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Superconducting condensation energy of CeCu2Si2 and theoretical implications

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Unconventional superconductivity occurs in a broad range of strongly correlated electron systems including the newly discovered iron pnictides and chalcogenides, various intermetallic rare earth metals, the cuprates and the organic superconductors. These systems are not only of varying effective dimensionality but their parent compounds out of which superconductivity emerges ranges from metals to bad metals and Mott insulators. The only unifying characteristic features seems that unconventional superconductivity occurs in close vicinity of zero-temperature instabilities which are most often magnetic in nature. Heavy fermion compounds represent prototype systems to address the interplay between quantum criticality and unconventional superconductivity [1]. In CeCu2Si2, the magnetic quantum phase transition and superconductivity occur at ambient pressure which allows for a detailed study of the energetics across the superconducting transition. Based on an in-depth study of the magnetic excitation spectrum of CeCu2Si2 in the normal and superconducting state we obtain a lower bound for the change in exchange energy [2]. The comparison with the superconducting condensation energy demonstrates that the built-up of magnetic correlations near the quantum critical point does drive superconductivity in CeCu2Si2. In addition, our comparison establishes a huge kinetic energy loss which we relate to the competition of Kondo screening and superconductivity as the opening of the gap weakens the Kondo effect [2,3]. We discuss the relation between kinetic energy loss and the nature of the underlying quantum critical point [1,3]. Our unexpected findings sheds further light on the emerging global phase diagram of heavy fermion compounds [4] and are believed to be relevant to other families of superconductivity which are also located in close proximity to magnetism.

[1] O. Stockert, S. Kirchner, F. Steglich, Q. Si, "Superconductivity in Ce- and U-based 122 heavy-fermion compounds," to be published in JPSJ (invited review paper).
[2] O. Stockert, J. Arndt, E. Faulhaber, C. Geibel, H. S. Jeevan, S. Kirchner, M. Loewenhaupt, K. Schmalzl, W. Schmidt, Q. Si, F. Steglich, "Magnetically driven superconductivity in CeCu2Si2," Nature Physics, 7, 119-124 (2011).
[3] S. Kirchner and Q. Si, to be published.
[4] Q. Si, "Quantum Criticality and Global Phase Diagram of Magnetic Heavy Fermions," Phys. Status Solidi B247, 476 (2010).