

## Astrophysical Big Bang Laboratory

### 長瀧天体ビッグバン研究室

PI: Shigehiro Nagataki (Doctor of Science), Chief Scientist

#### 1. Abstract

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

Deep understanding on mathematical and computational physics is very important to solve fundamental, unsolved problems in astrophysics. Our group has joined one of the Pioneering Projects, “Interdisciplinary Theoretical Science Research Group (iTHES)” (Group Director is Dr. Tetsuo Hatsuda) from FY2014, to solve such problems by enhancing communications with researchers of nuclear physics, condensed matter, chemistry, and biology in RIKEN. These activities should be also helpful to increase our group’s activities in astrophysics. Shigehiro Nagataki, the PI of ABBL, became a team leader of Interdisciplinary Mathematical and Computational Collaboration Team of iTHES. Due to the great success of iTHES, a new program, “Interdisciplinary Theoretical and Mathematical Science Program (iTHEMS)” has been approved by MEXT in FY2016 (Program Director is Tetsuo Hatsuda). iTHEMS has a same concept with iTHES, but iTHEMS includes Mathematics. Shigehiro Nagataki has been a Deputy Program Director of iTHEMS. We will achieve our scientific goal through good communications & collaborations among ABBL & iTHEMS members (iTHES is terminated at

the end of March, 2017 since it is 5-year project from April 2013).

To enhance activities in nuclear-astrophysics in RIKEN, which is one of our dreams, further communications & collaborations with Nishina Center, CNS (U. Tokyo), and WNSC (KEK) are crucial. The state-of-the-art equation of state for dense matter and nuclear reaction data for various channels can be provided by Nishina Center groups, which are essential to unveil the phenomena of SNe and GRBs. Our group had joint meetings with Dr. Nakatsukasa's group continuously since FY2013. Even after Dr. Nakatsukasa's moving to Tsukuba University, we have been organizing the joint meetings occasionally by inviting nuclear physicists as speakers. Shigehiro Nagataki joined one of the Pioneering Projects, "Extreme precisions to explore fundamental physics with exotic particles (Triple-E)" (Group Director: Dr. Hidetoshi Katori). This project definitely helped our group to enhance communications and collaborations with Nishina Center, especially Dr. Uesaka's group as well as CNS & WNSC. We also believe that our group could contribute especially to new science of RIBF through this project. Further, we are highly motivated to study more about nuclear-astrophysics by the discovery of the neutron star merger event in August 2017. Following these success, Shigehiro Nagataki is going to contribute to the RIKEN Pioneering project "RIKEN-Evolution of Matter in the Universe (r-EMU)" as a team leader of "Super-Nuclear Physics in Astrophysical Big Bangs" group from FY2019.

Super-computing is indispensable for unveiling the explosion mechanisms of SNe and GRBs. Full-understanding of them is still not achieved even by using K-computer. We would like to achieve the complete understanding of the explosion mechanisms using super-computers in RIKEN, National Astronomical Observatory of Japan (NAOJ), Yukawa Institute for Theoretical Physics (YITP), and Max Planck Institute for Astrophysics (MPA). Dr. Tomoya Takiwaki, who did numerical simulations of SNe by K-computer supported by HPCI Strategic Program Field 5 "The origin of matter and the universe" joined our group from 1<sup>st</sup> Aug. 2014, obtained lots of fruitful results on SNe and GRBs in our group, and got a permanent position of Assistant Professor at NAOJ successfully in 2016 (he is also keeping affiliation of ABBL as a visiting researcher). We will continue to encourage excellent researchers of this field to join our group from all over the world, so that our group in RIKEN keeps leading the world in this field.

As mentioned above, our group has already decided to lead the world in the field of astrophysical big bangs. For the purpose, we are seeking for top-ranked researchers in the world, encouraging them to join our group, and doing the-state-of-the-art researches in this

field. We are succeeding to have an international laboratory composed of 9 Japanese including PI and 10 non-Japanese (2 from Russia & China, and 1 from Italy, Hong-Kong, Thailand, USA, France, Germany), including Alumni who succeeded to get their next positions, such as a faculty position (full professor, tenured) at Yunnan Observatory in China, a lecturer position at Kyoto University (tenured), a lecturer position at National Institute of Technology Asahikawa College (tenured), an assistant professor position at NAOJ (tenured), an assistant professor position at Jagellonian University (tenure-track), Kavli IPMU at the University of Tokyo, Purdue University, and assistant professor position at Tohoku University (for outreach). Among the 12 alumni, 5 got tenure or tenure-track positions successfully. Among the total 19 members, 3 joined ABBL from Stanford Univ., 3 from Max Planck Institute, and 1 from UCLA. We are sure that we can establish a top-ranked lab. in the world and achieve our goals & dreams in the near future leading the world.

