



# Even denominator fractional quantum Hall states in monolayer graphene



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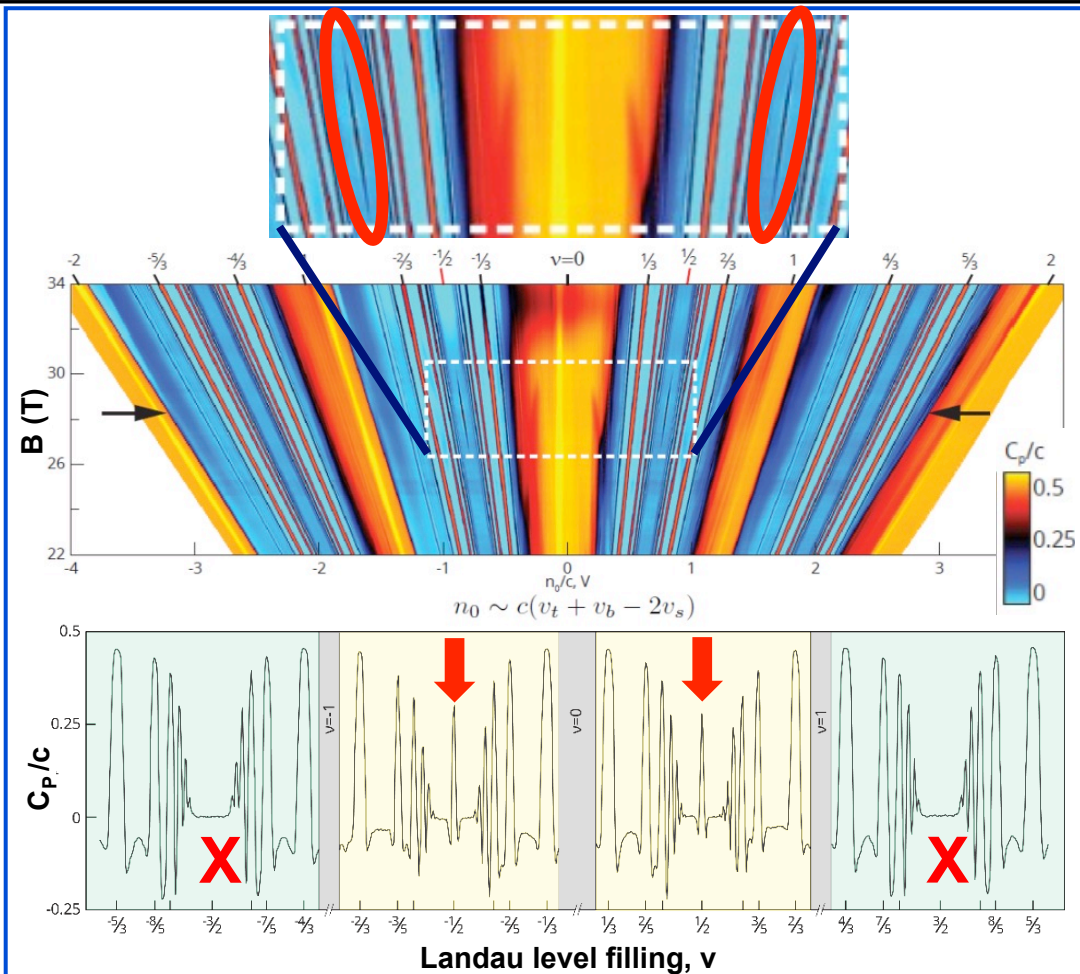
Graphene is a unique platform for studying the fractional quantum Hall (FQH) effect, a series of electronic states with excitations that exhibit fractions of an electron charge. In very low disorder devices of monolayer graphene, we report new and unexpected FQH states at Landau level filling  $\nu \pm 1/2$ , but not  $\pm 3/2$ .

We measured the capacitance of monolayer samples to reveal the presence of insulating FQH states. By sweeping the electron density using electrostatic gates, and applying large perpendicular magnetic fields up to 34T, we observed previously unobserved FQH states which only persist for a narrow range of magnetic fields, and only appear close to charge neutrality. The new FQH states appear at half-filling of a Landau level with either holes or electrons. The appearance of these even-denominator filling FQH states implies a quantum mechanical state with especially exotic properties. We attribute these states to close coupling to the dielectric substrate, consisting of hexagonal boron nitride.

Our work shows the important role the substrate can play in engineering new FQH states in graphene. It inspires new experimental and theoretical work to probe the nature of these unexpected FQH states.

**Facilities used:** DC Field Facility (Cell 12 Resistive Magnet, 45T Hybrid Magnet)

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Top: Penetration field capacitance ( $C_p$ ) plotted vs magnetic field ( $B$ ) and electron density ( $n_0$ ) showing both new and well studied fractional quantum Hall states, which appear as orange and red lines. The two new states are circled in red in the enlarged white dashed box. Bottom:  $C_p$  vs  $\nu$  at  $B = 28.3$ T, showing dozens of different FQH states, the peaks in  $C_p$ . Red arrows mark the new FQH states at  $\pm 1/2$ . Red "X's" highlight the absence of FQH states at  $\pm 3/2$ .