Developments in Correlated Materials in Low Dimensions (Two Dimensions)

Gregory A. Fiete
Northeastern University

2D is a "break down" dimension/boundary dimension

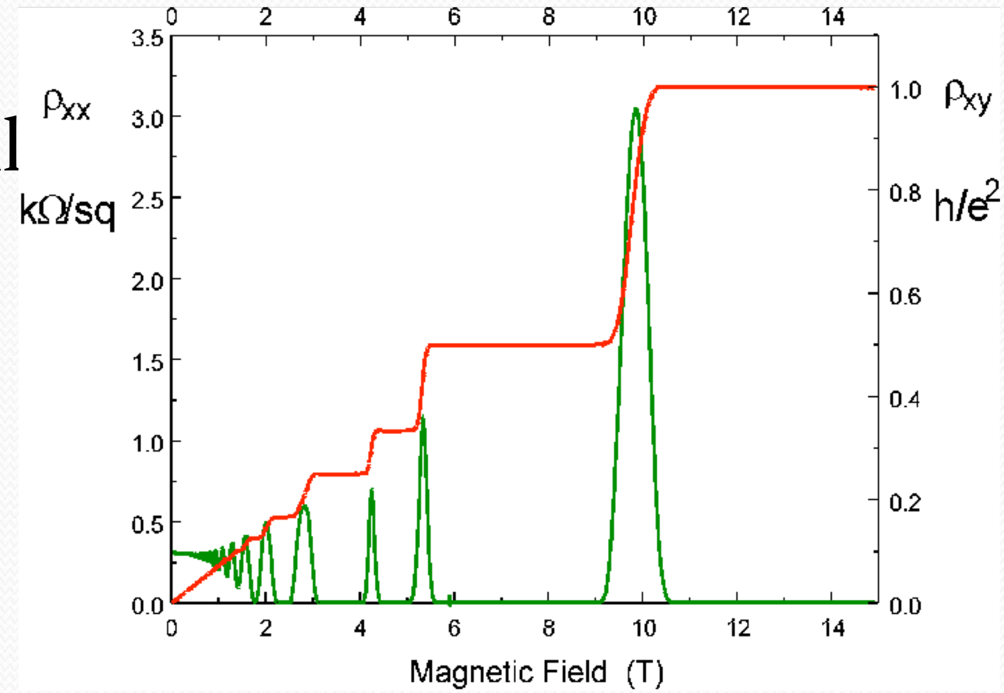
- Systems with continuous symmetries do not have finite temperature phase transitions (Mermin-Wagner).
- Strong competition between quantum fluctuations and thermal fluctuations.
- New types of quasi-particle statistics are permitted (beyond bosons and fermions): Abelian and non-Abelian anyons.
- Fermi liquid theory obtains logarithmic corrections.

2D offers outstanding opportunities for experimental control

- Gating and other methods allow one to tune Fermi energy.
- Substrate strain/chemistry can be used to control lattice and electronic structure.
- Light penetrates entire systems, not just surface layers.
- In some materials, weak inter-layer bonds allow for tuning relative angles of lattices, (e.g. Moire patterns).

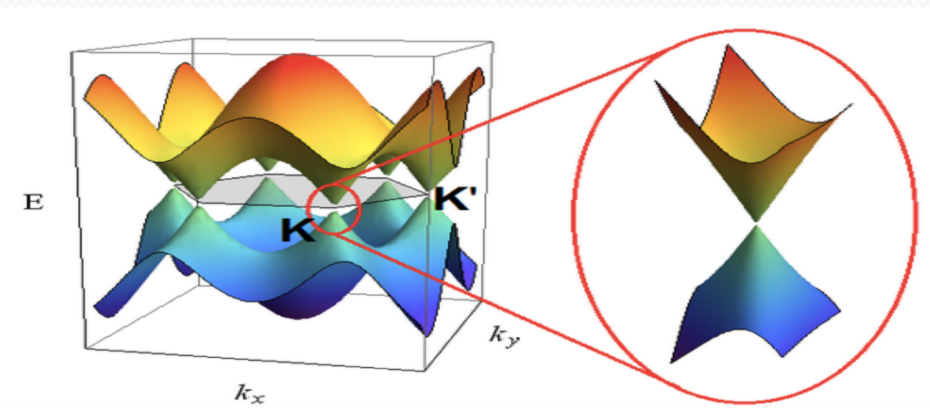
2D is the birthplace of topological states in condensed matter

