Gate-tunable quantum phase transition of the ground state of a magnetic impurity coupled to a superconductor

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A quantum dot coupled to a superconducting surface may act as a tunable magnetic impurity, controlled by an external gate potential. The competition of magnetism and superconductivity can give rise to sub-gap excitations at the superconductor surface (Yu-Shiba-Rusinov bound states) [1]. Further, if the tunnel coupling to one of the leads is strong enough, quantum correlation effects can lead to a Kondo resonance, corresponding to a magnetic moment screened by the conduction electrons. By tuning the gate, we modulate the Kondo temperature T_K in the normal state, and consequently the energy of the sub-gap bound states $E_{B\pm}$. When the bound state energy goes to zero, a quantum phase transition of the system between a screened and unscreened local spin state occurs. Our results demonstrate the universality of this transition taking place at $\Delta/T_K \approx 2.5$, confirming previous theoretical predictions [2].

[1] B. W. Heinrich, J. I. Pascual and K. J. Franke, Single magnetic adsorbates on s-wave superconductors, arXiv:1705.03672v2 (2017)
[2] M.-S. Choi et al, Kondo effect and Josephson current through a quantum dot between two superconductors, Phys. Rev. B **70**, 020502(R) (2004)

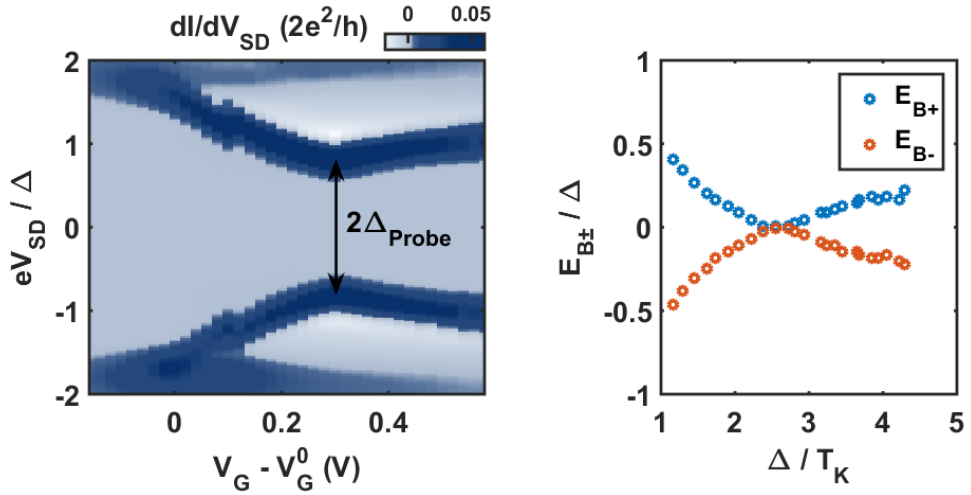

Figure 1: (a) Differential conductance mapping of the sub-gap states versus gate voltage. The system formed by a superconducting lead strongly coupled to the quantum dot is probed spectroscopically by a second, weaker coupled lead, also superconducting. (b) Extracted bounded states energy displaying the phase transition for $\Delta/T_K \approx 2.5$.