## 2. Key Words

Supernova Explosions, Gamma-Ray Bursts, Neutron Stars, Black Holes, Supernova Remnants, gravitational waves, neutrinos, r-process/Explosive Nucleosynthesis, Radiation Transfer, Relativistic MHD Flow, Particle Acceleration, High-Energy Cosmic Rays, General Relativity, Equation of State for Dense Matter, High Performance Super-Computing.

## 3. Members

### ***Principal Investigator***

Shigehiro Nagataki

Chief Scientist

Research Scientist

Masanori Arakawa

Junior Research Associate/Rikkyo U.

### ***Core Members***

Hiroataka Ito

Research Scientist

Toshio Terasawa

Visiting Scientist

Gilles Ferrand

Research Scientist

### ***Past Core Members***

Alexey Tolstov

Postdoctoral Researcher, Kavli IPMU,  
Univ. of Tokyo

Haoning He

Postdoctoral Researcher

Jirong Mao

Masaomi Ono

Faculty at Yunnan Observatory

Shiu-Hang Lee  
Lecturer at Kyoto University  
Visiting Scientist of RIKEN

Maria Giovanna Dainotti  
Assistant professor at Jagellonian U.  
Marie Curie Fellow at Stanford Univ.

Yuto Teraki  
National Institute of Technology  
Asahikawa College

Tomoya Takiwaki  
Assistant Professor at NAOJ  
Visiting Scientist of RIKEN

Tomohide Wada  
Assistant Professor at Tohoku U.  
(Outreach)

Maxim Barkov  
Postdoc at Purdue University  
Visiting Scientist of RIKEN

Annop Wongwathanarat  
Researcher at Max Planck Institute for  
Astrophysics

Jin Matsumoto  
Researcher at Leeds University

Donald Warren  
Research Scientist of iTHEMS, RIKEN

Susumu Inoue  
Research Scientist of iTHEMS, RIKEN

### *Assistant*

Tamaki Shibasaki

### *Long Term Visitors*

Camilia Demidem (Universite Paris-  
Diderot : 2018 年 6 月 19 日-8 月 21 日)

Yun-Feng Liang (Purple Mountain  
Observatory : 2018 年 7 月 7 日-8 月 19 日)

Lei Feng (Purple Mountain Observatory  
: 2018 年 7 月 7 日-8 月 19 日)

Ziqing Xia(Purple Mountain Observatory  
: 2018 年 8 月 1 日-8 月 31 日)

Maria Giovanna Dainotti (Stanford  
University: 2019 年 1 月 11 日-2 月 28 日)

### *Short Term Visitors*

Masamune Ooguri (RESCEU)

Naritaka Ooshita (U. Tokyo)

Luca Baiotti (Osaka U.)

Yutaro Yoshino (Rikkyo U.)

Atsuhiko Ebata (Rikkyo U.)

Hiroyoshi Iwasaki (Rikkyo U.)

Takaya Nozawa (NAOJ)

Jennifer West (U. of Toronto)

Shota Kisaka (Aoyama Gakuin U.)

Ryo Sawada (Kyoto U.)

Yuichi Harikane (U. Tokyo)

Yohei Kawazura (U. of Oxford)

Kou Takahashi (U. Bonn)

Takanobu Amano (U. Tokyo)

Yuki Takei (U. Tokyo)

Mamoru Matsuo (Chinese Academy of

Science)

Tomoya Takiwaki (NAOJ)

Takashi Sako (ICRR)

Masanori Iwamoto (U. Tokyo)

Leung Shing Chi (IPMU)

Kumiko Kotera (CNRS)

Yosuke Mizuno (U. Frankfurt)

