

Magnetically Driven Superconductivity in CeCu₂Si₂

Authors: O. Stockert, J. Arndt, E. Faulhaber, C. Geibel, H. S. Jeevan, S. Kirchner, M. Loewenhaupt, K. Schmalzl, W. Schmidt, Q. Si, and F. Steglich

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**Recommended and Commentary by Peter Wölfle,
Karlsruhe Institute of Technology, Germany**

Ever since unconventional pairing was discovered in superfluid ³He unconventional superconductivity has been searched for in metals as well. It is known that an important contribution to the pairing interaction in liquid ³He (the "glue" as it is called nowadays) is provided by exchange of spin excitations, the latter taking the role of phonons in conventional superconductivity. By now a large body of systems has been studied for which evidence for spin fluctuation mediated superconductivity exists. A direct proof of the involvement of spin fluctuations in the pairing has been suggested by Scalapino and White (Phys. Rev. B **58**, 8222 (1998)): a reduction of the magnetic energy in the superconducting state equal to the superconducting condensation energy. The idea is simple enough: the internal energy, i.e. the thermal expectation value of the Hamiltonian should reflect the pair condensation.

The paper by Stockert et al. reports results of inelastic neutron scattering on CeCu₂Si₂ (CCS), the first heavy fermion superconductor discovered by Frank Steglich and coworkers in 1979. In the meantime the phase diagram of CCS (in the temperature-pressure or temperature-composition plane) has been mapped out in detail: there is an antiferromagnetic phase ending in a quantum critical point around which a superconductive phase is formed. The precise information on the spin excitation spectrum reported here allows to evaluate the spin exchange energy E_x in the picture of localized f-electron moments at the Ce ions. As expected, E_x is lowered in the superconducting phase, on account of a gap in the spin excitation spectrum induced by pair correlations. However, the exchange energy gain exceeds the superconducting condensation energy by as much as a factor of 20, rather than being approximately equal to it. This is highly interesting and may offer the possibility to learn more about the many-body correlations in CCS.

A few comments are in order. First of all, a comparison of the condensation energy with the internal energy difference deep in the superconductive phase requires the assumption that the spin excitation spectrum in the normal state (either in zero magnetic field above T_c or in magnetic fields $H > H_{c2}$ below T_c) may be safely extrapolated to low temperature and zero field. This is presumably the case. Secondly, the heavy fermion compound CCS is usually modelled by an Anderson or Kondo lattice model. In some version of the Kondo

lattice model, where the RKKY interaction has been added explicitly, the spin exchange energy indeed has the form employed in the paper, but what about the Kondo spin exchange interaction? Thirdly, an alternative theoretical model would use a one band heavy quasiparticle picture. The quasiparticle spin exchange interaction might be modelled along the lines given in the paper. The finding that the spin exchange energy in the superconductive state is lowered substantially more than the condensation energy means that the quasiparticle kinetic energy must be increased by the corresponding amount. This is not at all surprising, assuming that the effective mass enhancement is in part coming from qp interaction with spin excitations. As these excitations freeze out in the sc state, the effective mass is expected to drop, leading to an increase in kinetic energy. These ideas need to be worked out in detail.

The value of the neutron scattering data and their interpretation reported by Stockert et al. lies in its offering (1) a more microscopic probe of spin fluctuation induced pairing, (2) a new way of unravelling the structure of fermionic and bosonic excitations in a heavy fermion system.