Inducing topological flat bands in bilayer graphene with electric and magnetic superlattices

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It was recently argued that Bernal stacked bilayer graphene (BLG) exposed to a 2D superlattice (SL) potential exhibits a variety of intriguing behaviors [1]. Chief among them is the appearance of flat Chern bands – with the possibility of Chern numbers C such that |C|>1 – that are favorable to the appearance of fractional Chern insulator states. Here, we explore extensions of the model of Ghorashi et al. [1] to find additional means of inducing flat Chern bands. We focus on the effects of out-of-plane orbital magnetic fields due to their tendency to flatten bands and induce band topology. In particular, we study fields that vary on length scales much larger than the atomic spacing in BLG, generating what we refer to as magnetic SLs. The magnetic SLs we investigate either introduce no net magnetic flux to the SL unit cell, or a single quantum of flux; in the latter case we employ a recently developed gauge-independent formalism to diagonalize the resulting magnetic continuum Hamiltonian [2]. We find that magnetic SLs on their own can induce flat bands with |C|>1, but richer behavior featuring multiple topological flat bands with |C|>1 can be observed when the magnetic SLs act in conjunction with commensurate electric SLs. Finally, we propose a method of generating flux quantum magnetic SLs along with concomitant electric SLs. The magnetic SL is generated by periodic arrays of flux vortices originating from type II superconductors, while the electric SL arises due to a magnetic SL-induced charge density on the surface of a magnetoelectric material. Tuning the vortex lattice and the magnetoelectric coupling permits control of both SLs, and we study their effects on the band structure of BLG.

[1] S. A. A. Ghorashi et al., Phys. Rev. Lett. **130**, 196201 (2023).
[2] J. Herzog-Arbeitman et al., Phys. Rev. B **106**, 085140 (2022).