Theory of moiré nematic state in twisted double-bilayer graphene

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Graphene-based moiré superlattice systems, such as twisted bilayer graphene, have attracted considerable interest in the last few years, as they display a remarkable variety of correlated phenomena. In particular, besides correlated insulating phases in the vicinity of integer fillings, separated by superconducting domes, there is evidence of other ordering tendencies at non-integer fillings; these, however, remain less explored. A notable example is provided by scanning tunneling microscopy measurements on twisted double-bilayer graphene, which reveal the presence of spontaneous three-fold symmetry breaking for partially filled flat bands, i.e. nematic order. Here we discuss how these experimental results allow us to determine the underlying microscopic form of the nematic order parameter. Through a detailed comparison of theory and experiment, we show that the dominant contribution to the observed nematic pattern arises from states at the moiré scale rather than at the microscopic scale of the individual graphene lattices. We will also discuss theoretically that twisted double-bilayer graphene allows for an unprecedented tunability of the orientation of the nematic director via the displacement field.

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