Spin-resolved Andreev levels in hybrid superconductor-semiconductor nanowire devices

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The combination of superconductors and low-dimensional conductors embodies a rich, yet largely unexplored physics. In this hybrid system, macroscopic properties enforced by superconductivity can be controlled through electrically tunable microscopic degrees of freedom, inherent to a relatively small number of confined electrons. Here we consider the prototypical case of a quantum dot (QD) coupled strongly to a superconductor (S) and weakly to a normal-metal (N) tunnel probe. Specifically, we address devices based on individual InAs/InP core/shell nanowires electrically contacted by vanadium and gold, where a single QD is naturally formed in the nanowire section between the S and N leads. We investigate the magnetic properties of the lowest-energy, sub-gap states, which are governed by a competition between superconducting pairing and Coulomb repulsion. In a magnetic field, only when the ground state is a spin singlet, can the Zeeman splitting of the (excited) doublet be revealed by tunnel spectroscopy. The splitting is strongly influenced by a level-repulsion effect with the continuum of quasi-particle states; and it can induce a quantum phase transition (QPT) to a spin-polarized state [1]. Our experimental results, supported by theory, hold relevance for current research on quantum-information devices and Majorana fermions in hybrid nanostructures.

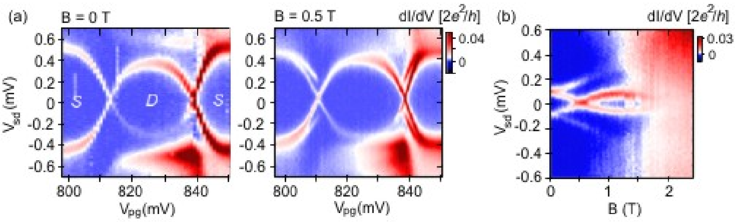

Figure 1: (a) Magnetic field-induced Andreev level splitting. The green (yellow) circles indicate the regions in which the ground state is a singlet (doublet). (b) Field-induced quantum phase transition from a singlet to a spin-polarized ground state. The QPT appears as a zero-bias peak.

[1] E. J. H. Lee, X. Jiang, M. Houzet, R. Aguado, C. M. Lieber and S. De Franceschi, arXiv:1302.2611.