

## 長瀧天体ビッグバン研究室

主任研究員 長瀧 重博 (Ph.D.)



### (0) 研究分野

分科会：物理

キーワード：

超新星、ガンマ線バースト、ブラックホール、中性子星、宇宙線

### (1) 研究背景と研究目標

我々の研究室は、超新星・ガンマ線バーストに関する様々な謎の解明に向け、理論的研究を行います。超新星・ガンマ線バーストは宇宙最大規模の爆発現象であり、その爆発メカニズムは良く分かっていません。我々はこの究極的な現象を、究極的な物理を駆使して解き明かしたいと考えています。場合によっては急速に進化している大型計算機を用いた大規模数値シミュレーションを駆使してこの究極的現象の解明にあたります。また超新星・ガンマ線バーストは物理と謎の宝庫であり（重力波、ニュートリノ、r-process元素合成、粒子加速現象、最高エネルギー宇宙線、高エネルギーニュートリノ、高エネルギーガンマ線等）、極限宇宙物理学の最高峰とも言うべき現象です。我々はこれら様々な謎の解明に向けて最先端の理論研究を行い、この宇宙最大爆発現象の全貌を明らかにします。我々の理論研究は、超新星・ガンマ線バーストに関する最先端の観測に物理的解釈を与え、次世代観測に対する予言・提言を発信します。我々は興味を共有する理研・全国・全世界の研究者皆様と協力・連携し、研究者の理想郷を理化学研究所に実現します。

### (2) 2019年度成果と今後の研究計画(中長期計画2025年度まで)

2019年度の長瀧天体ビッグバン研究室の主要な成果の一つは宇宙物理学の重大な未解決問題であったガンマ線バーストの放射機構の理解を大きく進展させることに成功したことです（項目(4)論文[1]にて正式に成果を発表）。この画期的な研究成果は、世界の中でも他の研究グループを圧倒する計算技術によってもたらされたものであり、理化学研究所主導でのプレスリリースを行っております（2019年4月）。この成果は新聞各社やインターネットニュースなどのメディアにも広く取り上げられ、また国立天文台・金沢大学でもプレスリリースとして紹介されています。この論文の筆頭著者である伊藤裕貴研究員は、一連の研究成果が評価され国際会議においても多くの招待講演を行い、また「理研梅峰賞」の受賞(2020年3月12日)にも至っています。

長瀧天体ビッグバン研究室は2013年度に発足し、超新星・ガンマ線バーストの研究を中心に、世界最先端の研究を行って来ました。今ではこの分野に於いて長瀧天体ビッグバン研究室は世界的に知られる研究室となっており、我々が発表する論文はいずれも高い注目を持って世界で読まれています。研究室後発足7年目となる長瀧天体ビッグバン研究室は、2019年度末までに計20名の研究員・特別研究員・SPDR/FPRを雇用し、14名が転出しました。この14名のうちパーマネントポジションを既に獲得した者が6名、パーマネントポジションのオファーを受けて2020度・2021度に着任する予定の者が2名おり、ほぼ毎年1名の割合でパーマネントポジションを外部に獲得しています。長瀧天体ビッグバン研究室は今後も高い研究のクオリティを保ち、更に発展させていきます。最終的には長瀧天体ビッグバン研究室メンバー全員が世界各地でパーマネントポジションを獲得し、各自の研究グループを立ち上げ、理研長瀧天体ビッグバン研究室と引き続き連携を促進・深化させていくことを目指しています。

2025年度までの中長期計画では、重力波天体がひとつのキーワードとなります。これまで長瀧天体ビッグバン研究室では既に超新星・ガンマ線バーストなど、重力波天体を扱って来ましたが、今後更に中性子星・ブラックホールなどのコンパクト天体を強く意識した研究を推進します。

### (3) 研究室メンバー

(2019年度)

