Observing Laughlin's pump using quantized edge states in graphene

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Laughlin's thought experiment of a quantized charge pump, central to understanding the integer quantum Hall effect (IQHE), has remained elusive to direct experimental observation due to the challenge of realizing pristine electronic edges. Here, we overcome this challenge by utilizing small, lithographically defined contacts on a graphene sample, creating a system functionally equivalent to a Corbino disk. The small contact size leads to a pronounced energy quantization of the confined edge states, enabling us to directly observe the discrete nature of Laughlin's charge pumping. We find pronounced conductance oscillations as a function of magnetic field and carrier density, with a periodicity that scales with the contact size, confirming the quantized nature of the pumping process. Our results provide a direct experimental realization of Laughlin's seminal thought experiment, highlighting the fundamental role of topology in the IQHE.

Figures

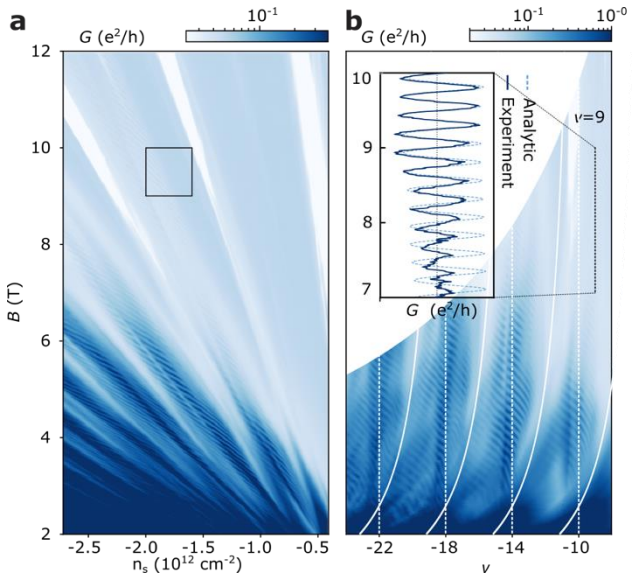

Figure 1: Transport measurement of Laughlin's pump. a. Two-terminal conductance measured with a 100 nm-radius contact as a function of a perpendicular magnetic field, B, and carrier density, ns. Oscillations appear within the Landau fan of the main bulk when the secondary bulk is gapped. **b.** Same as a, plotted as a function of the main bulk's filling v and magnetic field. Inset: linecut (dark blue) at filling factor v = 9 (dotted line), compared with a series of Lorentzians (light blue) fulfilling the resonance condition 1. Smooth experimental data background is removed for clarity.

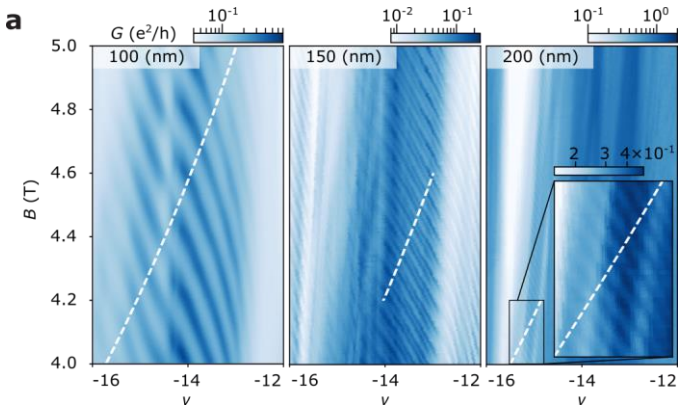

Figure 2: Scaling with contact size. Left to right: Two-terminal conductance measured as a function of the filling ν and the magnetic field B with contact radius 100 nm, 150 nm and 200 nm.