

Astrophysical Big Bang Laboratory

長瀧天体ビッグバン研究室

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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, has been 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, iTHES, and iTHEMS members.

To enhance activities in nuclear-astrophysics in RIKEN, which is one of our dreams, further communications & collaborations with Nishina Center 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. Our group has joined one of the Pioneering Projects, "Extreme precisions to explore fundamental physics with exotic particles (Triple-E)" (Group Director: Dr. Yasunori Yamazaki). This project definitely helps our group to enhance communications and collaborations with Nishina Center, especially Dr. Uesaka's group. We also believe that our group can contribute especially to new science of RIBF through this project.

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 1st 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 8 Japanese including PI and 9 non-Japanese (2 from Russia & China, and 1 from Italy, Hong-Kong, Thailand, USA, France), 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 8 alumni, 5 got tenure or tenure-track positions successfully. Among the total 17 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

Associate Chief Scientist

Haoning He

Postdoctoral Researcher

Core Members

Hiroataka Ito

Research Scientist

Masaomi Ono

Research Scientist

Past Core Members

Jin Matsumoto

Special Postdoctoral Researcher

Alexey Tolstov

Postdoctoral Researcher, Kavli IPMU,
Univ. of Tokyo

Annop Wongwathanarat

Foreign Postdoctoral Researcher

Jirong Mao

Faculty at Yunnan Observatory

Donald Warren

Foreign Postdoctoral Researcher

Shiu-Hang Lee

Lecturer at Kyoto University

Susumu Inoue

Research Scientist

Visiting Scientist of RIKEN

Gilles Ferrand

Research Scientist

Maria Giovanna Dainotti

Assistant professor at Jagellonian U.

Marie Curie Fellow at Stanford Univ.

Yuto Teraki

Postdoc at YITP at Kyoto U.

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

Assistant

Tamaki Shibasaki

Long Term Visitors

Zhaoming Gan (Shanghai Astronomical
Observatory : 2016/9/1 – 2016/10/31)

Short Term Visitors

Norita Kawanaka (U. Tokyo)

Kyohei Kawaguchi (Kyoto U.)

Eiji Kido (U. Tokyo)

Paz Beniamini (Hebrew U.)

Katsuaki Asano (U. Tokyo)

Yoshiyuki Inoue (JAXA)

Koh Takahashi (U. Tokyo)

Yutaka Ohira (Aoyama Gakuin U.)

Ko Nakamura (Waseda U.)

Yosuke Matsumoto (Chiba U.)

Oliver Just (MPA)

Yutaka Fujita (Osaka U.)

Kimitake Hayasaki (Chungbuk National
U.)

Ken Ohsuga (NAOJ)

Satoru Katsuda (Chuo U.)

Shota Shibagaki (U.Tokyo/NAOJ)

Ke Fang (U. Maryland)

Amir Levinson (Tel Aviv U.)

Kumiko Kotera (IAP)

Philipp Edelmann (Heidelberg Institute
for Theoretical Studies)

Michael Gabler (MPA)

Gavin Lamb (Liverpool John Moores U)

Denis Allard (APC)

Kotaro Kyutoku (KEK)

Xiaping Tang (MPA)

Kenichi Nishikawa (U. Alabama)

Alexander Kusenko (UCLA)

4. Achievements

(1) Press Release etc.

Maria, G, Dainotti (Past Member of
ABBL), “Black Holes and Gamma-Ray
Bursts”, American Astronomical Society,
Press Conference from AAS228, San
Diego, California, 12-16 June 2016.

Jin Matsumoto, “Synergetic Growth of
the Rayleigh-Taylor and
Richtmyer-Meshkov Instabilities in the
Relativistic Jet” Poster Prize at IAU
Symposium 324: New Frontiers in Black
Hole Astrophysics, 2016/9/12.

(2) Lectures

Susumu Inoue, Part-time Lecturer on

Mathematical Analysis III at Aoyama Gakuin U. April-July 2016.

Shigehiro Nagataki “Death of Massive Stars: Supernovae and Gamma-Ray Bursts with Explosive Nucleosynthesis” NIC School 2016, Niigata, Japan, 13 & 14 June 2016.

(3) Papers in Journals (Refereed)

R. U. Abbasi et al. “The energy spectrum of cosmic rays above $10^{17.2}$ eV measured by the fluorescence detectors of the Telescope Array experiment in seven years” *Astroparticle Physics*, Volume 80, p. 131-140, July 2016.

