2020 International Workshop on Quantum Information, Quantum Computing and Quantum Control

Shanghai University

Shanghai, China

January 2-5, 2020

Organized by

Department of Mathematics, SHU

2020 International Workshop on Quantum Information, Quantum Computing and Quantum Control

Purpose

Quantum computing and quantum information processing make use of quantum systems and their non-classical properties as computational resources to outperform their classical counterparts. It is expected that a quantum computer solves computationally hard tasks for a classical computer, such as prime-number factorization of a large number and combinatorial problems, in a practical time. Many scientists, including mathematicians, physicists and computer scientists, are working toward physical realization of a practical quantum computer. In this workshop, we discuss these topics and related subjects including quantum control to facilitate our mutual understanding of these subject. We hope this workshop will result in many collaborations among the participants.

Organizing Committee

Mikio Nakahara, Shanghai University, China

Yoshifumi Nakata, Kyoto University, Japan

Local Organizing Committee

Mikio Nakahara (**Chair**)

Naoki Watamura

Shingo Kukita

Xiaomei Jia

Lingji Lou

Information for Participants

Accomodation

Building 2, New Lehu Hotel, Shanghai University, 716 Jinqiu Road
上海市宝山区锦秋路 716 号上海大学北大门乐乎新楼 2 号楼

Transportation

1. **Pudong Airport**

   By Taxi: Directly take taxi to 716 Jingqiu Road, Shanghai University (Baoshan Campus, North Gate). (Total price is about 250 RMB.)

   By Metro: Metro Line 2 to Jing'an Temple exchange to Metro Line 7 to Shanghai University. (Total price is 8 RMB.)

2. **Hongqiao Airport & Shanghai Hongqiao Railway Station**

   By Taxi: Directly take taxi to 716 Jingqiu Road, Shanghai University (Baoshan Campus, North Gate). (Total price is about 70 RMB.)

   By Metro: Metro Line Line 2 to Jing'an Temple exchange to Metro Line 7 to Shanghai University (Baoshan Campus). (Total price is 6 RMB.)

3. **Shanghai Railway Station**

   By Taxi: Directly take taxi to 716 Jingqiu Road, Shanghai University (Baoshan Campus, North Gate). (Total price is about 50 RMB.)

   By Metro: Metro Line 3 to Zhenping Road exchange to Metro Line 7 to Shanghai University (Baoshan Campus). (Total price is 4 RMB.)

Contact Us

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Website:

`https://mikio-nakahara.com/workshop/IWQIQC2020/`

Programme

January 2, 2020 (Thursday)

Time	Venue: Lobby of Lehu Hotel (乐乎楼 1 号楼大厅)
17:00-18:00	Registration
18:00-19:00	Dinner at Lehu hotel restaurant

January 3, 2020 (Friday)

Time	Venue: **Siyuan Hall (思源厅)** Speaker/Title	Chair
08:30-09:00	Registration	Mikio Nakahara
09:00-09:30	Opening and Group Picture	
09:30-10:20	**Akio Hosoya** Einstein Synchronization by Quantum Teleportation	
10:20-10:50	Coffee and Tea	
10:50-11:30	**Xi Chen** Shortcuts to adiabaticity and quantum speed limits for coherent many-particle systems	Ping Ao
11:30-12:10	**Kazutaka Takahashi** On some variants of quantum speed limit	
12:10-13:10	Lunch at Lehu hotel restaurant	
13:10-13:50	**Ping Ao** Breaking adiabaticity barrier and 100% fidelity in quantum computing	Kazutaka Takahashi
13:50-14:30	**Jing Li** Efficient interaction control in few-body systems	
14:30-15:10	**Yue Ban** Efficient transfer of charge and spin states in quantum dot arrays via shortcuts to adiabaticity	
15:10-15:40	Coffee and Tea	
15:40-16:30	**Sorin Paraoanu** Adiabatic and superadiabatic processes with a superconducting circuit	Xi Chen
16:30-17:10	**Johannes Heinsoo** Unconditional reset of superconducting qubits and readout resonators using a quantumcircuit refrigerator	

17:10-17:50	**Yiu-Tung Poon** Higher Rank Matricial Range and Hybrid Quantum Error Correction	
18:00-	Dinner at Lehu hotel restaurant	

January 4, 2020 (Saturday)

Time	Venue: **Siyuan Hall (思源厅)** Speaker/Title	Chair
09:00-09:50	**Akio Fujiwara** Recent progress in asymptotic quantum statistics	Le Bin Ho
09:50-10:30	**Shingo Kukita** An upper bound on the number of compatible parameters in simultaneous quantum estimation	
10:30-10:50	Coffee and Tea	
10:50-11:30	**Yasushi Kondo** Realization of controllable open system with NMR	Shingo Kukita
11:30-12:10	**Le Bin Ho** Multiparameter quantum metrology with postselection measurements	
12:10-13:10	Lunch at Lehu hotel restaurant	
13:10-13:50	**Victor Montenegro** Quantum sensing with many-body systems	Abolfazl Bayat
13:50-14:30	**Etsuo Segawa** Quantum walk and Kirchhoff's law	
14:30-15:10	**Elham Hosseini Lapasar** Probing the Possibility of Non-Markovian Dynamics of Two-Qubit Open Quantum System in Spin-1/2 Chains	
15:10-15:40	Coffee and Tea	
15:40-16:30	**Yidun Wan** Quantum spacetime on a quantum simulator	Yasushi Kondo
16:30-17:10	**Abolfazl Bayat** Certification of quantum simulators	
17:10-17:50	**Yong-Cong CHEN** Resonant confinement of an excitonic polariton and ultra-efficient light harvest in artificial photosynthesis	

