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Title:

Quantum critical point in singe channel normal and topological superconductor junctions

Abstract:

"Majorana fermions emerge in condensed matter as boundary modes in some novel topological systems like p-wave superconductors [Kitaev, Phys. Usp. 44, 131 (2001)] and their study is important from both fundamental and application points of view [J. Alicea, Rep. Prog. Phys. 75, 076501 (2012)]. One of the best candidates for such topological systems are semiconductor nanowires with strong spin-orbit interaction, subject to a uniform magnetic field and in proximity to a s-wave superconductor [Oreg et al., PRL 105, 177002 (2010), Lutchyn et al., PRL 105, 077001 (2010)]. The first two ingredients lift the spin degeneracy at the Fermi energy and induce an effectively p-wave superconductivity in the nanowire. The signature of Majorana bound state at a NS interface is a perfect Andreev reflection at low energies and perfect normal reflection at high energies, creating a zero bias peak in the differential conductance. Recent observations of this peak [Mourik et al., Science 336, 1003 (2012) and Das et al., Nature Phys. 8, 887 (2012)] could be regarded as the discovery of Majroana fermions. However, this interpretation is overshadowed by uncertainties about the role of disorder and interactions in the bulk and interface and also by other possible origins of the zero bias peak in these systems.

We study the case of N normal channels coupled to a superconductor and following previous works [Pikulin et al., JETP Lett. 94, 693 (2011), Fulga et al., PRB 83, 155429 (2011)] relate the topology of such NS junctions to the determinant of their scattering matrix. We show that this correspondence leads to a quantized low-temperature conductance at N=1,2 whenever the Majorana bound state is present, independent of the presence of disorder in the normal wire or marginal boundary couplings at the NS interface. Moreover, it has been shown recently [Affleck et la. , J. Stat. Mech., P06011 (2013)] that a Majorana fermion coupled to two interacting channels acts as a switch at low energies, having perfect Andreev reflection in the more-strongly-coupled channel and perfect normal reflection in the other. It is also shown that the symmetric coupling of two channels is a quantum critical point (QCP) at which this system flows to a non-trivial low-temperature fixed point and exhibits a non-quantized universal conductance. We explore the possibility of realizing this QCP in a single-subband nanowire by coupling both spins to the Majorana fermion. This is achieved by the

application of a magnetic field gradient which lifts the spin degeneracy in the superconductor part and keeps it in the normal side.

We use numerical results to show that it is indeed possible to tune through a symmetric coupling point in this system. The observation of such QCP may provide stronger evidence for the existence of Majorana fermions at the topological NS interface."