

研究室名
17-2-2 理論天体物理学研究室
最近の研究課題とその取り組みの概要
重力崩壊型超新星は太陽質量の約 10 倍を超える大質量星がその進化の最終段階に示す大爆発現象である。超新星は一天体現象ではありながら、それ自体が中性子星、ブラックホール、マグネターといった極限的コンパクト天体の形成過程そのものであり、超新星の爆発機構を明らかにすることは、恒星進化論の最重要テーマの一つである。この問題に対して、星が持つ自転、磁場のようなマクロ物理と、ニュートリノ反応を始めとするミクロ物理の効果に着目した上で、主に数値シミュレーションを用いた研究を行なっている。 キーワード：恒星進化論、スーパーコンピューター、ニュートリノ、重力波、高密度状態方程式
研究室の構成員
固武 慶（教授）・博士（理学） 中村 航（助教）・博士（理学）
2021 年度の大学院生および卒論生の人数と研究テーマ
M2: 2 名（理論天体物理：超新星爆発の数値シミュレーション） 4 年次生：4 名（理論天体物理学、数値計算コード作成） 3 年次生：5 名（理論天体物理学）
教員の担当科目
固武 慶：(学部) 宇宙天体物理学、連続体力学、相対論、力学A、物理学A、 物理科学研究、卒業論文、物理学基礎ゼミナール 中村 航：物理学実験、物理科学実験、物理学基礎ゼミナール
教員の所属学会
固武 慶：日本物理学会、日本天文学会、理論天文学宇宙物理学懇談会 中村 航：日本天文学会、理論天文学宇宙物理学懇談会
最近 5 年間の学術論文
(査読付き原著論文) - Calore, F., Carenza, P., Eckner, C., Fischer, T., Giannotti, M., Jaeckel, J., Kotake, K., Kuroda, T., Mirizzi, A., Sivo, F., 3D template-based Fermi-LAT constraints on the diffuse supernova axion-like particle background, <i>Physical Review D</i>, Volume 105, Issue 6, article id.063028 (2022) - Mori, K., Takiwaki, T., Kotake, K., Horiuchi, S., Shock revival in core-collapse supernovae assisted by heavy axionlike particles, <i>Physical Review D</i>, Volume 105, Issue 6, article id.063009 (2022) - Mori, K., Takiwaki, T., Kotake, K., Presupernova ultralight axionlike particles, <i>Physical Review D</i>, Volume 105, Issue 2, article id.023020 (2022) - Masada, Y., Takiwaki, T., Kotake, K., Convection and Dynamo in Newly Born Neutron Stars, <i>The Astrophysical Journal</i>, Volume 924, Issue 2, id.75, 16 pp. (2022) - Kuroda, T., Fischer, T., Takiwaki, T., Kotake, K., Core-collapse Supernova Simulations and the Formation of Neutron Stars, Hybrid Stars, and Black Holes, <i>The Astrophysical Journal</i>, Volume 924, Issue 1, id.38, 20 pp. (2022) - Takiwaki, T., Kotake, K., Foglizzo, T., Insights into non-axisymmetric instabilities in three-dimensional rotating supernova models with neutrino and gravitational-wave signatures, <i>Monthly Notices of the Royal Astronomical</i>

