First experimental measure of fractional statistics.

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Recommended with a Commentary by Steven Kivelson, Stanford University.

A quantum Hall fluid is a seemingly featureless quantum liquid, with no broken symmetries and only short-range correlations. However, in theory, it can be characterized by a "topological order," whose most tangible implication is the existence of quasiparticles with fractional statistics. There is no real doubt that this characterization of the fractional quantum Hall liquid is correct. Indeed the idea of topological order has now been extended in many new and exciting ways and it is being touted as a route to decoherence free quantum computing – there are entire workshops on this sort of order attended by many of the best theorists in the field. And yet, until the recent experiment of F. E. Camino, Wei Zhou, and V. J. Goldman reported in cond-mat/0502406, no experiment has been carried out to directly detect fractional statistics or any other aspect of topological order.

The experiment of Camino *et al* is based on an interferometer in which quasiparticles (edge states) propagate around a large ring, of area A_L, which encircles a small ring, of area A_S. In the case in which the fluids in the device are integer quantum Hall fluids, whose excitations have familiar Fermi statistics, oscillatory Aharanov-Bohm like interference effects are seen as a function of varying magnetic field with a period determined by the quantum of flux and the area of the large ring, $\Delta B = \phi_0/A_L$ ($\phi_0 = hc/e$). Changing the number of quasiparticles on the small ring has no effect on the motion of the quasiparticles along the encircling edge, so no detectable interference effects are seen with period $\Delta B = \phi_0/A_S$. However, when the device is operated in the fractional quantum Hall regime, the principle oscillations have a period $\Delta B = \phi^*{}_0/A_S$, determined by an effective flux quantum, $\phi^*{}_0 = hc/e^* > \phi_0$, where e^* is the fractional charge of the quasiparticle. (In the present experiment, in which the device is operated with 2/5 quantum Hall fluid filling the inner ring and a 1/3 fluid encircling it, $\phi^*{}_0 = \phi_0$.)

Two aspects of this observation are particularly striking. In the first place, the fact that the state of the inner ring affects the interference on the outer ring reflects the topological character of the effect - the current carrying excitations encircle the inner ring, but presumably do not ever come close to it. So, to obtain an effect that depends on A_S at all is a direct indicator of a topological effect. Secondly, the effect is *not* periodic with period ϕ_0. This should be contrasted with the case of a superconducting ring, where $\phi^*{}_0 = (1/2)\ \phi_0$, so all Aharanov-Bohm effects still exhibit the fundamental periodicity implied by gauge invariance, $\Delta B = \phi_0/A$, with the new aspect being the persistence of the effect in the thermodynamic limit (due to off-diagonal long-range) and the emergence of a new fundamental period which is half the bare period.

The observed value of $\phi^*{}_0$ is consistent with theoretical expectations. In the present case, because the inner ring is not empty, but rather filled with 2/5 fluid, the lack of ϕ_0 periodicity does not contradict gauge invariance. However, because the 2/5 state is a gapped (*i.e*. insulating) state, one is tempted to expect that flux threaded through it would have no effect other than producing an Aharonov-Bohm phase. However, the same non-local correlations that are responsible for the fractional statistics and for the incompressibility of the fractional quantum Hall fluid mean that this naïve expectation is incorrect.

There are many follow-up experiments that need to be done, and it would be worthwhile to check the conclusions by comparing more detailed theory (including the temperature and voltage dependences expected from the theory of the chiral edge states) with experiment. However, the observations reported here are very dramatic, and I think it is already fair to conclude that this experiment has, for the first time, probed one of the most fundamental (topological) aspects of the fractional quantum Hall fluid.