

Hayato Arai

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Personal Information

Birth 13 June 1995 in Japan
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Education

Apr.2020 - Jan.2023 **Doctor of Mathematical Science**, Nagoya University, Japan
Official Advisor: François Le Gall (UnOfficial Adviser: Masahito Hayashi)

Apr.2018 - Mar.2020 **Master of Mathematical Science**, Nagoya University, Japan
Advisor: Masahito Hayashi

Apr.2014 - Mar.2018 **B.S. in Mathematics, Science**, Kyoto University, Japan
Advisor: Toru Umeda

Apr.2011 - Mar.2014 Zushi Kaisei High School, Japan

Employments

Feb.2023 - present JSPS Research Fellow (PD)

Apr.2022 - Jan.2023 JSPS Research Fellow (DC)

Apr.2021 - Mar.2022 Research Assistant of Prof. Le Gall François, Nagoya University

Apr.2020 - Mar.2021 Research Assistant, Graduate School of Mathematics, Nagoya University

Apr.2019 - Mar.2020 Research Assistant of Prof. Masahito Hayashi, Nagoya University

Teaching

- **Teaching Assistant, Practices of Mathematics**, Nagoya University, 2018.

Awards

- Mar.2020** **Graduate School of Mathematics Award for Masters Thesis** (top 10%),
Nagoya University.
- Nov.2019** **The 40th Quantum Information Technology Symposium (QIT40) Student Award** (top 20%),
The Institute of Electronics, Information and Communication Engineers, Japan
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Fellowships

- Apr.2022-present** **JSPS Grant-in-Aids for JSPS Research Fellows No. JP22J14947**,
JSPS.
- Oct.2021-Mar.2022** **Next Generation Researcher**,
Nagoya University (supported by JSPS Grant-in-Aid for JST SPRING No. JPMJSP2125).
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Scholarships

- Jul.2022** **Repayment Exemption for Students with Excellent Grades**
Type I (interest-free) scholarship (Exemption of all of loan)-FY2020-,
Japan Student Services Organization (JASSO).
- Jul.2020** **Repayment Exemption for Students with Excellent Grades**
Type I (interest-free) scholarship (Exemption of half of loan)-FY2018-,
Japan Student Services Organization (JASSO).

List of Publications and Brief Summaries (Eng.)

Refereed Journal Papers

- [1]. Hayato Arai and Masahito Hayashi, “Pseudo standard entanglement structure cannot be distinguished from standard entanglement structure.” *New Journal of Physics* **25**, 023009 (2023).
<https://doi.org/10.1088/1367-2630/acb565>
- [2]. Shintaro Minagawa and Hayato Arai and Francesco Buscemi, “von Neumann’s information engine without the spectral theorem.” *Phys. Rev. Research* **4**, 033091(2022).
<https://doi.org/10.1103/PhysRevResearch.4.033091>
(Hayato Arai has contributed to this work as equally as the first author Shintaro Minagawa, mentioned in Acknowledgement of this paper.)
- [3]. Yuuya Yoshida and Hayato Arai and Masahito Hayashi, “Perfect Discrimination in Approximate Quantum Theory of General Probabilistic Theories.” *Phys. Rev. Lett.* **125**(15), 150402 (2020).
<https://doi.org/10.1103/PhysRevLett.125.150402>
- [4]. Hayato Arai and Yuuya Yoshida and Masahito Hayashi, “Perfect Discrimination of Non-Orthogonal Separable Pure States on Bipartite System in General Probabilistic Theory.” *Journal of Physics A: Mathematical and Theoretical* **52**(46), 465304 (2019).
<https://doi.org/10.1088/1751-8121/ab4b64>

Preprints

- [5]. Hayato Arai and Masahito Hayashi, “Detection of Beyond-Quantum Non-locality based on Standard Local Quantum Observables.” arXiv:2301.04196 [quant-ph] (2023). (under submitting)
<https://arxiv.org/abs/2301.04196>

Brief Summaries

Our studies mainly address *General Probabilistic Theories* (GPTs), which deal with any general model that describes a physical system and is consistent with probabilistic principles. GPTs is a modern approach to discuss foundational topics in quantum theory with both physics and information theory. The aims of GPTs are roughly divided into the following.

