# Overview of ABBL, iTHEMS, and RBC


## ShigeHiro Nagataki

**Chief Scientist (PI) of Astrophysical Big Bang Laboratory (ABBL), Pioneering Research Institute (PRI), RIKEN.**
**Deputy Director of RIKEN Center for Interdisciplinary Theoretical & Mathematical Sciences (iTHEMS).**
**Director of RIKEN-Berkeley Center, iTHEMS, RIKEN.**



Pioneering Research Institute

iTHEMS RIKEN Center for Interdisciplinary Theoretical and Mathematical Sciences


**N3AS Annual Meeting 2025, UCB, Berkeley, the U.S. 6-7 Aug. 2025. Presentation Date: 7th Aug. 2025**

# Structure of RIKEN in 5th mid-long term (FY2025-FY2031)

Domain Director
T. Hatsuda

PI of ABBL, PRI
S. Nagataki

**TRIP Initiative**

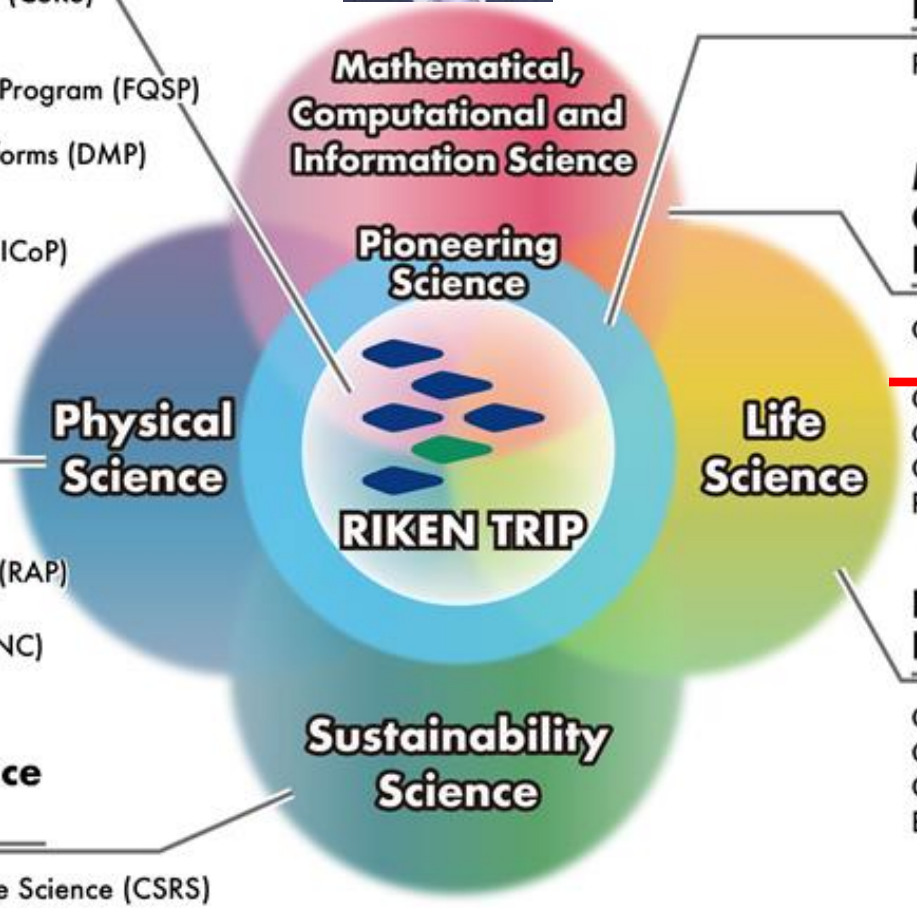
Data and Computational Sciences Integration Research Program (CoRe)
Advanced General Intelligence for Science Program (AGIS)
Fundamental Quantum Science Program (FQSP)
Program for Drug Discovery and Medical Technology Platforms (DMP)
Advanced Semiconductor Science Program (ASSP)
Industrial Co-creation Program (ICoP)
Baton Zone Program (BZP)

**Physical Science Domain**

Center for Emergent Matter Science (CEMS)
Center for Advanced Photonics (RAP)
Nishina Center for Accelerator-Based Science (RNC)
SPring-8 Center (RSC)

**Sustainablility Science Domain**

Center for Sustainable Resource Science (CSRS)
(BioResource Research Center (BRC))




**Pioneering Science Domain**

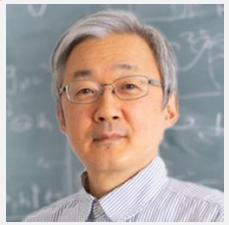
Pioneering Research Institute (PRI)

**Mathematical, Computational and Information Science Domain**

Center for Interdisciplinary Theoretical and Mathematical Sciences (iTHEMS)
Center for Computational Science (R-CCS)
Center for Quantum Computing (RQC)
Center for Advanced Intelligence Project (AIP)
RIKEN Information R&D and Strategy Headquarters (R-IH)

**Life Science Domain**

Center for Integrative Medical Sciences (IMS)
Center for Biosystems Dynamics Research (BDR)
Center for Brain Science (CBS)
BioResource Research Center (BRC)



Director of iTHEMS
S. Iso

Division Director of iTHEMS
T. Hatsuda

Director of RBC, iTHEMS
S. Nagataki

*TRIP (Transformative Research Innovation Platform of RIKEN platforms)

# Astrophysical Big Bang Laboratory (ABBL, FY2013- )

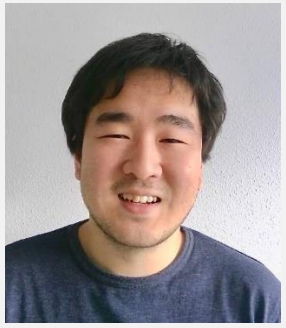
Shigehiro Nagataki

Chief Scientist (PI of ABBL)

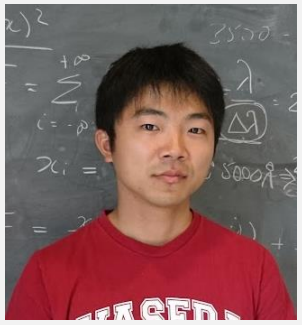
Akira Mizuta

Hirotaka Ito

Research Scientists
(Staff Members, Tenured)



Akira Dohi



Ryosuke Hirai

Ryo Higuchi

Ellis Owen

Special Postdoc Researchers
(SPDRs)
3yr Postdoc Program of RIKEN.

