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Quantum Tunneling of Phase Slips in Al Nanowires.[1]

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Superconductivity is a unique phenomenon which manifests itself, most strikingly, as the absence of electrical resistance at very low temperatures. While the resistance in 3-D Superconductors is exactly zero below the Normal-Superconducting transition temperature (T_c), in 1-Dimensional ones the proliferation of phase slips– small regions which become normal allowing the phase of the order parameter to rapidly change by 2π– can produce a residual resistance or destroy the superconductivity altogether. In the classical Langer, Ambegaokar, McCumber and Halperin theory, phase slips are caused by thermal excitation over free energy barrier that separates metastable states but Giordano suggested that Macroscopic Quantum Tunneling of phase slips through the barrier (Phys. Rev. Lett. 61, 2137 (1988)) could be significant at very low temperatures where thermally activated phase slips would be exponentially suppressed. However, despite intense experimental effort over the past 20 years, quantum tunneling of phase slips has remained controversial in 1-D superconductors. This talk will discuss the limiting case of 1-D superconductivity in an extremely long (100 μm) and narrow (5 nm–25 atoms) aluminum wire. In applied magnetic field, and at temperatures well below the superconducting transition, we find evidence ofm macroscopic quantum tunneling at temperatures where the classical theory of thermally activated phase slips would not be able to reproduce the experimental results (Phys. Rev. Lett. 97, 017001 (2006)). Not only are these results valid in linear regime, where most of the experimental data so far has been obtained, but they are consistent and supported by a newly proposed analysis in non-linear regime. These results help ruling out other scenario and establishing that, at temperatures much below T_c, the transport properties of superconducting 1-D nanowires are primarily determined by macroscopic quantum tunneling of phase slips.

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