Weekly Seminar

Fractional quantum anomalous Hall effects in rhombohedral pentalayer graphene

Xiao Li

City University of Hong Kong

Time: 3:00 pm, Nov.19, 2025 (Wednesday)

时间：2025年11月19日（周三）下午3:00

Venue: Room W563, Physics building, Peking University

地点：北京大学物理楼，西563会议室

Abstract

The fractional quantum anomalous Hall (FQAH) effect in rhombohedral pentalayer graphene (PLG) has attracted significant attention due to its potential for observing exotic quantum states [1-3]. This talk will discuss two projects exploring the FQAH effect in PLG. First, we present a self-consistent Hartree-Fock theory focusing on the convergence of the calculation with various reference fields and the stability of the FQAH states [4-5]. We demonstrate that the charge neutrality scheme ensures convergence with respect to the momentum cutoff and provides an unambiguous result. Based on the Hartree-Fock band structure, we perform exact diagonalization calculations to investigate the stability of the FQAH states in PLG. The second project examines the intriguing experimental observation of FQAH states at various fractional fillings giving way to integer quantum anomalous Hall (IQAH) states as the temperature is lowered [3]. We propose a mechanism for the appearance of FQAH states within a finite temperature range using a toy model consisting of a flat Chern band and impurities [6]. The effects of impurities on the system's behavior at finite temperatures are analyzed, and we posit that the crossover may arise from the competition between the energy penalty for thermal excitations and the increase in entropy. Numerical calculations using exact diagonalization support our theoretical argument, suggesting that impurities may play a crucial role in the crossover from FQAH to IQAH states in rhombohedral PLG. Together, these projects provide an improved and unified theoretical framework for understanding the FQAH effect in rhombohedral PLG and pave the way for future studies on this captivating quantum phenomenon.

References:

[1] Z. Lu, T. Han, Y. Yao, A. P. Reddy, J. Yang, J. Seo, K. Watanabe, T. Taniguchi, L. Fu, and L. Ju, Fractional quantum anomalous Hall effect in multilayer graphene, Nature **626**, 759 (2024).

[2] D. Waters, A. Okounkova, R. Su, B. Zhou, J. Yao,K. Watanabe, T. Taniguchi, X. Xu, Y.-H. Zhang, J. Folk, and M. Yankowitz, Interplay of electronic crystals with integer and fractional Chern insulators in moir épentalayer graphene, arXiv:2408.10133.

[3] Z. Lu, T. Han, Y. Yao, J. Yang, J. Seo, L. Shi, S. Ye, K. Watanabe, T. Taniguchi, and L. Ju, Extended Quantum Anomalous Hall States in Graphene/hBN Moir éSuperlattices, arXiv:2408.10203.

[4] K. Huang, X. Li, S. Das Sarma, and F. Zhang, Self-consistent theory of fractional quantum anomalous Hall states in rhombohedral graphene, Phys. Rev. B **110**, 115146 (2024).

[5] K. Huang, S. Das Sarma, and X. Li, Fractional quantum anomalous Hall effect in rhombohedral multilayer graphene with a strong displacement field, Phys. Rev. B **111**, 075130 (2025).

[6] K. Huang, S. Das Sarma, and X. Li, Impurity-induced thermal crossover in fractional Chern insulators, arXiv:2409.04349.

About the speaker

Dr. Xiao Li is an Associate Professor at Department of Physics, City University of Hong Kong (CityUHK). He received his bachelor's degree from Peking University in 2008 and PhD in Physics from the University of Texas at Austin in 2014. Between 2015 and 2018, he worked as a postdoc at Condensed Matter Theory Center, University of Maryland, College Park. Prof. Li joined CityUHK as an Assistant Professor in 2019 and was promoted to Associate Professor in 2024. Prof. Li is mainly interested in novel phases of matter arising from the intricate interplay of topology, disorder, and electron-electron interactions. His current research focuses on two main directions: exploring novel electronic phases in moir é heterostructures, where the precise stacking of two-dimensional materials creates unique quantum environments, and developing comprehensive theoretical frameworks for understanding exciton behavior in two-dimensional materials. Beyond two-dimensional materials, he is also interested in nonequilibrium phases of matter, such as localization physics in hermitian and non-hermitian systems, as well as the theory of quantum information scrambling.

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