Upshift of the fractional quantum Hall plateaux: evidence for repulsive scattering for composite fermions

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The fractional quantum Hall effect (FQHE) is observed in high-mobility two-dimensional electron systems in the low-temperature, high-magnetic-field regime. It is believed that the FQHE arises from strong electron-electron interactions, causing the two-dimensional electrons to condense into a fractional quantum Hall liquid. Jain [1] introduced the concept of "composite fermion" where each electron is bound to two magnetic flux quanta, and in this picture the FQHE can then be understood as a manifestation of the integer quantum Hall effect of composite fermions. At a Landau level filling factor $\nu=1/2$, a two-dimensional electron system can be transformed into a composite fermion system interacting with a Chern-Simons gauge field. A wide variety of experiments have demonstrated that at $\nu=1/2$ the effective magnetic field acting on the composite fermions is zero. Away from $\nu=1/2$, the effective magnetic field acts on the composite fermions is given by $B_{eff} = B_{ext}- B(\nu=1/2)$ where B_{ext} is the applied external magnetic field.

It is now well established that if there are an equal number of positively and negatively charged impurities, the quantum Hall plateaux in $\rho_{xy}(B)$ are expected to be centred about the classical value $\rho_{xy} = B/(en)$ where n is the 2D carrier density. Haug *et al.* [2] have shown that when repulsive or attractive scattering centres are deliberately introduced close to a two-dimensional electron gas (2DEG), the centres of the quantum Hall plateaux are shifted to higher or lower magnetic field, respectively. In this paper, we present magneto transport measurements on a high-quality GaAs electron system. We provide compelling evidence that the dominant scattering for the composite fermions is different from that for electrons. This is supported by studying the upshift of the n=1 quantum Hall plateau. Within the integer quantum Hall picture, the $\nu=1$ quantum Hall plateau is centred about the classical value $\rho_{xy} = B/(en)$ as clearly shown in figure 1. This result clearly demonstrates within the electron picture, there are approximately an equal number of positively and negatively charged impurities within our system. Alternatively, the $\nu=1$ integer quantum Hall state can be regarded as $\nu_{eff} = -1$ *integer* quantum Hall state for composite fermions where ν_{eff} is the effective filling factor. In this case, the centre of $\nu_{eff} = -1$ *integer* quantum Hall state (which is equivalent to the $\nu=1$ quantum Hall plateau) is shifted to higher effective magnetic field, suggesting that repulsive scattering is stronger than attractive scattering for the composite fermions. The fact that there is a small yet significant difference between the linear fits using two different models provides evidence that repulsive scattering can be more important for composite fermions.

References:
1. J. K. Jain, Phys. Rev. Lett. 63, 199 (1989).
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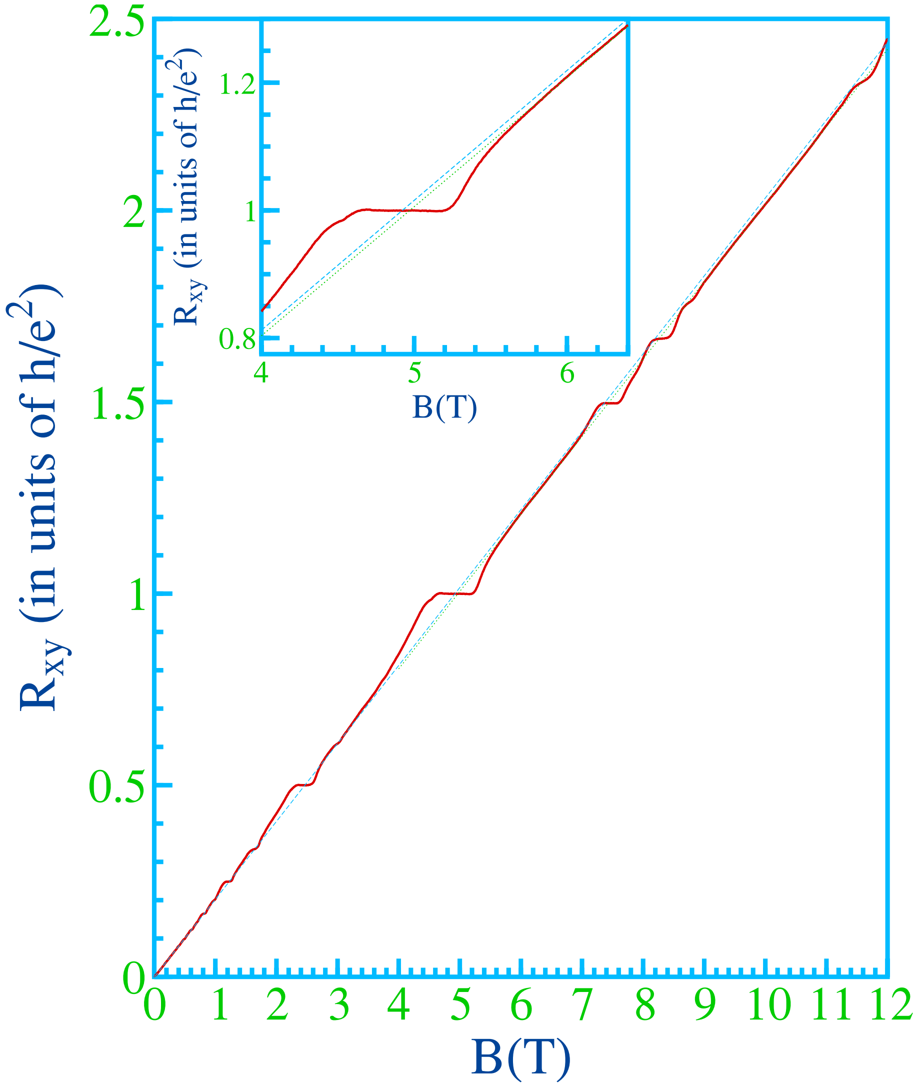

Figure 1 Hall resistance as a function of perpendicular magnetic field. The linear fit (in the blue line) corresponds to the extrapolation of the classical Hall effect for electrons. The linear fit (in the green line) corresponds to the extrapolation of the classical Hall effect for composite fermions. The inset shows the zoom-in of the ν=1 quantum Hall plateau.