- Society, Volume 508, Issue 1, pp.966–985 (2021)
7. Caputo, A., Carenza, P., Lucente, G., Vitagliano, E., Giannotti, M., Kotake, K., Kuroda, T., Mirizzi, A., Axionlike Particles from Hypernovae, *Physical Review Letters*, Volume 127, Issue 18, article id.181102 (2021)
 8. Takeda, M., Hiranuma, Y., Kanda, N., Kotake, K., et al., Application of the Hilbert-Huang transform for analyzing standing-accretion-shock-instability induced gravitational waves in a core-collapse supernova, *Physical Review D*, Volume 104, Issue 8, article id.084063 (2021)
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 10. Shibagaki, S., Kuroda, T., Kotake, K., Takiwaki, T., Characteristic time variability of gravitational-wave and neutrino signals from three-dimensional simulations of non-rotating and rapidly rotating stellar core collapse, *Monthly Notices of the Royal Astronomical Society*, Volume 502, Issue 2, pp.3066–3084 (2021)
 11. Cherry, J. F., Fuller, G. M., Horiuchi, S., Kotake, K., et al., Time of flight and supernova progenitor effects on the neutrino halo, *Physical Review D*, Volume 102, Issue 2, article id.023022 (2020)
 12. Shibagaki, S., Kuroda, T., Kotake, K., Takiwaki, T., A new gravitational-wave signature of low- $T/|W|$ instability in rapidly rotating stellar core collapse, *Monthly Notices of the Royal Astronomical Society: Letters*, Volume 493, Issue 1, p.L138–L142 (2020)
 13. Kuroda, T., Arcones, A., Takiwaki, T., Kotake, K., Magnetorotational Explosion of a Massive Star Supported by Neutrino Heating in General Relativistic Three-dimensional Simulations, *The Astrophysical Journal*, Volume 896, Issue 2, id.102, 18 pp. (2020)
 14. Yoshida, T., Takiwaki, T., Kotake, K., Takahashi, K., Nakamura, K., Umeda, H., Three-dimensional Hydrodynamics Simulations of Precollapse Shell Burning in the Si- and O-rich Layers, *The Astrophysical Journal*, Volume 908, Issue 1, id.44, 18 pp. (2021)
 15. Zaizen, M., Cherry, J. F., Takiwaki, T., Kotake, K. et al. Neutrino halo effect on collective neutrino oscillation in iron core-collapse supernova model of a 9.6 Msolar star, *Journal of Cosmology and Astroparticle Physics*, Issue 06, article id. 011 (2020).
 16. Zaizen, M., S., Horiuchi., Takiwaki, T., Kotake, K. et al. Three-flavor collective neutrino conversions with multi-azimuthal-angle instability in an electron-capture supernova model, *Physical Review D*, Volume 103, Issue 6, article id.063008, (2021)
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 18. Matsumoto, J., Takiwaki, T., Kotake, K., et al. 2D numerical study for magnetic field dependence of neutrino-driven core-collapse supernova models, *Monthly Notices of the Royal Astronomical Society*, (MNRAS) Volume 499, Issue 3, pp.4174–4194, (2020)
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 21. Sotani Hajime, Kuroda Takami, Takiwaki Takiwaki, Kotake Kei, "Dependence of outer boundary condition on protoneutron star asteroseismology with gravitational-wave signatures", *Phys. Rev. D* 99, 123024 (2019)
 22. Nakamura Ko, Takiwaki Tomoya, Kotake Kei, "Long-term Simulations of Multi-Dimensional Core-collapse Supernovae: Implications for Neutron Star

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23. Yoshida Takashi, Takiwaki Tomoya, Kotake Kei, Takahashi Koh, Nakamura Ko, Umeda Hideyuki, “One-, Two-, and Three-dimensional Simulations of Oxygen Shell Burning Just Before the Core-Collapse of Massive Stars”, ApJ, Volume 881, Issue 1, article id. 16, 20 pp. (2019)
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 27. O’ Connor Evan, Bollig Robert, Burrows Adam, Couch Sean, Fischer Tobias, Janka Hans-Thomas, Kotake Kei, Lentz Eric J, Liebendoerfer Matthias, Messer O E Bronson, Mezzacappa Anthony, Takiwaki Tomoya, Vartanyan David, “Global comparison of core-collapse supernova simulations in spherical symmetry”, Journal of Physics G: Nuclear and Particle Physics, 45, 104001(21pp), (2018)
 28. Masada Youhei, Kotake Kei, Takiwaki Tomoya, Yamamoto Naoki, “Chiral magnetohydrodynamic turbulence in core-collapse supernovae”, Physical Review D, 98, 083018(17pp), (2018), <http://dx.doi.org/10.1103/PhysRevD.98.083018>
 29. Kawahara Hajime, Kuroda Takami, Takiwaki Tomoya, Hayama Kazuhiro, Kotake Kei, “A Linear and Quadratic Time-Frequency Analysis of Gravitational Waves from Core-collapse Supernovae”, The Astrophysical Journal, 867, 126(13pp), (2018)
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 31. Kuroda Takami, Kotake Kei, Hayama Kazuhiro, Takiwaki Tomoya, “Correlated Signatures of Gravitational-wave and Neutrino Emission in Three-dimensional General-relativistic Core-collapse Supernova Simulations”, The Astrophysical Journal, Volume 851, Issue 1, article id. 62, (12 pp), (2017)
 32. Horiuchi Shunsaku, Nakamura Ko, Takiwaki Tomoya, Kotake Kei, “Estimating the core compactness of massive stars with Galactic supernova neutrinos”, Journal of Physics G: Nuclear and Particle Physics, 44, 11, 114001, (12pp), (2017)