18:00-	Dinner at Lehu hotel restaurant

January 5, 2020 (Sunday)

Time	Venue: **Siyuan Hall (思源厅)** Speaker/Title	Chair
09:00-09:50	**Barry C. Sanders** Randomized benchmarking for qudit Clifford gates	Zizhu Wang
09:50-10:30	**Yoshifumi Nakata** Classical-Quantum Hybrid Capacity by partial decoupling theorem	
10:30-10:50	Coffee and Tea	
10:50-11:30	**Gentil Dias de Moraes Neto** Experimental witness of many-body localization transition	Yoshifumi Nakata
11:30-12:10	**Zizhu Wang** A Marginally Interesting Story of Dominoes and Tiles	
12:10-13:10	Lunch at Lehu hotel restaurant	
13:10-13:50	**Marzieh Asoudeh** Quantum Secret Sharing without entanglement	Barry C. Sanders
13:50-14:30	**Yutaka Shikano** Quantum Random Numbers in Quantum Computer	
14:30-15:10	**Gen Kimura** Universal constraints on relaxation times of GKLS master equations	
15:10-15:40	Coffee and Tea	
15:40-16:30	**Vahid Karimipour** Quasi-Inversion of Qubit Channels	Yutaka Shikano
16:30-17:10	**Konstantin Tiurev** Towards the next-generation quantum repeaters	
17:10-17:50	**Yuichiro Matsuzaki** Quantum annealing with long-lived qubits	
18:00-	Dinner at Lehu hotel restaurant	

Note: Siyuan Hall (思源厅) (the 1st floor of New Lehu Hotel)

Abstract

Name: Akio Hosoya, ahosoya@phys.titech.ac.jp, ahosoya.bongo@gmail.com

Affiliation: Department of Physics, Tokyo Institute of Technology, Tokyo 152-8551, Japan

Title: Einstein Synchronization by Quantum Teleportation

Abstract: In the seminal paper on the special relativity published in 1905, Einstein considered a thought experiment for two spatially separated clocks to synchronise by exchanging light signals back and forth between them. The Einstein synchronisation of two distant clocks is still an important technology in the present age of GPS.

In 2010, Jozsa and his coworkers proposed a quantum protocol, which enables us to produce identical clock states at two distant places by using an entangled initial state. I will critically review their pioneering work and point out the fatal defects.

I then present a protocol of Einstein's synchronisation of two spatially separated clocks on the basis of quantum teleportation in which the Einstein-Podolsky-Rosen (EPR) state plays a central role. Our scheme does not contain the frame defining problem nor the phase contamination problem for the EPR state which appeared in their work[R. Jozsa, D. S. Abrams, J.P. Dowling, and C. P. Williams, Phys. Rev. Lett. **85**, 129802 (2010)].

Name: Xi Chen

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Department of Physical Chemistry, University of the Basque Country UPV/EHU, Apartado 644, 48080 Bilbao, Spain

Title: Shortcuts to adiabaticity and quantum speed limits for coherent many-particle systems

Abstract: .In this talk we shall first review how to design the shortcuts to adiabaticity for controlling BECs and soliton in trapping potentials based on Lagrangian variational method. Later, we focus on the effects of many-body coherence on the quantum speed limit and shortcuts to adiabaticity in ultracold atomic gases. Our approach is focused on two related systems, spinless fermions and the bosonic Tonks-Girardeau gas, which possess equivalent density dynamics but very different coherence properties. To illustrate the effect of the coherence on the dynamics we consider squeezing the anharmonic potential which confines the particles and find that the quantum speed limit exhibits subtle differences between the atomic species. Furthermore, we explore the driven dynamics by implementing a shortcut to adiabaticity, thus reducing spurious excitations. We conclude that collisions between the strongly interacting bosons can lead to changes in the coherence which results in larger speed limits.

Co-author(s):

Name: Kazutaka Takahashi, ktaka@qa.iir.titech.ac.jp

Affiliation: IIR, Tokyo Tech, Japan

Title: On some variants of quantum speed limit

Abstract: The quantum speed limit specifies a universal bound of the fidelity between the initial state and the time-evolved state. We apply this method to find a bound of the fidelity between the adiabatic state and the time-evolved state. The bound is characterized by the counterdiabatic Hamiltonian and can be used to evaluate the worst case performance of the adiabatic quantum computation. The result is improved by imposing additional conditions and we examine several models to find a tight bound. We also derive a different type of quantum speed limits that is meaningful even when we take the thermodynamic limit. By using solvable spin models, we study how the performance and the bound are affected by phase transitions.

Co-author(s):

Name: Ping Ao, aoping@sjtu.edu.cn

Affiliation: Shanghai Center for Quantitative Life Sciences and Department of Physics, Shanghai University, P. R. China

Title: Breaking adiabaticity barrier and 100% fidelity in quantum computing

Abstract: The control of time evolution of a quantum state under various physical constraints is investigated and solved in the context of a two-level system. We have discovered a general scheme of steering an eigen-energy state to a destination without net nonadiabatic transitions, and we discuss how the result may be tested and utilized in practice. Some further development related to dissipation will be discussed.

