Slave-spin approach to the Anderson-Josephson quantum dot

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We study an interacting quantum dot connected to two superconducting leads. The system is known to exhibit a quantum phase transition where the ground state changes from a singlet state (of BCS or Kondo nature) to a magnetic doublet state. This so-called '0-π' transition is driven by the competition between the dot-lead hybridization Γ, the superconducting gap Δ, and the interaction strength U.

Our approach is based on a slave-spin description, a semi-analytical technique that allows to take into account strong correlations on the dot by introducing an auxiliary two-level system variable.

At the mean-field level, the problem maps into a resonant level model with a renormalized coupling to the superconducting leads, coupled to an auxiliary spin-1/2 variable accounting for the parity of the dot. We obtain the mean-field phase diagram (Fig. 1), showing a transition between a Kondo (singlet) and a local moment (doublet) regime, corresponding to the 0-π transition of the junction. Moreover, by including fluctuations on top of the mean-field theory, we can describe finite-frequency dynamics of the effective spin variable. This leads to the formation of high-energy Hubbard bands in the spectral function and a coherent Kondo peak with a BCS gap at low energies (Fig. 2).

Figures

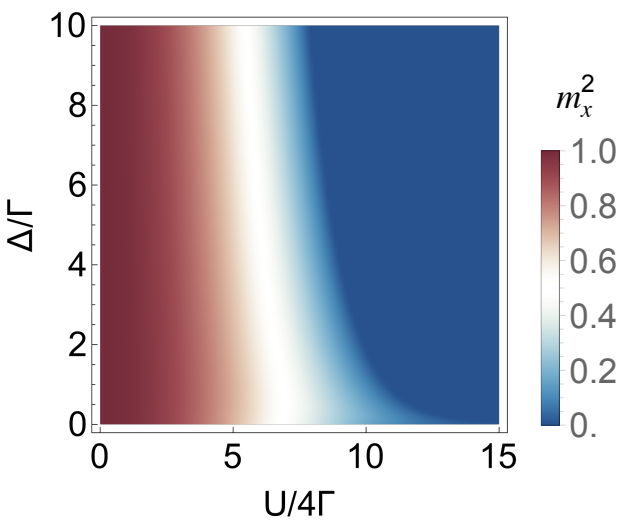

Figure 1: Phase diagram of the superconducting Anderson impurity model at half-filling. The blue color corresponds to a doublet state where the Kondo effect is suppressed.

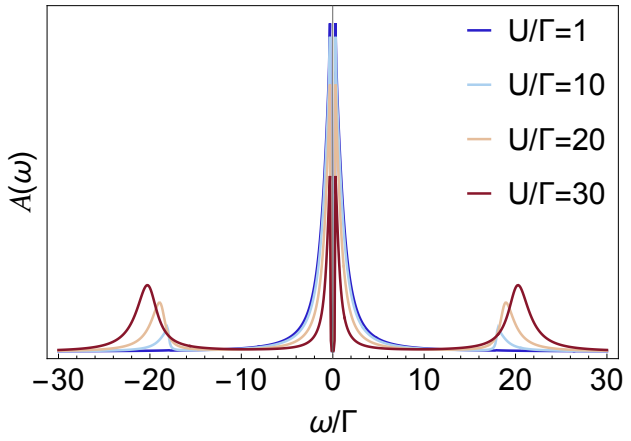

Figure 2: Dot spectral function for various interaction values.

References

[1] A. Keliri and M. Schirò, arXiv:2502.14843 [cond-mat.mes-hall] (2025).