Astrophysical Big Bang Laboratory (ABBL)
Chief Scientist: Shigehiro Nagataki (Ph.D.)

(0) Research field: Astrophysics Physics
Keywords: Supernovae (SNe), Gamma-Ray Bursts (GRBs), Black Holes (BHs), Neutron Stars (NSs), Cosmic Rays (CRs)

(1) Long-term goal of laboratory and research background

Our laboratory, Astrophysical Big Bang Laboratory (ABBL), was established on 1st Apr. 2013. Our group focuses on unveiling many mysteries surrounding explosive astrophysical phenomena such as supernovae (SNe) and gamma-ray bursts (GRBs). SNe and GRBs are the most powerful explosions in the universe, yet very little is known about their explosion mechanisms. These astrophysical big bangs fascinate us with their unknown physics and puzzling astronomical phenomena such as gravitational waves, r-process nucleosynthesis, particle acceleration, high-energy gamma-rays/neutrinos, and ultra-high-energy cosmic rays. Through our theoretical and computational approaches, we strive to reveal the complete pictures of these explosions and provide the-state-of-the-art physical interpretations for current, cutting-edge observations and useful predictions for future observations by the next-generation astronomical observatories. Furthermore, we are passionate about cooperating with researchers in RIKEN and all other interested groups in Japan and the world. Together, we would like to establish a Utopia in RIKEN for scientists.

(2) Current research activities (FY2023) and mid-term plan (until Mar. 2025)

In FY2023, the final year of the RIKEN Pioneering Project "Evolution of Matter in the Universe (r-EMU)", we achieved a number of achievements that can be regarded as representative results. As a result of discussions with experts in nuclear physics theory and experiments, led by Dr. Eiji Kido, we were able to summarize a theoretical study on the impacts of photonuclear dissociations on the calculation of the propagation of ultra-high-energy cosmic rays ((4) Representative research achievements [1]). Furthermore, the international collaboration group "Telescope Array," in which Dr. Eiji Kido, Dr. Ryo Higuchi, and Nagataki participate, successfully observed the second highest energy cosmic ray in human history, Amaterasu ((4) Representative research achievements [2]). Also, we reported a summary paper on the radiation mechanism of gamma-ray bursts, led by Dr. Hirotaka Ito, who had worked in ABBL for 10 years in total ((4) Representative research achievements [3]). We also reported a paper on the Cosmic Ladder led by Dr. Maria Dainotti, a former member of ABBL ((4) Representative research achievements [4]), and a paper on the thermal radiation of the neutron star in Supernova 1987A led by Dr. Akira Dohi ((4) Representative research achievements [5]).

ABBL started in FY2013 at RIKEN and has led the world for the sciences in SNe & GRBs. Nowadays, ABBL is one of the most famous laboratories globally, and each paper from ABBL is highly recognized in the community of SNe & GRBs. Until the end of FY2023 (11yr from the start), 25 researchers, postdoctoral researchers, and SPDR/FPR belonged to ABBL, and 17 people got successive positions successfully. Among 19, 9 got permanent positions. ABBL is developing further and further, keeping high research quality. Our goal is that each ABBL member will get a permanent position in the world, and each member will organize her/his research group to collaborate tightly with ABBL.

For the mid-term (until FY2024) goal of ABBL, Gravitational Wave is one of the keywords. ABBL has been studying SNe & GRBs, which are gravitational wave sources. ABBL is going to cover NSs & BHs more. There is a close relationship between SNe/GRBs and NSs/BHs since the former is the latter's mother. As a good example, we will study neutron star mergers that will emit gravitational waves, forming a BH. The dynamics depends on the equation-of-state (EOS) of neutron star matter. The neutron star mergers can be observed as kilo-novae brightened by the decay of r-process elements. Studies of neutron star mergers require substantial computational resources. ABBL believes that gravitational wave astrophysics fits very well with the sciences that RIKEN is leading.