+13 Visiting Scientists

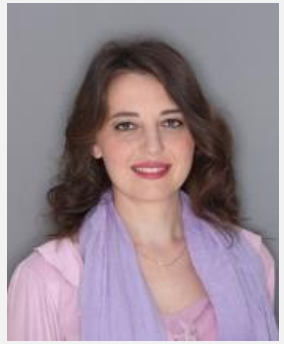
# The 21 Alumni of ABBL since 2013.


M. Ono


S.H.Lee


J. Mao


A. Tolstov


M. Dainotti

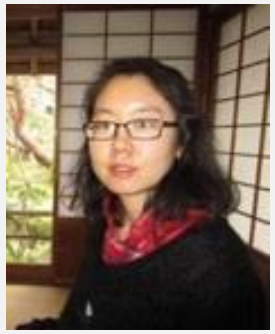

M. Barkov

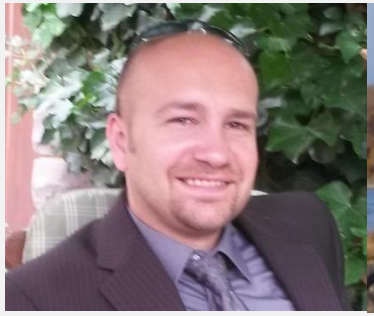

T. Takiwaki


J. Matsumoto


D. Warren

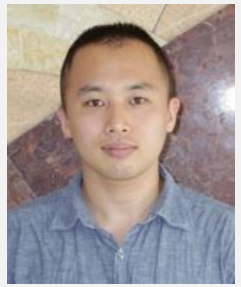

A. Wongwathanarat


H. He


O. Just


G. Ferrand


S. Inoue


Y. Teraki


T. Wada


H. Sotani


E. Kido


N. Nishimura


Y. Sekino


A. Kumar

1 Professor
4 Associate Professors
1 Lecturer
4 Assistant Professors

Left: My Office

Right: Postdocs' Office
(50 $\mathrm{m}^2$ for 3 postdocs)


Left: Secretariat &
Reception Room

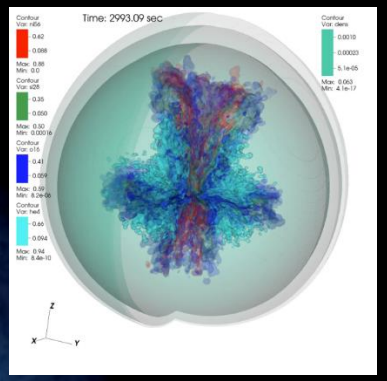
Right: Visitors' Office

We have one more office
(50 $\mathrm{m}^2$ for 2 staffs & 1PD).

