## **JITCP Seminar**

THE UNIVERSITY OF HONG KONG HKU-UCAS JOINT INSTITUTE OF THEORETICAL AND COMPUTATIONAL PHYSICS [Thursday Afternoon, 4:00 pm, In Person]

## Noise effects and threshold theorem in realistic quantum error corrections

## **Dr. Dong LIU**

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The "error threshold theorem" is pivotal for fault-tolerant quantum computation and Quantum Error Correction (QEC), but it presumes devices only susceptible to independent stochastic noise, overlooking coherent noise from imperfect gate control during both code space preparation and stabilizer checks. We examine stability of 2D topological surface code, addressing both stochastic Pauli and coherent noise on multi-qubit entanglement gates during code space preparation and stabilizer checks. We map an error detection protocol to a 3D Z\_2 lattice gauge theory linked to a 2D lattice model, introducing a theoretical tool to study coherent errors in Quantum Error Correction (QEC) and threshold theorem. Our results contradict the standard belief, revealing that imperfect initial state preparation can surprisingly fail QEC below the theoretical threshold, culminating in a finite logical error rate, even in the thermodynamic limit. This leads to a novel practical error threshold theorem highlighting the critical impact of coherent deviations in initial code space preparation of QEC.

In the last part of my talk, I'll discuss error mitigation and benchmarking for near-term quantum devices, introducing a noise-resilient design [2] and a benchmarking protocol, i.e., Channel Spectrum Benchmarking (CSB) [3]. Our approach identifies and mitigates noises, enhancing robust quantum processor development and providing critical insights into noise properties and process fidelity, contributing to the advancement of efficient, robust quantum computation.

References:

[2] Yanwu Gu, Yunheng Ma, N. Forcellini, Dong E. Liu, Phys. Rev. Lett. 130, 250601 (2023)

[3] Yanwu Gu, Wei-Feng Zhuang, Xudan Chai, Dong E. Liu, Nature Communications 14, 5880 (2023)

**Biography:** 

Dr. Dong E. Liu is an associate professor at Tsinghua University. He completed his undergraduate study at Peking University and obtained his PhD from Duke University. He held postdoc positions at Michigan State University and Microsoft Station Q from 2012 to 2017. In 2018, he joined the faculty at Tsinghua University and became an adjunct researcher at BAQIS in 2020, where he leads a quantum computer operating system research group. His research focus on the theoretical study of validation schemes for quantum devices, noise effects and system architectures for quantum computers, and non-equilibrium quantum many-body physics.

## In Person Seminar Thursday, October 26, 2023, 4:00 pm Room 522, 5/F, Chong Yuet Ming Physics Building, HKU

Sponsored by HKU-UCAS Joint Institute of Theoretical and Computational Physics, The University of Hong Kong *Phone: 28592360, Fax: 25599152. Anyone interested is welcome to attend.* 

<sup>[1]</sup> Yuanchen Zhao, Dong E. Liu, arXiv:2301.12859 (2023)