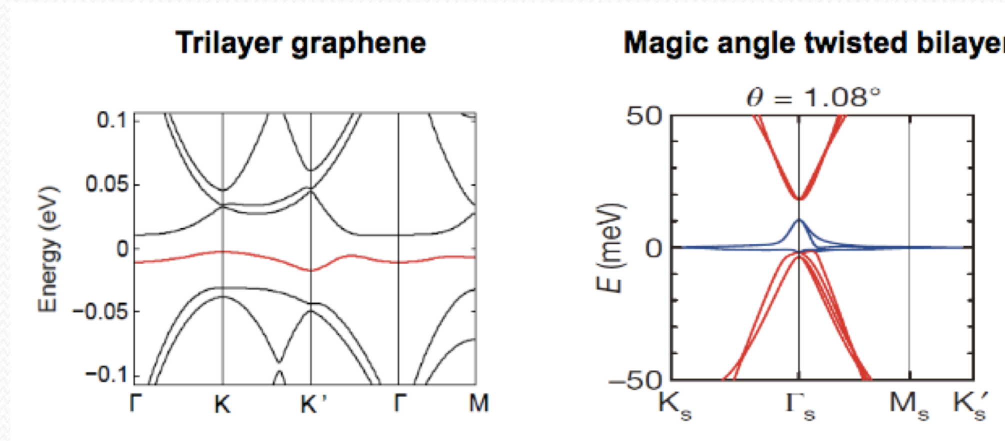
- Kosterlitz-Thouless
- Quantum Hall
- Quantum Anomalous Hall
- Quantum Spin Hall
- Fractional quantum Hall
- Fractional other…



- Chern numbers
- Z2 invariants
- Chern-Simons Theory (Topological Field Theory)

Honeycomb Lattices are Central to All Talks of this Session



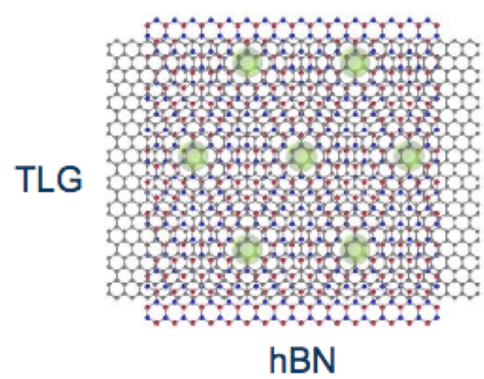


- <u>Gouri Chen</u>: Trilayer graphene on boron nitride moire superlattices
- <u>Liang Fu</u>: Bilayer moire patterned graphene (mostly)
- <u>Scott Crooker</u>: MoS_2, WSe_2
- <u>Pengcheng Dai</u>: CrI_3