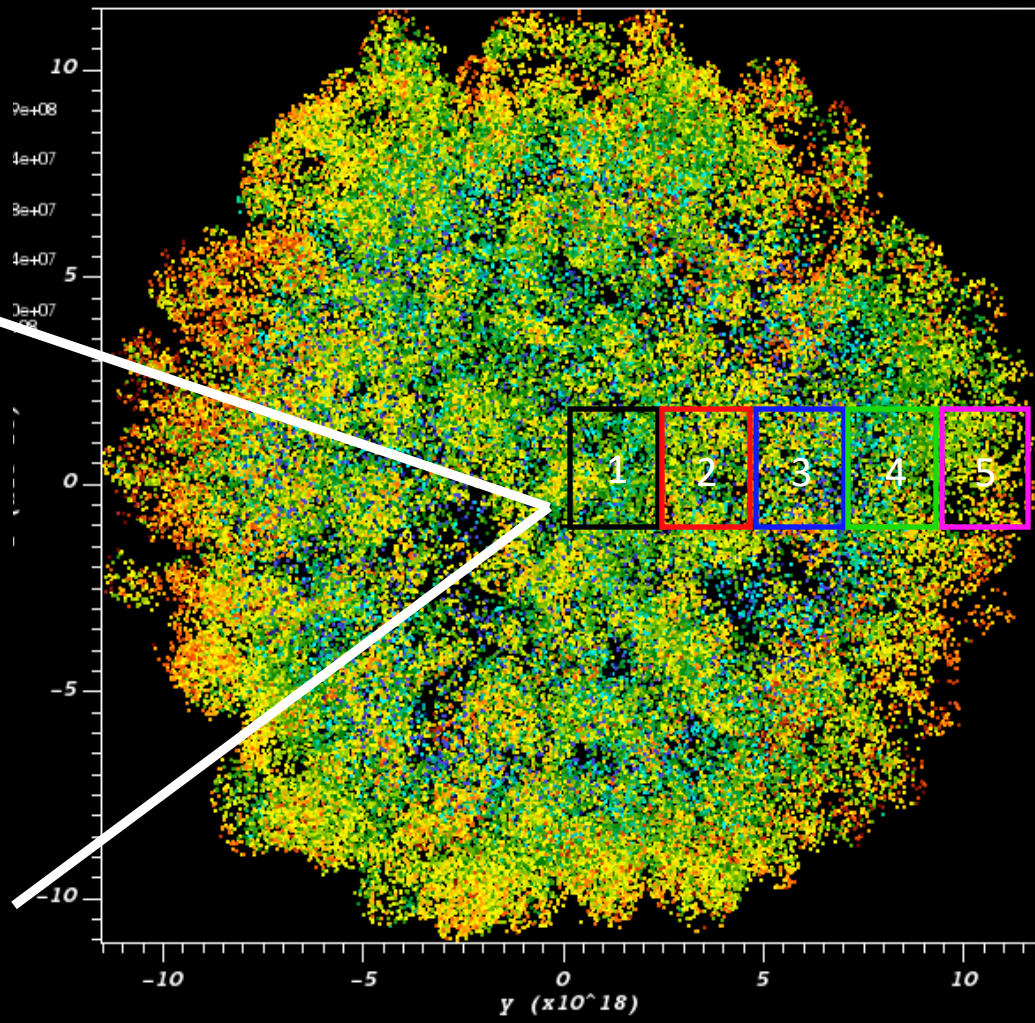
# Roads from SNe to SNRs

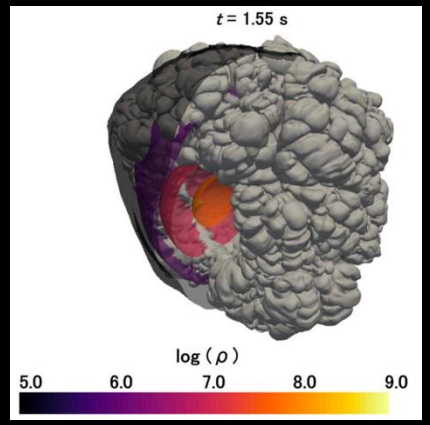






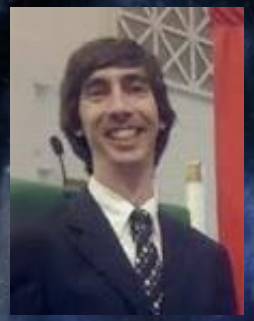









NS-NS/NS-BH Merger,
Short GRB,
Afterglow,
Kilonova,
Cosmology,…

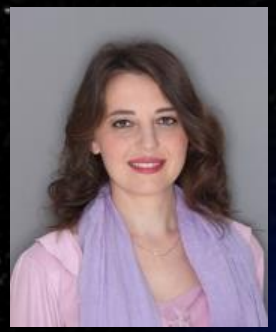










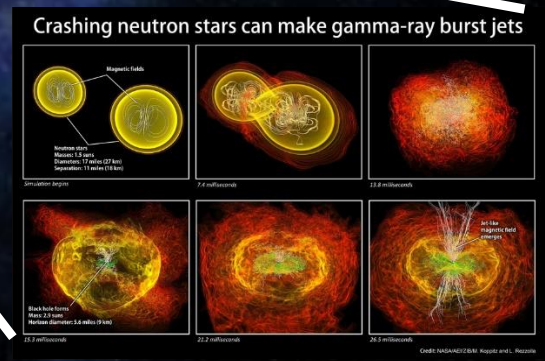
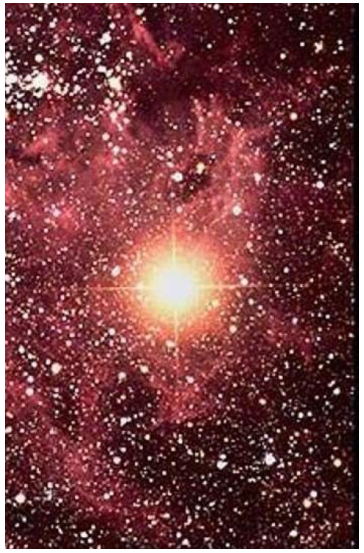



*Image Credit:*
*NASA/AEI/ZIB/M. Koppitz and L. Rezzolla*

Image credit: NASA, ESA, and D. Player (STScI)

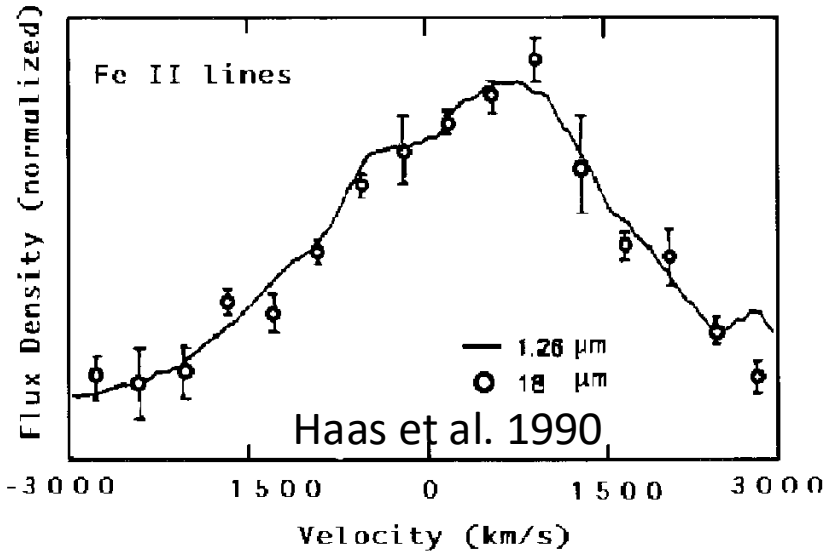
# The Nagataki Conjecture (2000) has been Proved.



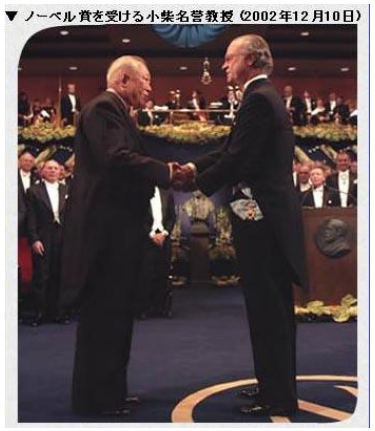
Supernova 1987A

Blue Shift Side: Toward Us.

Red Shift Side: Away from Us.




Haas et al. 1990




Prof. M. Koshiba was awarded the Nobel Prize in 2002.

- **SN1987A was a Bi-Polar like explosion.**
- **Explosion was stronger in Red Shift Side and weaker in Blue Shift Side.**
- **The Neutron Star of SN1987A should be moving toward the Blue Shift Side.**

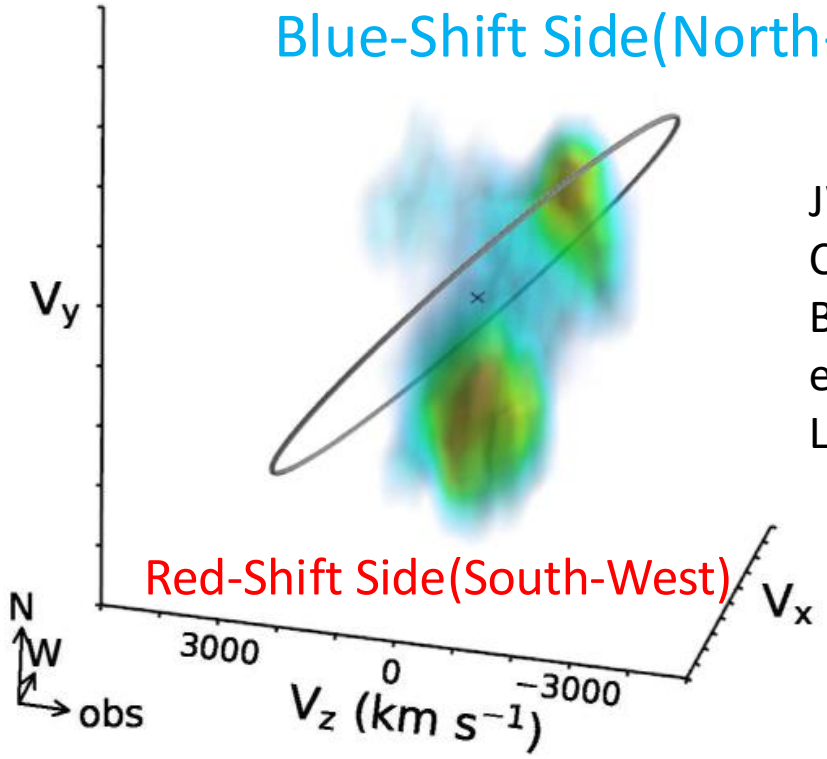
**Nagataki, Hashimoto, Sato, Yamada 1997**

