ENHANCEMENT OF UNCONVENTIONAL SUPERCONDUCTIVITY NEAR A LOCAL QUANTUM CRITICAL POINT

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Unconventional superconductivity has been observed on the border of magnetism in various strongly correlated systems. In many cases, non-Fermi liquid behavior in the normal state above the superconducting transition temperature is thought to arise from a quantum critical point (QCP) hidden beneath the superconducting dome. However, the role of quantum criticality in the formation of Cooper pairs remains unclear. We have studied this issue within an extended cluster dynamical mean-field theory approach to the Anderson lattice model. The method maps the lattice to a self-consistently determined problem describing two Anderson impurities (labeled 1 and 2) that each hybridize with a conduction band, that interact with one another via an Ising coupling, and that are also coupled via their spin difference $S_1^z - S_2^z$ to a bosonic bath that represents the effect of exchange with lattice sites outside the cluster. We have employed the numerical renormalization group and continuous-time quantum Monte Carlo methods to solve this effective problem and explore the nature of the antiferromagnetic QCP. When the magnetic fluctuations are three-dimensional in character, the QCP is of the conventional spin-density-wave (SDW) type where heavy quasiparticles exist on either side of the quantum phase transition. By contrast, two-dimensional magnetism gives rise to local quantum criticality where the Kondo scale vanishes continuously on approach to the QCP from the paramagnetic side, while at the QCP the staggered lattice susceptibility has a $T^{-\alpha}$ temperature dependence with $\alpha = 0.81(4)$ in excellent agreement with the value $\alpha \approx 0.75$ observed in experiments on $CeCu_{6-x}Au_x$. Superconducting pairing fluctuations are significantly enhanced in the vicinity of both types of QCPs. The existence of such enhancement near an SDW QCP is in accord with previous theoretical approaches. However, at every temperature studied, we find that the locally critical point produces a stronger pairing enhancement than in the SDW case. This makes local quantum criticality a novel and compelling mechanism for unconventional superconductivity.

Category: QC
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