上海数学与交叉学科研究院

SIMIS

Shanghai Institute for Mathematics and Interdisciplinary Sciences

## Simis Seminar series on Quantum computing, quantum simulation and strongly-correlated systems

**Professor Jianpeng Liu**

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# "Correlated and topological states in graphene-based heterostructures"

**Abstract**

In this talk, we will discuss correlated and topological states emerging from heterostructure systems consisted of graphene and other insulating substrates. First, we consider moire superlattices formed by rhombohedral multilayer graphene aligned with hexagonal boron nitride (hBN) substrate [1], where we provide a microscopic theory for the integer and fractional Chern insulator states emerging in these systems. Second, we consider a new type of Coulomb-coupled graphene-insulator heterostructures with gate tunable band alignment [2, 3]. By virtue of the similar work functions, charge carriers can be transferred between graphene and the insulating substrate under the control of gate voltages, which may give rise a long-wavelength electronic crystal at the surface of the substrate. The electronic crystal exerts a superlattice Coulomb potential on the Dirac electrons in graphene, which may generate unusual correlated and topological states in these non-moire systems. Reciprocally, the Wigner-crystal state formed at the surface of the insulating substrate may also be stabilized by cooperative interlayer Coulomb coupling. Lastly, motivated by the previous problems, we develop a GW+RPA method to study Wigner-crystal transitions in various interacting two-dimensional (2D) electronic systems [4]. Our method gives a critical Wigner-Seitz radius about 19.2 for regular 2D electron gas. When being applied to high-order Dirac fermion systems, our calculations suggest that both topologically trivial and nontrivial Wigner crystal states predicted by mean-field method would be significantly de-stabilized by charge fluctuations.

## References

[1] Z. Guo, X. Lu, B. Xie, J. Liu, Phys. Rev. B 110, 075109 (2024)
[2] X. Lu et al., Nat. Commun. 14 (1), 5550 (2023)
[3] Y. Wang, Nat. Nanotechnol. 17 (12), 1272 (2022)
[4] Z. Guo, J. Liu, arXiv:2409.14658 (2024).

**Biography of the speaker**

Jianpeng Liu graduated from Nankai University in 2010, and obtained Ph.D. degree from Rutgers University in 2015. Then, he has been working at Kavli Institute for Theoretical Physics at University of California Santa Barbara and Hong Kong University of Science and Technology as postdoc and research assistant professor. Now he is a tenured associated professor at School of Physical Science and Technology, ShanghaiTech University. Jianpeng Liu's research direction is theoretical and computational condensed matter physics, including but not limited to: correlation effects and topological properties in low-dimensional quantum materials, moire

superlattices, and heterostructures, magnetoelectric, piezoelectric, and nonlinear optical properties of novel quantum materials, as well as the development of many-body computational methods.

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**Date and Place: 8th November 2024, 13:30h-14:30h. Room: 1401**. Send comments or questions to: Miguel Tierz to tierz at simis.cn