**Nagataki, Shimizu, Sato 1998**

**Nagataki 2000**

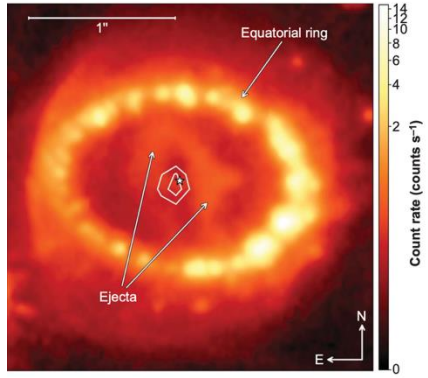
**S. Nagataki**

Blue-Shift Side(North-East)




Red-Shift Side(South-West)

JWST (NASA) Confirmed the Bi-polar like explosion. Larsson+ 23.




JWST (NASA) confirmed a compact source running toward the blue shift side. Fransson+ 24.

RIKEN Center for Interdisciplinary Theoretical and Mathematical Sciences

# iTHEMS

https://ithems.riken.jp/en


A Conceptual Image of iTHEMS

Mathematician,
Physicist,
Biologist,
Computational Scientist,
Information Scientist
under one roof

**Since Nov.1, 2016**

iTHEMS RIKEN Center for Interdisciplinary Theoretical and Mathematical Sciences

# iTHEMS members

As of March 2025

iTHEMS

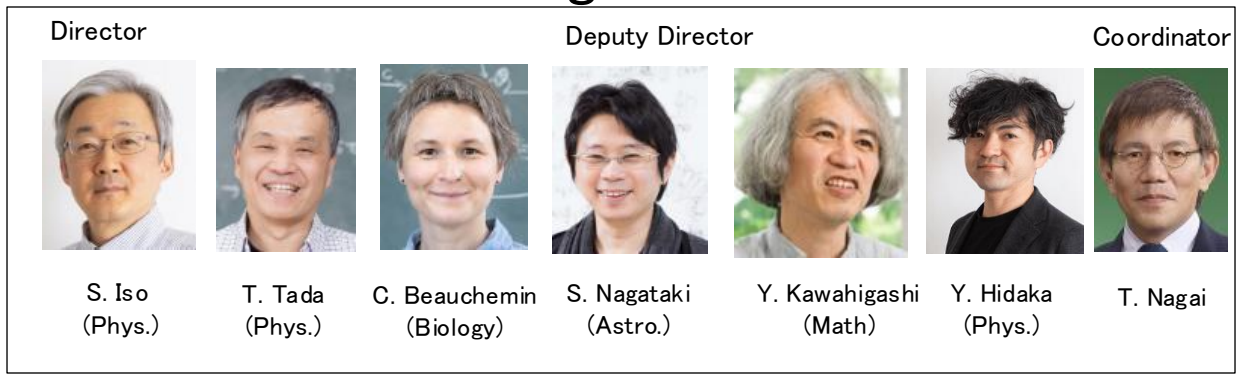
## Mathematician, Physicist, Biologist, Computational Scientist, Information Scientist under one roof

60 Young Researchers

17 Students.

Young Scientists are main players.

## A Real Image of iTHEMS




| Position | |
|---|---|
| Director | 1 |
| Deputy Director | 5 |
| Coordinator | 1 |
| Senior Advisor | 4 |
| Team Director | 8 |
| RIKEN ECL Unit Leader | 1 |
| Senior Research Scientist | 11 |
| Research Scientist | 14 |
| Special Postdoctoral Researcher | 16 |
| Postdoctoral Researcher | 19 |
| Student（JRA、JSPS PD Researcher） | 5 |
| Student（IPA、Student Trainee、Research Fellow） | 12 |
| Research Consultant | 3 |
| Senior Visiting Scientist | 11 |
| Visiting Scientist | 98 |
| Technical Staff Ⅰ | 1 |
| Research Associate | 1 |
| Research Administrator | 1 |
| Assistant | 9 |
| Research Part-time Worker Ⅰ／Ⅱ | 2 |
| Administrative Part-time Worker Ⅰ／Ⅱ | 4 |
| Multiple positions within the center | 2 |
| 合計 | 101 (225) |

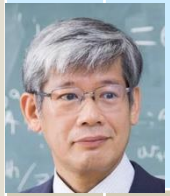
※Total of main duty and directly employed iTHEMS researchers (including concurrently employed researchers and non-employee

# From iTHES to iTHEMS, and From a Program to a Center

A transition from a compact, tightly connected structure to a broader, more diverse collaborative platform.

FY 2013 | 2014 | 2015 | 2016 | 2017 | FY 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | FY 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031

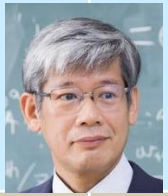
**iTHES**



Director: Tetsuo Hatsuda

- No internal structure
- Single campus @ Wako
- 60 researchers (wo/ visiting)

**iTHEMS (program)**



Director: Tetsuo Hatsuda

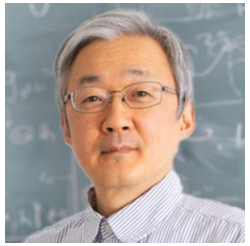
**iTHEMS (Center)**

Director: Satoshi Iso

- New Organization
  existing structure + new teams
  → **Research-scope largely expanded**
- Multiple campus
  Wako + Kobe + Yokohama + Nihonbashi
- More than 100 researchers

**3 big changes**

# Structure of RIKEN Center for iTHEMS (FY2025-)

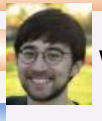


Director, Satoshi Iso

Division Director of App. Math. Science, Tetsuo Hatsuda

Director of RBC, Shigehiro Nagataki

**Division of Fundamental Mathematical Science** (Satoshi Iso)

- **Mathematical Genomics RIKEN ECL Research Unit** (Leo Speidel) —  **Wako**

**Division of Applied Mathematical Science** (Hatsuda)

- **AI for Science Team** (TBA.) — 
- **Mathematical Application Research Team** (Motoko Kotani) —  **Wako**
- **Quantum Mathematical Science Team** (Tetsuo Hatsuda) —  **Wako**
- **Medical Science Data-driven Mathematics Team** (Eiryo Kawakami) —  **Yoko-hama**
- **Medical Science Deep Learning Team** (Jun Seita) —  **Nihon-bashi**
- **Prediction Science Research Team** (Takemasa Miyoshi) —  **Kobe**
- **Mathematical Social Science Team** (Yohsuke Murase) —  **Wako**