References:

1. Steering an Eigenstate to a Destination. A Emmanouilidou, XG Zhao, P Ao and Q Niu. Phys. Rev. Lett. **85**, 1626 (2000)
2. Transitionless Quantum Driving. MV Berry. J Phys A**42**, 365303 (2009)

Co-author(s): YC Chen and XM Liu

Name: Jing Li, jing.li@oist.jp

Affiliation: Quantum Systems Unit, Okinawa Institute of Science and Technology Graduate University

Title: Efficient interaction control in few-body systems

Abstract: We study how to efficiently control an interacting few-body system consisting of two or three harmonically trapped bosons. Specifically, we investigate the process of modulating the inter-particle interactions to drive an initially non-interacting state to a strongly interacting one, which is an eigenstate of a chosen Hamiltonian. However, as driving the dynamics too quickly can result in unwanted excitations of the final state, we optimize the driven processes using shortcuts to adiabaticity, which are designed to reduce these excitations at the end of the interaction ramp, ensuring that the target eigenstate is reached.

Co-author(s): Thomás Fogarty, Lewis Ruks, Alan Kahan, and Thomas Busch

Name: Yue Ban, ybanxc@gmail.com

Affiliation: Department of Physical Chemistry, University of the Basque Country, Spain

Title: Efficient transfer of charge and spin states in quantum dot arrays via shortcuts to adiabaticity

Abstract: Long-distance transfer of quantum states is an indispensable part of large-scale quantum information processing. Novel schemes for the transfer of electron charge states and two-electron spin entangled states from one edge of a QD array to the other by coherent adiabatic passage is proposed. This protocol is mediated by pulsed tunneling barriers. In a second step, protocols of speeding up [1, 2] are sought for by shortcut to adiabaticity techniques. This significantly reduces the operation time and, thus, minimizes the impact of decoherence. For typical parameters of state-of-the-art solid state devices, the accelerated protocol has an operation time in the nanosecond range and terminates before a major coherence loss sets in. The scheme represents a promising candidate for entanglement transfer in solid state quantum information processing.

References

[1] Y. Ban *et. al.*, Nanotechnology, **29**, 505201 (2018).

[2] Y. Ban *et. al.*, Adv. Quantum Technol., **2**, 1900048 (2019).

Co-author(s): Xi Chen, Sigmund Kohler, and Gloria Platero

Name: Sorin Paraoanu sorin.paraoanu@aalto.fi

Affiliation: Department of Applied Physics, Aalto University, Finland

Title: Adiabatic and superadiabatic processes with a superconducting circuit

Abstract: The adiabatic theorem (Born and Fock, 1928) is a very powerful result in quantum physics. I will present a few results that demonstrate the stimulated Raman adiabatic passage (STIRAP) in a three-level artificial atom (a superconducting transmon circuit) as well as the realization of superadiabatic processes on the same experimental platform. In the case of superadiabatic STIRAP (saSTIRAP) I will show the correspondence with three-spin lattice system, how the counteradiabatic drive produces Peierls couplings, and how the evolution of the system can be controlled by a synthetic gauge-invariant phase. Finally, I will present the Majorana star representation of these protocols.

References:

KS Kumar, A Vepsäläinen, S Danilin, GS Paraoanu, Stimulated Raman adiabatic passage in a three-level superconducting circuit, Nature communications 7, 10628 (2016)

S Danilin, A Vepsäläinen, GS Paraoanu, Experimental state control by fast non-Abelian holonomic gates with a superconducting qutrit, Physica Scripta 93 (5), 055101 (2018)

A Vepsäläinen, S Danilin, GS Paraoanu, Optimal superadiabatic population transfer and gates by dynamical phase corrections, Quantum Science and Technology 3 (2), 024006 (2018)

A Vepsäläinen, S Danilin, GS Paraoanu, Superadiabatic population transfer in a three-level superconducting circuit, Science advances 5 (2), eaau5999 (2019)

Co-author(s): Shruti Dogra, Antti Vepsäläinen, Sergey Danilin, Karthikeyan Sampath Kumar

Name: Johannes Heinsoo, johannes@meetiqm.com

Affiliation: IQM Finland Oy and Aalto University, Finland

Title: Unconditional reset of superconducting qubits and readout resonators using a quantum-circuit refrigerator

Abstract: In quantum information processing with logical qubits, increasing the clock rate of the error correction cycles improves the qubit fidelity. The clock rate is limited by the duration of logical gates, qubit state readout, and initialization of qubits and readout circuits. Linear and non-linear superconducting resonators can be quickly initialized using a quantum-circuit refrigerator based on fast voltage pulsing of an SINIS junction [1,2]. We discuss our latest results to this end.

[1] V. Sevriuk et al., Appl. Phys. Lett. 115, 082601 (2019)

[2] D. Basilewitsch et al., New J. Phys. 21, 093054 (2019)

Co-authors: Vasilii Sevriuk (1), Jani Tuorila (1), Johannes Heinsoo (1), Caspar Ockeloen-Korppi (1), Joni Ikonen (2), Kuan Y. Tan (1), Eric Hyyppä (2), Matti Silveri (2), Matti Partanen (2), Máté Jenei (2), Giacomo Catto (2), Timm Mörstedt (2), Leif Grönberg (3), Jan Goetz (1), Mikko Mottonen (2)

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Name: Yiu-Tung Poon, ytpoon@iastate.edu

Affiliation: Department of Mathematics, Iowa State University, Ames, Iowa 50011, USA

Title: Higher Rank Matricial Range and Hybrid Quantum Error Correction

Abstract: The theory of quantum error correction originated at the interface between quantum theory and coding theory in classical information transmission and is at the heart of designing those fault-tolerant architectures. It was recognized early on during these investigations that the simultaneous transmission of both quantum and classical information over a quantum channel could also be considered. A coding scheme for such transmission is called a hybrid quantum error correcting code.