<査読付きProceedings>

1. Nakamura, K., Takiwaki, T., and Kotake, K. “Core-collapse simulation of SN 1987A binary progenitor and its multimessenger signals” Journal of Physics: Conference Series, Volume 2156, article id. 012232 (2022)
2. Horiuchi, S., Nakamura, K., Takiwaki, T., and Kotake, K. “Diagnosing the Structure of Massive Stars with Galactic Supernova Neutrinos” Proceedings of NuPhys2017, eConf C171220, p. 169-173 (2018)
3. Nakamura, K., Horiuchi, S., Tanaka, M., Hayama, K., Takiwaki, T., and Kotake, K. “Multi-messenger signals from core-collapse supernovae” Proceedings of the IAU Symposium, The Lives and Death-Throes of Massive Stars, Volume 329, pp. 428 (2017)
4. Nakamura, K., Takiwaki, T., Kuroda, T., and Kotake, K. “Systematic Features and Progenitor Dependence of Core-Collapse Supernovae” Proceedings of the 14th International Symposium on Nuclei in the Cosmos (NIC2016), id.010610 (2017)
5. Ikeda, E., Kotake, K. and Nakamura, K. “Gravitational Wave Emission from Long-Term Self-Consistent Two-dimensional Core-Collapse Supernova Models” Proceedings of NIC2016, id.020109/, 1-3 (2017)