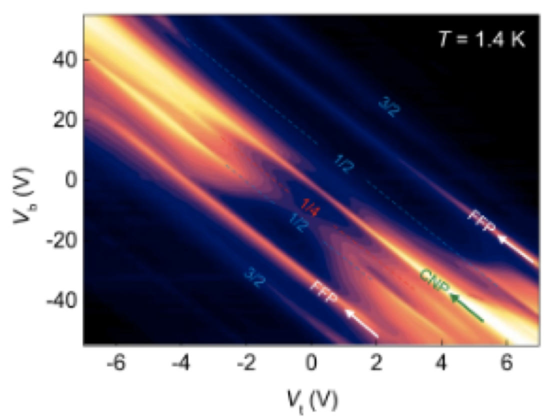
Trilayer graphene on hBN

- Gouri Chen

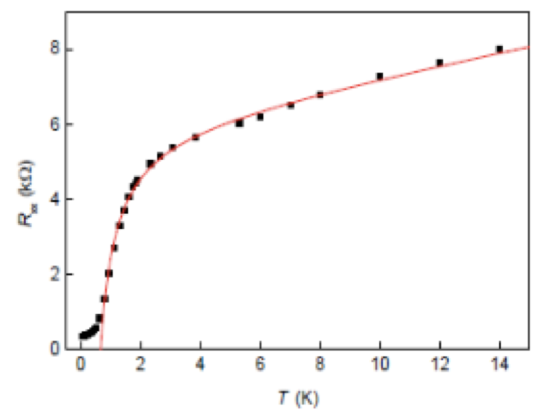
◆ Tunable Mott insulator in TLG/hBN



◆ Correlated quantum transport

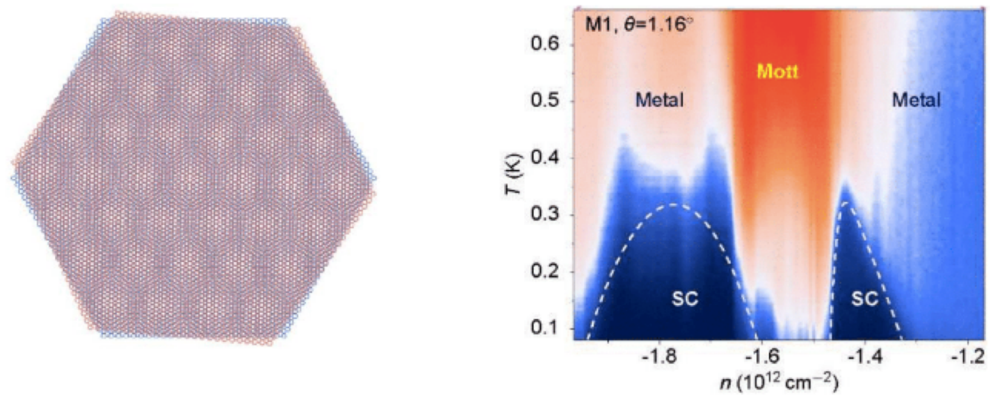


◆ Signatures of superconductivity



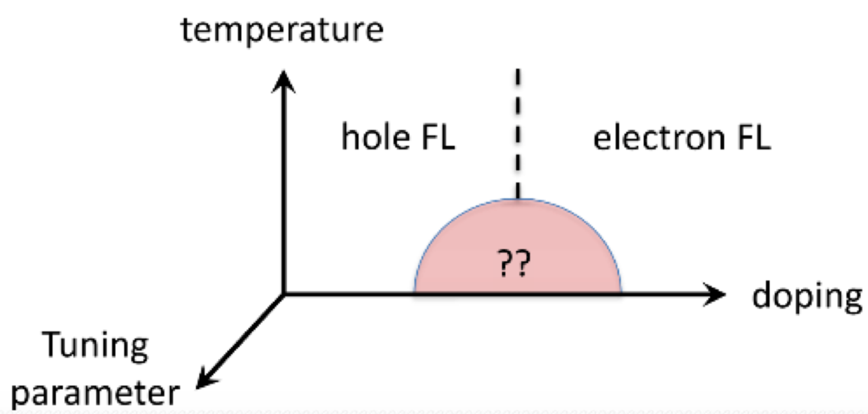
Bilayer graphene moire lattice

- Liang Fu



At θ~1°: 10,000 atoms per moire cell

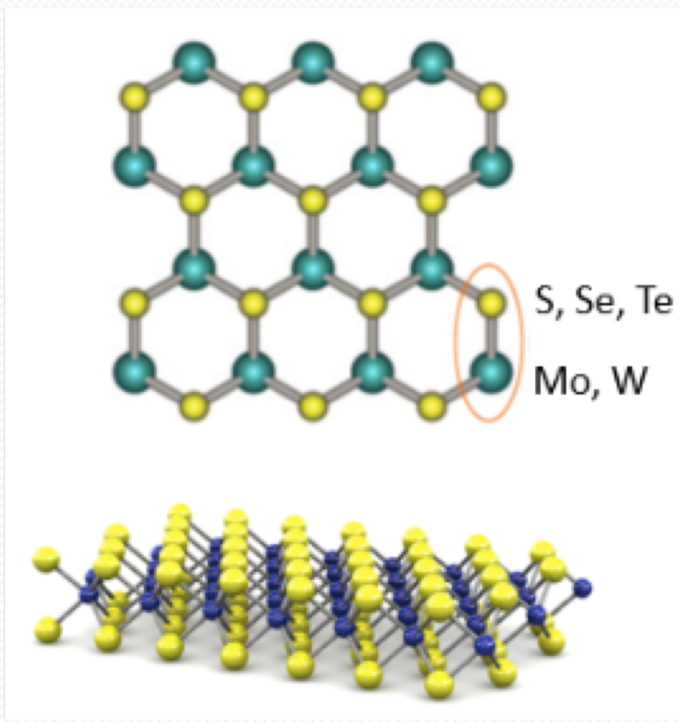
Cao et al, Nature **556**, 80 (2018)