1. To derive quantum theory by physically and information theoretically reasonable conditions.
2. To clarify the general bounds for informational tasks under certain physical conditions.
3. To explore other possibilities of mathematical models consistent with present experimental facts.

The references [3,4], which start with the second aim, discuss *State Discrimination* (SD) in *Entanglement Structures* (ESs). State discrimination is a fundamental task for both quantum computation and quantum communication. An ES is a model whose local systems are completely equivalent to standard quantum theory. The references [3,4] clarify that some ESs possess superior performance for SD to standard quantum theory. Moreover, the results imply that the superiority breaks the information spectrum, which is an essential structure for information processing.

The reference [1], which starts with the first and third aims, discusses the existence of pseudo-standard ESs that cannot be denied by a certain experimental verification of standard quantum theory. Also, the reference [1] shows that such models possess superior performance for SD. Moreover, the reference [1] clarifies that some group symmetric conditions derive standard quantum theory. These results imply that small transcendence of standard quantum theory enables small improvement of the performance for SD.

The reference [5], which starts with the third aim, gives a way to detect beyond quantum non-locality in ESs. Beyond quantum non-local states in ESs cannot be detected by Bell-CHSH inequality. In contrast to Bell-CHSH inequality, any beyond quantum non-locality in ESs can be detected by a certain tuple of standard quantum local observables. Moreover, the reference [5] also gives an experimental implementation of the detection in standard quantum theory.

The reference [2], which starts with the second aim, discusses thermodynamical behavior in general models. The reference [2] shows that the second law of thermodynamics based on entropy holds even in general models in which unique spectral decomposition does not hold. This result implies that the consistency of the second law is not sufficient for standard quantum theory in GPTs.

List of Presentations

(The symbols “◦” denote the presenter of each presentation.)

Refereed Oral Presentations in International Meeting

1. ◦Hayato Arai and Masahito Hayashi, “Pseudo standard entanglement structure cannot be distinguished from standard entanglement structure.” Beyond i.i.d. in Information Theory X, online, September 26–30, 2022.
2. ◦Sintaro Minagawa and Hayato Arai and Francesco Buscemi, “Von Neumann’s information engines without the spectral theorem.” Quantum extreme universe from quantum information, Kyoto, Japan, September 26–30, 2022.
3. ◦Sintaro Minagawa and Hayato Arai and Francesco Buscemi, “Von Neumann’s information engines without the spectral theorem.” Quantum Information and Probability: from Foundations to Engineering, Växjö, Sweden, July 14–17, 2022.
4. Yuuya Yoshida and ◦Hayato Arai and Masahito Hayashi, “Perfect discrimination in approximate quantum theory of general probabilistic theories.” 20th Asian Quantum Information Science Conference (AQIS), online, December 7–9, 2020.
5. Yuuya Yoshida and ◦Hayato Arai and Masahito Hayashi, “Perfect discrimination in approximate quantum theory of general probabilistic theories.” Beyond i.i.d. in Information Theory VIII, online, November 9–13, 2020.
6. ◦Hayato Arai and Yuuya Yoshida and Masahito Hayashi, “Perfect Discrimination of Non-Orthogonal Separable Pure States on Bipartite System in General Probabilistic Theory.” Beyond i.i.d. in Information Theory VII, Sydney, Australia, July 1–5, 2019.