Kimitake Hayasaki, Keitaro Takahashi, Yuuiti Sendouda, Shigehiro Nagataki “Rapid merger of binary primordial black holes: An implication for GW150914” *Publications of the Astronomical Society of Japan* Volume 68, Issue 4, id.66 8 pp. August 2016.

Wongwathanarat Annap, Grimm-Strele Hannes, Müller Ewald “APSARA: A multi-dimensional unsplit fourth-order explicit Eulerian hydrodynamics code for arbitrary curvilinear grids” *Astronomy & Astrophysics* Volume 595, A41, 26 October 2016.

R. U. Abbasi et al. “Search for EeV protons of galactic origin” *Astroparticle Physics*, Volume 86, p. 21-26, January

2017.

R. U. Abbasi et al. “First upper limits on the radar cross section of cosmic-ray induced extensive air showers” *Astroparticle Physics*, Volume 87, p. 1-17, January 2017.

Warren III Donald Cameron, Ellison, D.C., Barkov, M.V., Nagataki, S. “Nonlinear Particle Acceleration and Thermal Particles in GRB Afterglows” *Astrophysical Journal* 835, 248 (15p), 2017/02/01.

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

Susumu Inoue “AGN Winds and NGC 1068” MAGIC Collaboration Meeting, Zürich, Switzerland, 2016/06/15.

Susumu Inoue “Fast Radio Bursts and VHE Prospects” MAGIC Collaboration Meeting, Zürich, Switzerland, 2016/06/15.

Shigehiro Nagataki “Theoretical Studies on Supernovae and Gamma-Ray Bursts” *Frontiers of Nonlinear Physics*, Nizhny Novgorod-St. Petersburg, Russia, 2016/7/20.

Shigehiro Nagataki “Astrophysical Big Bangs” PACIFIC2016, Moorea, French Polynesia, 2016/9/14.

Susumu Inoue “Black Holes Astrophysics with the Cherenkov Telescope Array” New Frontiers in Black Hole Astrophysics (IAU Symposium 324), Ljubljana, Slovenia, 2016/09/16.

Susumu Inoue “Status of the Transients Science Working Group” CTA Consortium General Meeting, Bologna, Italy, 2016/10/26.

Shigehiro Nagataki “Massive Star Explosions” International Workshop on Quantum Many-Body Problems in Particle, Nuclear, and Atomic Physics, Da Nang, Vietnam 2017/3/10.

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

Warren III Donald Cameron, Ellison, D.C., Barkov, M.V., Nagataki, S. “GRB Afterglows produced by nonlinear diffusive shock acceleration” CTA Consortium Meeting Kashiwa, Japan, 2016/05/16.

Susumu Inoue “Gamma Ray Emission from AGN winds” CTA Consortium Meeting Kashiwa, Japan, 2016/05/16.

Wongwathanarat Annap, “3D Long-time Core-collapse Supernova Simulations” SNR2016: an odyssey in space after stellar death, Chania, Greece, 8 June 2016.

Wongwathanarat Annap, “Neutron star kicks by gravitational tug-boat mechanism” 10th BONN one day workshop on neutron stars, Bonn, Germany, 20 June 2016.

Warren III Donald Cameron, Ellison, D.C., Barkov, M.V., Nagataki, S. “Nonlinear cosmic ray acceleration in GRB afterglows” Kyoto Ultra-high Energy Cosmic Ray Meeting 2016, Kyoto, Japan, 2016/10/12.

He Haoning, Kusenko Alexander, Nagataki Shigehiro, Zhang Binbin, Yang Ruizhi, Fan Yizhong “A Monte Carlo Bayesian Search for the Plausible Source of the Telescope Array Hotspot” 2016 International Conference on Ultra-High Energy Cosmic Rays, Kyoto, Japan, 2016/10/12.

Warren III Donald Cameron, Ellison, D.C., Barkov, M.V., Nagataki, S. “Shock acceleration of cosmic rays in GRB afterglows, or: Low energy, high impact” Huntsville GRB symposium, Huntsville, USA, 2016/10/26.

Susumu Inoue “On Recent GRB Observations” MAGIC Collaboration Meeting, Dortmund, Germany, 2016/11/23.

Susumu Inoue “Status of the FRB Program” MAGIC Collaboration Meeting,

Dortmund, Germany, 2016/11/23.

Jin Matsumoto “Synergetic Growth of the Rayleigh-Taylor and Richtmyer-Meshkov Instabilities in the Relativistic Jet” Challenges of AGN jets, Mitaka, Japan, 2017/1/19.

Shigehiro Nagataki “Research Activities of ABBL & iTHEMS” Molecule 2017: Transient Universe in the Big Survey Era, Kyoto, Japan, 2017/1/24.