主任研究員（研究室代表者）：長瀧 重博

研究員：水田 晃（定年制）、伊藤 裕貴、Gilles Ferrand、小野 勝臣、木戸 英治、祖谷 元

SPDR: Oliver Just、Haoning He

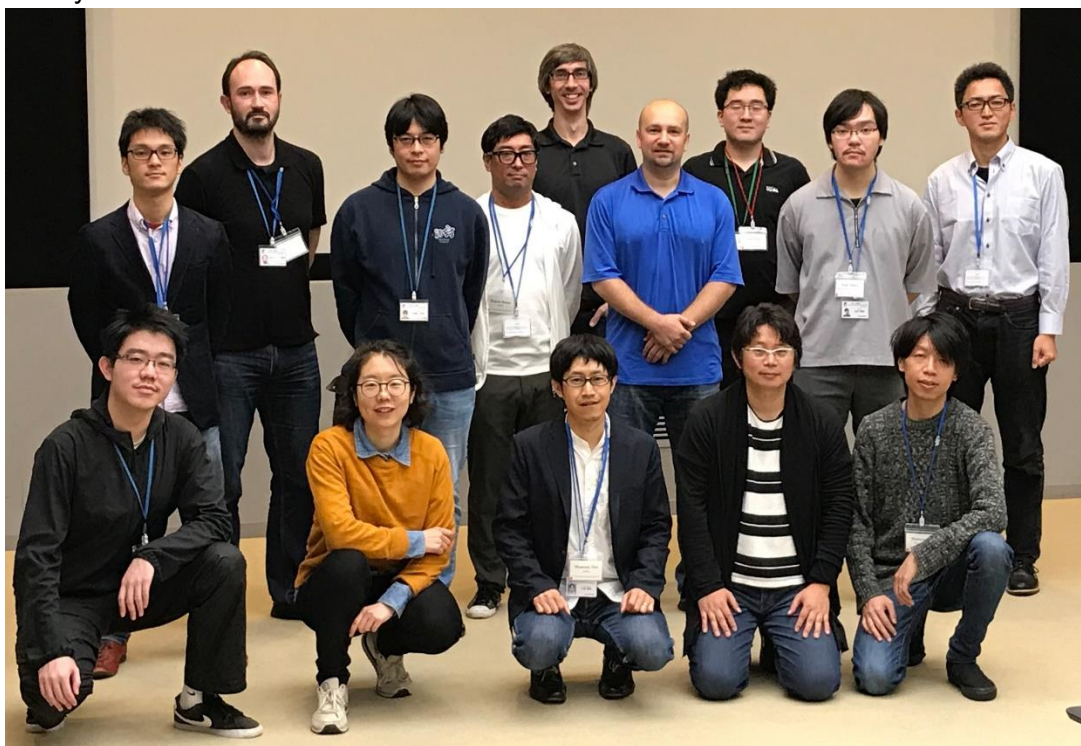
JRA: 荒川 真範、武井 勇樹

秘書：柴崎 環

### (4) 主要発表論文等

1. “The photospheric origin of the Yonetoku relation in gamma-ray bursts”, Hiroataka Ito, Jin Matsumoto; Shigehiro Nagataki; Donald C. Warren; Maxim V. Barkov; Daisuke Yonetoku, **Nature Communications**, Volume 10, id. 1504, (2019).
2. “From supernova to supernova remnant: the three-dimensional imprint of a thermonuclear explosion”, FERRAND Gilles, Warren Don, Ono Masaomi, Nagataki Shigehiro, Röpke Fritz, Seitzzahl Ivo, **The Astrophysical Journal**, Volume 877, Issue 2, article id. 136, 17 pp., (2019/06).
3. “Multi-TeV Flaring from High-energy Blazars: An Evidence of the Photohadronic Process”, Sarira Sahu, López Fortín, Carlos E.; Nagataki, Shigehiro, **The Astrophysical Journal Letters**, Volume 884, Issue 1, article id. L17, 7 pp., (2019).
4. “Hydrodynamic simulations unravel the progenitor-supernova-remnant connection in SN 1987A”, ORLANDO Salvatore, Ono Masaomi, Nagataki Shigehiro, Miceli Marco, Umeda Hideyuki, Ferrand Gilles, Bocchino Fabrizio, Petruk Oleh, Peres Giovanni, Takahashi Koh, Yoshida Takashi, **The Astrophysical Journal**, (2019).
5. “Matter Mixing in Aspherical Core-collapse Supernovae: Three-dimensional Simulations with Single-star and Binary Merger Progenitor Models for SN 1987A”, ONO Masaomi, Nagataki Shigehiro, Ferrand Gilles, Takahashi Koh, Umeda Hideyuki, Yoshida Takashi, Orlando Salvatore, Miceli Marco, **The Astrophysical Journal**, Volume 888, Issue 2, id.111, (2020).

