

High Pressure Fractional Quantum Hall Effect Measurements.

The Fractional Quantum Hall Effect (FQHE) is neatly described by a model of spinless Composite Fermions (CFs), allowing an interpretation as the Integer QHE of CFs [1]. While the simple model explains the principle series of fractions centred on $\nu=1/2$ and $1/4$, it is complicated for $\nu>1$ as electrons of both spin states will be present. In this experiment we used hydrostatic pressure to reduce the Landé g -factor and so test the consequences of including electron spin into the picture.

We measured ρ_{xx} and ρ_{xy} under high pressure using a 15 kbar pressure cell in a 30mK dilution fridge and 17T superconducting magnet [2]. At ambient pressure the GaAs-GaAlAs heterojunction had an electron density of $3 \times 10^{15} \text{m}^{-2}$ and a mobility of $312 \text{m}^2/\text{Vs}$ after photoexcitation. By 13.4 kbar, where $\mathbf{k} \cdot \mathbf{p}$ theory predicts g -factor will be reduced by 75%, the density was halved but the mobility was unchanged..

The effect on ρ_{xx} of changing pressure is shown in figure 1 for the region centred on $\nu=3/2$ at 40mK. It can be seen that while the $\nu=2$ minimum due to a Landau gap is unchanged, $\nu=1$ becomes much narrower as the pressure increases and the spin gap is reduced. A change in the fractions can also be seen. Initially $4/3$ and $5/3$ have similar strengths and there is a strong $7/5$. As the pressure increases $4/3$ is essentially unchanged, but $5/3$ gets much weaker and by 13 kbar is actually subsumed into the $8/5$ fraction. By treating the FQHE minima in ρ_{xx} as CF Shubnikov-de Haas oscillations we can measure the energy gap between CF levels [3]. (This is better than using activation measurements for weak features as it yields an energy difference between the centres of the energy levels and does not depend on

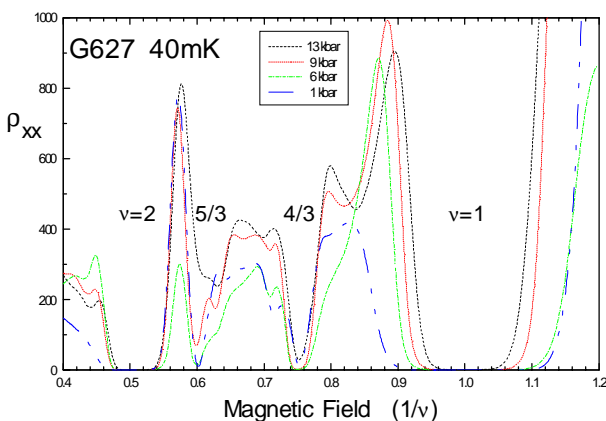


Figure 1: FQHE between $\nu=1$ and 2 showing the change in strength of the various fractions and a narrowing of the $\nu=1$ minimum as pressure increases.

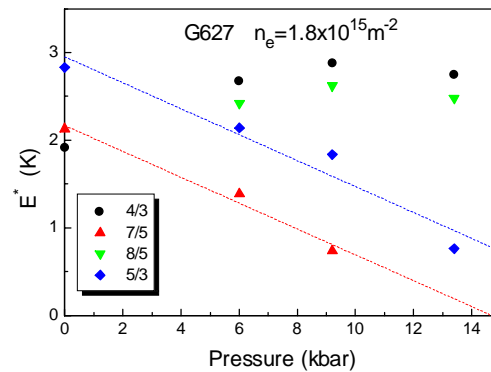


Figure 2: Contrast the reduction in FQHE energy gap with pressure for the $\nu=5/3$ and $7/5$ fractions with the constant values for $\nu=4/3$ and $8/5$.

the level width.) In figure 2 it can be seen quantitatively that decreasing the spin splitting (by increased pressure) causes the odd numerator fractions at $\nu=5/3$ and $7/5$ to decrease in strength relative to those at $4/3$ and $8/5$.

This is consistent with experiments that show an increase in strength of the odd numerator fractions when the spin splitting is increased, either by increasing the electron density [4] or tilting the magnetic field [5].

The results are explained by considering one set of CF energy levels for each spin state. For even/odd numerator fractions there are an even/odd number of occupied CF levels so the Fermi level then either lies in a quasi-Landau gap (even) or in a spin gap (odd). When the g -factor is changed so are the sizes of the different types of gap and hence the strengths of the fractions.

At the highest pressures, where the g -factor approaches zero, we see other even numerator fractions such as $\nu=2/3$, $4/3$, $4/5$ and $6/5$ are enhanced while the odd numerator fractions are suppressed. This is consistent with removal of the spin degeneracy. The newly emerged $4/5$ and $6/5$ states should then be regarded as $2/5$ and $3/5$ states of the degenerate system.

References

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