(3) Members

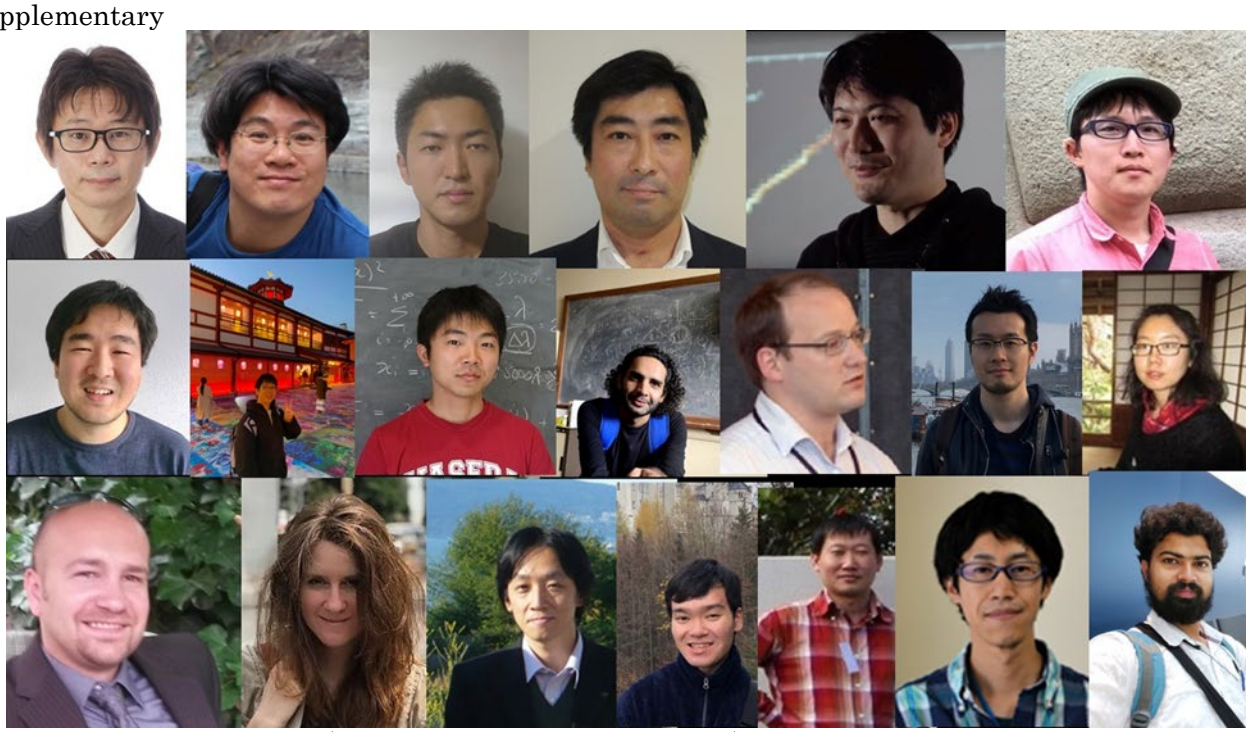
as of March, 2023

PI, Chief Scientist: Shigehiro Nagataki
Researchers: Akira Mizuta (Tenured), Eiji Kido, Hajime Sotani, Nobuya Nishimura
Postdoctral Researcher: Yuta Sekino (who moved to iTHEMS/Hamasaki Lab. in FY2023)
SPDR: Ryo Higuchi, Akira Dohi, Ryosuke Hirai
JRA: Takatoshi Ko
Secretary: Tamaki Shibasaki

(4) Representative research achievements

1. E. Kido et al.``Evaluations of uncertainties in simulations of propagation of ultrahigh-energy cosmic-ray nuclei derived from microscopic nuclear models", Astroparticle Physics, 152, 102866 (2023)
2. R. U. Abbasi, et al. ``An extremely energetic cosmic ray observed by a surface detector array", (The Telescope Array Collaboration), Science, 382, 6673, 903 (2023).
3. H. Ito, J. Matsumoto, S. Nagataki, Donald C. Warren, Maxim V. Barkov, Daisuke Yonetoku, “Numerical Simulation of Photospheric Emission in Long Gamma-Ray Bursts: Prompt Correlations, Spectral Shapes, and Polarizations”, Astrophys J. 961, Issue 2, id.243, (2024)
4. Bargiacchi, G.; Dainotti, M. G.; Nagataki, S.; Capozziello, S. “Gamma-ray bursts, quasars, baryonic acoustic oscillations, and supernovae Ia: new statistical insights and cosmological constraints” Monthly Notices of the Royal Astronomical Society, Volume 521, Issue 3, pp.3909-3924 (2023)
5. A. Dohi, E. Greco, S. Nagataki, M. Ono, M. Miceli, S. Orlando, B. Olmi, “Investigating Time Evolution of Thermal Emission from the Putative Neutron Star in SN 1987A for 50+ Years”, The Astrophysical Journal 949 (2023) 97