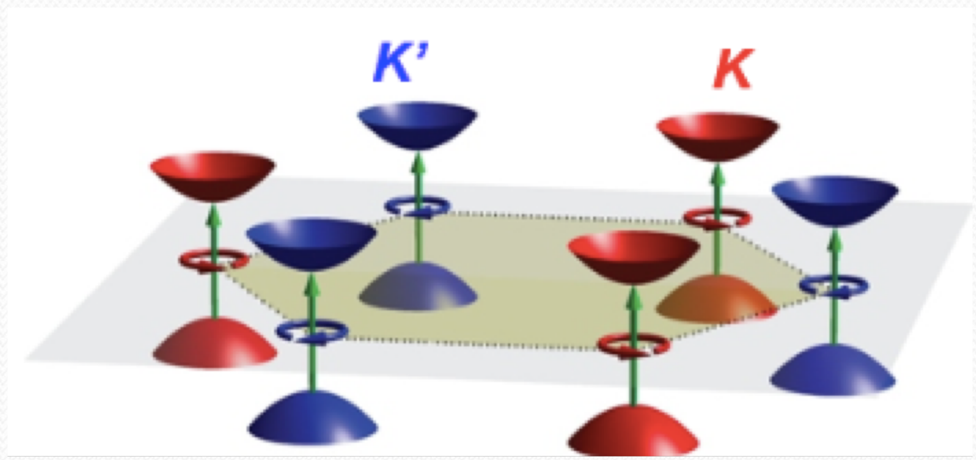


Role of van Hove singularity on phase diagram

Valley control with light in MoS_2 and WSe_2

- Scott Crooker



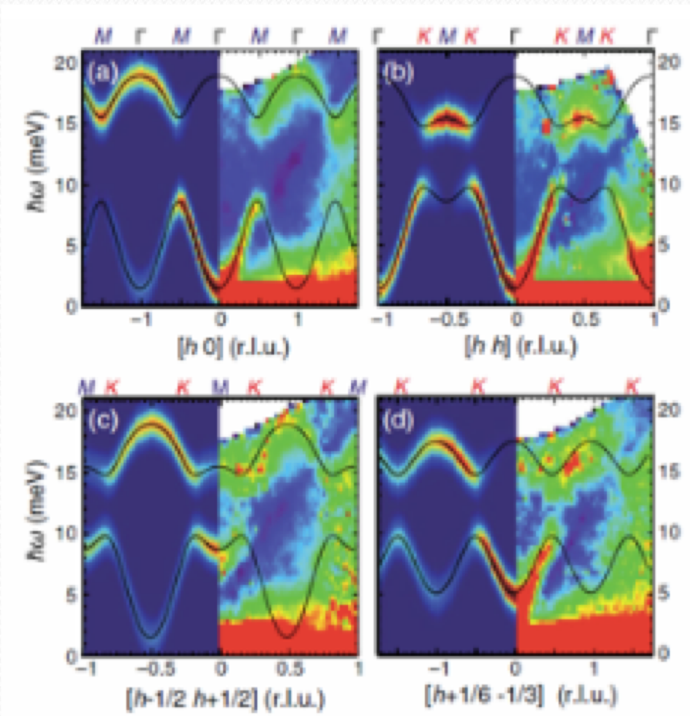


Independent coupling of light to different valleys
"Valleytronics"

Magnetic excitations in CrI_3

- Pengcheng Dai

$$H = -\sum_{i<j} [J_{ij}\mathbf{S}_i \cdot \mathbf{S}_j + \mathbf{A}_{ij} \cdot (\mathbf{S}_i \times \mathbf{S}_j)] - \sum_j D_z (S_j^z)^2$$



How important is exchange anisotropy?