**Division of Global Collaborations and Research Talent Development** (Tsukasa Tada)

- **Kyushu University Collaboration Team** (Ryoko Tomiyasu) —  **Wako/ Kyushu**
- **RIKEN-Berkeley Center** (Shigehiro Nagataki) —  **Berkeley/ Wako**

**Division of Social Cooperation and Outreach** (Tomoya Nagai)

**Office of the Center Director** (Tomoya Nagai) — 

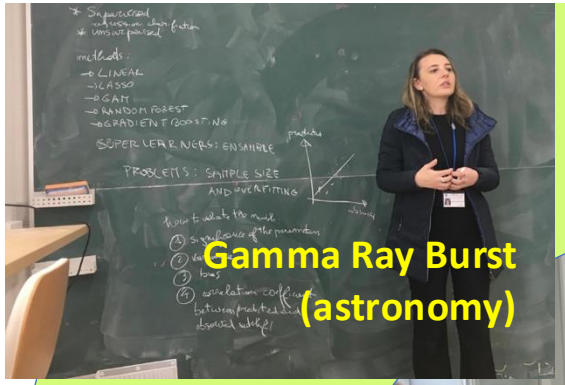
Mathematician,
Physicist,
Biologist,
Computational Scientist,
Information Scientist
under one roof
**Since Nov.1, 2016.**

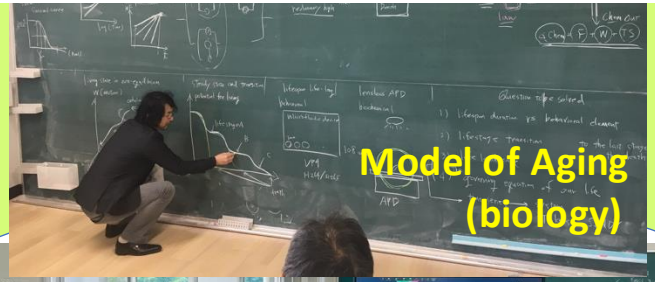
**Young Scientists are the Main Players.**

**Basic Concept of iTHEMS is unchanged.**
**"iTHEMS is iTHEMS."**

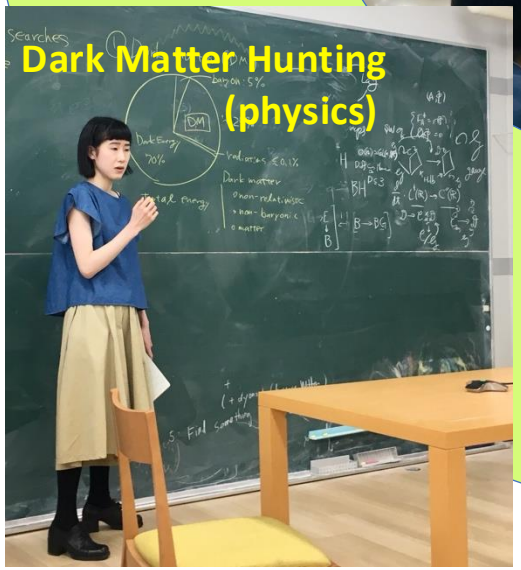
# Under One-Roof Activities 1: Coffee Meetings

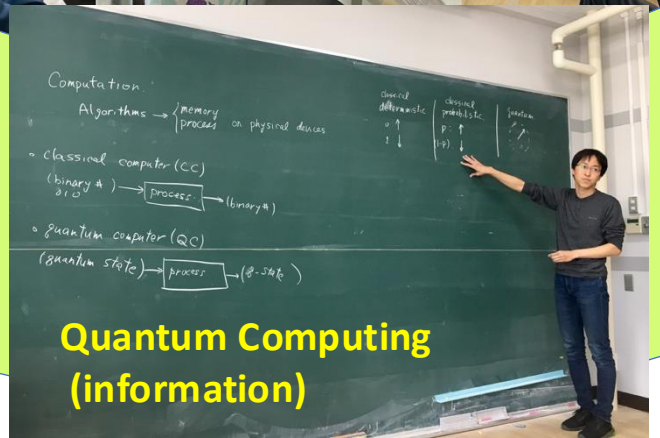
Coffee Meeting on Every Friday 12:30- and 15 min. talks





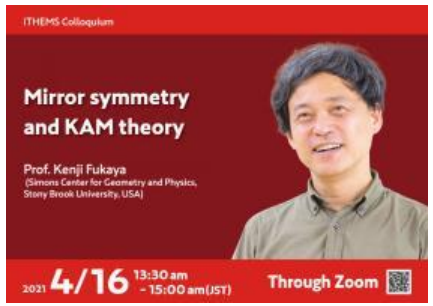



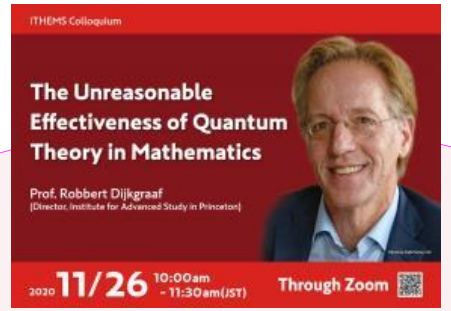

New collaborations among different fields

# Under One-Roof Activities 2: Colloquiums

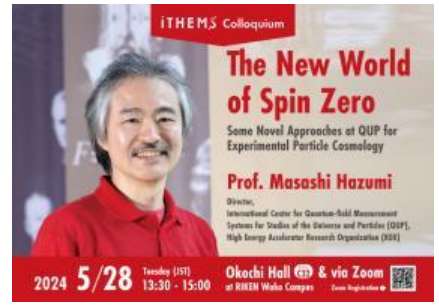
iTHEMS RIKEN Center for Interdisciplinary Theoretical and Mathematical Sciences







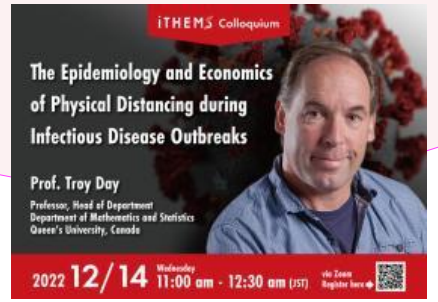




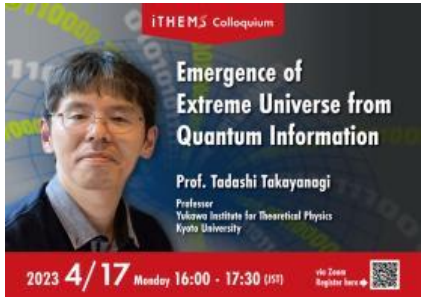











iTHEMS colloquiums

https://ithems.riken.jp/en/ac/colloquiums

Geometry

Cell dynamics

Math from Phys.

