

ITHEMS-UBC WORKSHOP 2026

Quantum Information: Entanglement of Mathematics and Physics

PROGRAM & TALK INFORMATION

21-23 SEPTEMBER 2026

**FRED KAISER BUILDING (ECE)
ROOM 2020/2030**

UNIVERSITY OF BRITISH COLUMBIA · VANCOUVER,
CANADA

3 DAYS | 21 TALKS | 3 DISCUSSION SESSIONS

Workshop website: www.topoquantum.vip/iTHEMSUBC

RIKEN iTHEMS · UBC Stewart Blusson Quantum Matter Institute · Co-hosted by RIKEN FQSP, RIKEN Quantum,
and RIKEN RQC

Quantum Information: Entanglement of Mathematics and Physics

PROGRAM

21–23 September 2026 | Fred Kaiser Building (ECE), Room 2020/2030, UBC

Monday, September 21		Condensed Matter, Topology, and Quantum Many-Body Physics	
TIME	SPEAKER	TALK TITLE	CHAIR
08:30–09:00	Morning Session & Breakfast		
09:00–09:10	Marcel Franz UBC / SBQMI	UBC introduction	Shunji Matsuura
09:10–09:20	Satoshi Iso RIKEN iTHEMS	iTHEMS introduction	
09:20–09:55	Akira Furusaki RIKEN CEMS / iTHEMS	Topology of gapped and gapless phases in quantum many-body systems	
09:55–10:30	Marcel Franz UBC / SBQMI	Altermagnets: A New Phase of Magnetic Quantum Matter	
10:30–10:50	Coffee break		
10:50–11:25	Ching-Kai Chiu RIKEN iTHEMS	Time-Reversal Symmetric Majorana Modes in 2D Weyl Heterostructures and Machida–Shibata Lattices	Akira Furusaki
11:25–12:00	Jasmin Bedow UBC	Majorana-based Topological Quantum Algorithms in Magnet-Superconductor Hybrid Structures	
12:00–13:10	Lunch (provided)		
13:10–13:45	Max McGinley UBC	Title to be announced	Ching-Kai Chiu
13:45–14:20	Olivia Di Matteo UBC / SBQMI	Title to be announced	
14:20–14:40	Coffee break		
14:40–15:15	Shunji Matsuura RIKEN iTHEMS	Quantum Krylov Learning	Ryuji Takagi
15:15–16:20	Focused discussion — Topology, entanglement, and quantum information		Ryuji Takagi
16:20–16:30	Wrap-up		
17:30	Reception / conference dinner		

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PROGRAM

21–23 September 2026 | Fred Kaiser Building (ECE), Room 2020/2030, UBC

Tuesday, September 22				Quantum Information, Quantum Computing, and Quantum Error Correction			
Time		Speaker		Talk Title		Chair	
08:30–09:00		Morning Session & Breakfast					
09:00–09:35		Bartosz Regula RIKEN RQC		How to really define entropies of quantum states?		Daochen Wang	
09:35–10:10		Ryuji Takagi University of Tokyo		Characterizing universal protocols in quantum information			
10:10–10:30		Coffee break					
10:30–11:05		Sisi Zhou Perimeter Institute		Efficient measurement protocols for multi-parameter quantum metrology		Masamichi Miyaji	
11:05–11:40		Yoshimasa Hidaka YITP, Kyoto University		Non-Abelian lattice gauge theory via topological quantum field theory: phases, thermalization, and quantum simulation			
11:40–12:50		Lunch (provided)					
12:50–13:25		Daochen Wang UBC Computer Science		An uncertainty principle for entanglement		Bartosz Regula	
13:25–14:00		Polina Feldmann UBC		A geometric framework for measurement-based quantum computing			
14:00–14:20		Coffee break					
14:20–14:55		Yosuke Kubota Kyoto University		SPT phases and homotopy theory		Masahito Yamazaki	
14:55–16:20		Focused discussion — Resource theory, computation, QEC, and mathematical structures				Masahito Yamazaki	
16:20–16:30		Wrap-up					