#### 4. Achievements

##### (1) Press Release etc.

Shigehiro Nagataki 「大質量星はなぜ爆発する？」RIKEN NEWS, No. 443, 2018年5月号。

Masaomi Ono (量子科学技術研究開発機構・早川岳人上席研究員、国立天文台・梶野敏貴准教授、東京大学国際高等研究所カブリ数物連携宇宙研究機構・野本憲一上級科学研究員、東京工業大学・千葉敏教授、九州大学・橋本正章教授等と共同発表)、「超新星爆発ニュートリノで宇宙核時計テクネチウム 98 が生成されることを予言」量子研、国立天文台、理研等でプレスリリース。

2018年9月4日。

##### (2) Papers in Journals (Refereed)

He Haoning, Nagataki Shigehiro, Kusenko Alexander, Fan Yi-Zhong, Wei Da-Ming, “Neutrinos from Choked Jets Followed by Type II Supernovae” *The Astrophysical Journal*, Volume 856, Issue 2, article id. 119, 10 pp, 04/01/18

T. Hayakawa (including A. Tolstov; M. Ono) “Neutrino process with primitive

meteorites and high power laser” AIP conference proceedings Vol. 1947, Issue 1, article id. 020021, 2018/04/25

Ruo-Yu Liu, 村瀬孔太、井上進、Chong Ge、Xiang-Yu Wang, “Can Winds Driven by Active Galactic Nuclei Account for the Extragalactic Gamma-Ray and Neutrino Backgrounds?” *Astrophysical Journal*, 858, 9, 2018 May 1

Abbasi, R. U. (including Ono, M.) (Telescope Array Collaboration) “Depth of Ultra High Energy Cosmic Ray Induced Air Shower Maxima Measured by the Telescope Array Black Rock and Long Ridge FADC Fluorescence Detectors and Surface Array in Hybrid Mode” *The Astrophysical Journal*, Vol. 858, Issue 2, article id. 76 (27pp.) 2018/05/09

Abbasi, R. U. (including Ono, M.) “Gamma Ray Showers Observed at Ground Level in Coincidence With Downward Lightning Leaders” *Journal of Geophysical Research: Atmospheres*, Vol. 123, Issue 13, pp. 6864-6879, 2018/05/18

Sahu, Sarira, de León, Alberto Rosales; Nagataki, Shigehiro, “The nature of the intrinsic spectra from the VHE emission of H 2356-309 and 1ES 1101-232” *The European Physical Journal C*, Volume 78, Issue 6, article id. 484, 11 pp. 01/06/2018

Sahu, Sarira, de León, Alberto Rosales; Nagataki, Shigehiro; Gupta, Virendra, “The origin of multi-TeV flares from the nearest blazar Markarian 421” *The European Physical Journal C*, Volume 78, Issue 7, article id. 557, 8 pp. 01/07/2018

Abbasi, R. U. (including Ono, M.) “Study of muons from ultrahigh energy cosmic ray air showers measured with the Telescope Array experiment” *Physical Review D*, Vol. 98, Issue 2, id. 022002 2018/07/03

M. G. Aartsen, 井上進 他 1008 名, “Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A” *Science*, 361, eaat1378, 2018 July 13

Abbasi, R. U. (including Ono, M.) “Evidence of Intermediate-scale Energy Spectrum Anisotropy of Cosmic Rays  $E \geq 10^{19.2}$  eV with the Telescope Array Surface Detector” *The Astrophysical Journal*, Vol. 862, Issue 2, article id. 91 (6pp.), 2018/07/26

Obergaulinger Martin, Just Oliver, Aloy Miguel, “Core collapse with magnetic fields and rotation” *Journal of Physics G: Nuclear and Particle Physics*, 45, 084001, 08/2018

Akira Mizuta, Ebisuzaki, Toshikazu;

Tajima, Toshiki; Nagataki, Shigehiro, “Production of intense episodic Alfvén pulses: GRMHD simulation of black hole accretion discs” *Monthly Notices of the Royal Astronomical Society*, Volume 479, Issue 2, p.2534-2546, 01/09/2018

Maxim Barkov, Valenti Bosch-Ramon, “A hydrodynamics-informed, radiation model for HESS J0632 + 057 from radio to gamma-rays” *Monthly Notices of the Royal Astronomical Society*, Volume 479, Issue 1, p.1320-1326, 2018/1/9

