FY 2025 Annual Report

Unit Name

Theory of Quantum Matter Unit

Professor Nic Shannon

Research Personnel

- Matthias Gohlke, Staff Scientist
- Yoshitomo Kamiya, Staff Scientist
- Tokuro Shimokawa, Staff Scientist
- Pranay Patil, Postdoctoral Scholar
- Ayushi Singhania, Postdoctoral Scholar

Students Supervised:

- Ananya Samanta (PhD Student)
- Snigdh Sabharwal (PhD Student)
- Jiahui Bao (PhD Student)
- Marina Razzhivina (PhD Student)
- Yusaku Hattori (Research Intern)

Rotation Student:

- Wirawat Kokaew (PhD Student)
- Khang Minh Le (PhD Student)

Scholarly Contributions and Creative Productions (by Faculty)

Journal Article

1. Sabharwal, S.; Gohlke, M.; Skrzypczyk, P.; Shannon, N.
   Characterizing Entanglement at Finite Temperature: How Does a “Classical” Paramagnet Become a Quantum Spin Liquid? arXiv 2025.
2. Cao, C.; Zhou, Y.; Tannu, S.; Shannon, N.; Joynt, R.
   Exploiting Many-Body Localization for Scalable Variational Quantum Simulation. Quantum 2025, 9.
3. Sadoune, N.; Liu, K.; Yan, H.; Jaubert, L. D.; Shannon, N.; Pollet, L.
   Human-Machine Collaboration: Ordering Mechanism of Rank-2 Spin Liquid on Breathing Pyrochlore Lattice. Physical Review Research 2025, 7.
4. Yamazaki, H.; Csire, G.; Kucska, N.; Shannon, N.; Gyorffy, B.; Takagi, H.; Újfalussy, B.
   Quantum Size Effects on Andreev Transport in Nb/Au/Nb Josephson Junctions: A Combined Ab Initio and Experimental Study. Physical Review Letters 2025, 134.
5. Shimokawa, T.; Sabharwal, S.; Shannon, N.

Can Experimentally-Accessible Measures of Entanglement Distinguish Quantum Spin Liquids from Disorder-Driven "Random Singlet" Phases? arXiv 2025.

6. Yu, Y.; Wang, X.-B.; Shannon, N.; Joynt, R.

   Warm Start Adaptive-Bias Quantum Approximate Optimization Algorithm. Physical Review A 2025, 112, 18.

7. Sabharwal, S.; Shimokawa, T.; Shannon, N.

   Witnessing Disorder in Quantum Magnets. Phys. Rev. Research 2025, 7.

Presentation at Conference

1. Shannon, N.

   "*Spin Liquids in Spin-1 Pyrochlore Magnets: Nematic Coulomb Phase, Intrinsic Spin Glass, and Its Realization in $NaCaNi_2F_7$*". Frustrated Systems - Mini Workshop, Indian Institute of Technology Madras, India (2026.03.26)

2. Shannon, N.

   "*What Can the Tools of Quantum Information Theory Teach Us about Quantum Magnets?*". Advanced School and Conference on Quantum Matter, International Centre for Theoretical Physics, Trieste, Italy (2025.12.01)

3. Shannon, N.

   "*What Can the Tools of Quantum Information Theory Teach Us about Quantum Magnets?*". The International Workshop on "Exotic Quantum Phases due to Unhappy Electrons", The University of Tokyo, Japan (2025.11.12)

4. Shannon, N

   "*What Can the Tools of Quantum Information Theory Teach Us about Quantum Magnets?"* International Workshop: "Quantum Spin Liquids 2025", HUN-REN Research Centre for Natural Science, Budapest, Hungary (2025.10.10)

5. Shannon, N.

   "*Spin-1 Moments on the Pyrochlore Lattice*". The 13th International Conference on Highly Frustrated Magnetism (HFM 2025), The University of Toronto, Toronto, Canada (2025.05.30)

Seminars

1. Shannon, N.

   "*Spin Liquids in Spin-1 Pyrochlore Magnets: Nematic Coulomb Phase, Intrinsic Spin Glass, and Its Realization in $NaCaNi_2F_7$*", The University of Tokyo, Tokyo, Japan (2026.03.30)

2. Shannon, N.

   "*What Can the Tools of Quantum Information Theory Teach Us about Quantum Magnets?*", Ochanomizu University, Tokyo, Japan (2025.11.11)

3. Shannon, N.

   "*What Can the Tools of Quantum Information Theory Teach Us about Quantum Magnets?*", Nils Bohr Colloquium, NORDITA, Stockholm, Sweden (2025.08.18)