Quantum Information: Entanglement of Mathematics and Physics

PROGRAM

21–23 September 2026 | Fred Kaiser Building (ECE), Room 2020/2030, UBC

Wednesday, September 23		Mathematics, QFT, Quantum Error Correction, and Quantum Gravity	
TIME	SPEAKER	TALK TITLE	CHAIR
08:30–09:00	Morning Session & Breakfast		
09:00–09:35	Yasuyuki Kawahigashi University of Tokyo / iTHEMS	Two-dimensional topological order, tensor networks and operator algebras	Yosuke Kubota
09:35–10:10	Carolyn Zhang UBC	Fusion-assisted decoding of non-Abelian topological order	
10:10–10:30	Coffee break		
10:30–11:05	Masahito Yamazaki Kavli IPMU, University of Tokyo	Title to be announced	Masazumi Honda
11:05–11:40	Aswin Parayil Mana University of Tokyo	Higher-order topological phases protected by noninvertible and subsystem symmetries	
11:40–12:50	Lunch (provided)		
12:50–13:25	Alex May Perimeter Institute	Magic and communication complexity	Mark Van Raamsdonk
13:25–14:00	Masamichi Miyaji RIKEN iTHEMS	Black hole interior volume and topology changes in quantum gravity	
14:00–14:20	Coffee break		
14:20–14:55	Mark Van Raamsdonk UBC Physics & Astronomy	Observable algebras and entropies for spacetime regions	Satoshi Iso
14:55–16:20	Final discussion — Entanglement across mathematics and physics; future iTHEMS–UBC collaboration		Satoshi Iso, Marcel Franz & Yasuyuki Kawahigashi
16:20–16:30	Closing remarks		

TALK ABSTRACTS

Monday, September 21

Condensed Matter, Topology, and Quantum Many-Body Physics

MONDAY · 09:20-09:55

Akira Furusaki

RIKEN CEMS / ITHEMS

Topology of gapped and gapless phases in quantum many-body systems

Symmetry-protected topological (SPT) phases are the set of ground states that cannot be connected to trivial product states when Hamiltonian is deformed continuously while keeping symmetry of interest. After briefly reviewing the classification of the SPT phases, I will discuss the topology of gapped and gapless phases in the parameter space (phase diagram) of quantum many-body systems.

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MONDAY · 09:55-10:30

Marcel Franz

UBC / SBQMI

Altermagnets: A New Phase of Magnetic Quantum Matter

I will discuss symmetry principles and electronic structure that distinguish altermagnets from conventional ferro- and antiferromagnets, and that make them a compelling material family for both theorists and experimentalists. I will also highlight their potential for applications in spintronics and information technologies. Time permitting, I will discuss how recently discovered metallic altermagnets may host unconventional superconducting phases which further expand the reach and the utility of this new phase of matter.

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MONDAY · 10:50-11:25

Ching-Kai Chiu

RIKEN ITHEMS

Time-Reversal Symmetric Majorana Modes in 2D Weyl Heterostructures and Machida-Shibata Lattices

Majorana zero modes are charge-neutral, self-conjugate quasiparticles bound to defects of topological superconductors, whose non-Abelian statistics make them promising for topological quantum computation. Class-D Majoranas require broken time-reversal symmetry, whereas Majorana Kramers pairs in class DIII form a distinct species realizable without magnetic fields. I will discuss two complementary realizations. First, in Machida-Shibata lattices of non-magnetic adatom corrals on a Rashba-coupled superconductor, competing emergent singlet and triplet pairings drive nontrivial DIII phases hosting Kramers pairs of Majorana zero modes at the ends of 1D chains. Second, in a 2D Weyl semimetal/d-wave superconductor heterostructure, the energy asymmetry of the helical edge bands allows Majorana corner modes to be tuned by gate voltages, enabling adiabatic relocation and exchange of time-reversal-symmetric pairs.

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MONDAY · 11:25-12:00

Jasmin Bedow

UBC

Majorana-based Topological Quantum Algorithms in Magnet-Superconductor Hybrid Structures

Majorana zero modes harbored by topological superconductors may be the key ingredient for the realization of fault-tolerant quantum computing and topologically protected quantum devices. Therein, magnet-superconductor hybrid (MSH) systems have proven to be an experimentally versatile platform for quantum engineering the emergence of topological superconductivity and the associated Majorana modes.

In this talk, I will show how topological nodal-point superconductivity (TNPS), for which strong evidence was observed in recent scanning tunneling microscopy experiments, can be realized in two-dimensional MSH systems using checkerboard and spiral magnetic structures. Due to its symmetry classification, this intriguing topological phase shows unique and edge-dependent low-energy modes, which can be used to identify the underlying topology.

Moreover, I will show how the ability to manipulate the magnetic structure of a 1D MSH network is a powerful tuning knob for the realization of topological quantum gates and algorithms with Majorana zero modes. In particular, I will demonstrate the simulation of the Bernstein-Vazirani algorithm, which lets one extract a hidden number from the topological system. Finally, I will discuss alternative architectures for topological quantum gates in 2D MSH systems and show how transitions between one-dimensional Majorana edge modes and zero-dimensional Majorana zero modes can be facilitated through magnetic vortices.

