Signatures of spin-charge separation in double--quantum-wire tunneling.

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In one dimension interactions and quantum fluctuations play a very special role and lead for quantum interacting particles to a state quite different from the standard Fermi liquid state, known as a Luttinger liquid. The two main characteristics of such a state are: (i) a power-law decay of the correlation functions, with a non-universal exponent depending on the interactions; (ii) a separation of the excitations in terms of excitations carrying only spin and no charge (spinons) and excitations carrying charge and no spins (holons). The Luttinger liquid is so far the only non-fermi liquid state for which we have reliable theoretical calculations.

Given its remarkable properties, there has been an intensive search for Luttinger liquid properties in one dimensional experimental systems. The power-law behavior of the correlation functions has been probed in spin chains (neutrons), organic conductors (optical conductivity), edge states in quantum hall effects (transport) and carbon nanotubes (transport), with convincing evidence for the power law scaling and thus Luttinger properties. But so far the spin charge separation has been elusive to prove. Some hints of it have been seen in photoemission but the evidence was far from being unambiguous.

To probe for such Luttinger liquid properties a remarkable experimental setup has been developed by A. Yacoby et al. consisting of two weakly coupled quantum wires, between which electrons can tunnel. The position of the band of one of the wires can be shifted both in energy (with a gate voltage) and in momentum (by application of a magnetic field). This gives a fine tuning of the tunneling in the wire that allows to perform spectroscopy. It is thus possible to probe the presence of two branches of excitations with different velocities in the wire, and thus for the spin charge separation in a Luttinger liquid. The theoretical analysis of the data cleverly exploits the finite size of the wire to make interference patterns, which allows to detect the small difference between the two velocities, and give a very convincing proof the spin-charge separation.