High Pressure Investigation of Skyrmions and Composite Fermions

The magnetorestistance of GaAs-GaAlAs single heterojunctions has been measured under pressures up to 22 kbar in a liquid clamp cell at 30mK. Under these conditions the electron *g*-factor may be dramatically reduced and becomes zero at ~18 kbar when the spin degeneracy is removed. By varying *g* with pressure we studied the spin dependence of the integer and fractional quantum Hall effect states. The energy gaps were measured from the temperature dependence of r_{xx}.

Of particular interest are the ferromagnetic states at n=1, and its composite fermion analogue n=1/3, which have just one completely full spin polarised Landau level. The excitations from these ground states involve spin reversal, but experimentally the energy gap is much larger than the single particle Zeeman energy (ZE=gm_BB). Instead the gaps are due to exchange interactions that scale with the Coulomb energy E_c. At large ZE the excitations measured in transport experiments are spin waves, but at smaller ZE there can be many spin reversals leading to a spin texture or Skyrmion formation. In these experiments we access very small values of h=ZE/E_c where Skyrmions are the favoured excitations.

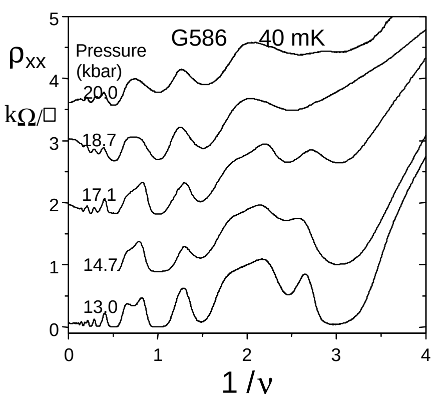

Figure 1 shows r_{xx} for sample G586 with a density of $5x10^{14}m^{-2}$ at pressures up to 20 kbar. It can be seen that increasing pressure leads to weaker features at the ferromagnetic states, while the unpolarised states at n=2/3 and 2/5 remain strong. The feature at 1/3 actually disappears in the 18.7 kbar trace, which is just where *g* becomes zero, and recovers at higher pressure after *g* has changed sign. The energy gaps are extracted by fitting the depths of the minima to the Liftshitz-Kosevich formula. To allow comparison between samples of different density and with theory these gaps are shown scaled by E_c in figs. 2 and 3 for n=1 and 1/3. Using data from samples with a higher density, there is a linear decrease in gap at large |h| as expected for spin wave excitation. However at small h these gaps decreases rapidly for sample G586. From the rate of decrease with h the number of spin flips involved in the excitation can be deduced. In neither case can the data at small h be fitted with the unit gradient expected for spin waves and this suggest multiple spin excitations are present. These may be Skyrmions at n=1 with some 36 spins reversed and composite Skyrmions at n=1/3 with 3 reversed spins. The size of the composite Skyrmion is in line with theoretical estimates [R.K. Kamilla, X.G. Wu and J.K. Jain, *Solid State Commun.* 99, 289 (1996)] and is much smaller than the Skyrmion at n=1 because the residual interactions between composite fermions are much weaker than between electrons.

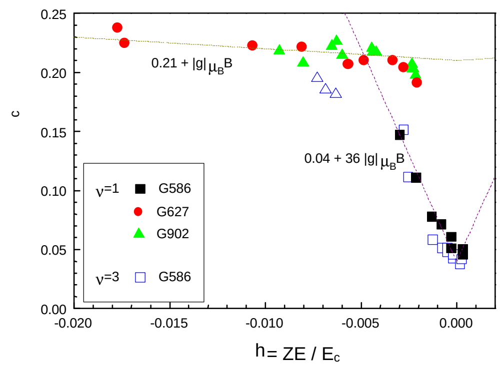

Fig. 2: *Energy gap at* n=*1 and 3 as a function of* h. *The two lines with slopes of unity and 36 correspond to spin waves and Skyrmions with 36 spin flips*

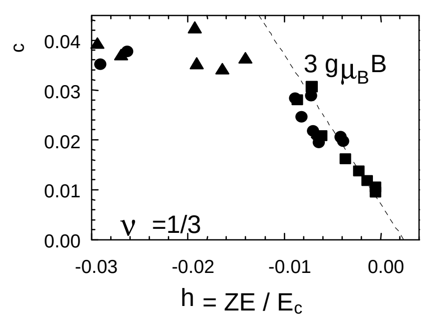

Fig. 3: *Energy gap at 1/3 as a function of* h. *The line corresponds to 3 spin flips.*

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