We introduce and initiate the study of a family of higher rank matricial ranges, which can be defined for a given quantum channel. In particular, for a noisy quantum channel, a hybrid quantum error correcting code exists if and only if the associated joint higher rank matricial range of the channel is non-empty. These matricial ranges are generalizations of the higher rank numerical ranges defined for quantum error correcting code of the quantum channel. We establish bounds on Hilbert space dimension in terms of the number of error operators for a given noisy quantum channel that guarantee a matricial range is non-empty, and hence additionally guarantee the existence of hybrid codes for that channel. We also discuss when hybrid codes can have advantages over quantum codes and present a number of examples.

We study efficient quantum error correction schemes for the fully correlated channel on an n-qubit system with error operators given by the Pauli matrices. When $n = 2k + 2$ is even, we describe a hybrid quantum error correction scheme that protects a $2k$-qubit state and 2 classical bits. Furthermore, we show that the encoding can be done by $3k + 2$ CNOT gates and a Hadamard gate on one qubit. We implement the scheme on IBM's online computers. We will discuss the significant differences in the results obtained from two machines, Tenerife and Yorktown.

Co-author(s): Ningping Cao, David W. Kribs, Chi-Kwong Li, Seth Lyles, Mike I. Nelson and Bei Zeng.

Name: Akio Fujiwara, fujiwara@math.sci.osaka-u.ac.jp

Affiliation: Department of Mathematics, Osaka University, Japan

Title: Recent progress in asymptotic quantum statistics

Abstract: Suppose that one has n copies of a quantum system each in the same state depending on an unknown parameter θ, and one wishes to estimate θ by making some measurement on the n systems together. This yields data whose distribution depends on θ and on the choice of the measurement. Given the measurement, we therefore have a classical parametric statistical model, though not necessarily an i.i.d. model, since we are allowed to bring the n systems together before measuring the resulting joint system as one quantum object. In that case the resulting data need not consist of (a function of) n i.i.d. observations, and a key quantum feature is that we can generally extract more information about θ using such "collective" or "joint" measurements than when we measure the systems separately. What is the best we can do as $n \to \infty$, when we are allowed to optimize both over the measurement and over the ensuing data processing? The objective of the present talk is to give a partial answer to this question by extending the theory of local asymptotic normality, which is known to form an important part of the classical asymptotic theory, to quantum statistical models.

Co-authors: Koichi Yamagata (The University of Elecro-Communications) and Richard D. Gill (Leiden University)

Name: Shingo Kukita, toranojoh@shu.edu.cn

Affiliation: Department of Mathematics, Shanghai University, China

Title: An upper bound on the number of compatible parameters in simultaneous quantum estimation

Abstract: Simultaneous estimation of multiple parameters is required in many practical applications. A lower bound on the variance of simultaneous estimation is given by the quantum Fisher information matrix. This lower bound is, however, not necessarily achievable. Although there exists a necessary and sufficient condition for its achievability, it is unknown how many parameters can be estimated while satisfying this condition. In this talk, we analyse an upper bound on the number of such parameters through linear-algebraic techniques. This upper bound depends on the algebraic structure of the quantum system used as a probe. We explicitly calculate this bound for two quantum systems: single qubit and two-qubit X-states.

Co-author(s):

Name: Yasushi Kondo, ykondo@kindai.ac.jp

Affiliation: Department of Physics, Kindai University, Japan

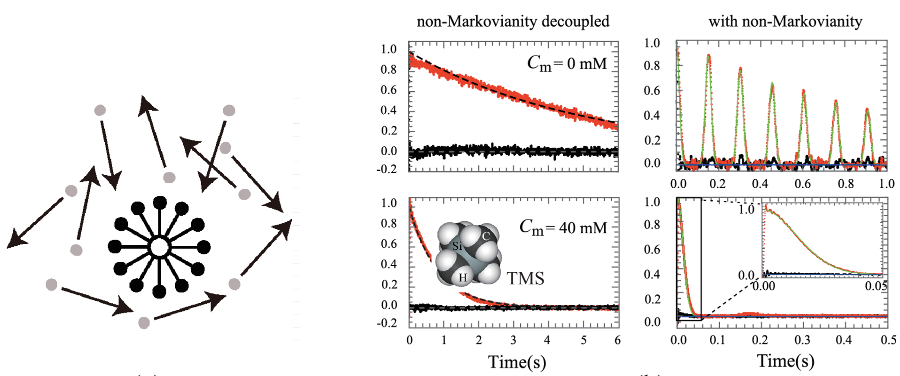
Title: Realization of controllable open system with NMR

Abstract: An open quantum system is now attracting much attention because a quantum device such as quantum computers and quantum sensors is an emerging technology. Here, we present a model of the open system that shows either time-homogeneous Markovian relaxations or non-Markovian relaxations depending on its parameters that we can control.

This model is fully described with the following master equation

$$\frac{d\rho_n}{dt} = \sum_{\ell=1}^{n} \left(-i \left[J\frac{\sigma_z \otimes \sigma_z^{(\ell)}}{4}, \rho_n \right] + \sum_{\pm} \gamma \left(2\mathcal{L}_{\mp}^{(\ell)} \rho_n \mathcal{L}_{\pm}^{(\ell)} - \{\mathcal{L}_{\pm}^{(\ell)}\mathcal{L}_{\mp}^{(\ell)}, \rho_n\} \right) \right)$$

where $\mathcal{L}_{\pm}^{(\ell)} = \sigma_0 \otimes \sigma_{\pm}^{(\ell)}/2$ and $\sigma_k^{(\ell)} = \sigma_0 \otimes \cdots \otimes \overbrace{\sigma_k}^{\ell' th} \otimes \cdots \sigma_0$, $(k = x, y, z, +, -)$ that is analytically solvable. More importantly, this model can be easily realized with star-topology molecules in isotropic liquids, and we can measure such a system with NMR techniques.



