Titles and Abstracts

Modular invariance in conformal field theory

Yasuyuki Kawahigashi
The University of Tokyo

A rational two-dimensional conformal field theory often gives a modular invariant partition function through the action of SL(2,Z) on the upper half plane. We present a new physical interpretation of such modular invariance and relate modular invariance, violation of Haag duality, and the Renyi entropy.

Bio: Kawahigashi received a Ph.D. at UCLA in 1989. He has held a position at the University of Tokyo since then with a one-year period at UC Berkeley as a Miller Research Fellows. He received the Spring Prize of Mathematical Society of Japan in 2002 and gave an invited talk at ICM in 2018. He has been an editor of 10 journals including Communications in Mathematical Physics.

Quantum computing of fluid dynamics via Hamiltonian simulation

Yue Yang(杨越)
Peking University

It is anticipated that quantum computing will be able to tackle hard real-world problems. Fluid dynamics, a highly challenging problem in classical physics and various applications, emerges as a good candidate for showing quantum utility. We report our recent progress on quantum computing of fluid dynamics. In theory, we propose a quantum spin representation of fluid dynamics, which transforms the Navier-Stokes equation into the Schrödinger-Pauli equation through the generalized Madelung transformation. In this way, the fluid flow can be regarded as a special quantum system, which is feasible for flow simulation on a quantum computer. In terms of algorithm, we propose a quantum Hamiltonian simulation algorithm, which is able to simulate compressible or incompressible flows and scalar convection-reaction-diffusion problems with quantum acceleration. In terms of hardware implementation, we have realized the quantum simulation of two-dimensional unsteady flow on a quantum processor. These results demonstrate the potential of quantum computing to simulate complex flows, including turbulence, in future endeavors.

Bio: Yue Yang, Professor and Chair of the Department of Mechanics and Engineering Science, Vice Dean of College of Engineering, Peking University. Yang received BE degree from Zhejiang University in 2004, MS degree from the Institute of Mechanics, Chinese Academy of Sciences in 2007, and PhD degree from California Institute of Technology in 2011, and then he was sponsored by the CEFRC Fellowship for postdoc research at Princeton University and Cornell University. Yang joined Peking University in 2013. He received the NSFC National Distinguished Young Researcher award, Xplorer Prize, and MOE Young Scientist Award. His research interests include turbulence, combustion, vortex dynamics, and quantum computing.

Kiteav quantum double

Xiaoyu Dong(董小玉)
Hefei National Laboratory

In 1+1D quantum systems, the underlying properties are often related to the topological order of a 2+1D system. Rather than starting from a 1+1D perspective, we investigate the phases and phase transitions of a 2+1D system with a boundary, which is effectively described by a 1+1D quantum model. We construct the gapped boundaries of Kitaev's quantum double directly from the topological order in the bulk, using Lagrangian condensable algebras of anyon condensation. This framework establishes a direct correspondence between the 2+1D topological order, anyon condensation, and the effective 1+1D model with a global symmetry.

Bio: Dr. Xiao-Yu Dong is a junior researcher at the Hefei National Laboratory. She received Ph.D. degree in Physics from Tsinghua University and subsequently undertook postdoctoral positions at the Max Planck Institute for the Physics of Complex Systems, California State University, Northridge, and Ghent University. Her current research focuses on numerical simulations of quantum many-body systems using tensor networks, topological order and topological phase transitions, and quantum error correction codes.

Mixed state phase transitions: Ising, Nishimori and self-duality

Guoyi Zhu(朱国毅)
Hong Kong University of Science and Technology (Guangzhou)

The rapid development of quantum technology brings the quantum measurement and noise as new ingredients to the quantum many-body physics, asking for deeper understanding of the mixed state phase of matter in open quantum systems. In this talk I will first discuss how the paradigmatic Ising phase transition is transformed to the strongly disordered Nishimori transition in an open quantum system, about its theory and experimental realization in the GHZ state preparation or decoherence of toric code. Then I will focus on the Kramers Wannier self-duality, a non-invertible algebraic symmetry, being generalized to the mixed state as an average symmetry that governs a new type of criticality.

Bio: Guo-Yi Zhu obtained his PhD degree in Physics from Tsinghua University in 2019, majoring in topological phases of matter and phase transitions from strongly correlated quanutm many-body systems. From 2019 to 2021, he works as a post-doctoral fellow for the Max-Planck-Institute for the Physics of Complex Systems in Germany, on the problems related to out-of-equilibrium quantum dynamics in topological and lattice gauge systems. Afterwards, he joins the Institute for Theoretical Physics, University of Cologne in Germany, in pursuit of the realization of long-range entangled states in the rising quantum computing platforms. Since July 2024, he joins the Hong Kong University of Science and Technology (Guangzhou) as an assistant professor. Overall, his research interests cover a broad spectrum in the fields of condensed matter physics and quantum information, tracking the main theme of understanding, characterizing and realizing entangled quantum matter.