Supplementary



長瀧研メンバーと関係者（長瀧研過去メンバー：Herman Lee(右下)、Donald Warren（上中央）、iTHEMSメンバー：Yongjia Huang(左下)、土肥明（上右から3人目））

Laboratory Homepage

[https://www.riken.jp/research/labs/chief/astro\\_big\\_bang/index.html](https://www.riken.jp/research/labs/chief/astro_big_bang/index.html)

[http://nagataki-lab.riken.jp/index\\_jp.html](http://nagataki-lab.riken.jp/index_jp.html)

(5) 業績データ

(A) プレスリリース等

Sarira Sahu “Evidencia del modelo fotohadrónico de erupciones de muy altas energías de blazares” UNAM Press Release 2019

[http://www.nucleares.unam.mx/noticias.php?publicacion=Sahu\\_Fortin\\_Nagataki\\_blazar&key=2500](http://www.nucleares.unam.mx/noticias.php?publicacion=Sahu_Fortin_Nagataki_blazar&key=2500)

O. Just, SPDR poster session, presentation of research results (awarded with SPDR poster prize, RIKEN Wako, Saitama, 01/23/20)

伊藤裕貴「ガンマ線バーストのスペクトルと明るさの相関関係に関する理論的研究」理研梅峰賞、2020年3月

(B) 授業・本

Maria Dainotti “Gamma-ray Burst Correlations” Copyright © IOP Publishing Ltd 2019 Online ISBN: 978-0-7503-1575-3 · Print ISBN: 978-0-7503-1573-9

長瀧重博「宇宙物理の研究を決意した、本との出会い」理研科学道 100 科学者の本棚 / 2019. 9. 26

(C) 論文 (査読あり)

Hirota Ito, Jin Matsumoto; Shigehiro Nagataki; Donald C. Warren; Maxim V. Barkov; Daisuke Yonetoku, “The photospheric origin of the Yonetoku relation in gamma-ray bursts”, Nature Communications, Volume 10, id. 1504, 2019/04.

FERRAND Gilles, Warren Don, Ono Masaomi, Nagataki Shigehiro, Roöpke Frtiz, Seitzzahl Ivo “From supernova to supernova remnant: the three-dimensional imprint of a thermonuclear explosion” The Astrophysical Journal, Volume 877, Issue 2, article id. 136, 17 pp. 2019/06

Ardevol-Pulpillo Ricard, Janka Hans-Thomas, Just Oliver, Bauswein Andreas “Improved leakage-equilibration-absorption scheme (ILEAS) for neutrino physics in compact object mergers” Monthly Notices of the Royal Astronomical Society 485, 4, 06/2019

The TA Collaboration (including Shigehiro Nagataki, Masaomi Ono, Hirota Ito, Haoning He, Eiji Kido) “Constraints on the diffuse photon flux with energies above 1018 eV using the surface detector of the Telescope Array experiment” Astroparticle

Physics, Vol.110, P.8-14, 2019/7

Janka Hans-Thomas, Melson Tobias, Stockinger Georg, Just Oliver “Effects of LESA in Three-Dimensional Supernova Simulations with Multi-Dimensional and Ray-by-Ray-plus Neutrino Transport” The Astrophysical Journal, 881, 36, 2019/08

Horowitz Charles, 16 other authors, Just Oliver, 21 other authors, “r-process nucleosynthesis: connecting rare-isotope beam facilities with the cosmos” Journal of Physics G: Nuclear and Particle Physics 46, 8, 08/2019

The CTA Collaboration (including Shigehiro Nagataki, Gilles Ferrand, Maxim Barkov) “Monte Carlo studies for the optimisation of the Cherenkov Telescope Array layout” Astroparticle Physics, Volume 111, p. 35-53, 2019/09

