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Title : Chiral symmetry and robust zero-mode Landau levels in disordered graphene and related materials

Abstract :
The presence of the zero-mode Landau levels is essential to the quantum Hall effect of monolayer and bilayer graphene. To explore the role of the chiral symmetry and the valley mixing for the robustness of zero-mode Landau levels against disorder, we have performed detailed numerical analysis based on the tight-binding lattice models as well as the analytical approach with the effective Dirac field. For monolayer graphene with massless Dirac fermions, the robustness of zero-mode Landau level against a chiral-symmetry respecting disorder (such as ripples) is demonstrated when the valley mixing is suppressed by the spatial correlation of disorder, yielding an unconventional Hall transition at the zero-mode Landau level [1]. It is further shown that the chiral symmetry can be generalized even for tilted Dirac fermions, which are observed in a certain organic conductor, to protect the robustness of the zero-mode Landau level [2]. The generalized chiral symmetry is equivalent to t
he requirement that the Dirac Hamiltonian is elliptic as a differential operator, and is relevant to the index theorem. For bilayer graphene, the sharpness of the zero-mode Landau levels against the disorder respecting the chiral symmetry is shown to exist even in an electric field [3] and in the presence of the trigonal warping [4]. The robustness of zero modes is also examined in a system without fermion doubling, which can be realized in cold atoms in an optical lattice. We find in such a system that the zero-mode Landau level exhibits anomalous sharpness even when the chiral-symmetry respecting disorder is uncorrelated in space [5].

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