Reverse unknown quantum processes

Xin Wang(王鑫)
HKUST (Guangzhou)

Reversing an unknown unitary evolution remains a formidable challenge, as conventional methods necessitate an infinite number of queries to fully characterize the quantum process. Here we introduce the Quantum Unitary Reversal Algorithm (QURA), a deterministic and exact approach to universally reverse arbitrary unknown unitary transformations using O(d^2) calls of the unitary, where d is the system dimension. Our construction resolves a fundamental problem of time-reversal simulations for closed quantum systems by affirming the feasibility of reversing any unitary evolution without knowing the exact process. The algorithm also provides the construction of a key oracle for unitary inversion in quantum algorithm frameworks such as quantum singular value transformation. We also propose the framework of virtual combs that exploit the unknown process iteratively with additional classical post-processing to simulate the process inverse.

Bio: Xin Wang, an Associate Professor at the Thrust of Artificial Intelligence, The Hong Kong University of Science and Technology (Guangzhou), focuses on quantum information and quantum artificial intelligence research. He previously worked as a Senior Researcher and Tech Lead at Baidu Research, where he led the development of the quantum machine learning platform Paddle Quantum. Before joining Baidu, he was a Hartree Fellow at the Joint Center for Quantum Information and Computer Science at the University of Maryland. Wang earned his Ph.D. from the University of Technology Sydney in 2018, receiving the prestigious Chancellor's Outstanding Thesis award. He has published over 70 papers in top-tier journals and conferences and has given numerous oral presentations at leading quantum computing and AI conferences. In 2020, he was invited to deliver a keynote speech at the top-tier quantum computing conference TQC. He has served as a program committee member for various international conferences and as an editor for the Quantum journal. He was selected for the National Young Talent program, Top Young Chinese Scholar in Artificial Intelligence, and World's Top 2% Scientists.

Automated Discovery of Branching Rules with Optimal Complexity for the Maximum Independent Set Problem

Jinguo Liu(刘金国)
Hong Kong University of Science and Technology (Guangzhou)

The branching algorithm is a fundamental technique for designing fast exponential-time algorithms to solve combinatorial optimization problems exactly. It divides the entire solution space into independent search branches using predetermined branching rules and ignores the search on suboptimal branches to reduce the time complexity. The complexity of a branching algorithm is primarily determined by the branching rules it employs, which are often designed by human experts. In this paper, we show how to automate this process with a focus on the maximum independent set problem. The main contribution is an algorithm that efficiently generates optimal branching rules for a given sub-graph with tens of vertices. Its efficiency enables us to generate the branching rules on-the-fly, which is provably optimal and significantly reduces the number of branches compared to existing methods that rely on expert-designed branching rules. Numerical experiment on 3-regular graphs shows an average complexity of O(1.0441^n) can be achieved, better than any previous methods.

Bio: Dr. Jinguo Liu acquired his Ph.D. training in Prof. Qiang-Hua Wang's group at Nanjing University on condensed matter physics. After that, he has been a postdoc in Prof. Lei Wang's group at the Institute of Physics (CAS) for two years, a full-time consultant in QuEra computing for half a year, and a postdoc in Prof. Mikhail Lukin's group at Harvard University for two years. His research direction is diverse, while all his studies are about developing new and better algorithms for solving existing or new problems. He is a passionate open source scientific software developer and he has the superpower of speeding up code in his lab by two orders.

Adaptive quantum optimization algorithms

Robert James Joynt
University of Wisconsin-Madison

One of the most promising types of quantum algorithms are those that solve combinatorial optimization problems. There are a number of difficulties that stand in the way: small gaps to excited states, barren plateaus in the energy, and incomplete expressibility of the states. These obstacles can be dealt with by making the quantum algorithms adaptable. I will describe several ways to do this, and show that considerable improvements over non-adaptive algorithms are possible.

Bio: Robert Joynt received his Ph.D. from the University of Maryland in 1982 and was a postdoctoral fellow at the Cavendish Laboratory of the University of Cambridge and the Institute for Theoretical Physics at ETH-Zurich. He has been Professor of Physics at the University of Wisconsin-Madison from 1986 to 2023, where he is now Emeritus Professor. He is also a Senior Fellow at the Kavli Institute for Theoretical Sciences in Beijing. His research has ranged from the quantum Hall effect to high-Tc superconductivity to neutron stars to quantum computing.

Testing non-Gaussian entanglement and its applications

Qiongyi He(何琼毅)
Peking University

Quantum entanglement is a distinctive feature of quantum physics and is key resource in many quantum information tasks. Entanglement in continuous-variable non-Gaussian states are of particular interest in quantum technology due to their potential applications in quantum computing and quantum metrology. However, how to create such states and detect its non-Gaussian entanglement remain a challenge since the sheer amount of information in such states grows exponentially and makes a full characterization impossible. Here, I would introduce our recent progress for creating non-Gaussian states and experimentally feasible approach to detect non-Gaussian entanglement.

