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Fractional quantum Hall physics in graphene

Jurgen H. Smet

Max-Planck-Institut für Festköperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany

Due to progress in graphene sample quality, rich interaction physics related to the fractional quantum Hall effect as well as the lifting of symmetries associated with the spin and pseudospin degrees of freedom of graphene's Fermi Dirac electrons starts to be disclosed. A key requirement to observe this fragile physics has so far been the fabrication of better quality samples. This has been accomplished by placing graphene on a flatter substrate, which is less prone to attract adsorbates, such as BN, or by suspending and in-situ current-annealing graphene. In the quest for observing even more fragile or novel incompressible states, probing a smaller area may circumvent the challenges of producing ever higher mobility samples, since the sample may be much cleaner on the nanometer scale. Here, we report two different approaches to locally access incompressible ground states:

Transport measurements normally provide a macroscopic, averaged view of the sample so that disorder prevents the observation of interaction-induced states. We demonstrate that transconductance fluctuations in a graphene field effect transistor reflect charge localization phenomena on the nanometer scale due to the formation of a dot network near incompressible quantum states. These fluctuations unveil higher order fractional quantum Hall states, although these states have remained hidden so far in conventional magnetotransport quantities.

Using a scanning single electron transistor to locally probe the compressibility is even more powerful, especially when combining the best of all worlds and performing such studies on a suspended and in-situ current annealed graphene flake. These experiments reveal for instance fractional quantum Hall states with unprecedented denominators for graphene. The observed sequence of fractional quantum Hall states partially deviates from the standard composite fermion sequence. Also phase transitions within fractional quantum Hall states abound.

The above experiments were carried out together with B. Feldman, A. Levin, D. Abanin, B. Halperin, A. Yacoby (Harvard University), D.-S. Lee, V. Skakalova, R.T. Weitz and K. von Klitzing (Max Planck Institute for Solid State Research).