Pseudogap and rotonic dispersion in a doped two-dimensional insulator

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Many fascinating quantum phenomena, such as the high-temperature superconductivity, were found in a two-dimensional (layered) insulator doped by foreign dopants. Although these dopants have been often ignored in theoretical models for the sake of brevity, it is true that they remain in actual materials. More importantly, these dopants seem to be arbitrarily distributed at first glance, but they may form a short-range order characterized by broad peaks in the structure factor arising from an average distance between dopants. In this talk, I will introduce our latest works using angle-resolved photoemission spectroscopy (ARPES) on the effect of short-range order to the electronic structure. The model system is a two-dimensional layered insulator (black phosphorus) doped by alkali metals. It could be modeled by a system of two-dimensional dipoles that consist of doped electrons and dopant ions. We found the short-range order is responsible for the pseudogap[1] and the anomalously aperiodic (rotonic) dispersion[2]. If time permits, I will also briefly discuss on sublattice quantum phases and Fermi arcs[3], and the direct measurement of a full quantum metric tensor in solids[4].

[1]S. H. Ryu, M. Huh, D. Park *et al.,* "*Pseudogap in a crystalline insulator doped by disordered metals*", Nature (596) 68 (2021).
[2]S. Park *et al.,* "*Electronic rotons and Wigner crystallites in a two-dimensional dipole liquid*", Nature (634) 813 (2024).
[3]Y. Chung *et al.,* "*Dark states of electrons in a quantum system with two pairs of sublattices*", Nature Physics (20) 1582 (2024).
[4]S. Kim, Y. Chung, Y. Qian *et al.,* "*Direct measurement of a quantum metric tensor in solids*", Science, accepted for publication (2025).