Bio: Qiongyi He, Peking University Boya Distinguished Professor. Her main research field is quantum optics and quantum information, including the detection, classification, quantification of various types of quantum correlations, as well as their applications in quantum information processing. To date, she has published over 100 journal papers, including Nature Physics, Nature Communications, Physical Review Letters, Science Bulletin. She has been awarded funding from National Science Fund for Distinguished Young Scholars, the Wang Daheng Optical Award, and the China Young Female Scientists Award.

Barren Plateaus and Local Traps: Solutions via Many-Body Localization and Applications to Phase Transition Detection

Chenfeng Cao(曹晨风)
Freie Universität Berlin

Variational quantum optimization is a pivotal approach for leveraging near-term quantum devices to achieve practical quantum advantages. However, it faces two major challenges that impede its scalability and effectiveness. The first challenge arises when quantum circuits become deep, leading to the barren plateau phenomenon, where the optimization landscape becomes exponentially flat. The second challenge emerges with shallow circuits, which are susceptible to exponential local traps, hindering the convergence to desirable solutions. In this talk, I will present two strategies addressing these distinct challenges. To mitigate the barren plateaus associated with deep circuits, we propose leveraging many-body localization (MBL) within Floquet-initialized quantum circuits. By initializing the circuit in the MBL phase, we inhibit the formation of a unitary 2-design, thereby maintaining area-law entanglement instead of volume-law entanglement. This approach effectively circumvents barren plateaus during the optimization process. In the presence of the second challenge—exponential local traps in shallow circuits—we explore new applications in quantum phase transition characterization. We introduce a hybrid algorithm that integrates quantum optimization with classical machine learning techniques—utilizing LASSO for identifying conventional phase transitions and Transformer models for detecting topological transitions. This method employs a sliding window of Hamiltonian parameters to learn appropriate order parameters and accurately estimate critical points.

Bio: Chenfeng is a Humboldt Research Fellow at Freie Universität Berlin, working with Prof. Jens Eisert. He obtained his Ph.D. in Physics from the Hong Kong University of Science and Technology in 2024 under the supervision of Prof. Bei Zeng and received his B.S. in Physics from the University of Chinese Academy of Sciences in 2019. From 2023 to 2024, he worked as a research consultant at Phasecraft, hosted by Prof. Ashley Montanaro. Chenfeng's research interests encompass various theoretical aspects of quantum information, with a focus on near-term quantum advantage, including quantum sampling advantage, quantum simulation, quantum error mitigation, and quantum machine learning.

Using quantum gradients to optimize parameterized quantum circuits

Keren Li(李可仁)
Shenzhen University

Parameterized Quantum Circuits (PQCs) are crucial in quantum machine learning and circuit synthesis, enabling the practical realization of complex quantum tasks. However, the learning of PQCs is primarily limited to classical optimization methods, facing issues such as gradient vanishing. In this work, we introduce a nested optimization model that utilizes quantum gradients to enhance the learning of PQCs for polynomial-type cost functions. Our approach leverages quantum algorithms to effectively navigate the optimization landscape, identifying and overcoming a typical type of gradient vanishing in learning a PQC. Through numerical experiments, we demonstrate the feasibility of our method on two tasks: the Max-Cut problem and polynomial optimization. Our method excels in generating circuits without gradient vanishing and effectively optimizes the cost functions. In addition, from the perspective of quantum algorithms, our model improves quantum optimization for polynomial-type cost functions, addressing the challenge of exponential growth in

sample complexity.

Bio: Li Keren, Assistant Professor and Associate Researcher at Shenzhen University, primarily focuses on quantum algorithms and their experimental implementation in nuclear spin and photon systems. He earned his PhD from Tsinghua University in 2019. Before joining Shenzhen University, he worked at Pengcheng Laboratory, researching quantum control and integrated optics algorithms. He has published over 30 papers in journals such as Physical Review Letters, Physical Review A, and npj Quantum Information.

A study of 1D lattice models with exact fusion category symmetry

Chenjie Wang(王晨杰)
The University of Hong Kong

I will discuss a construction of a family of 1D quantum lattice models that respect unitary fusion category symmetry. This family can be thought of as edge models of 2D symmetry-enriched topological states. An interesting feature of these models is that they often (but may not always) exhibit a gapless critical phase (i.e., a gapless region of codimension zero in the parameter space) due to the presence of category symmetry. I will discuss numerical results of some examples.

Bio: Chenjie Wang is currently an Associate Professor at University of Hong Kong. He graduated from University of Science and Technology of China, and obtained his PhD in physics from Brown University in 2012. He has been working on transport in quantum Hall systems and theories of strongly correlated topological phases. His recent research interests include theorie of topological phases of matter, quantum critical phenomena and localization physics.

