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A. 研究概要

2 次元トポロジカル物性物理学におけるテンソルネットワークを用いたフュージョン圏の研究と作用素環論の間の関係を調べた．フュージョン圏の対象を記述する 4-テンソルが作用素環論における bi-unitary connection と本質的に同じものであることは前からわかっていたが，本年度は 4-テンソルをつなぐ，zipper 条件を満た 3-テンソルが，作用素環論における string の flat field と同じものであり，フュージョン圏の射を与えることを証明した．これは当然期待される結果であるが，もっとも一般的な設定での証明を与えた．

We investigated the relationship between tensor-network approaches to fusion categories in two-dimensional topological condensed matter physics and operator algebra theory. It has been known that the 4-tensor describing objects of a fusion category is essentially identical to the notion of a bi-unitary connection in operator algebra theory. This year, we proved that the 3-tensor connecting these 4-tensors and satisfying the zipper condition coincides with the flat field of strings in operator algebra theory, and that it provides the morphisms of the fusion category. While this result is naturally expected, we established it in full generality.

B. 発表論文

1. Y. Kawahigashi, Projector matrix product operators, anyons and higher relative commutants of subfactors, Math. Ann. **387** (2023), 2157–2172.
2. Y. Kawahigashi, Two-dimensional topological order and operator algebras, Internat. J. Modern Phys. B **35** (2021), 2130003 (16 pages).
3. Y. Kawahigashi, A characterization of a finite-dimensional commuting square producing a subfactor of finite depth, Internat. Math. Res. Notices. **2023** (2023), 8419–8433.
4. Y. Kawahigashi, α-induction for bi-unitary connections, Quantum Topol. **15** (2024), 503–536.
5. D. E. Evans and Y. Kawahigashi, Subfactors and mathematical physics, Bull. Amer. Math. Soc. **60** (2023), 459–482.
6. V. Benedetti, H. Casini, Y. Kawahigashi, R. Longo, and J. M. Magan, Modular invariance as completeness, Phys. Rev. D **110** (2024), 125004.
7. Y. Kawahigashi, Flatness of α-induced bi-unitary connections and commutativity of Frobenius algebras, Internat. Math. Res. Notices **2025** (2025), rnaf255.
8. Y. Kawahigashi, The zipper condition for 4-tensors in two-dimensional topological order and the higher relative commutants of a subfactor arising from a commuting square, to appear in Lett. Math. Phys.

C. 口頭発表

1. Quantum symmetries in operator algebras and mathematical physics, Colloquium. Ohio State University (U.S.A.), April 2025.
2. Tensor networks, the zipper condition and subfactors, Seminar, Università di Roma “Tor Vergata” (Italy), May 2025.
3. Tensor networks, two-dimensional topological order and operator algebras, Mathematical and Computational Challenges in Quantum Computing Reunion Conference, UCLA Lake Arrowhead Lodge (U.S.A.), June 2025.
4. Anyons, tensor networks and operator algebras, Anyons from Small to Large Scales, Mittag-Leffler Institute (Sweden), July 2025.
5. Tensor networks in condensed matter physics and subfactors, The 4th Australia-China-Japan-Singapore-US Index Theory Conference-Analysis and Geometry on Manifolds, National University of Singapore (Singapore). August 2025.
6. Subfactors, tensor networks, and fusion

categories, Functional Analysis Seminar, UCLA (U.S.A.), October 2025.

7. Tensor networks, fusion categories and operator algebras, Mathematical Picture Language Project Seminar, Harvard University (U.S.A.), October 2025.
8. Modular invariance as completeness, Infinite-dimensional Algebra Seminar, MIT (U.S.A.), October 2025.
9. New types of symmetries in mathematical physics from operator algebras, Colloquium, Institute of Mathematics, Academia Sinica (Taiwan), November 2025.
10. 新しい対称性と作用素環，数理物理学，岡シンポジウム， 奈良女子大学，2025 年 12 月.

D. 講義

1. 数理科学の研究フロンティア：宇宙, 物質, 生命，情報：理研の若手研究者によるオムニバス講義のコーディネート．(教養学部 1,2 年生講義)
2. 作用素環論入門，国立台湾大学集中講義.

E. 修士・博士論文

1. (博 士) 粟 津 光 (AWAZU Hikaru): Amenability of group actions on compact spaces and the associated Banach algebras
2. (博士) 朱 浩哲 (ZHU Haozhe): Pure states of the second order irrational rotation algebra arising from automorphisms of the hyperfinite II_1 factor
3. (博 士)HAFID Ayoub: Noncommutative coarse metric geometry
4. (博士) 星野 泰佑 (HOSHINO Taisuke): Relative bi-exactness and structural results for graph-wreath product von Neumann algebras

F. 対外研究サービス

1. *Communications in Mathematical Physics* の editor.
2. *International Journal of Mathematics* の chief editor.
3. *Japanese Journal of Mathematics* の managing editor.
4. *Journal of Mathematical Physics* の associate editor.
5. *Journal of Mathematical Sciences, the University of Tokyo* の editor-in-chief.
6. *Journal of Topology and Analysis* の editor.
7. *Letters in Mathematical Physics* の editor.
8. *Mathematics Open* の editor.
9. *Reviews in Mathematical Physics* の associate editor.
10. *Taiwanese Journal of Mathematics* の editor.
11. Mathematical Physics Studies (Springer) の editor.
12. China-Japan-Korea Conference on Functional Analysis (Seoul National University, Korea, July 7–11, 2025) のオーガナイザー
13. Summer School 数理物理 “Complexity” (京大数理研，August 29–31, 2025) のオーガナイザー.
14. 第 25 回高木レクチャー (東大数理，October 18–19, 2025) のオーガナイザー
15. Subfactors and Applications (Oberwolfach, Germany, July 28–August 1, 2025) のオーガナイザー.
16. The 4th Australia-China-Japan-Singapore-US Index Theory Conference – Analysis and Geometry on Manifolds (Institute for Mathematical Sciences, Singapore, August 4–8, 2025) のオーガナイザー.
17. Operator Algebras and Mathematical Physics (International Centre for Mathematical Sciences, U.K., September 29–October 3, 2025) のオーガナイザー.
18. Theoretical studies of topological phases of matter (the University of Tokyo, Japan, December 1–5, 2025) のオーガナイザー.
19. East Asia Core Doctorial Forum in Mathematics (Seoul National University, Korea, January 12–15, 2026) のオーガナイザー.
20. ICM2030 招致委員会委員長.
21. 理化学研究所数理創造研究センター副センター長.