Sarira Sahu, López Fortín, Carlos E.; Nagataki, Shigehiro “Multi-TeV Flaring from High-energy Blazars: An Evidence of the Photohadronic Process” The Astrophysical Journal Letters, Volume 884, Issue 1, article id. L17, 7 pp., 2019/10/01

He Haoning, Xuefeng Wu “The Messenger Traveling Across the Universe” Chinese Science Bulletin Volume: 64, issue: 22, Page: 2265, 05/10/19

Just Oliver, Janka Hans-Thomas “NADA-FLD: a general relativistic, multidimensional neutrino-hydrodynamics code employing flux-limited diffusion” Monthly Notices of the Royal Astronomical Society, 490, 3, 2019/12

Masaomi Ono, Nagataki, Shigehiro; Ferrand, Gilles; Takahashi, Koh; Umeda, Hideyuki; Yoshida, Takashi; Orlando, Salvatore; Miceli Marco “Matter Mixing in Aspherical Core-collapse Supernovae: Three-dimensional Simulations with Single-star and Binary Merger Progenitor Models for SN 1987A” The Astrophysical Journal Vol.888, 111, 2020/1/15

ONO Masaomi, Nagataki Shigehiro, Ferrand Gilles, Takahashi Koh, Umeda Hideyuki, Yoshida Takashi, Orlando Salvatore, Miceli Marco “Matter Mixing in Aspherical Core-collapse Supernovae: Three-dimensional Simulations with Single-star and Binary Merger Progenitor Models for SN 1987A” The Astrophysical Journal, Volume 888, Issue 2,

id.111, 2020/01

Dmitry Khangulyan, Masanori Arakawa, Felix Aharonian “Detection of ultra-high-energy gamma rays from the Crab Nebula: physical implications” *Monthly Notices of the Royal Astronomical Society*, Volume 491, Issue 3, Pages 3217–3224, 2020/1.

Sarira Sahu, López Fortín, C. E.; Iglesias Martínez, M. E.; Nagataki, S.; Fernández de Córdoba, P. “The VHE SED modelling of Markarian 501 in 2009” *Monthly Notices of the Royal Astronomical Society*, Volume 492, Issue 2, p.2261-2267, 2020/02/01

Gilles Ferrand “Modeling and simulations of supernova remnants: A short review focused on recent progress in morphological studies” *Astronomische Nachrichten*, Volume 341, Issue 2, pp. 143-149 2020/02

Hirota Ito, Amir Levinson, Shigehiro Nagataki “Monte Carlo simulations of relativistic radiation-mediated shocks: II. photon-starved regime” *Monthly Notices of the Royal Astronomical Society*, Volume 492, Issue 2, p.1902-1913, February 2020

He Haoning, Shiu-Hang Lee, Shigehiro Nagataki, Alexander Kusenko “Neutrinos from the Galactic Center Hosting a Hypernova Remnant” *The Astrophysical Journal* 891:179 (13pp) 03/10/20

Hajime Sotani “Light curves from highly compact neutron stars with spot size effect” *Physical Review D* Vol.101, No.6, P.063013, 2020/3/11

Ko, Heamin, Cheoun, Myung-Ki; Ha, Eunja; Kusakabe, Motohiko; Hayakawa, Takehito; Sasaki, Hirokazu; Kajino, Toshitaka; Hashimoto, Masa-aki; Ono, Masaomi; Usang, Mark D.; Chiba, Satoshi; Nakamura, Ko; Tolstov, Alexey; Nomoto, Ken'ichi; Kawano, Toshihiko; Mathews, Grant J. “Neutrino Process in Core-collapse Supernovae with Neutrino Self-interaction and MSW Effects” *The Astrophysical Journal Letters*, Vol.891, L24, 2020/3/4

MARCOWITH Alexandre, Ferrand Gilles, Grech Mickael, Meliani Zakaria, Plotnikov Illya, Walder Rolf “Multi-scale simulations of particle acceleration in astrophysical systems”, *Living Reviews in*

*Computational Astrophysics*, Volume 6, Issue 1, article id.1, 2020/03.