4. Shannon, N.

   "*What Can the Tools of Quantum Information Theory Teach Us about Quantum Magnets?*", Queen Mary University of London, London, England (2025.08.13)

5. Shannon, N.

   "*What Can the Tools of Quantum Information Theory Teach Us about Quantum Magnets?*", The University of Bristol, Bristol, England (2025.08.07)

6. Shannon, N.

   "*An Introduction to Frustrated Magnetism*", Toyota RIKEN seminar, Nagoya University, Nagoya, Japan (2025.07.30)

7. Shannon, N.

"*What Can the Tools of Quantum Information Theory Teach Us about Quantum Magnets?*", Neils Bohr Institute, The University of Copenhagen, Copenhagen, Denmark (2025.06.20)

8. Shannon, N.

"*Inelastic Neutron Scattering Reinterpreted: What Can the Tools of Quantum Information Theory Teach Us about Quantum Magnets?*", LINXS, Lund, Switzerland (2025.06.19)

Poster Presentation at Conference

1. Shannon, N.

"*Inelastic Neutron Scattering Revisited: What Can Ideas from Quantum Information Teach Us about Quantum Magnets?*" LINXS at Science Village Inaugural Conference, Lund, Switzerland (2025.06.17)

Scholarly Contributions (by Unit Members)

Name of Unit Member	Type	Title	Outlet	Publisher	Year Pub
Tokuro Shimokawa	Journal Article	Magnetic excitations from the hexagonal spin clusters in the S = 1-2 distorted honeycomb lattice antiferromagnet Cu2(pymca)3(ClO4)	Physical Review B	American Physical Society	2025
Pranay Patil	Journal Article	Topological Phase Transitions in a Constrained Two-Qubit Quantum Control Landscape	Physical Review Letters	American Physical Society	2025
Matthias Gohlke	Journal Article	Spontaneous magnon decays from nonrelativistic time-reversal symmetry breaking in altermagnets	Physical Review B	American Physical Society	2025
Pranay Patil	Journal Article	Toward a Theory of Phase Transitions in Quantum Control Landscapes	Physical Review X	American Physical Society	2025
Pranay Patil	Poster Presentation at Conference	Tunable topological protection in Rydberg lattices via a novel quantum Monte Carlo approach	The 13th International Conference on Highly Frustrated Magnetism (HFM 2025), The University of Toronto, Toronto, Canada		2025
Tokuro Shimokawa	Poster Presentation at Conference	Multipartite entanglement at finite temperature: Application to identification problems among quantum spin liquid states	第12回富岳成果報告会, Tokyo, Japan		2025
Tokuro Shimokawa	Poster Presentation at Conference	Quantum criticality and multipartite entanglement via finite-temperature spin dynamics	30th International Conference on Low Temperature Physics, Bilbao Exhibition Centre, Bilbao, Spain		2025
Yoshitomo Kamiya	Poster Presentation at Conference	Magnetic field induced deformation of the spin density wave microphases in Ca3Co2O6	The 13th International Conference on Highly Frustrated Magnetism (HFM 2025), The University of Toronto, Toronto, Canada		2025
Ayushi Singhania	Poster Presentation at Conference	Benchmarking METTS for Finite-Temperature Simulations of Z2 Models: Applications to Rydberg atom ladder systems	The 13th International Conference on Highly Frustrated Magnetism (HFM		2025