Noncommutative polynomial optimization and Bell inequalities

Jie Wang(王杰)
Academy of Mathematics and Systems Science, CAS

In the first part, we review the classic non-commutative polynomial optimization, the Navascues-Pironio-Acin hierarchy of semidefinite relaxations, and its application in quantum information science -- computing the maximum quantum violation of linear Bell inequalities. State polynomials (polynomials in operators and expectations) are a further generalization of non-commutative polynomials. In the second part, we introduce the theory of state polynomial optimization, and present the generalization of Navascues-Pironio-Acin hierarchy for solving state polynomial optimization problems. Finally, we give a method for computing the maximum quantum violation of nonlinear Bell inequalities based on state polynomial optimization.

Bio: Jie Wang is an associate researcher at Academy of Mathematics and Systems Science, Chinese Academy of Sciences (AMSS-CAS). He received his PhD from AMSS-CAS in 2017. He conducted postdoctoral research at Peking University from 2017 to 2019, and from 2019 to 2021 at the French National Center for Science. He was selected in the “Chen Jingrun Future Star” Program of AMSS-CAS and the Special Project for Development of Young Talents of Operations Research Society of China. His research interests include: polynomial optimization, semidefinite programming, quantum information, etc.

Dimension liftings for quantum Computation of partial differential equations and related problems

Shi Jin(金石)
Shanghai Jiao Tong University

Quantum computers have the potential to gain algebraic and even up to exponential speed up compared with its classical counterparts, and can lead to technology revolution in the 21st century. Since quantum computers are designed based on quantum mechanics principle, they are most suitable to solve the Schrodinger equation, and linear PDEs (and ODEs) evolved by unitary operators. The most efficient quantum PDE solver is quantum simulation based on solving the Schrodinger equation. It will be interesting to explore what other problems in scientific computing, such as ODEs, PDEs, and linear algebra that arise in both classical and quantum systems, can be handled by quantum simulation.
We will present a systematic way to develop quantum simulation algorithms for general differential equations. Our basic framework is dimension lifting, that transfers nonlinear PDEs to linear ones, and linear ones to Schrodinger type PDEs. For non-autonomous PDEs and ODEs, or Hamiltonian systems with time-dependent Hamiltonians, we also add an extra dimension to transform them into autonomous PDEs that have only time-independent coefficients, thus quantum simulations can be done without using the cumbersome Dyson's series and time-ordering operators. Our formulation allows both qubit and qumode (continuous-variable) formulations, and their hybridizations, and provides the foundation for analog quantum computing.

Bio: Shi Jin, professor at Shanghai Jiao Tong University, foreign member of Academia Europaea-Academy of Europe, fellow of European Academy of Sciences. editor-in-Chief of Communications in Mathematical Sciences.

Generalized Quantum Stein's Lemma and Second Law of Quantum Resource Theories

Masahito Hayashi(林正人)
The Chinese University of Hong Kong, Shenzhen

The second law of thermodynamics is the cornerstone of physics, characterizing the convertibility between thermodynamic states through a single function, entropy. Given the universal applicability of thermodynamics, a fundamental question in quantum information theory is whether an analogous second law can be formulated to characterize the convertibility of resources for quantum information processing by a single function. In 2008, a promising formulation was proposed, linking resource convertibility to the optimal performance of a variant of the quantum version of hypothesis testing. Central to this formulation was the generalized quantum Stein's lemma, which aimed to characterize this optimal performance by a measure of quantum resources, the regularized relative entropy of resource. If proven valid, the generalized quantum Stein's lemma would lead to the second law for quantum resources, with the regularized relative entropy of resource taking the role of entropy in thermodynamics. However, in 2023, a logical gap was found in the original proof of this lemma, casting doubt on the possibility of such a formulation of the second law. In this work, we address this problem by developing alternative techniques to successfully prove the generalized quantum Stein's lemma under a smaller set of assumptions than the original analysis. Based on our proof, we reestablish and extend the second law of quantum resource theories, applicable to both static resources of quantum states and a fundamental class of dynamical resources represented by

classical-quantum (CQ) channels. These results resolve the fundamental problem of bridging the analogy between thermodynamics and quantum information theory.