Supplementary



ABBL Members in FY2023 (including visiting researchers (Maxim Barkov, Yuki Takei, Oliver Just, Haoning He, Jirong Mao, Atsushi Tamii, Noemie Globus, Yohei Kawazura, Masaomi Ono, Sudipta Hensh))

Laboratory Homepage
https://www.riken.jp/en/research/labs/chief/astro_big_bang/index.html
http://nagataki-lab.riken.jp/index_en.html

(5) Research Records

(A) 受賞・プレスリリース等

木戸英治、研究成果（プレスリリース）「テレスコープアレイ実験史上最大のエネルギーをもつ宇宙線を検出」、https://www.riken.jp/press/2023/20231124_1/index.html、2023年11月23日

Takatoshi Ko, “The newest unidentified historical supernova SN 1181 with a peculiar white dwarf”, Riken Summer School 2023, Wako, Sep. 2023 (poster award)

(B) 授業・本

西村信哉「星の錬金術：宇宙における重元素の起源」, CORE Uセミナー, 広島大学, 2023年2月3日.

(C) 論文（査読あり）

Hajime Sotani and Tomoya Naito, "Empirical neutron star mass formula based on experimental observables", Phys. Rev. C 107(3), 035802

M. Williams, et al., “Cross Section of the 83Rb(p,γ)84Sr and 84Kr(p,γ)85Rb reactions at energies characteristic of the Astrophysical γ Process”, Phys. Rev. C 107, 035803 (2023).

A. Coleman, et al., ``Ultra-High-Energy Cosmic Rays: The Intersection of the Cosmic and Energy Frontiers", Astroparticle Physics, 149, 102819 (2023).

R. Higuchi, T. Sako, T. Fujii, K. Kawata, E. Kido,``Effects of the Galactic Magnetic Field on the UHECR Correlation Studies with Starburst Galaxies", The Astrophysical Journal, 949, 2, id.107 (2023).

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Bargiacchi, G.; Dainotti, M. G.; Nagataki, S.; Capozziello, S. “Gamma-ray bursts, quasars, baryonic acoustic oscillations, and supernovae Ia: new statistical insights and cosmological constraints” Monthly Notices of the Royal Astronomical Society, Volume 521, Issue 3, pp.3909-3924 (2023)

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Acharyya, A. et al. “Sensitivity of the Cherenkov Telescope Array to TeV photon emission from the Large Magellanic Cloud” Monthly Notices of the Royal Astronomical Society, Volume 523, Issue 4, pp.5353-5387 (2023)

R. U. Abbasi, et al. (The Telescope Array Collaboration), `First High-Speed Video Camera Observations of a Lightning Flash Associated With a Downward Terrestrial Gamma-Ray Flash", Geophysical Research Letters, 50, 14 (2023).

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Higuchi R et al., “Estimation and reduction of the biases by the galactic magnetic field on the UHECR correlation studies”, EPJ Web of Conferences, Volume 283 (UHECR2022), id.03011 (2023)

H. Liu, Y. Gao, Z. Li, A. Dohi, W. Wang, G. Lv, R. Xu, “EOS-dependent millihertz quasi-periodic oscillation in low-mass X-ray binary”, Monthly Notices of the Royal Astronomical Society 525 (2023) 2054

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A. Dohi, W. Iwakiri, N. Nishimura, S. Nagataki, and M. Hashimoto, “Constraints on the Neutron-Star Structure from the Clocked X-Ray Burster 1RXS J180408.9-342058”, Astrophys J. 960, Issue 1, id.14, (2024)

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T. Ko, D. Tsuna, B. Hatsukad, T. Shigeyama, “Radio Emission from SN 1181 Hosting a White Dwarf Merger Product”, Publications of the Astronomical Society of Japan in press, (2024)

(D) 国際会議口頭発表（招待・基調講演）

Shigehiro Nagataki “Introduction to Stellar Physics and Supernova Explosions” SeMPowisko2023, Online Presentation, Presentation Date: 13th May 2023.

E. Kido, `` Nuclear reactions related to very high and ultra-high energy cosmic rays”, The 1st IReNA-Ukakuren Joint Workshop “Advancing Professional Development in Nuclear Astrophysics and Beyond”, Mitaka, Japan, Sep. 2023.

