Seminar

Resolving Quantum Criticality in the Honeycomb Hubbard Model

Xiao Yan Xu许霄琰

Shanghai Jiao Tong University

Time: 10:30 am, April 13, 2026 (Monday)

时间：2026年4月13日（周一）上午10:30

Venue: Room w563, Physics building, Peking University

地点：北京大学物理楼，西563会议室

Abstract

Quantum phase transitions driven by electronic correlations are central to understanding the physics of graphene and related two-dimensional materials. A paradigmatic example is the semimetal-to-Mott-insulator transition on the honeycomb lattice, governed by the Gross-Neveu-Heisenberg universality class, yet consensus on its critical exponents has remained elusive for over a decade due to severe finite-size effects and the absence of rigorous conformal bootstrap benchmarks. Here we resolve this long-standing controversy by performing projector determinant quantum Monte Carlo simulations on lattices of unprecedented size, reaching 10,368 sites. By developing a novel projected submatrix update algorithm, we achieve a significant algorithmic speedup that enables us to access the thermodynamic limit with high precision. We observe that the fermion anomalous dimension and the correlation length exponent converge rapidly, while the boson anomalous dimension exhibits a systematic size dependence that we resolve via linear extrapolation. To validate our analysis, we perform parallel large-scale simulations of the spinless t-V model on the honeycomb lattice, which belongs to the Gross-Neveu-Ising class. Our results for the t-V model show agreement with conformal bootstrap predictions, thereby corroborating the robustness of our methodology. Our work provides state-of-the-art critical exponents for the honeycomb Hubbard model and establishes a systematic finite-size scaling workflow applicable to a broad class of strongly correlated quantum systems, paving the way for resolving other challenging fermionic quantum critical phenomena. Our results provide definitive theoretical benchmarks for the relativistic Mott transition recently observed in twisted double bilayer WSe$_2$.
Ref: arXiv:2602.03656

About the speaker

Xiao Yan Xu received his Ph.D. from IOP, CAS in 2017, and then worked as a postdoctoral researcher at the Hong Kong University of Science and Technology and UC San Diego. He joined SJTU in 2021. He is primarily engaged in theoretical and computational research on strongly correlated electron systems, including quantum spin liquids, non-Fermi liquids, sign problems, quantum criticality, quantum entanglement, and interdisciplinary research at the intersection of quantum many-body physics with machine learning, quantum information, and ultracold atomic physics.