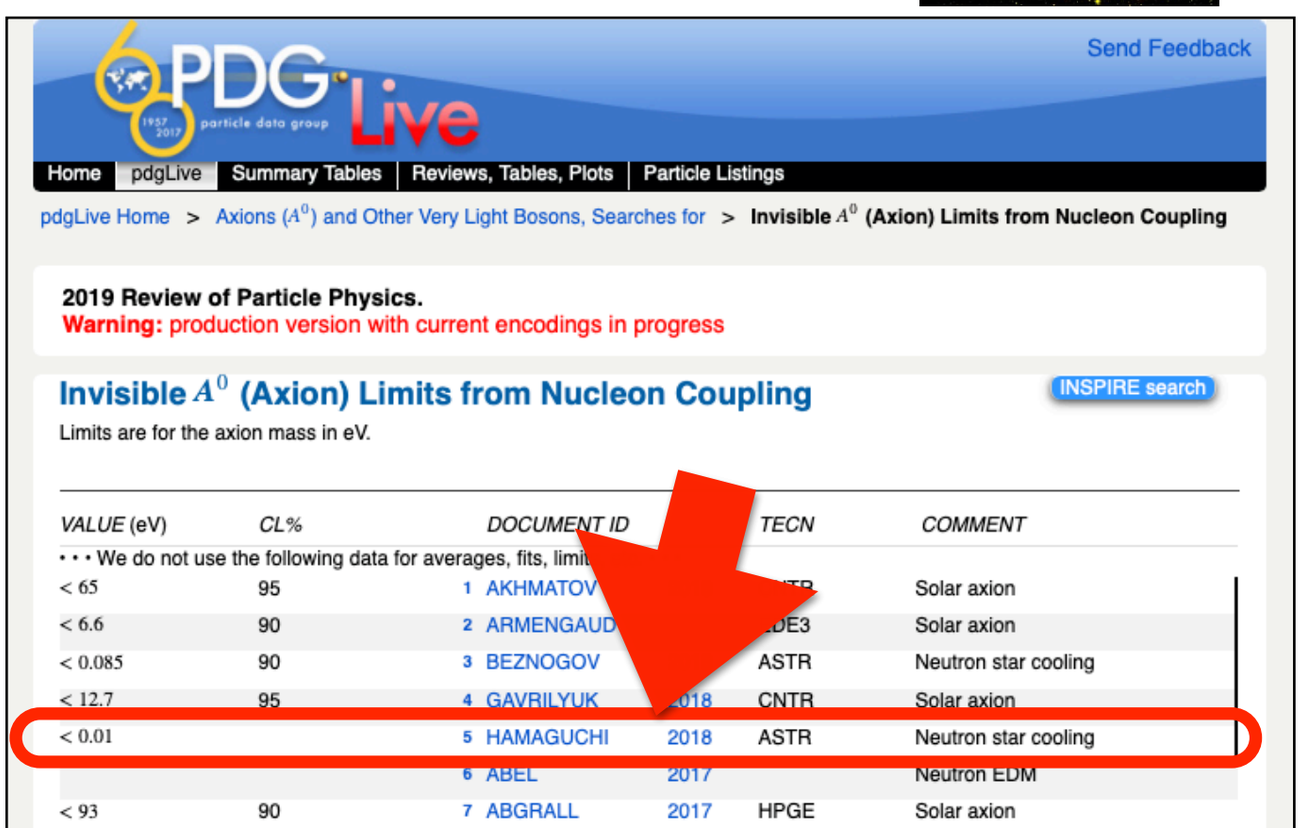

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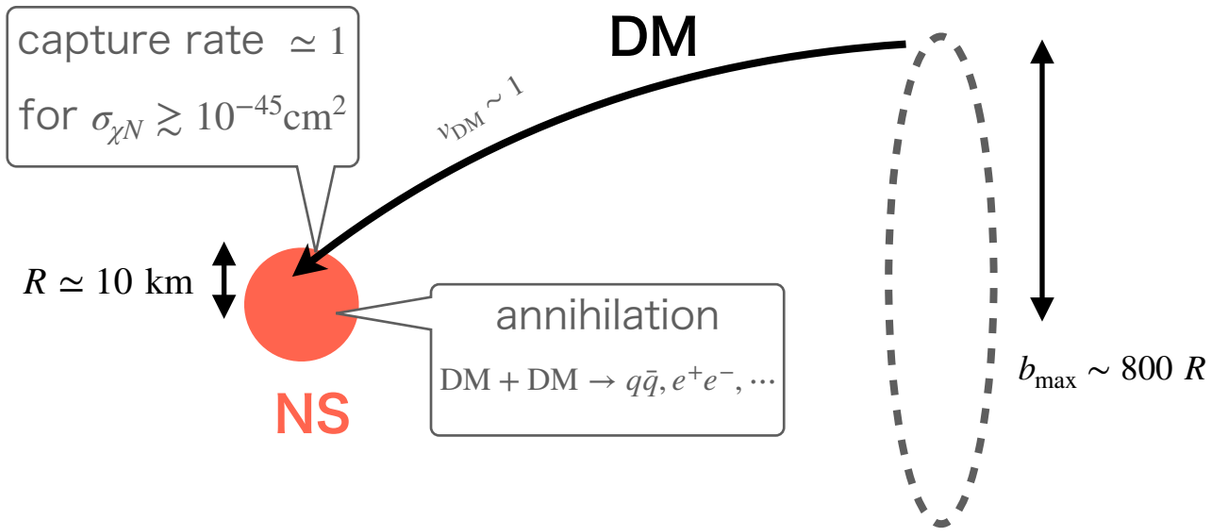
• Neutron Star and Dark Matter

Hamaguchi, Nagata, Yanagi

We studied the NS heating by the WIMP dark matter, including 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.



$$C\frac{dT}{dt} = -L_\nu - L_\gamma + L^{\rm heat}_{\rm rotochemical} + L^{\rm heat}_{\rm DM}$$

Activity Report – Matsuo Lab

Yutaka Matsuo

The University of Tokyo

February 13, 2020

Symmetry behind superstring and gauge theories

- Virasoro algebra is an infinite dimensional algebra which plays the role of gauge symmetry of string theory.
- It is a quantum deformation of infinitesimal holomorphic transformation $\partial z = f(z)$, which is relevant to the world volume symmetry of strings.
- In 2009, Alday, Gaiotto and Tachikawa conjectured a direct relation between the instanton partition function of supersymmetric gauge theory and Virasoro conformal block.

$$Z^{\mathrm{inst}}(q) = \sum_{\vec{\lambda}} q^{|\lambda|} Z_\lambda = \langle V(\infty) V(1) V(q) V(0) \rangle$$

- It implies that there should be a universal symmetry, which generalizes the Virasoro algebra, and plays a fundamental role in higher dimensional physics that include the supersymmetric gauge theories and string theory.

- In selected paper 1, (with Kanno and Zhang, 2013), we found recurrence formulae of instanton functions, which realize a new algebraic structure which include the Virasoro symmetry, but written in a different form.
- It turns out that the symmetry we found agrees with the degenerate version of the quantum toroidal algebra, which was studied by mathematicians for many years.
- The proof of AGT conjecture was understood as the S-duality symmetry of the toroidal algebra (Schiffmann and Vasserot). We extended the proof to more general types of quiver gauge theories (selected papers 4,5)
- In the selected paper 2, (with Bourgine and Zhang 2016), we use the symmetry to compute the one-point function, and showed that it produces a quanum version of Seiberg-Witten curve which appears in $N = 2$ super Yang-Mills,

$$y + \frac{1}{y} = P(z)$$

Activity of Dr. Nishioka (Assistant Prof.)

- Dr. Tatsuma Nishioka formally belongs to my group but works independently.
- His recent focus is to apply AdS/CFT to quantum information theory.
- He has been examining quantum entanglement as a measure of degrees of freedom in various QFT
- In theories with supersymmetry he introduced a new measure named supersymmetric Renyi entropy, which is exactly calculable even in strongly-interacting theories and reveals intrinsic features of quantum entanglement in field theories.
- More recently he examined whether there exists a good measure of degrees of freedom in quantum field theories with non-local operators (defects), and proposed a generalized notion of a C-theorem under renormalization group flows localized on defects.