(D) 国際会議口頭発表 (招待講演、基調講演)

Masaomi Ono “Evolution from supernovae to their supernova remnants: 3D numerical modeling for the case of SN 1987A” *Mini-workshop on massive stars, core-collapse supernovae, and nucleosynthesis*, Taipei, Taiwan 2019/4/9

Maxim Barov “Different aspects of the interaction of stars with AGN jets” *workshop on Very High Energy Phenomena Around Supermassive Black Holes*, Purdue Univ. the US 11/Apr/2019

Shigehiro Nagataki “From Central Engine to Afterglow” 2019 Nanjing GRB Conference, Nanjing, China, 2019/05/17

Maxim Barkov “Fast pulsar bow-shock nebulae and filaments” the 14th International Conference on Numerical Modeling of Space Plasma Flows (ASTRONUM 2019), Paris, France July 1-5 2019

Oliver Just “How to deal with neutrinos in simulations of neutron-star mergers and core-collapse supernovae?” *Workshop on Nuclear and Astrophysics Aspects for the R-Process*, Trento, Italy, 2019/07

Haoning He “On the Origin of IceCube Observed High Energy Neutrinos” *Workshop to bring together experts on High Energy Astrophysics from Japan and Israel*, Wako & Kobe, Japan, 07/18/19

Hirota Ito “Numerical Simulations of Photospheric Emission in Gamma-Ray Bursts” *Workshop to bring together experts on High Energy Astrophysics from Japan and Israel*, Wako & Kobe, Japan, 07/22/19

Akira Mizuta “BH spin parameter dependence for episodic Alfvén pulse generation from BH accretion disks” *Workshop to bring together experts on High Energy Astrophysics from Japan and Israel*, Wako & Kobe, Japan, 07/22/19

Oliver Just “Role of Neutrinos in Neutron-Star Mergers” *Workshop to bring together experts on High Energy Astrophysics from Japan and Israel*, Wako & Kobe, Japan, 07/22/19



Oliver Just “What can we learn about the r-process and nuclear equation of state from neutron-star merger observations?” GSI FAIRNESS Workshop, Genova, Italy, 07/2019

Gilles Ferrand “From the thermonuclear supernova to the supernova remnant” workshop “Progenitors of Type Ia Aug. Supernovae”, Lijiang, Yunnan, China, 2019/08/06

Shigehiro Nagataki “Evolution of SN1987A”, PACIFIC2019, Moorea, French Polynesia, 2019/09/01

Hirota Ito “The photospheric origin of the Yonetoku relation in gamma-ray bursts” Ioffe Workshop on GRBs and other transient sources: 25 Years of Konus-Wind Experiment, Санкт-Петербург, ロシア, 09/09/2019

Akira Mizuta “Alfvén pulses from black hole accretion disk into jets via 3D global GRMHD simulations” Workshop on CHALLENGES AND INNOVATIONS IN COMPUTATIONAL ASTROPHYSICS, St. Petersburg, Russia, 2019/9

Haoning He “Astrophysical Diffuse models from 1 TeV to 1 EeV” Workshop on Diffuse Workshop on Global Fit, Chiba University and the Tokyo University, Tokyo Japan, 09/14/19

Shigehiro Nagataki “Anisotropies in SN1987A”, Workshop on Anisotropies in core-collapse supernova explosions, Palermo, Italy, 2019/10/21

Masaomi Ono “Three-dimensional simulations of SN 1987A: nucleosynthesis, X-ray emission, and molecule formation” Collaborative Meeting on Supernova Remnants between Japan and USA, Wako, Saitama, 2019/11/08

Gilles Ferrand “From the thermonuclear supernova to the supernova remnant” Collaborative Meeting on Supernova Remnants between Japan and USA, Wako, Saitama, 2019/11/08

Yuki Takei “Constructing a numerical radiative transfer model for interaction-powered supernovae” Collaborative Meeting on Supernova Remnants between Japan and USA, Wako, Saitama, 2019/11/07

