Gamma_5 quasiparticles and avoided quantum criticality in U(Ru,Rh)_2Si_2

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Abstract

We discuss recent specific heat data in high magnetic fields on URu_2Si_2 and 4\% Rh-doped URu_2Si_2 as well as previously published de Haas-van Alphen data at lower magnetic fields in pure URu_2Si_2; both of which are consistent with quasiparticle bands formed from a hybridization between 5f-electron \Gamma_5 doublets and regular conduction electrons. The system exhibits itinerant electron metamagnetism that gives rise to a putative quantum critical point at \~\sim 34 -37 \textdegree T (depending on the \% of Rh) that is subsequently unstable to field-induced phases.

Keywords: U(Ru,Rh)_2Si_2; quasiparticles; quantum criticality; metamagnetism; electric quadrupoles

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A first order phase transition takes than a quantum critical point actually being realized at heat fitting parameters from 38 \( \mu \)T. Both become progressively more narrow as magnetic fields above 38 \( \mu \)T are applied, and the c-axis.

Energetic fields are thus significantly different, with VRuSi2 having a lower carrier density. This is partly due to the bandstructure yielding smaller closed sections of Fermi surface [4] and partly due to the gapping of much of the Fermi surface within the HO phase; both giving rise to a lower electronic contribution to the specific heat as \( T \to 0 \). Superexchange interactions are also far more significant for U than for Ce, thereby increasing the likelihood of ordered phases.

Figure 2 shows an intensity plot of the quasiparticle density of states (DOS) calculated using a model that is able to explain the \( T \)-dependent specific heat data at magnetic fields above \( \mu \)H \( \sim \) 34.4 T in 4% Rh-doped VRu2Si2 [7]; the specific heat is very similar to that of pure URu2Si2 at these fields. The quasiparticle band model is fitted to the data for \( \mu \)H > 38 T, where the magnetic field causes the separation of the pseudospin up and pseudospin down bands to be strongly field dependent. The same is also true for the bandwidth, which becomes progressively more narrow as \( H \to H_m \), therefore being consistent with a putative quantum critical point at \( H_m \). The intensity plot for \( \mu \)H < 38 T is based on a linear extrapolation of specific heat fitting parameters from 38 T and above [7]. Rather than a quantum critical point actually being realized at \( H_m \), a first order phase transition takes place at \( \sim \) 38 T into a field-induced ordered phase [7]. The resultant form of the density of electronic states within the ordered phase is unknown, but we should expect a gap (or pseudogap) of order 3 meV or higher to open up around the Fermi energy (if we naively apply BCS theory to the optimal ordering temperature [7]).

The quasiparticles in URu2Si2 (and Rh-doped URu2Si2) are unique in that they acquire electric quadrupolar as well as Ising spin of freedom as a consequence of hybridization. Superexchange interactions can therefore lead to competing electric quadrupolar and Ising antiferromagnetic ordered groundstates, with the former becoming increasingly favorable in strong magnetic fields. Since the former involves charge degrees of freedom, it may be more strongly coupled to the crystal lattice, possibly explaining why the phase transitions become first order at low \( T \).

Returning now to general question of order parameters in pure VRu2Si2 for \( H < H_m \) it is now rather clear that theoretical models for the HO phase must take into consideration the fate of the electric quadrupolar and Ising degrees of freedom of the itinerant \( \Gamma_5 \) quasiparticles. Antiferroquadrupolar order has been proposed, although only from a purely local moment perspective [8].

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