最近 5 年間の学術著書	
	Kotake Kei and Kuroda Takami, "Gravitational Waves from Core-Collapse Supernovae", Handbook of Supernovae, Springer, (Eds. Alsabti, Athem W., Murdin, Paul), (pp1~27), (2017)
最近 5 年間の学術国際会議での発表	
1	Ko Nakamura, "Gravitational wave analysis for long-term 3D CCSN simulations" International workshop "Probe into core-collapse SuperNovae via Gravitational Wave and neutrino signals (SNeGWv2021)", zoom, 2021 年 12 月 (招待講演)
2	Kei Kotake, "Exploding massive stars in supercomputers and multi-messenger probe into the central engine" the Belgian Gravitational-wave meeting, Universit catholique de Louvain, Belgium, 2021 年 10 月 (招待講演)
3	Kei Kotake, "Core-collapse supernova modeling in the Multi-messenger era" IPAM Workshop: Computational Challenges in Multi-Messenger Astrophysics (GWAWS1), UCLA, 2021 年 10 月 (招待講演)
4	Ko Nakamura, "Three-dimensional supernova simulation of SN 1987A progenitor with implications for multi-messenger signals" The 16th International Symposium on Nuclei in the Cosmos (NIC-XVI), zoom, 2021 年 9 月
5	Kei Kotake, "Core-collapse supernovae: neutrinos and gravitational waves" 17th International Conference on Topics in Astroparticle and Underground Physics (TAUP2021), Valencia, 2021 年 8 月 (招待講演)
6	Ko Nakamura, "Core-collapse simulation of SN 1987A binary progenitor and its multimessenger signals" 17th International Conference on Topics in Astroparticle and Underground Physics (TAUP 2021), Valencia, 2021 年 8 月
7	Ko Nakamura, "Core-collapse supernova simulation of a three-dimensional 25 solar-mass progenitor model" YITP-OzGrav Workshop, zoom, 2021 年 7 月
8	Ko Nakamura, "Gravitational wave signal based on a realistic core-collapse supernova model" The 4th Annual Area Symposium "Gravitational wave physics and astronomy: Genesis", zoom, 2021 年 1 月
9	Kei Kotake, "GW and Neutrino signals from core-collapse supernovae" The Evolution of Massive Stars and Formation of Compact Stars: from the Cradle to the Graves, 早稲田大学 (国内開催の国際学会), 2020 年 2 月 (招待講演)
10	Ko Nakamura, "Core-collapse supernova simulations from a 3D progenitor model" The Evolution of Massive Stars and Formation of Compact Stars: from the Cradle to the Grave, 早稲田大学 (国内開催の国際学会), 2020 年 2 月
11	Kei Kotake, "Neutrino and GW signals from core-collapse supernovae Neutrinos from the Lab to the Cosmos" Institute of Nuclear Theory, Univ. Washington, 2020 年 1 月 (招待講演)
12	Ko Nakamura, "Neutron star kicks predicted from multi-dimensional core-collapse supernova simulations" International workshop 4M-COCOS, Fukuoka, 2019 年 10 月
13	Ko Nakamura, "Systematic features of core-collapse supernovae" Workshop on CCSN explosions and related physics, Exeter, 2019 年 8 月
14	Kei Kotake, "SN Gravitational-waves at the crossroads: synergetic analysis with SN neutrinos", ECT* workshop on "SN neutrinos at the crossroads" (招待講演), Trento, Italy, 2019 年 5 月
15	Kei Kotake, "Explosion physics of massive stars and the multi-messenger signals" IAU Symposium 350 on "Laboratory Astrophysics: from Observations to Interpretation" (招待講演), Jesus College, University of Cambridge, 2019 年 4 月
16	Ko Nakamura "Multi-D long-term simulations of core-collapse supernovae" XIXth Workshop on Nuclear Astrophysics, Germany, 2019 年 3 月
17	Ko Nakamura "Systematic features of neutrino from core-collapse supernovae" International symposium on "Revealing the history of the universe with underground particle and nuclear research", Tohoku Univ (国内学会の国際学会), 2019 年 3 月 (招待講演)
18	Kei Kotake, "A new GW signature from low T/ W instability of rapidly rotating core-collapse" Texas Symposium of relativistic astrophysics, Univ. Portsmouth,

	2019 年 12 月
19	Kei Kotake “Gravitational-wave Astronomy of Compact Objects 55th Karpacz Winter school of theoretical physics “Nuclear Astrophysics in the multi-messenger era”, Polandake: Neutrinos and multi-messenger signatures for a galactic supernova, 2019 年 2 月
20	Ko Nakamura “Core-collapse simulations for a binary evolution model of SN 1987A progenitor” 10th DTA Symposium, NAOJ, 2019 年 1 月
21	Kei Kotake, “Neutrinos and multi-messenger signatures for a galactic supernova”, The 19th International Workshop on Next generation Nucleon Decay and Neutrino (NNN18) (招待講演) Vancouver, Canada, 2018 年 11 月
22	Kei Kotake, “Gravitational-wave and Neutrino Signatures from core-collapse supernovae”, GW-genesis workshop on “Deciphering multi-dimensional nature of core-collapse supernovae via gravitational-wave and neutrino signatures” (SNeGWv2018)、富山国際会議場 (国内開催の国際学会), 2018 年 10 月
23	Ko Nakamura “Multi-messenger Signal Predictions from Multi-dimensional Core-collapse Supernova Simulations” GW-genesis workshop on “Deciphering multi-dimensional nature of core-collapse supernovae via gravitational-wave and neutrino signatures” (SNeGWv2018)、富山国際会議場 (国内開催の国際学会), 2018 年 10 月
24	Kei Kotake, “Gravitational-wave and neutrino signatures from core-collapse supernovae: review and perspectives”, Gamma-ray bursts and supernovae: from the central engines to the observers, Institute Astrophysics, France, 2018 年 7 月
25	Kei Kotake, “Neutrino and Gravitational-wave Signatures from Core-Collapse Supernovae”, Gravitational-waves, ElectroMagnetic and Dark-Matter, Physics (GEMMA2018) (招待講演), Lecce, Italy 2018 年 6 月
26	Kei Kotake, “Exploding and Non-Exploding Core-Collapse Supernova Models in 3D and the Multi-messenger Analysis”, TDLI Workshop on the Exploding Universe (招待講演), 上海、China 2018 年 5 月
27	Ko Nakamura “Neutron Star Kick induced by Aspherical Core-collapse Supernova Explosions” Physics of Core-Collapse Supernovae and Compact Star Formations, Waseda Univ., 2018 年 3 月
28	Ko Nakamura “Diagnosing the Structure of Massive Stars with Galactic Supernova Neutrinos” NuPhys2017: Prospects in Neutrino Physics, London, 2017 年 12 月
29	Kotake Kei “Multi-Messenger Probes into the Multi-D Supernova Neutrino Mechanism” (招待講演), CoCoNuT meeting 2017, Garching, ドイツ 2017 年 10/20-10/25
30	Kotake Kei “Gravitational-waves Signals from Core-collapse Supernovae; what can we learn for sure?”, Wuhan GW workshop, (招待講演), 武漢大学、中国, (2017 年 10/6-8)
31	Ko Nakamura “Systematic features of core-collapse supernova based on multi-D simulations” Workshop on the Progenitor-Supernova-Remnant Connection, Germany, 2017 年 7 月
32	Kotake Kei “Gravitational wave signatures from multi-dimensional core-collapse supernova models” (招待講演), GWPAAW 2017, Annecy, フランス (2017 年 5/30-6/2)

