Superconductivity and Strong Correlations in (un-)Twisted Graphene Multilayer Structures

Stevan Nadj-Perge

California Institute of Technology

Since the discovery of magic-angle twisted bilayer graphene, the family of graphene-based strongly correlated superconductors has expanded considerably. In this talk, I will discuss several recent scanning tunneling microscopy experiments performed on the magic-angle twisted trilayer graphene (MATTG) [1, 2], in which we identified striking signatures of interaction-driven spatial symmetry breaking. Over a filling range of about two to three electrons or holes per moiré unit cell, we observed atomic-scale reconstruction of the graphene lattice that accompanies a correlated gap in the tunneling spectrum. This restructure shows as a Kekulé supercell – implying spontaneous inter-valley coherence – and persists in a wide range of magnetic fields and temperatures that coincide with the development of the gap. Moreover, large-scale maps covering several moiré unit cells further reveal a slow evolution of the Kekulé pattern, indicating that atomic-scale reconstruction coexists with translation symmetry breaking at the much longer moiré scale. I will discuss the possible origins of this reconstruction and its possible connections to insulating and superconducting phases in MATTG. If time permits, in the second part of the talk, I will introduce an untwisted graphene-based system, Bernal bilayer graphene coupled to monolayer tungsten diselenide (WSe_2) that, in the presence of a large displacement electric field, also exhibits a range of strongly correlated phases and superconductivity that can be significantly enhanced by spin- orbit coupling [3].

[1] H. Kim, Y. Choi, C. Lewandowski, A. Thomson, Y. Zhang, R. Polski, K. Watanabe, T. Taniguchi, J. Alicea, and S. Nadj-Perge, Nature **606**, 494–500 (2022).

[2] H. Kim, Y. Choi, É. Lantagne-Hurtubise, C. Lewandowski, A. Thomson, L. Kong, H. Zhou, E. Baum, Y. Zhang, L. Holleis, K. Watanabe, T. Taniguchi, A. F. Young, J. Alicea, and S. Nadj-Perge, Nature **623**, 942–948 (2023).

[3] Y. Zhang, R. Polski, A. Thomson, É. Lantagne-Hurtubise, C. Lewandowski, H. Zhou, K. Watanabe, T. Taniguchi, J. Alicea and S. Nadj-Perge, Nature **613**, 268–273 (2023)