Observation of Developing Fractional Quantum Hall States at Even-Denominator Fillings 1/6 and 1/8

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Two-dimensional (2D) electron systems confined to modulation-doped semiconductor structures provide a nearly ideal testing ground for exploring new physical phenomena. We have had very recent breakthroughs in the molecular beam epitaxy growth technique of GaAs quantum wells, which allows layer-by-layer growth of pristine GaAs/AlGaAs with extremely few impurities (less than one residual impurity for every 10 billion Ga/Al/As atoms) [1-4]. The new generation of GaAs quantum wells hosting 2D electron and hole systems with record mobilities have already led to the discovery of a plethora of new quantum phases in the extreme quantum limit [5-9].

2D electrons in the lowest Landau level host numerous exotic many-body phenomena, including fractional quantum Hall states (FQHSs) at odd-denominator fillings, and composite Fermi liquid states at half and quarter fillings. At very small fillings $\nu < 1/5$, pinned Wigner crystal states are dominating and experiments have revealed highly insulating phases in this regime, although hints of FQHSs have been reported in high-quality samples at certain fillings such as $\nu = 1/7$. In our recent experiments, we observe numerous even- and odd-denominator FQHSs at extremely small fillings $1/5 \leq \nu \leq 1/9$, superimposed on a highly insulating background, in ultrahigh-quality, dilute, GaAs 2D electron systems. The odd-denominator FQHSs we observe follow the Jain sequences of *six-flux* and *eight-flux* composite fermions [$\nu = p/(6p \pm 1)$ and $\nu = p/(8p \pm 1)$], revealing the close competition between Wigner crystal and FQHSs. Remarkably, developing FQHSs also emerge at *even-denominator* fillings $\nu = 1/6$ and 1/8. These are the smallest fillings at which an even-denominator FQHS is observed.

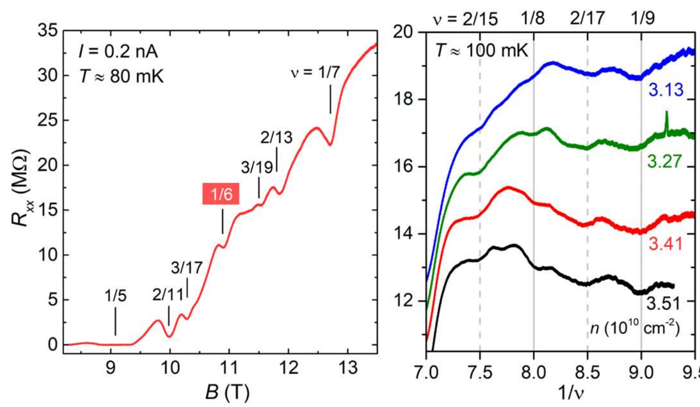

Fig.1. Magneto-transport data for our ultrahigh-mobility 2D electron systems, exhibiting numerous developing FQHSs at extremely small Landau level fillings.

The emergence of an even-denominator FQHS at $\nu = 1/6$ (and 1/8) is unexpected. These states have not been reported in any 2D carrier system, or predicted by existing theories. They are likely *single-component*, *non-Abelian* states emerging from the pairing of six-flux and eight-flux composite fermions. We systematically studied the enigmatic 1/6 FQHS as a function of temperature, 2D electron density, quantum well width, and charge distribution. The single-layer charge distributions of our 2DESs and the robustness of the 1/6 FQHS with significantly imbalanced charge distributions also support a single-component non-Abelian origin.

References:

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