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Interplay of magnetism and superconductivity

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Magnetism and pressure : a single quantum critical point may be a dogma not the correct view.

We extend our studies on the Kondo lattice $CeRu_2Si_2$ [1] to negative pressure where, at $P_C = .3$ GPa, the localized magnetism disappears. From P_C to $P_{KL} \sim P_C$ a phase separation occurs with the coexistence of antiferromagnetic (AF) and paramagnetic (Pa) phase. In these mixed states, the magnetic coherence length $\ell_{KL} \sim m*$ is finite with a nanoscale length of 100 Å [2]. Of course this implies first order transition; The physical picture is not at all of spin fluctuation but that of a Kondo lattice (KL) where the main mechanism is the longitudinal magnetic fluctuation coupled with atomic displacements. A Kondo condensate exists with lifetime $\tau_{KL} \sim m*^2$. The collective counterflow circulation of electron and hole induces a tiny ordered moment $M_o \sim m*^{-1}$. Of course, long range order (AF) or (S) superconductivity will lead to switch from an instable Kondo cloud to a coherent phase.

Kondo condensate and field orientation.

Under magnetic field, the pseudo-metamagnetic transition at H_M above P_C is the continuation of the critical end point of the metamagnetic transition observed for $P < P_C$. Below H_M, speculatar evidence of the orientation of the Kondo condensate may be given by its positive linear field magnetoresistivity which can be regarded as a longitudinal Hall effect. The Kondo condensate flow goes against the forced current. Similar effects may exist in a Nernst experiment [3]. Above H_M, the majority spin carrier will become slowly undressed while the minority spin carrier appears localized.

Superconductivity at negative pressure.

At negative pressure; almost right at P_C as $CeRh_2Si_2$, $CeRu_2Si_2$ may be a superconductor. Furthermore for $P < P_C$, the orbital limit of the upper critical field $H_{C2}(T) \sim (m * T_C^)2$ can exceed H_M. As strong deformations are associated with the metamagnetic transition at H_M, a new field induced superconducting phase (A1) may be stabilized just at T_{A1} where its thermal expansion reaches a temperature maxima at $H_{C2}(T_{A1}) = H_{C2}(A1)$. At $H_M < H_{C2}(A1)$ the usual second order transition at $H_{C2}(T)$ will switch to first order at T_0 since the usual expansion of the lattice at the superconducting phase transition is dangerously increased by the dilatation at H_M [4]. The strong antagonist variations of $H_M \sim m*^{-1}$ and H_{C2} allows the A1 phase to exist only in a very narrow P range near P_C.

From dream to reality.

The negative pressure scenario of $CeRu_2Si_2$ seems to correspond to the $CeCoIn_5$ situation[5].

Perspectives:

- A single quantum critical point is an error, due to excessive theoretical focus to P_C. The real problem of quantum first order transitions will deliver new phenomena. - The Cooper pairing is due to the atomic displacement enhanced by the huge Grüneisen coefficient. - The feedback of the deformation to the nature of the magnetism and the Cooper pairing of the quasiparticles leads to a great diversity of the heavy fermion matter. - The two unconventional superconductors UPt_3 and $PrOs_4Sb_{12}$ are beautiful examples.

[1] J. Flouquet et al, ICM Conference, Rome, (2003), to be published.
[2] J. Flouquet, to be published in Prog. Low Temp. Phys. Ed. W. Halperin, Elsevier (2004).
[3] R. Bel et al, to be published (2003).
[4] J. Flouquet, to be published (2003).
[5] G. Knebel, to be published (2003).