New Fractional Quantum Hall States in Graphene

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Introduction

The band structure of graphene is described by a four-fold degenerate Dirac Hamiltonian, allowing for exotic electronic quasiparticle excitations to be explored in condensed-matter systems. At high magnetic fields and unlike at small magnetic fields, electron-electron interactions can become important, resulting in a breaking of the four-fold degeneracy and giving rise to novel correlated states. Studying these states in transport has remained elusive due to disorder but recently improvements in device quality has allowed for these states to be investigated, which have now been seen by us at the NHMFL.

Experimental

We measured heterostructures of Boron-Nitride and graphene with electronic mobilities up to 400,000 cm^2/Vs in both 31T of Cell 9 and Hybrid 45T magnet. The magnetoresistance was measured as a function of temperatures between 300mK and 10K using a conventional lock-in measurement. The density of the sample was controlled using a proximal graphite layer setup in "field-effect" geometry, allowing for the density dependence of the magnetoresistance to be measured.

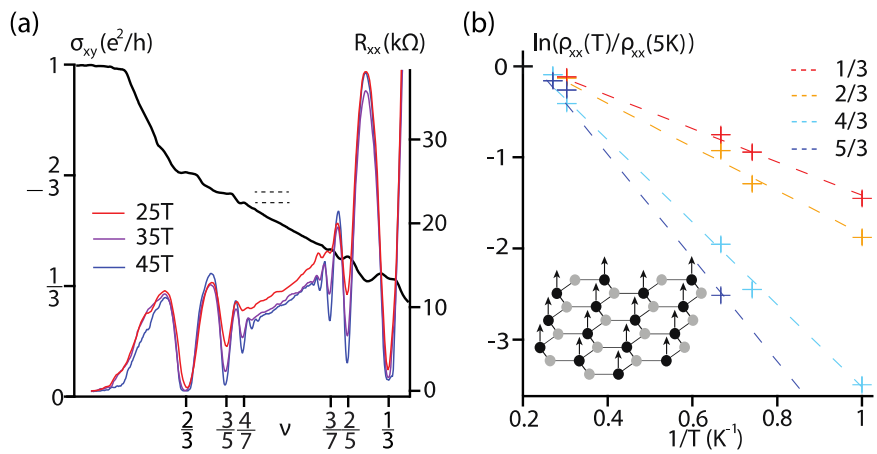

Fig 1: (a) Longitudinal R_{XX} resistance and transverse conductance σ_{XY} as a function of magnetic field for fractional quantum Hall states in the n=0, where previously unseen fractions are observed. (b) Arrhenius plot of the energy gaps at 1/3, 2/3, 4/3 and 5/3 used to help construct an understanding of the ground state at each fraction (inset).

Results and Discussion

The sample measured in Cell 9 (up to 31T) and in Cell 15 (up to 45T) at the NHMFL and the results for the longitudinal resistance R_{XX} and transverse conductance σ_{XY} are shown in Fig. 1(a) where the degeneracy-split n=0 (we have also measured n=1, data not shown) Landau level is measured at T=300mK. Importantly, measured peaks in R_{XX} and plateaus in σ_{XY} are seen at fractions that haven't been observed in transport before – specifically at nu=2/5, 3/5, 3/7, and 4/7. The most robust gap of these new fractions is nu=3/5 is studied as a function temperature and compared to previous seen fractional gaps at 1/3, 2/3 and 4/3.

Conclusions

We have used the high magnetic fields available at he NHMFL to probe the novel ground states in graphene where, due to the large fields, the interactions between electrons cannot be neglected. In particular, we have seen signatures of broken valley symmetry states in fractional quantum Hall plateaus that have previously been missing in transport measurements.

Acknowledgements

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