Hofstadter's Butterfly in Moiré Superlattices

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Introduction

In 1976, Douglas Hofstadter predicted that electrons subject to a periodic potential and a magnetic field display a complex fractal energy structure. This remarkable energy structure is expected to have dramatic signatures in electronic transport, including unconventional non-monotonic sequences of quantum Hall plateaus.

Direct confirmation of these predictions has proved challenging, due mainly to the requirement that the period length of the potential be similar to the magnetic length. When graphene is placed on hexagonal boron nitride, a moiré pattern forms due to the slight mismatch between the two crystal lattices. This pattern acts as a periodic potential modulation, and can have a length scale of up to 15 nm, depending on the relative rotation of the crystals. This periodicity is an ideal size for observing Hofstadter physics, as the corresponding magnetic fields are in the range of tens of tesla.

Experimental

Bilayer graphene on hexagonal boron nitride samples were measured in the 31 tesla resistive magnet in cell 9 at the NHMFL in a top loading sample-in-vapor He^3 refrigerator.

Results and Discussion

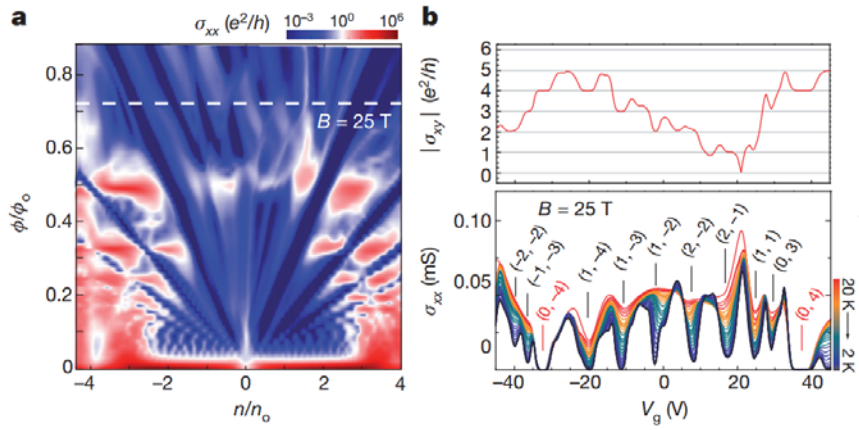

Fig. 1

Fig. 1a shows the conductivity of the sample as a function of carrier density and magnetic field. At high magnetic fields, we observe minima corresponding to gaps that do not follow a simple ratio of carrier density to magnetic field. These new gaps are accompanied by unconventional Hall plateaus, plotted in Fig 1b top. Additionally, temperature dependence measurements (Fig 1b bottom) show that these new gaps are much smaller than normal cyclotron gaps. By looking at the line traced by the gap in density-field space, we are able to label all of the gaps that we observe with two topological numbers (noted in parentheses in Fig 1b bottom) corresponding to the line's slope and intercept. Taken together these measurements represent conclusive observation of the physics of Hofstadter's butterfly.

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References

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