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Title: Topology and quantum geometry in 2D moiré materials

Over the last 15 years there have been exciting developments in condensed matter physics where the topological properties have been experimentally probed and tested against theoretical models. This revolution has been possible because condensed matter systems allow realization, or engineering, of novel effective low-energy Hamiltonians. The electronic bands in such materials possess Berry curvature and topological invariants like Chern numbers that arise due to quantum properties of the Bloch wavefunctions of the electrons. Twisted moiré lattices are an exciting tunable platform to realize non-trivial topological electronic bands.

After a broad pedagogical introduction, I will discuss our experiments where we probe the Berry curvature of the flat bands in moiré superlattice made from two layers of twisted bilayer graphene. Existence of Berry curvature hotspots leads to bulk valley Hall effect [1]. While Berry curvature and its effects in materials have been studied, detecting changes in the topological invariant, Chern number, is challenging; particularly changes of valley Chern type. In this regard, twisted double bilayer graphene (TDBG) has emerged as a promising platform to gain electrical control over the Berry curvature hotspots and the valley Chern numbers of its flat bands. In addition, strain induced breaking of the three-fold rotation symmetry in moiré superlattice, leads to a non-zero first moment of Berry curvature called the Berry curvature dipole, which can be sensed using nonlinear Hall (NLH) effect. We reveal, using TDBG, that the Berry curvature dipole detects topological transitions in the bands and changes its sign. In TDBG, the perpendicular electric field tunes the valley Chern number and the Berry curvature dipole simultaneously providing us a tunable system to probe the physics of topological transitions [2].

References:

1. Sinha* and Adak* et al. Nature Communications, 11, 5548 (2020).
2. Sinha* and Adak* et al. arXiv:2204.02848, accepted at Nature Physics.