Single-celled organism

Particle Cosmology

Physics and Society

Infectious diseases

Quantum information

Optimal transport

Epidemiology

Turbulence

Quantum gravity

Gravitational waves

Population dynamics

# Research Highlights

## Interdisciplinary Collaboration in iTHEMS

### Mathematician + Biologist + Physicists
### "Network reduction based on topology "

*Theorem 4.* Let $\Gamma$ be a regular chemical reaction network with kinetics $\boldsymbol{r}(\boldsymbol{x})$ and let $\gamma$ be an output-complete subnetwork of $\Gamma$. We assume that the subnetwork $\gamma$ does not have an emergent conserved charge. We consider a reduced network $\Gamma' = \Gamma/\gamma$.

If $\gamma$ is a buffering structure, then we have the isomorphisms,

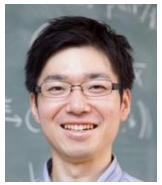
$$\ker S/\ker S_{11} \cong \ker S', \quad \operatorname{coker} S/\operatorname{coker} S_{11} \cong \operatorname{coker} S'. \tag{196}$$

Furthermore, when $(\boldsymbol{r}, \boldsymbol{x})$ is steady-state reaction rates concentrations of $\Gamma$, whose components we separate into those in $\gamma$ and $\Gamma \setminus \gamma$ as

$$\boldsymbol{r} = \begin{pmatrix} \boldsymbol{r}_1 \\ \boldsymbol{r}_2 \end{pmatrix}, \quad \boldsymbol{x} = \begin{pmatrix} \boldsymbol{x}_1 \\ \boldsymbol{x}_2 \end{pmatrix}, \tag{197}$$

then, $(\boldsymbol{r}_2, \boldsymbol{x}_2)$ is a steady-state solution of $\Gamma'$.

H. Miyazaki (iTHEMS→NTT)

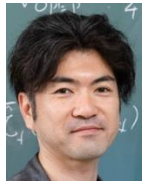


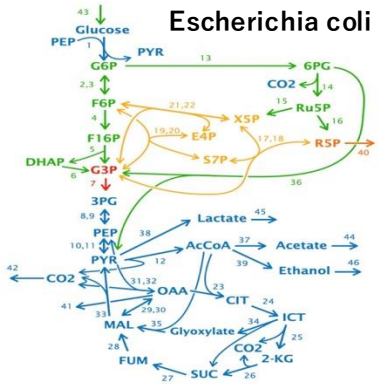
T. Okada (iTHEMS→Kyoto)

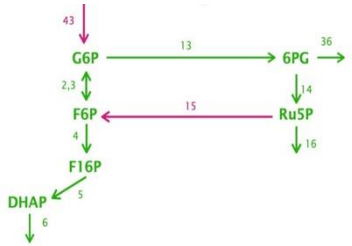
Math Phys ⊗ Bio Phys

Y. Hirono (APCTP/iTHEMS)

Y. Hidaka (Kyoto/iTHEMS)






Physical Review Research **3**, 043123 (2021)

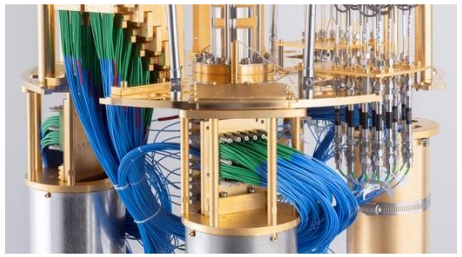
## Industry-Academia Collaboration of iTHEMS & UCB/LBNL

### IBM + UCB/LBNL + RIKEN iTHEMS
### "Quantum computing with error mitigation"

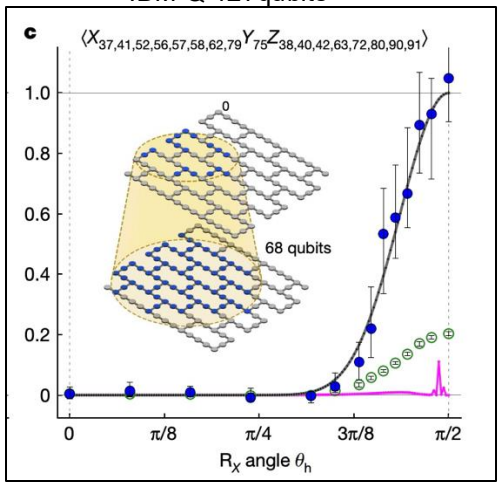
$$H = -J \sum_{\langle i,j \rangle} Z_i Z_j + h \sum_i X_i,$$

$$e^{-iH_{ZZ}\delta t} = \prod_{\langle i,j \rangle} e^{iJ\delta t Z_i Z_j} = \prod_{\langle i,j \rangle} R_{Z_i Z_j}(-2J\delta t)$$

$$e^{-iH_X \delta t} = \prod_i e^{-ih\delta t X_i} = \prod_i R_{X_i}(2h\delta t),$$

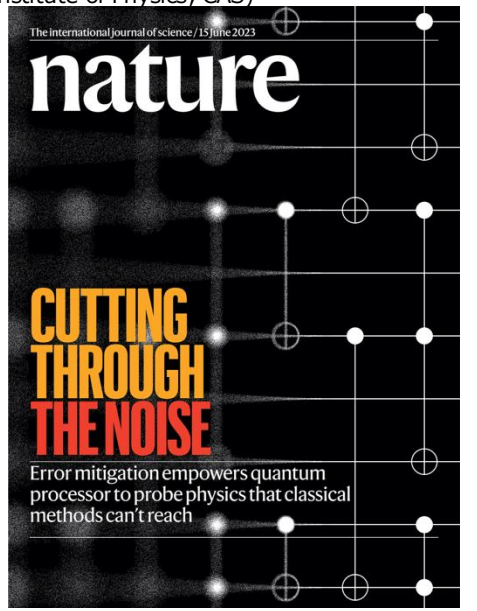


IBM-Q 127qubits




Y. Wu (RIKEN iTHEMS→ Institute of Physics, CAS)

Michael Zaletel (UCB/LBNL)




Nature **618**, 500 (2023)

