Multiple quantum phase transtitons in low-bandwidth two-impurity Kondo systems

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Since the seminal papers of Jones and Varma [1,2], the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction Y between two Kondo impurities is conventionally modeled by a Heisenberg coupling term J_H. It gives rise to a quantum phase transition between the Kondo and the RKKY phases in the two-impurity Kondo model for arbitrarily large Kondo couplings, even in the presence of charge fluctuations. However, the significance of this result is still controversial. Firstly, the transition is extremely fragile to particle-hole asymmetry, smearing the critical point into a crossover in its presence [3,4]. This has lead to the common belief that it cannot be realized in a realistic 2-impurity system and has made its relevance for lattice models debatable. Moreover, in the model Y and the Kondo exchange J_K are considered independent, although Y is genuinely generated from J_K, and the Kondo temperature depends on Y, as has been shown experimentally [5] and theoretically [6].

Recently, it has been shown that the quantum phase transition can be restored for weaker particle-hole symmetry by parameter fine-tuning [7]. We revisit the problem to show, by numerical renormalization group calculations, that in the geometry of two impurities, coupled each to a different host as in [5], Y induced solely by J_K and the inter-host exchange coupling J_Y causes the transition for a properly symmetric case, if J_K is not too strong. Moreover, another phase transition occurs then at very strong J_Y, which is not present in Jones-Varma model [1,2], and counter-intuitively drives the system to the Kondo-like state again, although with non-universal impurity spectral density. The two critical values of J_Y head towards each other for increasing J_K, and above a critical value of J_K both transitions are replaced by a single crossover. We explain the phase diagram by analyzing the relevant quasi-particle picture and propose an experiment in magic-angle bi-layer graphene where our predictions could hopefully be tested.

References:

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