Fermi liquid description for Andreev-Kondo transport through a quantum dot coupled to normal and superconducting leads

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We provide a Fermi-liquid description for low-lying energy states, at $|\omega| \ll \Delta$, of an Anderson impurity connected to one superconducting with an energy gap Δ and one normal-metal electrode. In this system the interplay between the Andreev scattering and Kondo effect occurs at low temperatures. Specifically the crossover between the Cooper-pairing singlet and the Kondo singlet affects transport properties. This system has a $U(1)$ symmetry in the Nambu pseudo-spin space in the special cases, i) the particle-hole symmetric case, and ii) the large gap limit $\Delta \to \infty$. We studied the large gape limit in a previous work [1], mapping the original Hamiltonian exactly onto a single-channel Anderson model that describes the interacting Bogoliubov particles, the total the number of which is conserved in the two special cases. In the present report, we consider the corrections due to finite Δ, starting from the $\Delta \to \infty$ limit. Specifically, we calculate order $1/\Delta$ corrections of the conductance. We also show that the conductance can generally be expressed in terms of the phase shift and Bogoliubov angle at zero temperature, using the Ward identity to evaluate the contribution of the vertex corrections.

[1] Yoichi Tanaka, N. Kawakami and A. Oguri: J. Phys. Soc. Jpn. **76**, 074701 (2007).