Warren III Donald Cameron, Ellison, D.C., Barkov, M.V., Nagataki, S. “A nonlinear diffusive shock acceleration model for GRB afterglows” Transient Universe in the Big Survey Era, Kyoto, Japan, 2017/1/24.

Susumu Inoue, Kiyotomo Ichiki, Hayato Shimabukuro “Fast Radio Bursts as Cosmological Probes: Small-Scale Power Spectrum and Cosmic Reionization” Fast Radio Bursts: New Probes of Fundamental Physics and Cosmology, Aspen, USA, 2017/2/13.

Wongwathanarat Annap “Linking 3D CCSN simulations with observations” IAU symposium 331: SN1987A, 30 years later, Reunion, France, 20 February 2017.

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

Shigehiro Nagataki “Current Status & Future Prospects of ABBL & iTHEMS” RESCEU-RIKEN Workshop 2016, 2016/7/25.

Susumu Inoue “Fast Radio Bursts as Cosmological Probes” RIKEN-RESCEU Joint Seminar 2016, Tokyo, Japan, 2016/07/26.

Hiroataka Ito, Amir Levinson, Shigehiro Nagataki “Physics of Relativistic Radiation Mediated Shocks” RIKEN-RESCEU meeting, Tokyo, Japan, 2016/07/26.

Jin Matsumoto “Condition for the growth of the Rayleigh-Taylor instability at the relativistic jet interface” RIKEN-RESCEU meeting, Tokyo, Japan, 2016/07/26.

Warren III Donald Cameron, Ellison, D.C., Barkov, M.V., Nagataki, S. “Nonlinear cosmic ray acceleration in GRB afterglows” RIKEN-RESCEU meeting, Tokyo, Japan, 2016/07/27.

Jin Matsumoto “宇宙ジェット研究におけるデータ同化の展望” 理研データ同化ワークショップ, Kobe, Japan, 2016/10/14.

Susumu Inoue “Transient Science with CTA” 高エネルギーガンマ線でみる極限宇宙 2016, Kashiwa, Japan, 2016/12/16.

Susumu Inoue “CTA による突発天体のマルチメッセンジャー・サイエンス” CRC 将来計画タウンミーティング, Kashiwa, Japan, 2017/3/14.

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

Susumu Inoue, Ruo-Yu Liu, Kohta Murase “活動銀河核ウィンドによるフィードバックと銀河系外 PeVatron” 日本物理学会 秋期年会, Miyazaki, Japan, 2016/9/21.

Susumu Inoue, Ruo-Yu Liu, Kohta Murase “宇宙線と銀河形成” 高エネルギー宇宙物理学研究会, Sagamihara, Japan, 2016/11/30.

Hiroataka Ito, Amir Levinson, Boris Stern, Shigehiro Nagataki “相対論的輻射媒介衝撃波の物理”, 高エネルギー宇宙物理学研究会, Sagamihara, Japan, 2016/12/2.

He Haoning, Lee Shiu-Hang, Nagataki Shigehiro, Kusenko Alexander “High Energy Neutrinos and Gamma Rays from the Galactic Center” The extreme Universe viewed in very-high-energy gamma rays 2016, Kashiwa, Japan, 2016/12/15.

Shigehiro Nagataki “ABBL の宇宙と iTHEMS の宇宙” iTHEMS 神戸研究会, Kobe, Japan, 2016/12/26.

Shigehiro Nagataki “Introduction of Interdisciplinary Theoretical &

Mathematical Sciences” 特異点と時空、および関連する物理, Tokyo, Japan, 2016/12/27.

Susumu Inoue “電波分散および 21cm 吸収線系を用いた観測的宇宙論” 銀河進化と遠方宇宙 (IV), Kumamoto, Japan, 2017/1/8.

Hiroataka Ito, Amir Levinson, Boris Stern, Shigehiro Nagataki “定常解から探る相対論的輻射媒介衝撃波のガンマ線バーストの放射への影響” 日本天文学会春季年会, Fukuoka, Japan, 2017/3/15.

Susumu Inoue, Ruo-Yu Liu, Kohta Murase “活動銀河核ウィンドにおける宇宙線加速・非熱的放射と銀河フィードバックへの示唆” 日本天文学会春季年会, Fukuoka, Japan, 2017/3/16.

Susumu Inoue, Yasunobu Uchiyama, Matthieu Renaud, Keiichi Wada “銀河系ディスクへの低温ガスの降着に伴う宇宙線加速と非熱的放射” 日本天文学会春季年会, Fukuoka, Japan, 2017/3/16.