Name of Unit Member	Type	Title	Outlet	Publisher	Year Pub
			2025), The University of Toronto, Toronto, Canada		
Jiahui Bao	Poster Presentation at Conference	On the origin of spin nematic order in Sr2IrO4	The 13th International Conference on Highly Frustrated Magnetism (HFM 2025), The University of Toronto, Toronto, Canada		2025
Yoshitomo Kamiya	Presentation at Conference	Designing Magnetoelectric Effects Using Organic Quantum Spin Trimers	2nd international conference on Quantum Magnetism and Topology, Lahan Hotel, Pohang, Korea		2025
Tokuro Shimokawa	Presentation at Conference	What can we learn about quantum magnets from experimentally accessible measures of entanglement?	高次にもつれた量子相探索の展開, Yukawa Institute for Theoretical Physics, Kyoto University, Japan		2025
Tokuro Shimokawa	Presentation at Conference	量子フィッシャー情報量のフラストレート磁性体への応用	21st Quantum Spin Workshop (第21回量子スピン系研究会）, Shimonoseki, Yamaguchi, Japan		2025
Matthias Gohlke	Presentation at Conference	Characterizing entanglement at finite temperature: how does a classical paramagnet become a quantum spin liquid?	DPG Spring Meeting of the Condensed Matter Section, Dresden University of Technology, Germany		2025
Tokuro Shimokawa	Presentation at Conference	Novel magnetic phenomena in frustrated random spin systems via large scale computations and real material data	Extreme universe Fifth Annual Meeting, Matsuyama, Japan		2025
Matthias Gohlke	Presentation at Conference	Stability of topological magnon edge modes: A case study	JPS 80th Annual Meeting, Hiroshima University, Japan		2025
Tokuro Shimokawa	Presentation at Conference	Quantum criticality and multipartite entanglement via finite-temperature spin dynamics	JPS 80th Annual Meeting, Hiroshima University, Japan		2025
Yoshitomo Kamiya	Presentation at Conference	Designing Magnetoelectric Effects Using Organic Quantum Spin Trimers	JPS 80th Annual Meeting, Hiroshima University, Japan		2025
Yoshitomo Kamiya	Presentation at Conference	Designing Magnetoelectric Effects Using Organic Quantum Spin Trimers	高次にもつれた量子相探索の展開, Yukawa Institute for Theoretical Physics, Kyoto University, Japan		2025
Matthias Gohlke	Presentation at Conference	Thermal pure matrix product state in two dimensions: tracking thermal equilibrium from paramagnet down to the Kitaev spin liquid state	The 13th International Conference on Highly Frustrated Magnetism (HFM 2025), The University of Toronto, Toronto, Canada		2025

Name of Unit Member	Type	Title	Outlet	Publisher	Year Pub
Tokuro Shimokawa	Presentation at Conference	Quantum criticality and multipartite entanglement via finite-temperature spin dynamics	The 13th International Conference on Highly Frustrated Magnetism (HFM 2025), The University of Toronto, Toronto, Canada		2025
Tokuro Shimokawa	Seminars	Can experimentally-accessible measures of entanglement distinguish quantum spin liquid and random singlet phases?	Korea Advanced Institute of Science and Technology, Korea		2025
Yoshitomo Kamiya	Seminars	Designing Magnetoelectric Effects Using Organic Quantum Spin Trimers	Shanghai Jiao Tong University		2025

Other Institutional Service

Term 2 2019 - Ongoing — International Activities Committee of Grant-in-Aid for Scientific Research on Innovative Areas "Quantum Liquid Crystals", [Fiscal Year: 2019-4-1]

Workshops and Seminars [Organized and Hosted by Faculty/Units]

Speaker Name(s)	Title	Location	Co-Organizers	Date
Nic Shannon	International Workshop on Exotic Quantum Phases due to Unhappy Electrons	Tokyo	Tsuyoshi Kimura (Univ. of Tokyo) Nic Shannon (OIST) Tetsuo Hanaguri (RIKEN) Yoshihiko Okamoto (Univ. of Tokyo) Minoru Nohara (Hiroshima Univ.)	2025-11-12
Nic Shannon	Second International Workshop on Quantum Spin Ice	Herzberg	Romain Sibille, Tom Fennell and Michel Kenzelmann (Paul Scherrer Institute) Michel Gingras (University of Waterloo) Nic Shannon (OIST)	2025-10-14

Collaborations

Prof. Nic Shannon (OIST), Prof. Robert Joynt (UW-Madison), Prof. Xiang-Bin Wang (Tshinghua University), Dr Yunlong Yu (Tshinghua University), Warm-start adaptive-bias quantum approximate optimization algorithm

Dr. Matthias Gohlke (OIST), Dr. Paul McClarty (LLB, Paris-Saclay, France), Prof. Jeffrey G. Rau (University of Windsor, Canada), Topological magnons without decay

Dr. Yoshitomo Kamiya (OIST), Prof. Cristian Batista (UTK), Prof. Yuko Hosokoshi (OMU), Dr. Shengzhi Zhang (NHFML), Designing magnetoelectric effects using spin trimers

Dr. Matthias Gohlke (OIST), Dr. Yoshitomo Kamiya (OIST), Mr. Snigdh Sabharwal (OIST), Dr. Fengfeng Song (ISSP), Tensor-network evaluation of genuine multipartite entanglement

Dr. Matthias Gohlke (OIST), Prof. Alexander L. Chernyshev (University of California, USA), Mr. Rintaro Eto (Waseda University), Prof. Masahito Mochizuki (Waseda University), Dr. Alexander Mook (University of Mainz, Germany), Prof. Jairo Sinova (University of Mainz, Germany), Spontaneous Magnon Decay in Altermagnets