Akira Mizuta “General-relativistic

magnetohydrodynamics” 2nd Toyama International Symposium on Physics at the Cosmic Frontier, Toyama, Japan, 2020/3

(E) 国内会議口頭発表 (招待・基調講演)

Akira Mizuta “相対論的ジェット of 物理” 京都大学数理解析研究所 共同研究(公開型) 「宇宙惑星ジェットの数理」 京都大学、京都、2019/7

Shigehiro Nagataki “Super-Nuclear Physics in Astrophysical Big Bangs” Workshop of RIKEN Pioneering Project, Wako, RIKEN, 2019/08/02

Masaomi Ono “Three-dimensional simulations of supernova 1987A: nucleosynthesis and molecule formation in the supernova ejecta” First r-EMU Symposium, Wako, Saitama 2019/08/02

Gilles Ferrand “From the supernova to the supernova remnant” First r-EMU Symposium, Wako, Saitama 2019/08/02

Oliver Just “What can we learn from observations of neutron-star mergers?” First r-EMU Symposium, Wako, Saitama 2019/08/02

(F) 国際会議口頭発表

Haoning He, “High Energy Neutrinos from the Deaths of Massive stars” Conference on Gamma-Ray Bursts and Related Astrophysics in Multi-Messenger Era, Nanjing, China, 05/17/19

Haoning He “Neutrinos From A Past Hypernova In The Galactic Center” The 6th AMON workshop, Chiba Univ., Chiba, Japan, 05/21/2019

Masaomi Ono “Three-dimensional simulations from supernovae to their supernova remnants: the dynamical and chemical evolution of SN 1987A” The 15th International Symposium on Origin of Matter and Evolution of Galaxies (OMEG15), Kyoto Japan, 2019/7/4

Haoning He “Perspective of Detecting Very High Energy Gamma Ray Photons Associated with Neutrinos by LHAASO” The 10th International Workshop on Air Shower Detection at High Altitude, Nanjing, China, 01/09/2020

Masaomi Ono “Three-dimensional simulations from supernovae to their supernova remnants: nucleosynthesis and molecule formation in the supernova ejecta of SN 1987A” Multi-

dimensional Modeling and Multi-Messenger observation from Core-Collapse Supernovae (4M-COCOS) Fukuoka, Japan, 2019/10/21

Haoning He “Neutrinos From The Galactic Center Hosting A Hypernova Remnant” Galactic Center Workshop, Keio Univ, Yokohama, Japan, 10/24/19

Hirota Ito “Numerical simulation of photospheric emission in gamma-ray bursts” Yamada Conference LXXI: Gamma-ray Bursts in the Gravitational Wave Era 2019, Yokohama, Japan, 2019年10月30日

Haoning He “Neutrinos from Choked Jets Accompanied by Type-II Supernovae” Workshop on Subaru Telescope 20th Anniversary, Hawaii, USA, 11/19/19

Eiji Kido “Recent results and the status of the Telescope Array experiment” TeVPA 2019, Sydney, Australia, 2019/12/3

Gilles Ferrand “From the thermonuclear supernova to the supernova remnant” 14th Würzburg Workshop in Heidelberg, Heidelberg, Germany, 2019/12/16

#### (G) 国内会議口頭発表

武井勇樹 「輻射輸送計算による II 型超新星の光度曲線モデル構築」日本天文学会 2019 年秋季年会 熊本大学、熊本、日本、2019/09/13

荒川真範 「かに星雲における PeV 電子の起源の解明」第 19 回高宇連研究会「高宇連博士論文発表会・研究会」Zoom (COVID-19 のため立教大学から変更) 2020/Mar/2

#### (H) 海外セミナー発表

Masaomi Ono “3D numerical modeling from supernovae to their supernova remnants: the dynamical and chemical evolution for the case of SN 1987A” National Tsing Hua University, Hsinchu, Taiwan, 2019/4/12

Gilles Ferrand “Modelling and simulations of supernova remnants” XMM-Newton science workshop on "Astrophysics of hot plasma in extended X-ray sources" Madrid, Spain, 2019/06/06

Shigehiro Nagataki “Evolution of SN1987A” KIPAC Tea Talk, Stanford University, the US, 2019/08/13