E. Kido, `` The latest results of the Telescope Array experiment”, 52nd International Symposium on Multiparticle Dynamics (ISMD 2023), Gyöngyös, Hungary, Aug. 2023

E. Kido, ``Recent results from the Telescope Array experiment”, 58th Rencontres de Moriond 2024, La Thuile, Italy, Mar. 2024

Nobuya Nishimura “Theoretical studies of r-process: Heavy-element nucleosynthesis in stellar explosions”, Annual Meeting of JSPS/NRF/NSFC A3 Foresight Program “Nuclear Physics in the 21st Century”, Xi’an (China), 30 Nov.－4 Dec. 2023

Nobuya Nishimura “The impacts of nuclear-physics uncertainties on heavy-element nucleosynthesis”, N3AS-RIKEN iTHEMS Workshop “Multi-Messenger Astrophysics”, Hawaii Island (USA), 26 Nov. 2023.

Nobuya Nishimura “Nucleosynthesis beyond iron in supernovae and neutron-star mergers”, “Oahu Nuclear physics Collaborative Meeting”, Waikiki (USA), 13-16 Oct. 2023.

Nobuya Nishimura, “Nuclear-physics uncertainties of heavy-element nucleosynthesis in stellar explosions” 73rd OMEG-SSANP Workshop, 15 Mar. 2024, Soongsil University (Korea)

Akira Dohi, Emanuele Greco, Shigehiro Nagataki, Masaomi Ono, Marco Miceli, Salvatore Orlando, Barbara Olmi, “On the Thermal Emission Scenario to Find NS 1987A by Lynx”, Joint RIKEN/N3AS Workshop on Multi-Messenger Astrophysics, Hilton Waikoloa Village, Waikoloa, HI, Big Hawaiian Island in America, Nov. 26, 2023

(E) 国内会議口頭発表（招待・基調講演）
木戸英治、「地表検出器による将来計画のレビュー」、次世代の最高エネルギー宇宙線観測の実現へ向けて、大阪電気通信大学、2023年5月

西村信哉「核反応と崩壊で探る宇宙の核種進化」, 理論核物理研究会「現代核物理の広がりと展望」, 九州大学（福岡）, 2023年7月19-21日.
西村信哉「爆発天体での元素合成：安定から遠く離れて」, 沼津ワークショップ, ぬましん COMPASS（静岡）, 2023年3月27日

西村信哉「宇宙におけるp核の起源と陽子過剰核の原子核反応」, 研究会「星の進化と爆発天体における核反応の物理」, 理研RIBF（埼玉）, 2023年2月20-21日.

西村信哉「中性子捕獲が鍵となる宇宙の元素進化」, 東京大学（東京）, 2023年2月9日.

黄 天鋭, 「白色矮星連星合体で生じたIax型超新星爆発残骸SNR 1181の性質」, 小研究会 相対論的現象で探る宇宙の進化Ⅳ, 沖縄, 2024年3月

Shigehiro Nagataki “Enjoy Astrophysics Just for 1 Hour!” Third Mini-Workshop on the Early Universe, Ishigaki, Japan, Presentation Date: 9th Feb. 2023.

Shigehiro Nagataki “Supernovae as Origins of Cosmic Rays and Life” OIST x iTHEMS workshop series - Will We Find Answers? Exploring the Mysteries of the Universe and Life - Series 1 Cosmic ray and Life project, OIST, Japan, Presentation Date: 4th Mar. 2024.

長瀧重博 “Roads from Supernovae to Supernova Remnants橋本先生祝賀記念研究会に沿えて” 橋本正章先生古稀記念研究会「中性子星を中心とした宇宙核物理研究のこれまでとこれから」九州大学 数理IMIオーディトリアム - ウエスト1号館 D棟 4階 413号室 2024年3月9日

(F) 国際会議口頭発表
Akira Mizuta, ``Numerical study of growth of Kelvin-Helmholtz instability in collisionless shock experiments”, International Workshop

on New Developments in Laboratory Astrophysics, 2024.1 (Kyusyu Univ., Fukuoka)

E. Kido for the Telescope Array Collaboration, “Updates of the surface detector array of the TAx4 experiment”, 38th International Cosmic Ray Conference (ICRC2023), Nagoya, Japan, 2023

Hajime Sotani, "SN GWs and asteroseismology", LIGO-Virgo-KAGRA collaboration meeting, Toyama International Conference Center, Toyama, Japan, Sep. 11-15, 2023

Hajime Sotani, "Neutron star mass and radius constraints using the high-frequency QPOs of GRB 200415A", 4th Quarks and Compact Stars workshop (QCS2023), Yangzhou University, Yangzhou, China, Sep. 23-26, 2023.