Hayakawa, (including Ono, Masaomi “Short-Lived Radioisotope  $^{98}\text{Te}$  Synthesized by the Supernova Neutrino Process” *Physical Review Letters* Vol. 121, Issue 10, id. 102701, 2018/09/04

Abbasi, R. U. (including Ito, H., Nagataki, S., Ono, M.) (Telescope Array Collaboration) “The Cosmic Ray Energy Spectrum between 2 PeV and 2 EeV Observed with the TALE Detector in Monocular Mode” *The Astrophysical Journal*, Vol. 865, Issue 1, article id. 74 (18pp.), 2018/09/24

Martinez Rodriguez, Héctor; Badenes, Carles; Lee, Shiu-Hang; Patnaude, Daniel J.; Foster, Adam R.; Yamaguchi, Hiroya; Auchettl, Katie; Bravo, Eduardo; Slane, Patrick O.; Piro, Anthony L.; Park, Sangwook; Nagataki, Shigehiro, “Chandrasekhar and Sub-Chandrasekhar Models for the

X-Ray Emission of Type Ia Supernova Remnants. I. Bulk Properties” The Astrophysical Journal, Volume 865, Issue 2, article id. 151, 16 pp. (2018). 01/10/2018

FERRAND Gilles, WARREN Don, “Engaging the Public with Supernova and Supernova Remnant Research Using Virtual Reality” CAPjournal, 24, 25-31, 2018-10

Abbasi, R. U. (including Ono, M.) “Testing a Reported Correlation between Arrival Directions of Ultra-high-energy Cosmic Rays and a Flux Pattern from nearby Starburst Galaxies using Telescope Array Data” The Astrophysical Journal Letters, Vol. 867, Issue 2, article id. L27 (5pp.), 2018/11/08

桂川美穂、中島真也、松村英晃、田中孝明、内田 裕之、Shiu-Hang (Herman) Lee、内山泰伸、荒川真範、高橋忠幸, “Suzaku X-ray observations of the mixed-morphology supernova remnant CTB 1”, Publications of the Astronomical Society of Japan, Volume 70, Issue 6, id.110, 2018/12/1

Just Oliver, Bollig Robert, Janka Hans-Thomas, Obergaulinger Martin, Glas Robert, Nagataki Shigehiro, “Core-collapse supernova simulations in one and two dimensions: comparison of codes and approximations” Monthly

Notices of the Royal Astronomical Society, 481, 4786-4814, 12/2018

山崎翔太郎, 木坂将太、寺澤敏夫、榎戸輝明, “Relativistic fireball reprise: radio suppression at the onset of short magnetar bursts” Mon. Not. R. Astron. Soc., vol. 483, 4175-4186, 2018/12/13

Orlando, S. Miceli, M.; Petruk, O.; Ono, M.; Nagataki, S.; Aloy, M. A.; Mimica, P.; Lee, S.-H.; Bocchino, F.; Peres, G.; Guarrasi, M. “3D MHD modeling of the expanding remnant of SN 1987A. Role of magnetic field and non-thermal radio emission” Astronomy & Astrophysics, Vol. 622, id. A73 (15pp.) 2019/01/29

Kusakabe, Motohiko Cheoun, Myung-Ki; Kim, K. S.; Hashimoto, Masa-aki; Ono, Masaomi; Nomoto, Ken'ichi; Suzuki, Toshio; Kajino, Toshitaka; Mathews, Grant J. “Supernova Neutrino Process of Li and B Revisited” The Astrophysical Journal, Vol. 872, Issue 2, article id. 164 (20pp.), 2019/02/20

Glas Robert, Just Oliver, Janka Hans-Thomas, Obergaulinger Martin, “Three-dimensional Core-collapse Supernova Simulations with Multidimensional Neutrino Transport Compared to the Ray-by-ray-plus Approximation”, The Astrophysical Journal, 873, 45, 03/2019

(3) Oral Presentations at International Meetings (Invited Talks)

Maxim Barkov “3D dynamics and morphology of bow-shock Pulsar Wind Nebulae” Workshop on Relativistic Plasma Astrophysics, West Lafayette, IN, USA, 05/09/2018

Maxim Barkov “Scenarios for Ultrafast Gamma-Ray Variability in AGN” ASTRONUM-2018, SAINT PETERSBURG, RUSSIAN FEDERATION, 09/06/2018