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MONDAY · 13:10-13:45

Max McGinley

UBC

*Title to be announced**Abstract to be announced.*[Back to Monday, September 21 program ↑](#)

MONDAY · 13:45-14:20

Olivia Di Matteo

UBC / SBQMI

*Title to be announced**Abstract to be announced.*[Back to Monday, September 21 program ↑](#)

MONDAY · 14:40-15:15

Shunji Matsuura

RIKEN iTHEMS

Quantum Krylov Learning*Abstract to be announced.*[Back to Monday, September 21 program ↑](#)

TALK ABSTRACTS

Tuesday, September 22

Quantum Information, Quantum Computing, and Quantum Error Correction

TUESDAY · 09:00–09:35

Bartosz Regula

RIKEN RQC

How to really define entropies of quantum states?

We overview the many possible definitions of entropic quantities of quantum states, including Rényi relative entropies and smooth entropies derived from them. We discuss how operational problems in quantum information such as hypothesis testing help identify which of the definitions are really “correct” and practically meaningful. Focusing on the problem of quantum randomness extraction, we show that rethinking how to define smooth Rényi conditional entropies can lead to significantly tighter achievability results that improve on all previously known approaches, which then leads to improved bounds on the extractable key in quantum key distribution. We show that the new approach to smooth conditional entropies naturally connects with operator space techniques in non-commutative probability theory, which allows us to prove the optimality of our estimates.

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TUESDAY · 09:35–10:10

Ryuji Takagi

University of Tokyo

Characterizing universal protocols in quantum information

Universal protocols are the processes constructed without knowing the input state, and thus work for any input state universally. I present recent developments in characterizing the performance of universal protocols in several operational settings. Through these examples, I discuss how this viewpoint—whether we possess the knowledge of the input state—provides new insights into quantum information and resource theory, and how it could serve as a bridge between other disciplines, such as quantum computation and learning theory.

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TUESDAY · 10:30–11:05

Sisi Zhou

Perimeter Institute

Efficient measurement protocols for multi-parameter quantum metrology

Multi-parameter estimation is ubiquitous but fundamentally challenging because different parameters generally cannot all be estimated simultaneously, as reflected by the uncertainty principle. This makes optimal measurement design both conceptually and experimentally difficult. Inspired by recent advances in quantum learning, I will present measurement protocols for several multi-parameter sensing problems that are efficiently implementable while remaining near-optimal in sensitivity.

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TUESDAY · 11:05–11:40

Yoshimasa Hidaka

YITP, Kyoto University

Non-Abelian lattice gauge theory via topological quantum field theory: phases, thermalization, and quantum simulation

Hamiltonian lattice gauge theory avoids the sign problem of Euclidean Monte Carlo and is a natural target for quantum computers. I will present a formulation of non-Abelian lattice gauge theory based on topological quantum field theory with defects, in which physical states are represented by string-nets of Wilson lines and the quantum deformation $SU(2) \rightarrow SU(2)_k$ renders the Hilbert space finite. As applications, I will discuss the confinement–topological phase transition in (2+1) dimensions, the thermalization of Yang–Mills theory on a cube, and a quantum simulation on the Quantinuum H1 quantum computer (REIMEI).

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TUESDAY · 12:50–13:25

Daochen Wang

UBC Computer Science

An uncertainty principle for entanglement

Consider two orthonormal bases of a bipartite Hilbert space such that states in one basis are weakly entangled and states in the other are strongly entangled. We establish a quantitative version of the following uncertainty principle: every state that is localized in one basis must be delocalized in the other. More specifically, we lower bound the sum of the Shannon entropies of any state's coefficient distributions in the two bases by the difference between the entanglement Rényi entropies of their basis states. The result follows from new lower and upper bounds on the entanglement of superpositions that may be of independent interest. Based on joint work with Mitali Nanda.

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TUESDAY · 13:25–14:00

Polina Feldmann

UBC

A geometric framework for measurement-based quantum computing

Boosting the classical side-processing in mod-2 measurement-based quantum computing (MBQC) to universal classical computation requires contextuality. In the temporally flat case, the contextuality of an MBQC algorithm is witnessed by a topological (cohomological) invariant. However, in general, MBQC is adaptive and thus temporally ordered. We present a geometric framework that encompasses the temporally ordered case. The framework is based on projective faces, which encode product relations among operators that commute on a subspace. Every realization of the MBQC algorithm can be represented by merging, measurement by measurement, the appropriate projective faces from a generating set. When paired with a non-contextual value assignment, our framework gives rise to a chain complex, which we use to extend the cohomological framework for contextual MBQC to the temporally ordered case. The algebraic structure of the geometric framework and its relation to quantum logic deserve further investigation.

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TUESDAY · 14:20–14:55

Yosuke Kubota

Kyoto University

SPT phases and homotopy theory

Symmetry-protected topological (SPT) phases capture robust patterns of many-body entanglement protected by symmetry. In this talk, I will explain a homotopy-theoretic approach to the study of SPT phases initiated by Kitaev, based on the idea that the spaces of invertible phases would form a generalized cohomology theory, which is built on a rigorous functional-analytic realization of quantum spin systems.