(a) (b)

(a) A star-topology molecule with magnetic impurities (gray circles) in an isotropic liquid. (b) Observed Markovian and Non-Markovian relaxations of a Si nuclear spin in TMS molecule. C_{m} is the concentration of magnetic impurities.

Co-author(s): Le Bin Ho, Yuichiro Matsuzaki and Masayuki Matsuzaki

References

[1] Le Bin Ho, Yuichiro Matsuzaki, Masayuki Matsuzaki, and Yasushi Kondo, New J. Phys. **21** (2019) 093008.

Name: Le Bin Ho, binho@kindai.ac.jp

Affiliation: Department of Physics, Kindai University, Japan

Title: Multiparameter quantum metrology with postselection measurements

Abstract: Quantum mechanics imposes the fundamental precision limit of parameter estimation. Approaching this limit is one of the main tasks in quantum metrology. Most investigations have so far focused on the estimation of a single parameter [1]; the simultaneous estimation of multiparameter has recently been paid more attention [2]. The precision of estimation is bounded by the quantum Cramér-Rao bound (QCRB). Although the QCRB is easy to be achieved in a single parameter estimation case, it may not be attainable in multiple cases.

In this work, we propose a measurement framework with postselection for the simultaneous estimation of multiparameter [3]. Therein, a system characterized by a set of parameters interacts with a measurement apparatus (MA) and be postselected onto a final state. The measurements on the final state of the MA yield an estimation of the parameters. We first derive classical and quantum Cramér-Rao bounds and then discuss the ultimate precision attainable in our framework. As an example, we discuss the simultaneous estimation of a phase (ϕ) and its fluctuation (Γ) as shown in Fig. 1 below. We found the POVM set that allows all the parameters can attain the ultimate limit precision simultaneously.

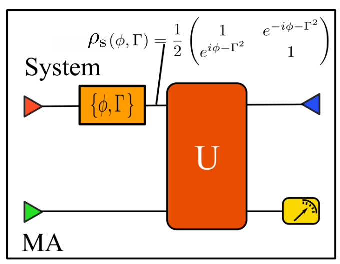


Figure 1: Scheme for postselection measurement

Co-author(s): Yasushi Kondo

References:

[1] C. L. Degen, F. Reinhard, and P. Cappellaro, *Rev. Mod. Phys.*, **89**, 035002 (2017).
[2] M. Szczykulska, T. Baumgratz, and A. Datta, *Adv. in Phys. X*, **1**, 621 (2016).
[3] L. B. Ho and Y. Kondo, arXiv: 1811.08046 (2018).

Name: Victor Montenegro, vmontenegro@uestc.edu.cn

Affiliation: Institute of Fundamental and Frontier Science, University of Electronic Science and Technology of China, P. R. China

Title: Quantum sensing with many-body systems.

Abstract: Estimation of weak external fields is essential in current and frontier technological applications. The interest in measuring modest deviations of the system of interest range from enhanced inertial navigation using high-precision accelerometers to improved medical imaging using high-accuracy magnetic field sensors. Remarkably, quantum systems can serve to deliver such an ultimate precision limit. In particular, some quantum states have shown to be highly beneficial for quantum sensing protocols, such as N00N and GHZ states. However, they are (still) quite challenging to attain experimentally, and even if realized, they are fragile against quantum and thermal fluctuations present in their surroundings. Quantum many-body systems are then an excellent platform to exploit their natural correlations and fragility in the presence of small external disturbances, i.e., a quantum many-body probe as a sensor. In light of this, we consider a quantum many-body system composed of N interacting spin-1/2 particles with transverse-field Ising Hamiltonian in the presence of a random, static, and unknown magnetic field to estimate. The first part of our work examines the critical behavior of the Ising chain as, in principle, the random field will alter the well-known critical field in the absence of an external field. We show that criticality, obtained from the magnetic field such that maximizes the fidelity susceptibility, does not necessarily imply Heisenberg scaling; in fact, we show that this statement holds only for a restricted range of parameters. The second part of our work is devoted to giving a full quantum estimation strategy to sense a multi-directional random field. It is known that systems at criticality exhibit Heisenberg scaling, the quantum Fisher information scales as $\sim N^2$. However, as the random field is unknown, one cannot adjust the controlled transverse field appropriately and, therefore, we wonder if our sensing protocol will still perform adequately without being at criticality. To answer this, we first focus on estimating either the longitudinal or the transversal components of the random field by sampling the ground state of the system with spin configurations measurements. The accumulated statistics are then processed employing Bayesian analysis. Our results show that, in the single parameter estimation case, the quantum Cramer-Rao bound is fully saturated, ensuring the optimality of our quantum single-parameter sensing protocol. A step forward is to estimate the longitudinal and transversal components simultaneously, for which we developed both joint and adaptive strategies. We show that adaptive strategy always outperforms when compared to the joint case, exhibiting lower relative errors, and lower variances of the estimated random field.