Bio: Masahito Hayashi received the B.S. degree from the Faculty of Sciences, Kyoto University, Japan, in 1994, and the M.S. and Ph.D. degrees in mathematics from Kyoto University, Japan, in 1996 and 1999, respectively. He worked in Kyoto University as a Research Fellow of the Japan Society of the Promotion of Science (JSPS) from 1998 to 2000, and worked in the Laboratory for Mathematical Neuroscience, Brain Science Institute, RIKEN from 2000 to 2003, and worked in ERATO Quantum Computation and Information Project, Japan Science and Technology Agency (JST) as the Research Head from 2000 to 2006. He worked in the Graduate School of Information Sciences, Tohoku University as Associate Professor from 2007 to 2012. In 2012, he joined the Graduate School of Mathematics, Nagoya University as Professor. He worked in the Shenzhen Institute for Quantum Science and Engineering, Southern University of Science and Technology as Chief Research Scientist from 2020 to 2023. In 2023, he joined School of Data Science, The Chinese University of Hong Kong, Shenzhen as Professor and was granted as Presidential Chair Professor. He also joined Shenzhen International Quantum Academy as Chief Research Scientist.
Also, he worked in Centre for Quantum Technologies, National University of Singapore as Visiting Research Associate Professor from 2009 to 2012 and as Visiting Research Professor from 2012 to 2024. He also worked in Shenzhen Institute for Quantum Science and Engineering, Southern University of Science and Technology, China as a Visiting Professor from 2018 to 2020. He joined Department of Information Engineering, The Chinese University of Hong Kong as Adjunct Professor in 2024.

Randomized quantum measurements in quantum information processing

Huangjun Zhu(朱黄俊)
Fudan University

Quantum measurements are the key for extracting information from quantum systems and for connecting the quantum world with the classical world. For many applications in quantum information processing, randomized measurements have proved to be much more efficient in information extraction. In this talk I will discuss the applications of randomized measurements in various tasks, including quantum state verification, entanglement certification, and shadow estimation etc. As important mathematical tools underlying randomized measurements, the roles of complex projective designs and unitary designs will be highlighted.

Bio: Prof. Huangjun Zhu got Bachelor, Master, and PhD degrees from Zhejiang University, Peking University, and National University of Singapore, respectively. After postdoctoral research at Perimeter Institute and Cologne Institute for Theoretical Physics, he joined Department of Physics, Fudan University in January 2018. His main research interest is quantum information theory, including quantum measurements, quantum characterization, verification, and validation (QCVV), entanglement theory, and blind quantum computation etc.

Quantum algorithms and applications in the noisy intermediate-scale quantum era

Hsi-Sheng Goan(管希聖)
Taiwan University

In the noisy intermediate-scale quantum (NISQ) era, quantum computing devices are characterized by limited sizes, imperfect quantum gates, and the absence of quantum error correction (QEC). Despite these limitations, the quality and reliability of NISQ devices have been steadily improving, with the goal of achieving a significant increase in reliable circuit depths through qubit fabrication advancements error mitigation techniques. Therefore, it is crucial to explore quantum algorithms and applications that use NISQ devices and can demonstrate advantages over traditional approaches with improved performance before fully error-corrected fault-tolerant quantum computers become available. In this talk we will discuss quantum computational approaches refined to overcome the challenge of limited quantum resources in the NISQ era in the fields of quantum computational chemistry and quantum machine learning.

Bio: Professor Hsi-Sheng Goan received his Ph.D. degree in physics from the University of Maryland, College Park, USA, in 1999. He then worked as a Postdoctoral Research Fellow at the University of Queensland, Brisbane, Australia, from 1999 to 2001. From 2002 to 2004, he was a Senior Research Fellow awarded the Hewlett-Packard Fellowship at the Center for Quantum Computer Technology, University of New South Wales, Sydney, Australia, before he took up a faculty position at the Department of Physics, National Taiwan University (NTU) in 2005. He has been a Professor of Physics at NTU since 2011 working in the fields of Quantum Computing and Quantum Information, Quantum Control, Open Quantum Systems, Mesoscopic (Nano) Physics, and Quantum Optics He is currently the Director of the Center for Quantum Science and Engineering at NTU, and the Director of the IBM Quantum Hub at NTU.

Mathematical Aspect of Boson Sampling

Kwek Leong Chuan(郭龙泉)
Nanyang Technological University

Boson-sampling, and its scattershot counterpart, is a non-universal quantum computer that is believed achieved significant computational advantage over classical computing. It is significantly more straightforward to build than any universal quantum computer proposed so far. In this talk, we review aspects of boson sampling and Gaussian boson sampling and its realization on integrated photonic chips.

Bio: LC Kwek is a Principal Investigator (PI) at the Center for Quantum Technologies, National University of Singapore and Professor of Education and Engineering, National Institute of Education, Singapore. He is currently a co-Director of the Quantum Science and Engineering Centre at the Nanyang Technological University. Dr Kwek has published more than 300 publications with several papers in Nature Photonics, Nature Communications, Physical Review Letters, Review of Modern Physics, and so forth. He is the PI or co-PI for numerous projects totaling more than $25 million). He supervises nearly 30 PhD students. He is also an elected Fellow of the American Association for the Advancement of Science, Institute of Physics (UK) and the Institute of Physics Singapore.

