

Tuning the heavy-fermion ground state in Ce-115 by Cd doping and hydrostatic pressure

L. D. Pham, T. Park, S. Maquilon, J. D. Thompson and Z. Fisk, *Reversible tuning of the heavy-fermion ground state in CeCoIn₅*, Phys. Rev. Lett. **97**, 056404 (2006)

Recommended with a commentary by H. v. Löhneysen
Universität Karlsruhe, Physikalisches Institut
and Forschungszentrum Karlsruhe, Institut für Festkörperphysik, Germany

The Ce-115 family of heavy-fermion compounds has taken center stage in the physics of strongly correlated metals due to its intimate – and not yet fully understood – vicinity of magnetic order (MO) and superconductivity (SC). The present paper adds an important new pitch to this field.

Pham and coworkers have replaced some In atoms in CeCoIn₅, CeRhIn₅, CeIrIn₅ by Cd. Note that Co, Rh and Ir belong to the same column of the periodic table and are therefore isoelectronic. However, topologically different phase diagrams arise on Cd addition. Nominally 7.5 at% suffice to induce magnetic order (presumably antiferromagnetism, although neither susceptibility nor elastic neutron-scattering results are shown) through two sets of intersecting lines of transitions in the first compound. In the second, a rectangular co-existence region bounded by three lines of transitions are indicated while in the last, there appears to be no co-existence of superconductivity and magnetism and possibly a quantum critical point separating them in the limit $T \rightarrow 0$. In fact, the actual Cd concentration may be smaller than the nominal concentration by a factor of 10, but we keep with the authors and quote only the nominal concentration in order to avoid confusion. For 7.5 at% < x < 12 at%, a two-phase region of MO at higher temperature and SC at lower T exists, and SC vanishes above 12 at%. The authors find that the resulting (T,x) phase diagram with *increasing* x looks exactly like the (T,p) phase diagram of CeRhIn₅ - which orders antiferromagnetically at ambient pressure – when starting from the high-pressure SC phase with *decreasing* hydrostatic pressure p . Indeed, applying pressure to Cd-doped CeCoIn₅ ($x = 10$ and 15 at%) *reverses* the effect of progressive Cd doping, and tracks the pressure dependence of pure CeRhIn₅.

Of course, it is not too surprising that doping with a non-isoelectronic element (i.e., Cd vs. In), plays a different role than just chemical pressure: from the smaller lattice constants of Cd-doped CeCoIn₅, chemical pressure would be expected to drive the system in the same direction as external hydrostatic pressure. Previous studies on isoelectronically substituted heavy-fermion systems, e. g. CeCu₂(Si_{1-x}Ge_x)₂ [1] and CeCu_{6-x}Au_x [2] have shown just this, perhaps modified by effects of anisotropies of compressibility and chemical pressure at least in the latter case. What makes the Ce-115 system so interesting and quite unique is, however, the fact that one can play with both the polyvalent and transition-metal element to tune the different ground states and, moreover, that one can do so with very minute amounts of impurities and with moderate pressures. This leads the authors to the conclusion that the observed Fermi surface instabilities, i. e. superconductivity or magnetic order, can be induced by small Fermi-level shifts and that these possibly antagonistic phases result from

instabilities of different parts of the Fermi surface. Why the topology of the phase diagram differs for the three different compounds on addition of Cd remains an interesting mystery to resolve.

The findings of Pham et al. therefore offer the avenue to detailed studies of Fermi-liquid instabilities in heavy-fermion systems, also of major relevance to the issue of quantum criticality. It will be most interesting to combine these studies with measurements in magnetic field, where the (T, p, B) phase diagram of CeRhIn₅ has already been investigated recently by the same group [3].

[1] O. Trovarelli et al., Phys. Rev. B 56 678 (1997)

[2] A. Germann and H. v. Löhneysen, Europhys. Lett. 9, 367 (1989)

[3] T. Park et al., Nature (London) 440, 5 (2006)