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TALK ABSTRACTS

Wednesday, September 23

Mathematics, QFT, Quantum Error Correction, and Quantum Gravity

WEDNESDAY · 09:00-09:35

Yasuyuki Kawahigashi

University of Tokyo / iTHEMS

Two-dimensional topological order, tensor networks and operator algebras

Tensor categories describe a new type of symmetry appearing in two-dimensional topological order and tensor networks give useful tools to study their mathematical structures. We present relations between this approach and operator algebraic methods in the Jones theory of subfactors.

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WEDNESDAY · 09:35-10:10

Carolyn Zhang

UBC

Fusion-assisted decoding of non-Abelian topological order

Maximum likelihood decoders perform decoding on noisy quantum states by measuring a set of syndromes, classically computing an optimal recovery based on these syndromes, and then performing that recovery. For the toric code state under incoherent Pauli noise, the maximum likelihood decoder using syndromes corresponding to the local anyon excitations reaches the intrinsic mixed-state information theoretic recoverability threshold, which maps onto a point along the Nishimori line of the random-bond Ising model. For non-abelian topological orders, maximum likelihood decoders using local anyon syndromes do not in general reach information theoretic thresholds. We show that using enlarged syndrome sets that include measurements that resolve non-abelian anyon fusion outcomes leads to improved maximum likelihood decoders. A hierarchy of increasingly refined syndrome sets gives rise to a hierarchy of effective mixed states from the perspective of the decoder. We analyze the thresholds for these decoders using a mapping to classical partition functions, which allows for efficient classical simulation.

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WEDNESDAY · 10:30-11:05

Masahito Yamazaki

Kavli IPMU, University of Tokyo

*Title to be announced**Abstract to be announced.*[Back to Wednesday, September 23 program ↑](#)

WEDNESDAY · 11:05–11:40

Aswin Parayil Mana

University of Tokyo

Higher-order topological phases protected by noninvertible and subsystem symmetries

In this talk, I will discuss Kramers–Wannier duality and the Kennedy–Tasaki transformation in lattice spin systems. I will then generalize these notions to spin models with subsystem symmetries. Next, I will introduce the notion of symmetry-protected topological (SPT) phases protected by non-invertible symmetries and present a systematic procedure for their classification. Building on these ideas, I will discuss generalizations to higher dimensions, where SPT phases are protected by both subsystem and non-invertible symmetries. We find that some of these phases can be distinguished as higher-order SPT phases, which host boundary modes on higher-codimensional boundaries.

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WEDNESDAY · 12:50–13:25

Alex May

Perimeter Institute

Magic and communication complexity

Magic is a key resource considered in quantum computing, and has been identified as necessary for the appearance of quantum advantage. In this work, we relate magic in quantum circuits to the communication complexity of Boolean functions, a well-studied but apparently distinct topic. These connections lead to two useful outcomes: First, we give new techniques for proving lower bounds on the number of magic gates needed in quantum circuits computing Boolean functions. Second, we establish new, strong, forms of quantum advantage in communication complexity.

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WEDNESDAY · 13:25–14:00

Masamichi Miyaji

RIKEN ITHEMS

Black hole interior volume and topology changes in quantum gravity

Topology change has been one of the main theme in the study of quantum gravity, as it diagnoses the microscopic spectral statistics of quantum gravity microstates. Yet, it is highly nontrivial to incorporate these quantum effects into the bulk observables such as black hole interior volume. These observables are also interesting from the dual CFT point of view as their close relationship to the Krylov state complexity. In this talk, I describe several distinct ways to define BH interior observables, and explain how they are related to the boundary Krylov complexity. I will particularly emphasize the existence of infinitely many maximal volume timeslices in the presence of baby universe, which leads to an over-complete length basis and a divergence in naive definitions of length. Such divergence disappears once we construct proper complete length basis using Gram-Schmidt orthogonalization. Consequently, we can see the transition to smaller interior BH at late times. As a closely related topic, if time allows, I will also explain a generalization of the ETH matrix model which describes multi-closed universe, whose microscopic Hilbert space is given by $H \otimes \bar{H}$.

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WEDNESDAY · 14:20–14:55

Mark Van Raamsdonk

UBC Physics & Astronomy

Observable algebras and entropies for spacetime regions

In semiclassical gravity, the generalized entropy of a region is defined to be the area of the boundary (in units of $4 G_N$) plus the entropy of the quantum fields in the interior. We describe how for a certain class of regions that we call extremal, this generalized entropy obeys monotonicity and strong subadditivity properties similar to certain quantum entropies. The set of extremal regions has similar mathematical properties to the set of subalgebras of an algebra of observables. We suggest that there may be a correspondence between spacetime regions and subalgebras in some underlying fundamental description of the quantum gravity theory. We provide evidence for this using tensor networks that are used as toy models of holographic quantum gravity theories.

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