Topological polarization in moiré materials

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Recent observations of ferroelectricity in moiré materials [1,2] have motivated the study of their polar properties. In twisted systems where the local stacking configurations break inversion symmetry, the stacking domains have a nonzero polarization, and can be identified as moiré polar domains (MPDs) [3,4]. The experimentally observed ferroelectricity has been attributed to the bending of the domain walls separating the MPDs in response to an applied out-of-plane electric field. As a result, the MPDs with polarization (anti-)aligned to the field (shrink) grow in size.

Additionally, this local symmetry breaking in moiré materials also gives rise to an in-plane component of polarization, the form of the total polarization being determined purely from symmetry considerations [5]. The in-plane component reveals that the MPDs are topologically nontrivial, forming a network of merons and antimerons (half-skyrmions and half-antiskyrmions). From a theoretical perspective, the unconventional nature of MPDs makes them difficult to describe. In particular, standard descriptions of local polarization in a supercell do not correctly describe MPDs, and are not guaranteed to be gauge invariant. A correct definition of local polarization textures in crystal supercells has recently been proposed, which is naturally gauge invariant, and correctly describes the MPDs in twisted systems without relying on the configuration space approximation [6].

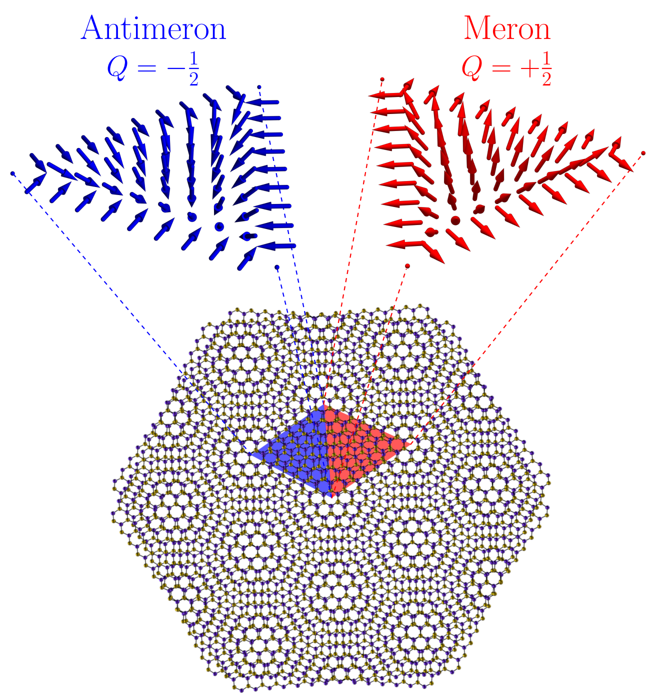

FIG. 1. Sketch of a twisted hBN bilayer. The MPDs in a single moiré cell are highlighted in blue and red, which have equal and opposite polarization. The normalized polarization field in the MPDs are sketched above, which form antimerons ($Q = -\frac{1}{2}$) and merons ($Q = +\frac{1}{2}$), respectively.

[1] K. Yasuda, et. al., *Science* (2021)
[2] K. Ko, et. al., *Nat. Mater.* (2023)
[3] D. Bennett and B. Remez, *npj 2D Mater. Appl.* (2022)
[4] D. Bennett, *Phys. Rev. B* (2022)
[5] D. Bennett, et al., *Nat. Commun.* (2023)
[6] D. Bennett, et al., *Phys. Rev. Res.* (2023)

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