Pairing and Topology in Flat Bands

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First part of this report is about the mechanism of superconductivity in magic-angle twisted bilayer graphene (MATBG). We first present a pairing theory where phonon-mediated inter-valley anti-Hund's coupling (JA) overcomes huge on-site Coulomb repulsion (U) and lead to a strongly correlated superconducting (SC-SC) phase. Then, using a variational Gutzwiller study, we numerically map the phase diagram at filling v=+-2.5, revealing a crossover/transition from a weakly correlated BCS phase to the SC-SC phase as U is increased. This SC-SC phase exhibits a nematic p-wave-like singlet pairing and a nodal structure dictated by the Berry phase (Euler obstruction). We also discuss two proximate normal states - the heavy Fermi liquid and the ``small Fermi liquid'' - as potential parent states of the SC-SC.

If time permitted, in the second part I will talk about systematic constructions of exactly flat bands that exhibit stable topology in lattice models. By allowing non-analytic but continuous Bloch wavefunctions at isolated band-touching points, one can bypass fundamental no-go theorems to realize exactly flat bands with stable topological invariants (e.g., Chern numbers and Z2 indices in 2D and 3D) in finite-range hopping models. All such constructions can be mapped to exact critical tensor-network representations of topological states.