Co-author(s): Abolfazl Bayat

Name: Etsuo Segawa, segawa-etsuo-tb@ynu.ac.jp

Affiliation: Graduate School of Environment and Information Sciences, Yokohama University

Title: Quantum walk and Kirchhoff's law

Abstract: We propose a quantum walk model converging to a stationary state with an bounded initial state. We find that the scattering significantly depends on the reversibility of the underlying random walk of this quantum walk. We obtain that the stationary state can be expressed by the electric circuit if the underlying random walk is reversible.

Co-author: Yusuke Higuchi

Name: Elham Hosseini Lapasar, elhamhosseini@guilan.ac.ir

Affiliation: Department of Physics, Faculty of Science, University of Guilan, Iran

Title: Probing the Possibility of Non-Markovian Dynamics of Two-Qubit Open Quantum System in Spin-1/2 Chains

Abstract: We have considered the one-dimensional spin-1/2 systems. In the spin chain, selecting two nearest neighbor spins as an open quantum system, the rest of the chain plays the role of structured environment. Different spin-1/2 chain systems due to the different interactions between spins are considered. We have studied the non-markovian dynamics and dynamcis of entanglement in an open quantum system in spin-1/2 chain. The dynamics of the systems are generated by XY Heisenberg interaction in the presence of a transverse magnetic field, and XX Heisenberg interaction and three-spin interaction (TSI) among all the nearest three spins in the chain. Using fermionization technique and a general measure which is based on the trace distance, non-Markovianity in the open quantum systems is evaluated. Entanglement between the pair of spins has been also studied. Consequently, we have shown that the non-Markovianity and the entanglement strongly depends on the interactions. This study might be significant in considering memory of quantum systems.

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Name: Yidun Wan, ydwan@fudan.edu.cn

Affiliation: Department of Physics, Fudan University, Shanghai, P. R. China

Title: Quantum spacetime on a quantum simulator

Abstract: Quantum simulation has shown its irreplaceable role in many fields, where it is difficult for classical computers to contribute much. On a four-qubit Nuclear Magnetic Resonance (NMR) quantum simulator, we experimentally simulate the spin network states by simulating quantum spacetime tetrahedra. The fidelities between our experimentally prepared quantum tetrahedra are all above 95%. We then use the quantum tetradedra prepared by NMR to simulate a spinfoam vertex amplitude, which displays the local dynamics of quantum spacetime. By measuring the geometric properties on the corresponding quantum tetrahedra and simulating their gluing, our experiment serves as a basic module that represents the Feynman diagram vertex in the spinfoam formulation of Loop Quantum Gravity(LQG). This is an initial attempt to study LQG and/or other quantum spacetime by quantum information processing.

Co-author(s):

Name: Abolfazl Bayat, abolfazl.bayat@uestc.edu.cn

Affiliation: Institute of Fundamental and Frontier Sciences, University of Electronic Science and Technology of China, Chengdu 610051, China

Title: Certification of quantum simulators

Abstract: Quantum simulators are engineered devices controllably designed to emulate complex and classically intractable quantum systems. A key challenge lies in certifying whether the simulator is truly mimicking the Hamiltonian of interest. However, neither classical simulations nor quantum tomography are practical to address this task because of their exponential scaling with system size. Therefore, developing novel certification techniques, suitable for large systems, is highly desirable. Here, in the context of fermionic spin-based simulators, we propose a global many-body spin to charge conversion scheme, which crucially does not require local addressability. A limited number of charge configuration measurements performed at different detuning potentials along a spin chain allow to discriminate the low-energy eigenstates of the simulator. This method, robust to charge decoherence, opens the way to certify large spin array simulators as the number of measurements is independent of system size and only scales linearly with the number of eigenstates to be certified.

Co-author(s): Benoit Voisin, Gilles Buchs, Joe Salfi, Sven Rogge, and Sougato Bose

Name: Yong-Cong CHEN, chenyongcong@shu.edu.cn

Affiliation: Shanghai Center for Quantitative Life Sciences & Physics Department, Shanghai University, China

Title: Resonant confinement of an excitonic polariton and ultra-efficient light harvest in artificial photosynthesis

Abstract: We uncover a novel phenomenon from a recent artificial light-harvesting experiment [Angewandte Chemie Intl. Ed. 55, 2759 (2016)] on organic nanocrystals of self-assembled difluoroboron chromophores.

A resonant confinement of polariton under strong photon-exciton coupling is predicted to exist within the microcavity of the crystals own natural boundaries. Moreover, the radiative energy of a localized exciton falls into the spectrum of the confinement.

The spontaneous emission of an excited pigment would undergo a two-step process. It should first decay to an excitonic polariton trapped by the cavity resonance. The captive intermediate could then funnel the energy directly to doped acceptors, leading to the observed over 90% transfer efficiency at less than 1/1000 acceptor-donor ratio.

The proposed mechanism is supported by parameter-free analyses entirely based on experiment data. Our finding may imply possible polariton-mediated pathways for energy transfers in biological photosynthesis.