(8) Outreach

Shigehiro Nagataki “先生、ブラックホールってなんですか？ 理化学研究所・長瀧先生に聞いてみた” ネットリか, 2016/6/4.

<http://netallica.yahoo.co.jp/news/20160604-31251612-netallicaq>

Shigehiro Nagataki “「重力波」ってなんだったの？ 理化学研究所・長瀧先生に聞

いてみた” ネタリか, 2016/6/5.

<http://netallica.yahoo.co.jp/news/20160605-60039541-netallicaq>

Shigehiro Nagataki “京コンピュータで解明する超新星爆発の爆発メカニズム” 埼玉県立熊谷西高等学校見学会, Wako, Saitama, 2016/11/14.

Shigehiro Nagataki “宇宙の誕生・現在・未来：人類は宇宙をどこまで理解したか” 平成 28 年度和光市民大学, Wako, Japan, 2016/12/15.

Shigehiro Nagataki “Exploring Extreme Universe at RIKEN” アジアリーダーシップトレック, Wako, Japan, 2017/1/20.

Shigehiro Nagataki “Exploring Extreme Universe at RIKEN” HOPE Meeting 2017, Wako, Japan, 2017/3/2.

(9) Seminar Talks (International)

Hirotaka Ito, Shigehiro Nagataki, Jin Matsumoto, Don Warren, Shiu-Hang Lee, Alexey Tolstov, Maxim Barkov, Akira Mizuta, Shoichi Yamada, Asaf Pe'er, Masaomi Ono, Maria Dainotti, Seiji Harikae “Photospheric Emission from Structured Jet” The University of Texas at Austin, USA, 2016/10/31.

Wongwathanarat Annop “Connecting core-collapse supernova simulations with observations” Mahidol University, Bangkok, Thailand, 28 Feb 2017.

Shigehiro Nagataki “Astrophysical Big Bangs” UCLA Seminar, UCLA, USA, 2017/3/17.

(10) Seminar Talks (Domestic)

Wongwathanarat Annop “Linking core-collapse simulations with observations” DTA colloquium, NAOJ, Tokyo, Japan, 12 Oct 2016.

Masaomi Ono, “Three dimensional numerical modeling of the evolution from supernovae to their supernova remnants” 早稲田大学理論宇宙物理学研究室セミナー, Waseda U., Tokyo, Japan, 2017/1/20.

(11) Poster Presentations at International Meetings

Susumu Inoue “Cosmic Ray Production of Light Elements induced by Galactic Winds” Nuclei in the Cosmos XIV, Niigata, Japan, 2016/6/21.

Susumu Inoue, Kiyotomo Ichiki, Hayato Shimabukuro “Probing Small-Scale Density Fluctuations of Baryons and Dark Matter with Fast Radio Bursts” Signals from the Deep Past, Valletta, Malta, 2016/7/18.

Warren III Donald Cameron, Ellison, D.C., Barkov, M.V., Nagataki, S. “Nonlinear cosmic ray acceleration during gamma-ray burst afterglows”

Huntsville GRB symposium, Huntsville,
USA, 2016/10/26.

Jin Matsumoto “Synergetic Growth of
the Rayleigh-Taylor and
Richtmyer-Meshkov Instabilities in the
Relativistic Jet”, 平成 28 年度天文シミュ
レーションプロジェクトユーザーズミー
ティング, Mitaka, Japan, 2016/11/29.

Jin Matsumoto “Synergetic Growth of
the Rayleigh-Taylor and
Richtmyer-Meshkov Instabilities in the
Relativistic Jet” 7 years of MAXI :
monitoring X-ray transients, Wako,
Japan, 2016/12/5.

(12) Poster Presentations at
Domestic Meetings

Hiroataka Ito, Amir Levinson, Boris Stern,
Shigehiro Nagataki “Steady-state
solution of relativistic radiation
mediated shocks” 第 29 回理論懇シンポ
ジウム, Sendai, Japan, 2016/12/20.

(13) Meetings organized or
co-organized by our group

RESCEU-RIKEN Joint Meeting 2016,
25-27 July 2016, U. of Tokyo, Hongo,
Tokyo, Japan.

Nuclei in the Cosmos School, 13-17 June
2016, Niigata U., Niigata, Japan.

Nuclei in the Cosmos, 20-24 June 2016,
Toki-Messe, Niigata, Japan.

Particle Astrophysics and Cosmology
Including Fundamental Interactions
(PACIFIC) Moorea, French Polynesia
10-17 September 2016.