Generalized quantum asymptotic equipartition

Kun Fang(方堃)
The Chinese University of Hong Kong, Shenzhen

We establish a generalized quantum asymptotic equipartition property (AEP) beyond the i.i.d. framework where the random samples are drawn from two sets of quantum states. In particular, under suitable assumptions on the sets, we prove that all operationally relevant divergences converge to the quantum relative entropy between the sets. More specifically, both the smoothed min- and max-relative entropy approach the regularized relative entropy between the sets. Notably, the asymptotic limit has explicit convergence guarantees and can be efficiently estimated through convex optimization programs, despite the regularization, provided that the sets have efficient descriptions. We give four applications of this result: (i) The generalized AEP directly implies a new generalized quantum Stein's lemma for conducting quantum hypothesis testing between two sets of quantum states. (ii) We introduce a quantum version of adversarial hypothesis testing where the tester plays against an adversary who possesses internal quantum memory and controls the quantum device and show that the optimal error exponent is precisely characterized by a new notion of quantum channel divergence, named the minimum output channel divergence. (iii) We derive a relative entropy accumulation theorem stating that the smoothed min-relative entropy between two sequential processes of quantum channels can be lower bounded by the sum of the regularized minimum output channel divergences. (iv) We apply our generalized AEP to quantum resource theories and provide improved and efficient bounds for entanglement distillation, magic state distillation, and the entanglement cost of quantum states and channels. At a technical level, we establish new additivity and chain rule properties for the measured relative entropy which we expect will have more applications.

Bio: Prof. Kun Fang is a tenure-track assistant professor in the School of Data Science at The Chinese University of Hong Kong, Shenzhen (CUHK-Shenzhen). Before joining CUHK-Shenzhen, he served as a senior researcher and tech lead at the Institute for Quantum Computing, Baidu, from 2020 to 2023. Prior to that, he worked as a postdoctoral researcher at the University of Cambridge and the University of Waterloo from 2018 to 2020. He earned his PhD in Quantum Information from the University of Technology Sydney in 2018 and obtained his Bachelor’s degree in Mathematics from Wuhan University in 2015. His research interests lie in understanding the capabilities and limitations of quantum resources, as well as their usage in quantum computation and quantum communication.

On the boundary of quantum computing advantage

Junyu Liu(刘峻宇)
University of Pittsburgh

Quantum computing is one of the most exciting future computing technologies based on fundamental law of matrix mechanics. However, the room of quantum algorithms, and when they could offer potential advantages against classical counterparts in practical applications, is highly obscure. In this talk, we will try to help illustrate the boundary of quantum advantages by novel methods provided from advanced tools developed in computer science. First, we will introduce GroverGPT, a large language model simulating quantum searching with 8 billion training parameters. On certain metrics, we could also show that they could outperform OpenAI's GPT-4o. Moreover, we show that the model has significant generalization capabilities and could simulate the result of Grover's quantum circuit with experiments up to 20 parameters, with evidence that the model could "learn" partially the nature of quantum algorithms, which helps illustrate the boundary of classical simulability of quantum Turing machines especially when they are noisy. Second, we show an end-to-end pipeline on the practical noiseless and fault-tolerant resource estimations of the HHL algorithm, a famous quantum algorithm for matrix inversion with provable quantum speedups and is BQP-complete. For a given quantum error correction code setup, we explicitly perform the resource count and identify the space, time, and energy costs for performing HHL algorithms fault-tolerantly, and illustrate when it will outperform classical counterparts for a general setup of condition numbers, row sparsity, precision and the size of matrix. Our works indicate that it is possible to illustrate a practical boundary between quantum and classical computing using most advanced tools in high-performance computing and large language models.

Bio: Dr. Junyu Liu(刘 峻 宇) is an assistant professor of computer science in the University of Pittsburgh (2024-). He previously work at the University of Chicago and IBM, associated with the Chicago Quantum Exchange with a maximally five-year position (2021-2024), with Prof. Liang Jiang and Fred Chong. He got his PhD (2016-2021) from California Institute of Technology, advised by Prof. Clifford Cheung, John Preskill and David Simmons-Duffin, and his bachelor's degree (2012-2016) from the School of the Gifted Young in University of Science and Technology of China (USTC). His current primary research interest us to find practically useful quantum technologies in academia and industry, and their potential connection to computer science and quantum physics, including quantum computing, quantum machine learning, quantum communication, quantum sensing, and quantum-resistant cryptography. He also has various industrial experiences in quantum technologies, including SeQure (co-founder, 2022-), qBraid (scientific advisor, 2022-2024), CQE-IBM (postdoc, 2021-2024), and PsiQuantum (intern, 2020), Dr. Liu has the track-record in publishing in word-leading conferences and journals in quantum information science and engineering, including Nature Communications, Nature's NPJ Quantum Information, PRX Quantum, PRL, ICLR, and IEEE.