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Title: Randomized benchmarking for qudit Clifford gates

Abstract: We introduce unitary-gate randomized benchmarking (URB) for qudit gates by extending single- and multi-qubit URB to single- and multi-qudit gates. Specifically, we develop a qudit URB procedure that exploits unitary 2-designs. Furthermore, we show that our URB procedure is not simply extracted from the multi-qubit case by equating qudit URB to URB of the symmetric multi-qubit subspace. Our qudit URB is elucidated by using pseudocode, which facilitates incorporating into benchmarking applications

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Title: Classical-Quantum Hybrid Capacity by partial decoupling theorem

Abstract: One of the major goals in quantum information theory is to find a good quantum error correcting code (QECC) to reliably transmit information via a noisy quantum channel. In many cases, the information to be transmitted is either quantum or classical. We here consider the task of simultaneous transmissions of both quantum and classical information with the assistance of shared entanglement in the one-shot scenario. This task is known as the one-shot entanglement-assisted quantum-classical hybrid communication, which is one of the most general settings in the sense that most existing situations in the literature can be reduced from the task. We first derive one-shot direct and converse bounds by using the *one-shot partial decoupling* theorem. We then apply our result to the setting of quantum memory, where each physical qubits are exposed to the independent phase-flip error, and numerically show that the errors are dramatically suppressed due to the random QECC we have proposed.

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Title: Experimental witness of many-body localization transition.

Abstract: Many-body localisation (MBL) is the reminiscent of Anderson localisation in interacting systems. The importance of MBL, which has attracted a lot of attention in recent years, comes from the fact that it challenges the very foundations of quantum statistical physics, leading to striking theoretical and experimental consequences such as breaking both: (i) ergodicity; and (ii) eigenstate thermalisation hypothesis and thus absence of thermalisation. Despite the massive interest in MBL, so far, the discrimination between the MBL and the ergodic phases using experimentally measurable quantities is still challenging, mainly due to difficult to perform quantum state tomography and measure quantum entanglement in many body systems. We realize such a many-body localized system in 12-qubit superconducting quantum processor, which represents a spin-1/2 XY model featuring programmable disorder and long-range spin-spin interactions. We provide essential signatures of MBL phase transition, by measurements of the fluctuations in simple observables that require only a few local expectation values and we found a critical point that agreed with previous numerical studies using hard to measure experimental quantities as mean energy level statistics and the block entanglement entropy. Our results open a concrete possibility towards the experimental exploration of many-body transition for large experimental systems where numerical studies and quantum tomography are prohibitive and finite size effects are negligible.

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Title: A Marginally Interesting Story of Dominoes and Tiles

Abstract: We study the properties of the set of marginal distributions of infinite translation-invariant systems in the 2D square lattice. In cases where the local variables can only take a small number d of possible values, we completely solve the marginal or membership problem for nearest-neighbors distributions ($d = 2, 3$) and nearest and next-to-nearest neighbors distributions ($d = 2$). Remarkably, all these sets form convex polytopes in probability space. This allows us to devise an algorithm to compute the minimum energy per site of any TI Hamiltonian in these scenarios exactly. We also devise a simple algorithm to approximate the minimum energy per site up to arbitrary accuracy for the cases not covered above. For variables of a higher (but finite) dimensionality, we prove two no-go results. To begin, the exact computation of the energy per site of arbitrary TI Hamiltonians with only nearest-neighbor interactions is an undecidable problem. In addition, in scenarios with $d \geq 2947$, the boundary of the set of nearest-neighbor marginal distributions contains both flat and smoothly curved surfaces and the set itself is not semi-algebraic. This implies, in particular, that it cannot be characterized via semidefinite programming, even if we allow the input of the program to include polynomials of nearest-neighbor probabilities.

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Title: Quantum Secret Sharing without entanglement

Abstract: I describe a quantum secret sharing scheme in which no entanglement is used. Instead the parties manipulate a single state sequentially and pass this state to each other. After one round of this manipulation and passing, the parties make a public announcement which leads to the establishment of a secure secret key between all parties. The scheme can be used between N parties and they can use any d-dimensional state.

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Title: Quantum Random Numbers in Quantum Computer

Abstract: A cloud quantum computer is similar to a random number generator in that its physical mechanism is inaccessible to the users. In this respect, a cloud quantum computer is a black box. In both devices, the users decide the device condition from the output. A framework to achieve this exists in the field of random number generation in the form of statistical tests for random number generators. In the present study, we generated random numbers on the 20-qubit cloud quantum computer and evaluated the condition and stability of its qubits using statistical tests for random number generators. As a result, we observed that the qubits varied in bias and stability. Statistical tests for random number generators may provide a simple indicator of qubit condition and stability, enabling users to decide for themselves which qubits inside a cloud quantum computer to use. This work is basically collaborated with Kentaro Tamura (Keio University).

Reference: K. Tamura and Y. Shikano, arXiv:1906.04410

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Title: Universal constraints on relaxation times of GKLS master equations

Abstract: It is well-known that quantum Markovian dynamics is generally described by GKLS master equations, where the corresponding time-evolution maps are TPCP (trace preserving and completely positive) semigroup. In this talk, we present constraints on relaxation times universally valid for all GKLS master equations.

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Title: Quasi-Inversion of Qubit Channels

Abstract: It is well known that a general quantum channel cannot be reversed unless it is a unitary channel. In this talk we ask how close we can get to an inverse of a quantum channel. More precisely we ask if it is possible to optimally increase the average fidelity of a quantum channel by appending another channel to its end. Calling this appended channel the quasi-inverse, we show that for qubit channels, the quasi inverse is always a unitary channel. We make a complete classification of the quasi inverse of qubit channels and show that their nature depend crucially on the nature of the affine map of the original channels, i.e. on whether the matrices of the affine map are symmetric or not. Several examples of qubit channels are discussed and at the end it is shown how these ideas can be extended to higher dimensional quantum channels.