# RIKEN-Berkeley Center (RBC)

## located on the 3rd floor of the Physics Building in UCB

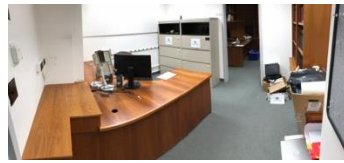


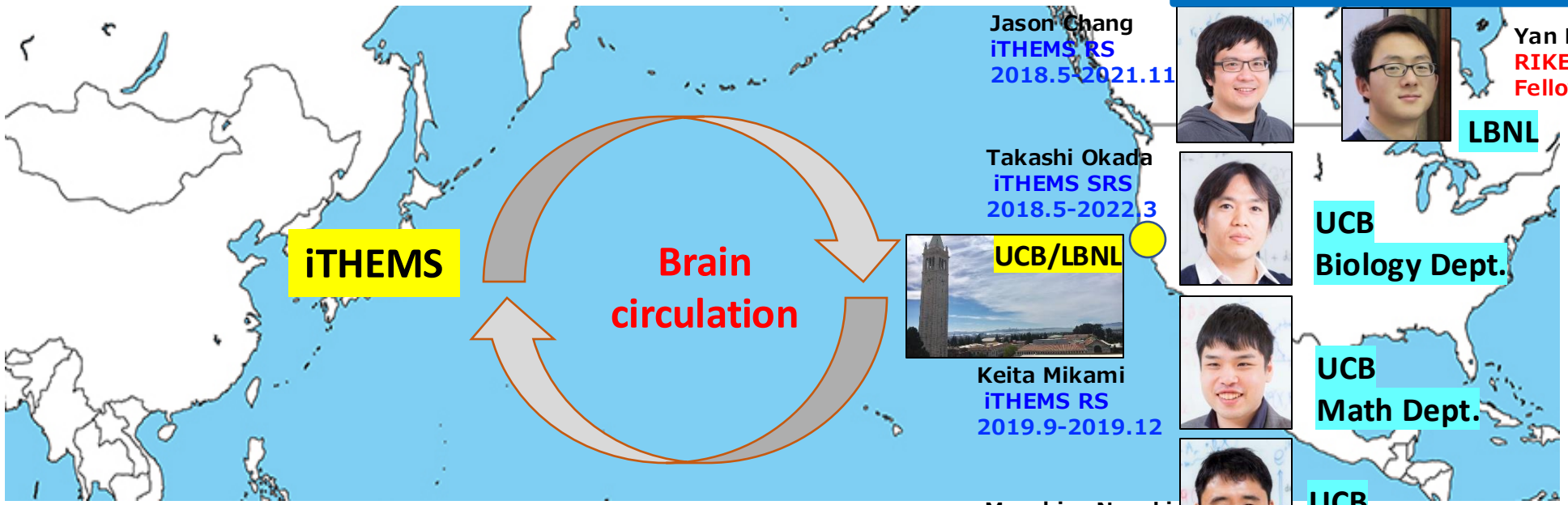

Joint Offices:

- NSF Physics Frontier Center
- CNRS Centre Pierre Binetruy
- RIKEN-Berkeley Center

# RIKEN Berkeley Center 2025

## iTHEMS-LBNL Office, 2017 -






Jason Chang
iTHEMS RS
2018.5-2021.11





Yan Lyu
RIKEN-Berkeley
Fellow, 2023.9-

LBNL

Comp. Phys.

Takashi Okada
iTHEMS SRS
2018.5-2022.3



UCB
Biology Dept.

Theo. Biology



Keita Mikami
iTHEMS RS
2019.9-2019.12

UCB
Math Dept.

Math.

Masahiro Nozaki
iTHEMS SPDR
2019.2-2020.3

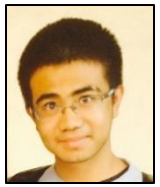
UCB
Physics Dept.

## RIKEN-Berkeley Center in UCB, 2022 -

**RIKEN-Berkeley "Mathematical Quantum Science initiative"**
JST ASPIRE Program (2024.2.1-2029.3.31) PI: Tetsuo Hatsuda


RIKEN-Berkeley Center
iTHEMS • Berkeley

Wick Haxton
iTHEMS SVS
2018.4-
N3AS (2016-)



Quantum Info.
Cond.Matt.

Yantao Wu. 2021.6-
iTHEMS PDR, 2024.8

### RIKEN-Berkeley Fellows

Ermal Rrapaj
2022.11
-2023.4

Manuela Saez
2022.11-
2023.5

Jan Shutte-Engel
2023.7-

Yuuka Kanakubo
2024.10-

Yuki Fujimoto
2024.10-
2025.6

Gabriele Di Ubaldo
2024.10-

Professor at UCB
SRS/VS at RBC

Yasunori Nomura

Director of RBC

Hiro Nagataki
2025.04-

Nucl. Part. Astro phys.

RBC is supported by the JST ASPIRE Program:
**RIKEN-Berkeley Mathematical Quantum Science Initiative**

ASPIRE
Adopting Sustainable Partnerships for Innovative Research Ecosystem

413,000,000 JPY (about 2.8MUSD) for 2024.2.1-2029.3.31.

PI: Tetsuo Hatsuda

RIKEN
Center for Interdisciplinary Theoretical and Mathematical Sciences (iTHEMS)
Quantum Mathematical Science Team
Team Director

iTHEMS RIKEN Center for Interdisciplinary Theoretical and Mathematical Sciences

https://ithems.riken.jp/en

Co-PI: Wick Haxton

UC Berkeley
NSF Physics Frontier Center (N3AS)
Director

N3AS Network for Neutrinos, Nuclear Astrophysics, and Symmetries
PHYSICS FRONTIER CENTER

https://n3as.berkeley.edu/

# Themes and members

Thema leaders

| | | | |
|---|---|---|---|
| Doi | RBV | RBF | Quantum Matter |
| Hatsuda | RBV | RBF | Quantum Computation |
| Nagataki | RBV | RBF | Quantum Universe |
| Kawahigashi | RBV | RBF | Quantum Mathematics |

RBV =RIKEN Berkeley Visitor (1-3 months)
RBF =RIKEN-Berkeley Fellow (1-3 years)

Haxton Lab. N3AS, UCB Phys.) | Zaletel Lab. (UCB Phys.) | Briceño Lab. (UCB Phys.) | Walker -Loud group (LBNL NSD) | Rrapaj group (LBNL NERSC) | Kasen Lab. (UCB Phys.) | Nomura Lab. (UCB BCTP) | Voiculescu Lab. (UCB Math.)