Non-Refereed Oral Presentations in International Meeting

1. ◦Hayato Arai and Masahito Hayashi, “Pseudo standard entanglement structure cannot be distinguished from standard entanglement structure.” SUSTech-Nagoya workshop on Quantum Science 2022, online, May 31–June 3, 2022.
2. ◦Hayato Arai and Yuuya Yoshida and Masahito Hayashi, “Perfect discrimination in approximate quantum theory of general probabilistic theories.” Nagoya-SUSTech Quantum Information Workshop, Nagoya, Japan, April 11–13, 2019.
3. ◦Hayato Arai, “Physics as a Physical Phenomenon,” International & Transdisciplinary Symposium on Advanced Future Studies, Kyoto, Japan, Feb 8–10, 2017.

Refereed Poster Presentations in International Meeting

1. ◦Hayato Arai and Masahito Hayashi, “Pseudo standard entanglement structure cannot be distinguished from standard entanglement structure.” The 26th Quantum Information Processing (QIP), Ghent, Belgium, February 6–10, 2023.
2. ◦Hayato Arai and Masahito Hayashi, “Pseudo standard entanglement structure cannot be distinguished from standard entanglement structure.” Quantum extreme universe from quantum information, Kyoto, Japan, September 26–30, 2022.
3. Yuuya Yoshida and ◦Hayato Arai and Masahito Hayashi, “Perfect Discrimination of Non-Orthogonal Separable Pure States on Bipartite System in General Probabilistic Theory,” The 24rd Quantum Information Processing (QIP), online, February 1–5, 2021.
4. Hayato Arai and ◦Yuuya Yoshida and Masahito Hayashi, “Perfect Discrimination of Non-Orthogonal Separable Pure States on Bipartite System in General Probabilistic Theory,” The 23rd Quantum Information Processing (QIP), Shenzhen, China, January 6–10, 2020.

5. Hayato Arai and Yuuya Yoshida and Masahito Hayashi, “Perfect Discrimination of Non-Orthogonal Separable Pure States on Bipartite System in General Probabilistic Theory.” The 19th Asian Quantum Information Science Conference (AQIS), Seoul, Korea, August 19–23, 2019.

Non-Refereed Poster Presentations in International Meeting

1. Hayato Arai and Yuuya Yoshida and Masahito Hayashi, “Perfect Discrimination of Non-Orthogonal Separable Pure States on Bipartite System in General Probabilistic Theory,” Quantum Information Processing in Non-Markovian Quantum Complex Systems 2019 (QIPQC2019), Nagoya, Japan, December 9–12, 2019.

Non-Refereed Oral Presentations in Domestic Meeting

1. Hayato Arai and Masahito Hayashi, “Detection of Beyond-Quantum Non-locality based on Standard Local Quantum Observables.” The 48th Quantum Information Technology Symposium (QIT), Kyoto, May 29–30, 2023.
2. Hayato Arai and Masahito Hayashi, “Detection of Beyond-Quantum Non-locality based on Standard Local Quantum Observables.” 2023 Spring Meeting on The Physical Society of Japan (JPS) , online, March 22-25, 2023.
3. Hayato Arai and Masahito Hayashi, “Non-standard entanglement structure of Local unitary self-dual models as a saturated situation of repeatability in General Probabilistic Theories.” The 45th Quantum Information Technology Symposium (QIT), online, November 30–December 1, 2021.
4. Shintaro Minagawa and Hayato Arai and Francesco Buscemi, “Assuming the validity of the second law of thermodynamics in general probabilistic theories – consequences and constraints on models –.” The 45th Quantum Information Technology Symposium (QIT), online, November 30–December 1, 2021.
5. Yuuya Yoshida and Hayato Arai and Masahito Hayashi, “Perfect Discrimination in Approximate Quantum Theory of General Probabilistic Theories.” The 43th Quantum Information Technology Symposium (QIT), online, December 10–11, 2020.
6. Hayato Arai and Yuuya Yoshida and Masahito Hayashi, “Perfect Discrimination of Non-Orthogonal Separable States in General Probabilistic Theory,” The 40th Quantum Information Technology Symposium (QIT), Hukuoka, Japan, May 20–21, 2019.