Maxim Barkov “3D dynamics and morphology of bow-shock Pulsar Wind Nebulae” ASTRONUM-2018, Panama City Beach, Florida, USA, 06/27/2018

伊藤裕貴 “Numerical Simulations of Photospheric Emission from Collapsar Jets” Fifteenth Marcel Grossmann Meeting, ローマ、イタリア, 2018/7/2

Shigehiro Nagataki “Theories of Central Engine for Long Gamma-Ray Bursts” 25th Anniversary of the Rencontres du Viet Nam “Windows on the Universe”, Quy Nhon, Vietnam, 6 Aug. 2018

伊藤裕貴 “ Prompt Emission of Gamma-ray Bursts” , Windows on the Universe, クイニョン、ベトナム, 2018/8/7

Shigehiro Nagataki “From Central Engine to Gamma-Ray Emission for

Long Gamma-Ray Bursts” PACIFIC2018.9, Moorea, French Polynesia, 31 Aug. 2018

Masaomi Ono “3D numerical modeling of SN 1987A: the dynamical and chemical evolution from the supernova to the supernova remnant” Workshop on “Physics at HIAF High-Energy Beam Lines” 北京、中国 2018/12/15

Shigehiro Nagataki “Theories of Massive Star Explosion” International Seminar on Emerging Trends in Physics and Applications, Odisha, India, 03 Feb. 2019

(4) Oral Presentations at Domestic Meetings (Invited/Keynote Talks)

小野勝臣 “SN 1987A における核合成から分子形成まで” 核宇宙インフォーマル勉強会, 理化学研究所, 和光市, 日本 2018/04/25

伊藤裕貴 “ Relativistic Radiation Mediated Shocks ” Jet and Shock Breakouts in Cosmic Transients, 京都市、日本, 2018/5/16

長瀧重博 “中性子星の中身をどこまで探れるか?” 熱場の量子論とその応用 2018, 和光市, 2018年8月29日

伊藤裕貴 “ Prompt Emission of Gamma-ray Bursts” Prompt Emission of Gamma-ray Bursts, Windows on the Universe, 三鷹市、日本, 2019/1/22



小野勝臣 “超新星 1987A での爆発的要素合成及び分子形成” 核データと重元素合成を中心とする宇宙物理研究会, 札幌市、日本, 2019/03/07

小野勝臣 “超新星爆発における分子形成と超新星残骸の物理” 日本物理学会, 福岡市、日本, 2019/03/17

長瀧重博 “ジェット状超新星からガンマ線バーストまで: 橋本先生との思い出” 宇宙の物質進化と元素合成~30 年の歩みとこれから~, 六本松市, 2019 年 3 月 18 日

(5) Oral Presentations at International Meetings (Contributed Talks):

Just Oliver “Nucleosynthesis, Jets, and EOS constraints From Neutron-Star Mergers” The Exploding Universe, Shanghai, China, May 28, 2018

He Haoning “Search for GeV flare coincident with the IceCube neutrino flare” PACIFIC 2018.9 symposium, Moorea French Polynesia, 2018/09/01

Just Oliver “Neutrino-Transport Effects in Neutron-Star Mergers and Core-Collapse Supernovae” Theoretical Astrophysics Workshop, Taipei, Taiwan, September 26, 2018

Just Oliver “Neutrino-hydrodynamical models of neutron-star mergers”

Chemical evolution and nucleosynthesis across the Galaxy, Heidelberg, Germany, November 28, 2018

(6) Oral Presentations at Domestic Meetings (Contributed Talks)

長瀧重博 “巨大星爆発の数理” RIKEN iTHEMS のアウトリーチについての研究会 2018, 玉原市, 2018 年 6 月 3 日

井上進 “中性子星合体における高エネルギー現象と r プロセス” 重力波観測時代の r プロセスと不安定核, 和光市、日本, 2018/06/21

Masaomi Ono “3D numerical modeling of SN 1987A: the evolution from the explosion to the supernova remnant, nucleosynthesis, and molecule formation inside the ejecta” An informal SN/SNR workshop, 京都大, 京都市、日本, 2018/07/25

伊藤裕貴 “星とジェットの相互作用で説明するプリカーサー放射” 日本天文学会秋期年会, 姫路市、日本, 2018/9/21

FERRAND Gilles “From the (thermonuclear) supernova to the supernova remnant” 10th DTA symposium “Stellar deaths and their diversity”, Mitaka, Japan, 2019-01-21