Error Correction in Dynamical Codes

Xiaozhen Fu(付小真)
University of Maryland, College Park

Floquet codes and dynamical codes offer a new avenue for quantum error correcting codes. In this talk, I will discuss a general formalism for analyzing the error correcting properties of these codes. Specifically, we extend the notion of distance of static stabilizer codes and subsystem codes to the unmasked distance of dynamical codes, and we develop an algorithm that determines what syndrome information can be learnt given an arbitrary dynamical code and use this to obtain the code's unmasked distance. Further, we use the tools developed for the algorithm to reveal the structure of a generic Floquet code. Based on joint work with Daniel Gottesman.

Bio: Xiaozhen Fu is a doctoral student at the University of Maryland, College Park. Her research interests involve quantum error correction and fault tolerance.

From symmetric quantum circuits to quantum Fisher information metrics

Iman Marvian Mashhad
Duke University

In this talk, I present an overview of two ongoing projects. First, I discuss quantum circuits with gates that respect a global symmetry or, equivalently, conserve a global charge, such as the total energy of the system. Recent studies have shown that, in the presence of symmetry, the locality of gates imposes severe restrictions on the set of realizable unitaries. I explain how the nature of these restrictions strongly depends on the properties of the symmetry. For instance, some restrictions arise exclusively in the case of non-Abelian symmetries. Additionally, I briefly discuss recent work on the statistical properties of random circuits with symmetry-respecting gates (arXiv:2408.14463).
In the second part of my talk, I present recent results on quantum Fisher information metrics and their applications in the resource theories of quantum thermodynamics and asymmetry. Specifically, I highlight a recent result that provides an operational interpretation of the RLD quantum Fisher information metric in the context of coherence distillation (arXiv:2409.05974).

From Science-for-QC to QC-for-Science

Chaoyang Lu(陆朝阳)
University of Science and Technology of China

I will go through our recent efforts in my group using photons and atoms to build increasingly large-scale quantum computers and, in turn, how these early quantum computers can already be used for studies of fundamental problems in mathematics, quantum physics, and condensed matter physics. We use the protocol of Gaussian boson sampling to demonstrate quantum computational advantage, with up to 255 detected photons [Zhong et al. Science 2020, PRL 2021, Deng et al. PRL 2023]. We develop an AI-enabled constant-time-overhead rearrangement protocol to prepare a 2024 defect-free atomic array [Lin et al. 2024]. Using a single atom trapped in an optical tweezer and cooled to the motional ground state in three dimensions, we faithfully realize the Einstein-Bohr recoiling-slit gedankenexperiment tunable at the quantum limit [Zhang et al. 2024]. Based on a bottom-up quantum engineering approach, we experimentally created the fractional quantum Hall state using strongly interacting photons [Wang et al. Science 2024]. We further use the quantum computing platform to rule out a real-value description of standard formalism of quantum theory [Chen et al. PRL 2022].

Bio: Chao-Yang Lu is a Chair Professor in Physics at the University of Science and Technology of China (USTC). He completed his BS and PhD degrees at the USTC and the University of Cambridge in 2011. He has been appointed as the Deputy Director of the Shanghai Center for Quantum Sciences and as the Executive Director of the Quantum Computing Division at the Hefei National Laboratory since 2022. His current research interest includes quantum computation, solid-state quantum photonics, quantum teleportation, superconducting circuits, and atomic arrays. He is the author of over 160 papers in major research journals which have attracted >32000 citations. His work has been selected as by Physics World as "Breakthrough of the Year" in 2015, by APS Physics as one of the top ten "Highlights of the Year" in 2021 and 2022, and by UNESCO as "World's top 10 digital innovation technologies" in 2021. He is an OSA/Optica/APS Fellow, and a recipient of the EPS Fresnel Prize, AAAS Newcomb Cleveland Prize, Nishina Asian Award, IUPAP-ICO Young Scientist Prize in Optics, OSA Adolph Lomb Medal, APS Rolf Landauer and Charles H. Bennett Award in Quantum Computing, CLEO James P. Gordon Memorial Speakership, and OCPA

Achievement in Asia Award. He serves as the Divisional Associate Editor for Physical Review Letters, and recent appointed as the Chairman of World Association of Young Scientists.

Three-dimensional fracton topological orders with boundary Toeplitz braiding

Peng Ye(叶鹏)
Sun Yat-Sen University

In this talk, we explore a class of three-dimensional (3D) fracton topological orders that exhibit exotic boundary phenomena called "Toeplitz braiding" in the thermodynamic limit. These systems are constructed by stacking 2D twisted Z_N topologically ordered layers along the z-direction, coupled while maintaining translation symmetry. The effective field theory is described by an infinite-component Chern-Simons theory with a block-tridiagonal Toeplitz K-matrix. A key finding is the connection between boundary zero modes in the K-matrix spectrum and the emergence of Toeplitz braiding, where mutual braiding phase angles between boundary anyons oscillate and remain nonzero in the thermodynamic limit. Interestingly, the integer-valued Hamiltonian matrix of the 1D Su-Schrieffer-Heeger model can serve as a nontrivial K-matrix, demonstrating the presence of robust boundary zero modes without relying on symmetry protection. We will also discuss numerical results and potential future directions, including the construction of 3D lattice models to realize this phenomenon.