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Title: Towards the next-generation quantum repeaters

Abstract: Quantum repeaters have been proposed as a means to overcome transmission loss of quantum information. The conventional quantum repeater architecture relies on long-lived quantum memories, which despite the rapid progress is still an experimental challenge. The all-photonic repeater architectures, on the other hand, do not require quantum memories at the repeater nodes. Instead, multiphoton graph states play the central role in entangling distant repeater stations. In this work, we present a detailed theoretical analysis of a protocol for the deterministic generation of such multiphoton entangled states from a single quantum emitter. We devise a mathematical framework for assessing the fidelity of photonic states and apply our theoretical formalism to a realistic quantum dot-based emitter embedded in a photonic crystal waveguide. According to our theoretical considerations, generation of a few entangled photons is achievable with fidelities exceeding those of the conventional fusion methods.

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Title: Quantum annealing with long-lived qubits

Abstract: Quantum annealing (QA) is a way to solve combinatorial optimization problems. Typically, a superconducting flux qubit (FQ) was used to demonstrate the QA, and the FQs in these implementations have a short coherence time such as tens of nano seconds. To exploit the quantum properties, it is necessary to use qubits with a longer coherence time. However, such a long-lived qubit usually has a weaker coupling strength with another qubit, and this makes it difficult to perform the QA that requires the coupling strength as strong as the frequency of the qubit. Here, we propose to use a spin lock technique for implementing the QA with long-lived qubit. The spin lock technique effectively reduces the resonant frequency of the qubits in the rotating frame, and such an effective resonant frequency can be comparable with the coupling strength even when we use the standard long-lived qubits such as superconducting transmon qubits, capacitively shunted flux qubits, and nitrogen vacancy centers in diamond. Our results pave the way for the realization of the practical QA that exploits quantum advantage with long-lived qubits.

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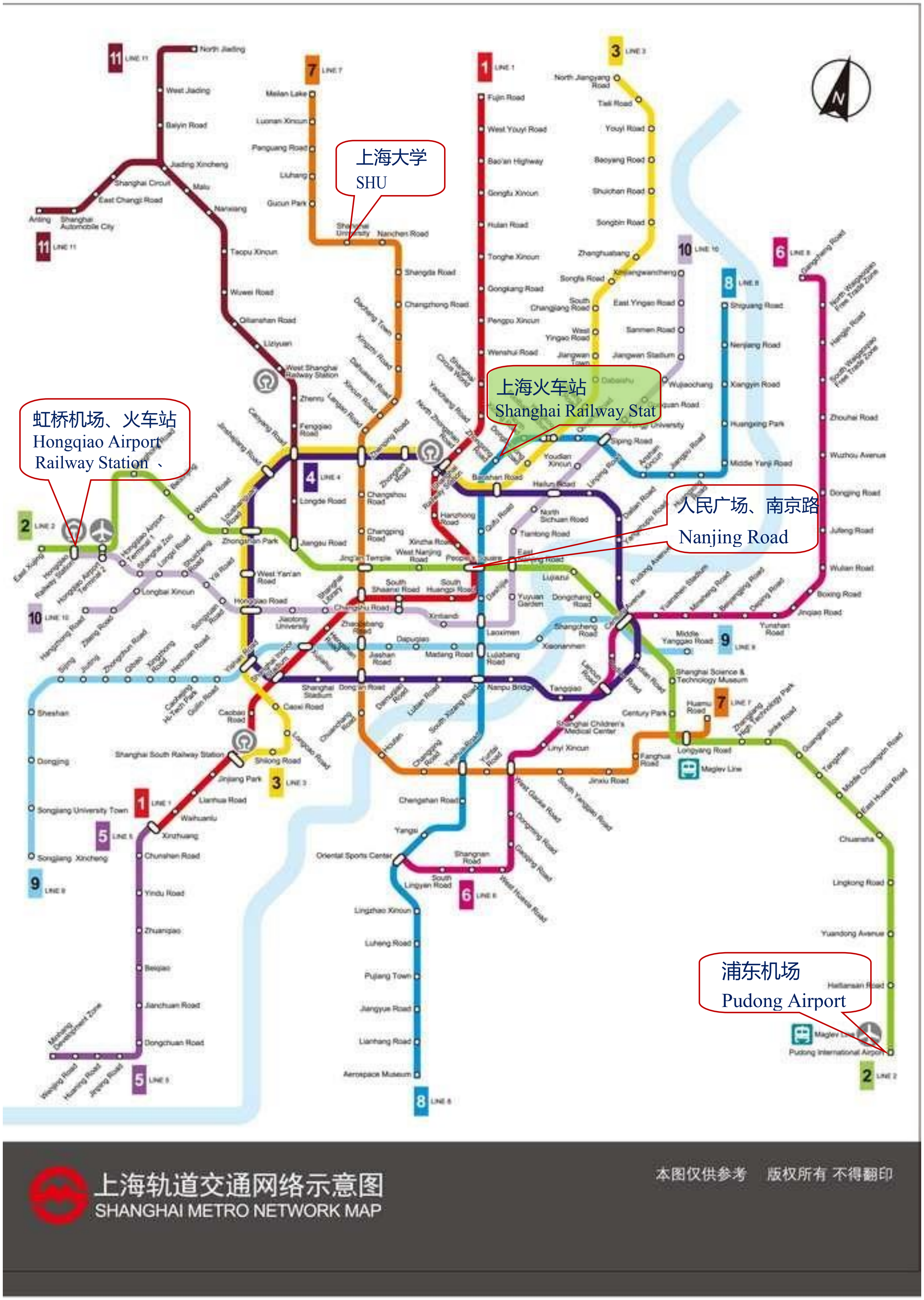
Shanghai University Map (Baoshan Campus)

Metro Map



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