Hajime Sotani, "Asteroseismology of Neutron Stars", Joint RIKEN/N3AS Workshop on Multi-Messenger Astrophysics, Hilton Waikoloa Village, Waikoloa, HI, USA, Nov. 26.

Hajime Sotani, "Constraint on the mass and radius of GRB 200415A using the high-frequency QPOs", Hawaii 2023, Hilton Waikoloa Village, Waikoloa, HI, USA, Nov. 26 - Dec. 1. 2023.

Nobuya Nishimura “Optical properties of magneto-rotational jet-driven supernovae associated with r-process nucleosynthesis”, 17th International Symposium on Nuclei in the Cosmos (NIC XVII), Daejeon (Korea), 17-22 Sep. 2023.

Nobuya Nishimura “Impacts of Nuclear-reaction uncertainty on heavy-element nucleosynthesis”, T3 Workshop, Ohio (USA), 14-17 Aug. 2023.

Nobuya Nishimura “Observational signature of magneto-rotational supernovae associated with r-process nucleosynthesis”, CeNAM Frontiers Meeting, Michigan (USA), 24 May 2023.

Nobuya Nishimura "The impacts of nuclear-physics uncertainties on explosive nucleosynthesis in core-collapse supernovae”, ASRC International Workshop "Nuclear Astrophysics with Stable Beams”, 20-22 Feb. 2024, Tokai

Yuta Sekino, Hiroyuki Tajima, Shun Uchino,“Spin conductivity spectrum in ultracold atomic gases”, 54th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Spokane Convention Center in Spokane, Washington USA, June 5-9, 2023

Akira Dohi, “EOS Dependence of Type-I X-ray Bursts”, ASRC International Workshop " Nuclear Astrophysics with Stable Beams (NAPS)”, Tokai Village Museum, Tokai, Ibaraki, Japan, 20-22. Feb. 2024

Akira Dohi, Wataru Iwakiri, Nobuya Nishimura, Tsuneo Noda, Shigehiro Nagataki, Masa-aki Hashimoto, “Constraints on Neutron Star Structure from Clocked Burster 1RXS J180408.9-342058”, The 1st IReNA-Ukakuren Joint Workshop “Advancing Professional Development in Nuclear Astrophysics and Beyond”, National Observatory of Japan (NAOJ), Japan, Aug. 28 – Sep. 1, 2023

Akira Dohi, Wataru, Iwakiri, Nobuya Nishimura, Tsuneo Noda, Helei Liu, Shigehiro Nagataki, and Masa-aki Hashimoto, “Impact of Neutron-Star Structure on Type-I X-ray Bursts”, Frontiers in Nuclear Astrophysics 2023, Facility for Rare Isotope Beams (FRIB) in Michigan State University, Lansing, America, May 21-26, 2023

T. Ko et al. “The newest unidentified historical supernova SN 1181 with a peculiar white dwarf”, East Asian Young Astronomers Meeting 2024 (EAYAM2024), Chiang Mai, Jan. 2024

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Takatoshi Ko, "Introduction of SNR 1181 and a massive white dwarf in its center", One Day Meeting with Prof. Roger Blandford, Wako, Jul. 2023

(G) 国内会議口頭発表

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木戸英治，長瀧重博，樋口諒，H. He, N, Globus, D. Warren III 他 Telescope Array Collaboration、「TA実験419：TA実験ホットスポットの起源天体探索II」，日本物理学会，オンライン，2024 年3 月

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西村信哉「超新星爆発の元素合成：再訪」、研究会「中性子星を中心とした宇宙核物理研究のこれまでとこれから」、2024年3月9日、九州大学

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樋口 諒, “テレスコープアレイ実験・オージェ実験による最高エネルギー宇宙線の全天観測とその展望”，プラネタリウムで俯瞰する多波長全天/広域サーベイ，名古屋, 7月(2023)

樋口　諒, “最高エネルギー宇宙線探査への磁場の影響”，宇宙線で繋ぐ文明・地球環境・太陽系・銀河 2023, 東北大学, 9月(2023)

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土肥明, “X-ray Burst Studies: Current Status and Future Development”，「中性子星を中心とした宇宙核物理研究のこれまでとこれから」，九州大学, 福岡, 日本, 2024年3月9日

土肥明, 谷口億宇, 西村信哉, 祖谷元, 木村真明, “X線スーパーバーストに対する炭素燃焼の核反応率の影響”，日本天文学会2023年秋季大会, 大学, 2023年9月

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