Bio: Peng Ye graduated with a bachelor's degree from the Department of Physics at Sun Yat-sen University in 2007 and earned a Ph.D. from the Institute for Advanced Study at Tsinghua University in 2012. From 2012 to 2018, he worked as a postdoctoral researcher at the Perimeter Institute for Theoretical Physics in Canada and the University of Illinois at Urbana-Champaign in the United States. Since August 2018, he has been a full professor and Ph.D. advisor at the School of Physics at Sun Yat-sen University. His research interests focus on quantum many-body theory.

Leveraging Harmonic Analysis and Discrete Mathematics to Strengthen the Privacy of U.S. Census Data

Chendi Wang(王晨笛)
Xiamen University

The U.S. Decennial Census plays a critical role in policy-making, including federal funding allocation and redistricting. In 2020, the Census Bureau implemented differential privacy to protect individual data through a noise injection method. This raised the question of whether stronger privacy guarantees could be achieved or if the full privacy budget was utilized. In this paper, we address this by applying harmonic analysis and discrete mathematics to track privacy losses using f-differential privacy. Our results show that between 8.50% and 13.76% of the privacy budget remained unused across various geographical levels. We demonstrate that the Census Bureau could reduce unnecessary noise injection by up to 24.82%, improving the accuracy of privatized census data without compromising privacy. This reduction in noise also enhances the utility of private census data in downstream applications, such as analyzing the relationship between earnings and education.

Bio: Chendi Wang is currently an Assistant Professor at the Paula and Gregory Chow Institute for Studies in Economics, the Wang Yanan Institute for Studies in Economics (WISE), and the School of Economics at Xiamen University. He earned his Ph.D. from The Hong Kong Polytechnic University and completed his postdoctoral research at the Wharton Department of Statistics and Data Science at the University of Pennsylvania, as well as the Shenzhen Research Institute of Big Data. Chendi has published several papers in top-tier machine learning conferences, including ICML, ICLR, and NeurIPS, with one of his works being featured as an oral presentation at ICML 2024.

Strong-to-weak spontaneous symmetry breaking meets average symmetry-protected topological order

Shuo Yang(杨硕)
Tsinghua University

Recent studies have unveiled new possibilities for discovering intrinsic quantum phases that are unique to open systems, including phases with average symmetry-protected topological (ASPT) order and strong-to-weak spontaneous symmetry breaking (SWSSB) order in systems with global symmetry. In this work, we propose a new class of phases, termed the double ASPT phase, which emerges from a nontrivial extension of these two orders. This new phase is absent from prior studies and cannot exist in conventional closed systems. Using the recently developed imaginary-Lindbladian formalism, we explore the phase diagram of a one-dimensional open system with ℤ_^σ×ℤ_2^τ symmetry. We identify universal critical behaviors along each critical line and observe the emergence of an intermediate phase that completely breaks the ℤσ2 symmetry, leading to the formation of two triple points in the phase diagram. These two triple points are topologically distinct and connected by a domain-wall decoration duality map. Our results promote the establishment of a complete classification for quantum phases in open systems with various symmetry conditions.

Bio: Shuo Yang received her B.S. degree in physics from Nankai University in 2006 and her Ph.D. in theoretical physics from the Institute of Theoretical Physics, Chinese Academy of Sciences in 2010. From 2010 to 2017, she conducted postdoctoral research at the University of Maryland, College Park, the Max Planck Institute for Quantum Optics, and the Perimeter Institute for Theoretical Physics. She joined the Department of Physics at Tsinghua University in 2017 and was promoted to associate professor in 2019. Her main research directions are condensed matter theory and quantum physics, including tensor networks, topological states of matter, and the interplay between condensed matter physics and quantum information

Pauli path integral for simulating noisy variational quantum algorithm

Yuguo Shao(邵钰菓)
Tsinghua University

Large-scale variational quantum algorithms (VQA) are widely recognized as a potential pathway to achieve practical quantum advantages. However, the presence of quantum noise might suppress and undermine these advantages, which blurs the boundaries of classical simulability. To examine noise effects on VQAs, we introduce a new classical simulation approach based on the Pauli path integral. This approach enables approximate calculation of operator expectation values under single-qubit Pauli noise, with controllable truncation error and polynomial computational cost. Furthermore, we apply this method to simulate IBM's 127-qubit quantum computations, yielding consistent results.

This work is a collaboration with Fuchuan Wei, Song Chen, and Zhengwei Liu.

Bio: Yuguo Shao, PhD student at Tsinghua University. His main research field is quantum information, including classical simulation and quantum error correction.