Doi Hatsuda Nagataki Kawahigashi

**PI:**
**T. Hatsuda**

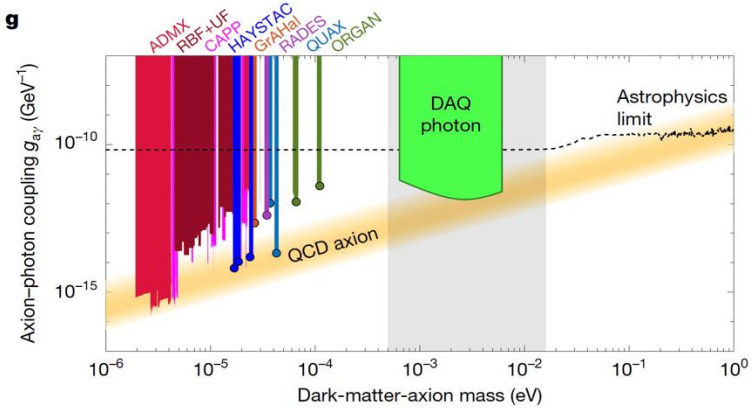
**Co-PI:**
**W. Haxton**

S. Aoki, Coordinator
(2024/12/1-)
Res:Admin=7:3

# Highlights of RIKEN-Berkeley Fellows in Berkeley

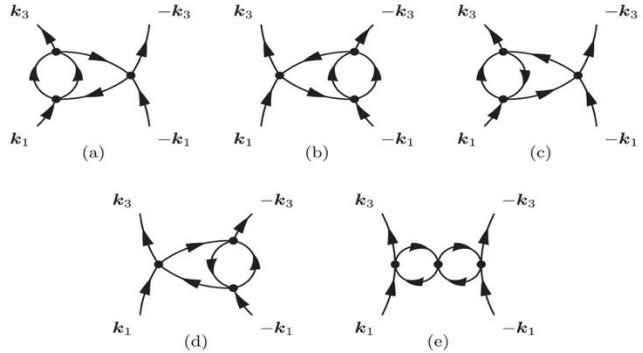
**Jan Shuette-Engel**
**2024. Feb.-**

## Observation of the axion quasiparticle in 2D $MnBi_2Te_4$ Nature **641** (2025)62




**Yuki Fujimoto**
**2024. Oct.-**
**2025 Jun.**

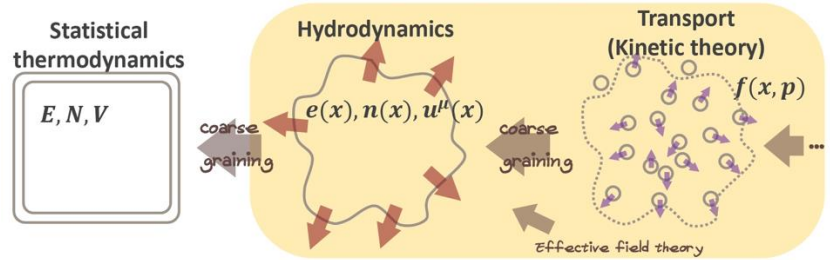
## Renormalization-group approach to Kohn-Luttinger superconductivity: Amplification of the pairing gap from $l^4$ to $l$, Phys. Rev. **B111**(2025)184510




**Yuka Kanakubo**
**2024. Oct.-**

## Dynamical evolution/collective dynamics

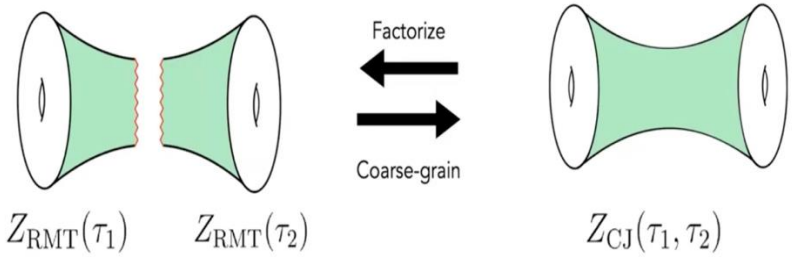
Invited Lecture to Early Carrier Researchers at Int. Conf. “Quark Matter 2025”




**Gabriele Di Ubaldo**
**2024. Oct.-**

## Modular-invariant random matrix theory and $AdS_3$ wormholes

arXiv:2503.00101 [hep-th] (2025)



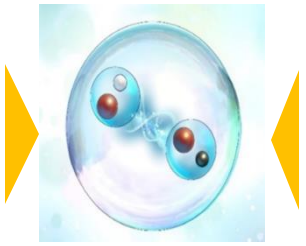
# Highlight of the RBF in Japan & Difficulty encountered at RBC.

"Doubly Charmed Tetraquark (a new exotic particle) from Lattice QCD" Phys. Rev. Lett. **131**, 161901 (2023)

**Yan Lyu (2023.9-)**

FUGAKU@RIKEN

Yan found the Tetraquark in 2023 (theory).



tetraquark

ALICE@LHC

LHC found the Tetraquark in 2021 (experiment).

## Issues with U.S. immigration control

One of the ASPIRE RIKEN-Berkeley Fellows has been unable to enter the U.S. since May 2024, due to immigration policy. His J-1 visa application was rejected because of his undergraduate institution.

Currently, Yan Lyu is working at RIKEN iTHEMS in Japan.

# Joint Meetings among N3AS, UCB, LBNL, ABBL, iTHEMS, and RBC.

N3AS Network for Neutrinos, Nuclear Astrophysics, and Symmetries
PHYSICS FRONTIER CENTER

NSF

**iTHEMS and ABBL joined N3AS in Sep. 2020.**


**FY2023:**
**Joint RIKEN/N3AS workshop on Multi-Messenger Astrophysics in Hawaii (Nov.26, 2023).**

**FY2024:**
**N3AS Annual Meeting (Jun. 1-2, 2024) at UC Berkeley.**
**8 iTHEMS/RBC members joined the meeting.**

**FY2024:**
**Joint workshop on quantum Information Science at LBNL (Sept. 3–6, 2024).**

**FY2024:**
**Joint N3AS-iTHEMS workshop on Quantum Information Science in Multi-Messenger Astrophysics at RIKEN (Jun. 16-18, 2024)**

**FY2025:**
**iTHEMS Now and Next 2025 (Jul. 24-25, 2025).**
**Kelsey Lund, Patric Cheong, Mia Kumamoto, and Baha Balantekin joined it, supported by the N3AS program.**

**FY2025:**
**Tetsuo, Satoshi, Hiro, Shuntaro, Camilia, Keiya are joining the annual meeting of N3AS now!**