Interplay of magnetism and superconductivity in correlated nanoscale systems

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Magnetic impurities immersed in a superconductor give rise to the formation of the Yu-Shiba-Rusinov states – the sub-gap states that can be probed by Andreev spectroscopy in quantum dot superconducting heterostructures. When the coupling between a magnetic impurity and a superconducting host grows, a phase transition between the Kondo-screened and unscreened phases emerges, followed by the formation of the many-body singlet state, whose spatial extension is referred to as the Kondo screening cloud. We analyze the properties of this cloud in the case of spin-1/2 impurity attached to an s-wave superconductor. We show that, although the Kondo state does not form in the unscreened phase, the Kondo cloud does exist in both quantum phases, however, while screening is complete in the screened phase, it is only partial in the unscreened phase. We also demonstrate that the compensation, a quantity introduced to characterize the integrity of the cloud, is universal, and can be related to the magnetic impurities' g-factor. Moreover, focusing on the sub-gap transport regime, we inspect the transport properties of strongly correlated coupled quantum dot systems, pointing at nonlocal pairing as a source of spin exchange and Kondo screening. Finally, we discuss the transport behavior of magnetic impurities in the presence of one-dimensional topological superconductors exhibiting Majorana zero-energy modes.

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