Interacting Dirac fermions in graphene-based heterostructures

Graphene-based heterostructure systems have drawn significant attention recently due to the discoveries of various exotic phenomena such as correlated insulators, unconventional superconductivity, and orbital magnetic states. In this talk we consider the unusual interaction effects of Dirac fermions in two types of graphene heterostructure systems: the magic-angle twisted bilayer graphene (TBG) and graphene-insulator heterostructures. For magic-angle TBG, we will discuss the nature of the correlated ground states at both integer and commensurate fractional fillings of the topological flat bands, and we will show that both electron-electron interactions and electron-phonon couplings would play crucial roles [1]-[2]. We further consider a situation that graphene is placed on top of a band-aligned insulating substrate. By virtue of the band alignment, charge carriers can be transferred from graphene to the insulating substrate under the control of gate voltages. This may yield some long-wavelength charge order at the surface of the substrate through the Wigner-crystallization like mechanism. The long-wavelength charge order in turn exerts a superlattice Coulomb potential to the Dirac electrons in graphene, which reduces the non-interacting Fermi velocity, such that e-e Coulomb interactions would give rise to gapped Dirac states concomitant with interaction-enhanced Fermi velocities [3]-[4].

References:

[1] Phys. Rev. Lett. 128, 247402 (2022)
[2] Nano Letters (2022), https://doi.org/10.1021/acs.nanolett.2c02010
[3] arXiv:2206.05659 (2022)
[4] arXiv:2110.02899v2 (2021)