

Spin Screening Cloud in Local Moment Phases

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A magnetic impurity in a metal is screened by conduction electrons via the Kondo effect. However, if the local density of states (LDOS) of the electrons near the impurity exhibits a pseudogap or hard gap at the Fermi level, the screening becomes imperfect, leading to a local moment (LM) phase. It has been believed that in the LM phase, the impurity spin is not screened but decoupled from the conduction electrons. In contrast to this common belief, we show that in the LM phase, the impurity spin is screened by the conduction electrons by computing quantum entanglement between the impurity spin and conduction electrons. The electrons form a spin screening cloud spatially extended over a distance, which is a generalization of the Kondo cloud. For the pseudogap LDOS, we employ the numerical renormalization group method and show that the cloud spatially decays algebraically with increasing distance from the impurity. For the hard gap LDOS, we use the density matrix renormalization group method, and the spin cloud decays exponentially. In each case, the spatial distribution of the spin cloud follows a single universal function of a rescaled distance by a characteristic length of the system.

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