Shigehiro Nagataki “Physics of Gamma-Ray Bursts” INPA seminar, LBNL, the US, 2019/08/16

Gilles Ferrand “From the thermonuclear supernova to the supernova remnant” CEA Astrophysics Division, High Energies and Theory group Saclay, France 2019/12/19

#### (I) 国内セミナー発表

Gilles Ferrand “3D simulations of supernova remnants” Waseda University High Energy Astrophysics Group, 2019/06/06

#### (J) 国際会議ポスター発表

Yuki Takei “Constructing a Model for Interaction-Powered Supernovae Using Radiative Transfer Simulations” Fifty-One Ergs 2019, NC State University, Raleigh, NC, USA, 2019/5/20

Shigehiro Nagataki, Ferrand Gilles, Warren Donald C., Ono Masaomi, Röpke Friedrich K., Seitenzahl Ivo “From the thermonuclear supernova to the supernova remnant: the three-dimensional imprint of a thermonuclear explosion” Supernova Remnants: An Odyssey in Space after Stellar Death II, Chania, Greece 2019/June/03

Orlando Salvatore; Miceli Marco; Peres Giovanni; Ono Masaomi; Nagataki Shigehiro; Ferrand, Gilles “3D MHD Simulations from the Onset of the SN to the Full-fledged SNR: Role of Ejecta Clumps on Matter Mixing” Supernova Remnants: An Odyssey in Space after Stellar Death II, Chania, Greece 2019/June/03

SAFI-HARB Samar, Ramsay Michael, Ferrand Gilles, West Jennifer “A New Version of SNReat: the High Energy Catalogue of Supernova Remnants” Supernova Remnants: An Odyssey in Space after Stellar Death II, Chania, Greece 2019/June/03

Yuki Takei “Constructing a Model for Interaction-Powered Supernovae Using Radiative Transfer Simulations” Planet2/RESCEU Summer School From the Solar System to the Universe, Akita, Japan, 2019/08/23

Akira Mizuta “Time variabilities in disks and jets caused by magnetic field activities” Workshop on Active Galactic Nucleus Jets in the Event Horizon Telescope Era, Tohoku Univ.,

Sendai, Japan, 2020/1

(K) 国内会議ポスター発表

Akira Mizuta “3次元一般相対論的磁気流体シミュレーションによる相対論的ジェット形成の物理” SKA Japan シンポジウム, 国立天文台、三鷹市、日本, 2019/09

Masaomi Ono “3D Simulation of Supernova Explosions Toward Understanding the Evolution from Supernovae to Their Remnants” 第6回「京」を中核とする HPCI システム利用研究課題 成果報告会, 東京、2019/11/1

Akira Mizuta “ロングガンマ線バーストジェットの伝播” 高エネルギー宇宙物理研究会 2019, 蔵王アストリアホテル、山形市、日本, 2019/12

Akira Mizuta “ブラックホール降着流の3次元一般相対論的磁気流体シミュレーション” 第32回理論懇シンポジウム「天文学・宇宙物理学の変遷と新時代の幕開 国立天文台、三鷹市、日本, 2019/12

Haoning He “On the Origin of IceCube Observed High Energy Neutrinos” FY 2019 SPDR Research Report Session, RIKEN Wako, Saitama, 01/23/20

Oliver Just “Nucleosynthesis and jets in neutron-star mergers and the explosion mechanism of massive stars” FY 2019 SPDR Research Report Session, RIKEN Wako, Saitama, 01/23/20

(L) 主催・共催した会議

Workshop to bring together experts on High Energy Astrophysics from Japan and Israel, Wako & Kobe, Japan, 07/18-23/19

Collaborative Meeting on Supernova Remnants between Japan and USA, Saitama & Kyoto, Japan 2019/11/07-12

(M) アウトリーチ

Gilles Ferrand “Virtual Reality and Robotics” RIKEN Robotics Retreat, Keihanna Science City, Japan, 2019/09/12

長瀧重博 「元素はどのように生まれてきたのか」朝日カルチャーセンター、藤沢、神奈川、2019/11/30