New Fractional Fractal Quantum Hall States in Graphene

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Recently we showed that magnetotransport in moiré-patterned graphene enables measurement of the fractal spectrum known as the Hofstadter butterfly. Here we report measurement of the butterfly spectrum in very high mobility devices. We observe that the Hofstadter spectrum supports conventional fractional quantum Hall Effect (QHE) states. More surprisingly, we find evidence of a new kind of fractional QHE, emerging at the highest achievable magnetic fields[1].

Hints of an unexplainable Hall plateau were first observed in the cell 9, 31T magnet. Further measurements in the cell 15, 45T hybrid magnet enabled high resolution maps of the Butterfly minigaps over sufficient field range to unambiguously confirm that the new QHE states project to a fractional Bloch Band filling index.

For the the first time we report the coexistence of conventional fractional quantum Hall effect together with integer gap states associated with the fractal Hofstadter spectrum. Above 30T, a new series of states appear at fractional Bloch filing index. ***These fractional Bloch band QHE states are not anticipated by existing theoretical pictures and point towards a new type of many-body state.*** Our findings demonstrate the Hofstadter spectrum to be a rich new system in which to study emergent behavior.

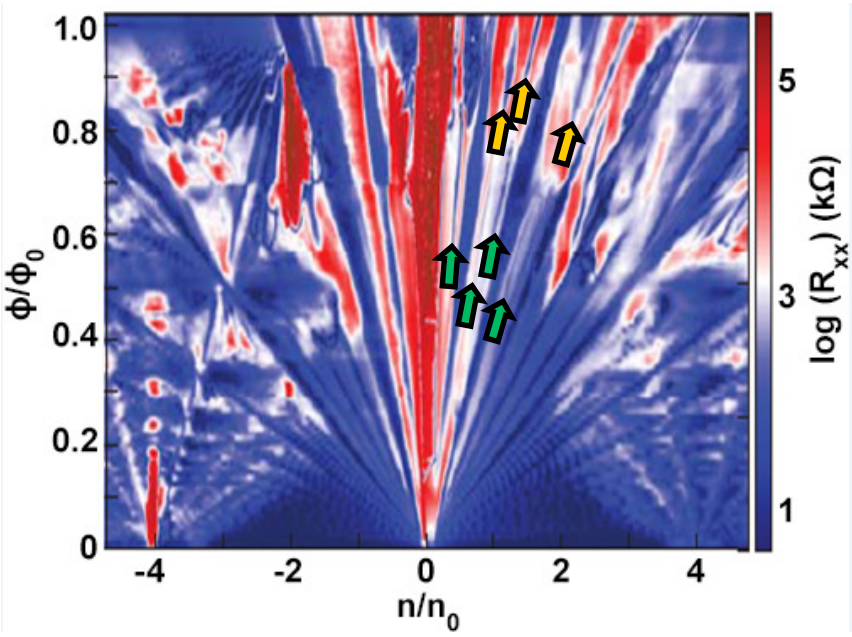

Figure: Fractal energy level structure of graphene aligned with a boron nitride substrate. This is a plot of normalized magnetic flux ϕ/ϕ_o (spanning 0<H<45T) versus carrier doping per plaquet, n/n_o. The minima in resistivity (blue streaks) follow the equation: $n/n_o = t\,\phi/\phi_o + s$. Green arrows indicate minima associated with fractional quantization of t. Yellow arrows indicate fractional quantization of s, the new fractional Bloch band states.

Facilities: NHMFL, 31 T magnet (cell 9), 45 T magnet (cell 15).

Citations: [1] **Wang L**, **Gao Y**, **Wen B**, **Han Z**, **Taniguchi T**, **Watanabe K**, **Koshino M**, **Hone J**, **Dean CR**. Evidence for a fractional fractal quantum Hall effect in graphene superlattices. *Science* 350: 1231–1234, 2015. DOI: 10.1126/science.aad2102.