Prof. Nic Shannon (OIST), Prof. SungBin Lee (KAIST), Mr. Jenmin Park (KAIST), Prof. Han Yan (University of Tokyo), Spin liquid in Yb-based hyperkagome magnets

Prof. Nic Shannon (OIST), Prof. Rico Pohle (Shizuoka University), Spin liquid and intrinsic spin glass in $NaCaNi_2F_7$

Ms. Marina Razzhivina (OIST), Prof. Nic Shannon (OIST), Prof. Rico Pohle (Shizuoka University), Spin dynamics in frustrated magnets

Prof. Nic Shannon (OIST), Prof. Owen Benton (QMUL), Dr. Kimberly Remund (National Yang Ming Chiao Tung University), SCGA for spin-1 magnets

Dr. Tokuro Shimokawa (OIST), Prof. Masayuki Hagiwara (Osaka University), Prof. Zentaro Honda (Saitama University), Mr. Sho Inoue (Osaka University), Dr. Alexander I. Kolesnikov (Oak Ridge National Lab), Prof. Masaaki Matsuda (Oak Ridge National Lab), Prof. Yasuo Narumi (Osaka University), Quantum distorted honeycomb magnets

Mr. Jiahui Bao (OIST), Dr. Matthias Gohlke (OIST), Prof. Nic Shannon (OIST), Prof. Karlo Penc (HUN-REN Wigner Research Centre for Physics, Hungary), Nature of spin nematic state in the square lattice Iridates

Dr. Yoshitomo Kamiya (OIST), Dr. Mingcheng Yi (University of Tokyo), Matrix product operator state tomography

Prof. Nic Shannon (OIST), Dr. Chenfeng Cao (Freie Universitaet Berlin), Prof. Robert Joynt (UW-Madison), Prof. Swamit Tannu (UW-Madison), Ms Yeqing Zhou (UW-Madison), Many body localisation for variational quantum simulation

Dr. Matthias Gohlke (OIST), Prof. Yuta Mizukami (Tohoku U), Kitaev-like Frustrated Magnets in Strong Magnetic Fields

Dr. Matthias Gohlke (OIST), Mr. Snigdh Sabharwal (OIST), Prof. Nic Shannon (OIST), Prof. Paul Skrzypczyk (University of Bristol), Genuine multiple entanglement in proximate spin liquids

Mr. Snigdh Sabharwal (OIST), Prof. Nic Shannon (OIST), Dr. Tokuro Shimokawa (OIST), Entanglement witness for triangular-lattice magnets

Dr. Pranay Patil (OIST), Prof. Anders W. Sandvik (Boston University), Entanglement entropy of a transverse field Ising glass

Dr. Yoshitomo Kamiya (OIST), Dr. Yuichi Otsuka (RIKEN), Dr. Hitoshi Seo (RIKEN), Electron-phonon quantum Monte Carlo simulations

Mr. Yusaku Hattori (U of Tokyo), Mr. Snigdh Sabharwal (OIST), Prof. Nic Shannon (OIST), Dr. Tokuro Shimokawa (OIST), Disorder in XX spin chain

Dr. Pranay Patil (OIST), Dr. Nicolo Beato (MPIPKS, Dresden), Dr. Marin Bukov (MPIPKS, Dresden), Control landscapes for quantum state preparation

Mr. Jiahui Bao (OIST), Dr. Yoshitomo Kamiya (OIST), Breathing kagome plateaus

Prof. Nic Shannon (OIST), Dr. Tokuro Shimokawa (OIST), Dr. Jonas Sonnenschein (OIST), Prof. Rico Pohle (Shizuoka Univ), Breathing bilayer kagome magnet

Dr. Pranay Patil (OIST), Dr. Ayushi Singhania (OIST), Benchmarking METTS for Finite-Temperature Simulations of Z_2 Models: Applications to Rydberg atom ladder systems

Prof. Nic Shannon (OIST), Dr. Ludovic D.C. Jaubert (CNRS), Dr. Ke Liu (LMU), Prof. Lode Pollet (LMU), Mr. Nicolas Sadoune (LMU), Prof. Han Yan (ISSP), Application of machine learning to frustrated magnetism

Prof. Nic Shannon (OIST), Dr. Gábor Csire (Wigner Research Center, Budapest), Balázs Győrffy (University of Bristol), Dr. Nóra Kucska (Wigner Research Center, Budapest), Prof. Hidenori Takagi (MPI-FKF, Germany) Prof. Balázs Újfalussy (Wigner Research Center, Budapest), Dr Hiroki Yamazaki (RIKEN), Andreev Transport in Nb/Au/Nb Josephson Junctions