Disorder and quantization in symmetry broken quantum Hall states in graphene

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Résumé

The Quantum Hall effect (QHE) is known to be stabilized by disorder, thanks to the emergence of bulk localized states that do not participate in quantized transport along the edge. However, disorder also induces the loss of QHE quantization: if a large enough energy (called hopping energy) is provided, charge carriers trapped in a localized state will have the possibility to tunnel from state to state, making the bulk conducting. This phenomenon occurs even at temperatures much lower than the Landau level (LL) spacing, is usually described in the framework of variable range hopping (VRH) (1), and corresponds to a rich physics governed by universal scaling (2, 3). The competition between these two antagonistic effects of disorder is set by the interplay between two energy scales (LL spacing and disorder broadening) (4).

To explore this interplay, we have probed the temperature dependence of QH states in graphene in a Corbino geometry (5), over three orders of magnitude. The fourfold spin and valley symmetry of graphene is lifted at high magnetic field, providing two well-separated scales for the energy level spacing (6): cyclotron gap for a fully filled LL, and spin/valley gaps for the symmetry broken states. Tuning the carrier density with an electrostatic gate allows us to probe states with vastly different gaps at otherwise fixed magnetic length and disorder. We observe a difference of two orders of magnitude in the extracted hopping energies and thus in the localization lengths between cyclotron gap states and symmetry broken states. To understand such discrepancy, we propose a scenario of localization length saturation based on the overlap of localized states from different LL, preserving the plateau quantization at T=0 but rendering it more fragile at finite temperature. Finally, our measurements also suggest that there may be a contribution to disorder that is spin- and valley-polarization dependent.

References

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