Massachusetts Institute of Technology
Department of Physics

Condensed Matter Theory Seminar

"Can you make a magnet out of carbon?"

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Abstract: In most materials, electrons fill bands, starting from the lowest kinetic energy states. The Fermi level is the boundary between filled states below and empty states above. This is the basis for our understanding of how metals and semiconductors work. But what if all the electrons within a band had the same kinetic energy (this situation is called a "flat band")? Then electrons could arrange themselves so as to minimize their Coulomb repulsion, giving rise to a wide variety of possible states including superconductors and magnets. Until recently, flat bands were achieved only by applying large magnetic fields perpendicular to a 2D electron system; in this context they are known as Landau levels. Fractional quantum hall effects result from Coulomb-driven electron interaction within a Landau level. Recently, Pablo Jarillo-Herrero of MIT and coworkers demonstrated flat minibands in graphene-based superlattices, discovering correlated insulators and superconductors at different fillings of these minibands. We have now discovered dramatic magnetic states in such superlattice systems. Specifically, in magic-angle twisted bilayer graphene which is also aligned with a hexagonal boron nitride (hBN) cladding layer, we observe a giant anomalous Hall effect as large as 10.4 kΩ, and signs of chiral edge states. This all occurs at zero magnetic field, in a narrow density range around an apparent insulating state at 3 electrons (1 hole) per moire cell in the conduction miniband [1]. Remarkably, the magnetization of the sample can be reversed by applying a small DC current. Although the anomalous Hall resistance is not quantized, and dissipation is significant, we suggest that the system is an incipient Chern insulator, a type of topological insulator similar to an integer quantum Hall state. In a quite different superlattice system, ABC-trilayer graphene aligned with hBN, again near 3 electrons (1 hole) per moire cell a Chern insulator emerges [2]. This time the flat band is a valence miniband, and a magnetic field of order 100 mT is needed to quantize the anomalous hall signal. This trilayer system can be tuned in-situ to display superconductivity instead of magnetism [3]. We will discuss possible magnetic states, complementary probes to examine which state actually emerges as the ground state in each system, and what one might do with such states.

[1] A.L. Sharpe et al., "Emergent ferromagnetism near three-quarters filling in twisted bilayer graphene", Science 365, 6453 (2019).
[2] G. Chen et al., "Tunable Correlated Chern Insulator and Ferromagnetism in Trilayer Graphene/Boron Nitride Moire Superlattice", arXiv:1905.06535 (2019).
[3] G. Chen et al., "Signatures of tunable superconductivity in a trilayer graphene moiré superlattice", Nature 572, 215 (20

3:30pm
Wednesday, September 18, 2019
Duboc Room (4-331)

Host: Leonid Levitov