最近 5 年間の代表者としての学外資金導入実績

固武 慶:

科研費・新学術領域研究(研究領域提案型)(計画研究) 「重力波天文学で解き明かす超新星の物理」(期間 2017~2021 年度、108,030 千円)

科研費・基盤研究 A「大質量星の多次元進化から迫る爆発的コンパクト天体形成の統一的解明」(期間 2017~2020 年度、24,700 千円)

中村 航:

科研費・基盤 C「超新星起源マルチメッセンジャー信号の解析に向けた数値モデルの構築」(期間 2020~2022 年度、3,640 千円)

科研費・新学術領域（研究領域提案型）「超新星重力波検出に向けた現実的な超新星重力波テンプレートの作成」（期間 2020～2021 年度、2,600 千円） 科研費・新学術領域（研究領域提案型）「現実的な 3 次元超新星モデルに基づく超新星背景ニュートリノ解析」（期間 2020～2021 年度、2,340 千円） 科研費・若手研究 B「超新星元素合成の系統的研究」（期間 2016～2018 年度、1,430 千円） 科研費・新学術領域（研究領域提案型）「超新星ニュートリノで探る大質量星コア構造」（期間 2017～2018 年度、2,600 千円）
最近 5 年間の代表者としての学内資金導入実績
基盤研究機関研究所（爆発天体研究所）（期間 2019～2023 年予定） 推奨研究プロジェクト(一般):「重力波天文学時代に備える現実的な空間 3 次元超新星モデリング」（期間 2020～2022 年度、3,000 千円） 推奨研究プロジェクト(若手):「多次元数値シミュレーションで解き明かす超新星ニュートリノの放射メカニズム」（期間 2017～2019 年度、4,850 千円） 総合科学研究(若手):「スパコン重力波」（期間 2017～2018 年度、3,000 千円）
最近 5 年間の学会等学術団体における役職など
固武 慶： 国立天文台：すばる望遠鏡 TAC 委員，シミュレーションプロジェクト運営委員会委員 Astroparticle Physics, Publication of Astronomical Society of Japan 編集委員 (editorial board member) 中村 航： 公益社団法人 日本天文学会 学会誌「天文月報」編集委員
最近 5 年間の一般向け論文と著書、行政報告書など
該当なし
最近 5 年間の一般（非学術）集会での発表論文
該当なし
最近 5 年間の学術団体以外の団体での啓蒙活動や社会貢献活動とその役職など
該当なし
その他特筆事項
該当なし