伊藤裕貴 “Relativistic Radiation Mediated Shocks” RIKEN-RESCEU joint seminar, 文京区、日本, 2019/3/19

小野勝臣 “Three dimensional simulation from supernovae to their supernova remnants: the dynamical and chemical evolution of SN 1987A ” RIKEN - RESCEU joint seminar 2019, RIKEN, iTHEMS, RESCEU, 東京都、日本、2019/03/20

FERRAND Gilles “From the (thermonuclear) supernova to the supernova remnant” RIKEN - RESCEU Joint Seminar, Tokyo, Japan, 2019-03-20

Just Oliver “Modeling Core-Collapse Supernovae and Remnants of Neutron-Star Mergers” Physics of Core-Collapse Supernovae and Compact Star Formations, Waseda University, Tokyo, Japan, March 23, 2019

(7) Seminar Talks (International)

He Haoning “On the origin of the IceCube neutrinos” Seminar, Nanjing China, 12/28/18

He Haoning “On the origin of the IceCube neutrinos” Seminar, Zhuhai China, 01/10/19

Just Oliver “Neutrino-hydrodynamical modeling of neutron-star mergers and related nucleosynthesis” Seminar of astronomy group at University Brussels, Brussels, Belgium, January 30, 2019

Just Oliver “Outflows from neutron-star mergers” RIKEN-RESCEU Joint Seminar, Tokyo, Japan, March 20, 2019

(8) Seminar Talks (Domestic)

Just Oliver “Nucleosynthesis, Jets, and Equation-of-State Constraints From Neutron-Star Mergers” RIKEN grant proposal seminar, Wako, Japan, April 25, 2018

Demidem Camilia “Numerical simulations of shocks, turbulence and particle acceleration in relativistic MHD” YITP seminar, Kyoto, Japan, 2018/07/24

Demidem Camilia “Numerical simulations of shocks, turbulence and particle acceleration in relativistic MHD” ICRR seminar, Kashiwa, Japan, 2018/08/2

伊藤裕貴 “光子のエスケープを考慮した相対論的輻射媒介衝撃波の解から探る衝撃波ブレイクアウトに伴う放射” 日本天文学会秋期年会、小金井市、日本、2019/3/16

小野勝臣 “超新星爆発から超新星残骸まで” 「宇宙の物質進化と元素合成 -30年のあゆみとこれから-」九州大学 福岡市、日本、2019/03/18

(9) Poster Presentations at

Domestic Meetings

伊藤裕貴 “Physic of relativistic radiation

mediated shocks in photon strved regime” 高エネルギー宇宙物理学研究会 2018, 文京区、日本, 2018/9/5-7

(10) Meetings organized or co-organized by our group  
Shigehiro Nagataki (SOC)  
“PACIFIC2018.9” Moorea, French Polynesia, 31 Aug. – 6 Sep. 2018

長瀧重博（組織委員）  
「核データと重元素合成を中心とする宇宙核物理研究会」 2019年3月6-8日、北海道大学学術交流会館。

Astrophysical Big Bang Laboratory  
RIKEN - RESCEU Joint Seminar 2019,  
U. Tokyo (Hongo), 19-20 March 2019.

(11) Outreach  
長瀧重博 “巨大星の爆発と中性子星・ブラックホール” 理化学研究所和光地区一般公開2018, 和光市, 2018年4月21日

長瀧天体ビッグバン研究室 “バーチャルリアリティで超新星体験” 理化学研究所和光地区一般公開2018, 和光市, 2018年4月21日

長瀧重博 “巨大星の爆発と中性子星・ブラックホール” 三鷹ネットワーク大学講座, 三鷹市, 2018年6月19日

長瀧重博 “ブラックホールと連星中性子星合体” 新潟県立高田高校見学プログラ

ム, 和光市, 2018年8月22日

長瀧重博 “巨大星の爆発と中性子星・ブラックホール” IS&I研究会, 代々木, 2018年10月17日

長瀧重博 “iTHEMS が取り組む異分野融合型研究” 拠点博士課程学生交流セミナー2018, 名古屋, 2018年11月7日

長瀧重博 “巨大星の爆発と中性子星・ブラックホール” サイエンスカフェ, 八王子市, 2019年2月17日