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Magnetic Field-Induced Quantum Critical Point in CeAuSb₂

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Abstract. Transport, magnetic and thermal properties at high magnetic fields (H) and low temperatures (T) of the heavy fermion compound CeAuSb₂ are reported. At $H=0$ this layered system exhibits antiferromagnetic order below $T_N = 6$ K. Applying B along the inter-plane direction, leads to a continuous suppression of T_N and a quantum critical point at $H_c \cong 5.4$ T. Although it exhibits Fermi liquid behavior within the Neel phase, in the paramagnetic state the fluctuations associated with H_c give rise to unconventional behavior in the resistivity (sub-linear in T) and to a $T \ln T$ dependence in the magnetic contribution to the specific heat. For $H > H_c$ and low T the electrical resistivity exhibits an unusual T^3 -dependence.

Keywords: Quantum-criticality, Ce based heavy-Fermion compound.

PACS: 75.30.Mb, 75.20.Hr, 75.30.Kz, 75.40.-s

INTRODUCTION

Quantum criticality [1] is common to a large variety of very different phenomena ranging from low-dimensional quantum systems to high-temperature superconductivity, disorder-induced criticality (e.g. Griffiths phase) and heavy fermion compounds at the verge of antiferromagnetic (AF) order. For strongly correlated electrons a quantum critical point (QCP) is obtained when either (i) the long-range order is suppressed to $T=0$ (second order phase transition) or (ii) the critical end-point terminating a line of first-order transitions is depressed to $T=0$. [2] A QCP can be tuned by an external variable, such as pressure, chemical composition or the magnetic field H . [3] H is an ideal control parameter, since it can be reversibly and continuously tuned towards the QCP. [4] In alloys the disorder driven effects cannot be separated from the quantum criticality of the translational invariant system. [4] Hence, it is essential to consider stoichiometric systems. Two compounds with field-tuned QCP, YbRh₂Si₂ and Sr₃Ru₂O₇, reached prominence due to the non-Fermi liquid (NFL) behavior triggered by the quantum fluctuations associated with the QCP. In this manuscript we present a Ce-compound, CeAuSb₂, exhibiting a field-tuned QCP with unusual transport and thermodynamic

properties. YbRh₂Si₂, Sr₃Ru₂O₇ and CeAuSb₂ have a field-tuned QCP as a common thread, yet their properties are considerably different. This points towards a lack of universality among the different systems as a fundamental component of quantum criticality.

RESULTS AND DISCUSSION

Here, we report on anomalous properties of the tetragonal metallic compound CeAuSb₂, which at $H = 0$ orders AF [5] with $T_N = 6.0$ K. For $T < T_N$, $\rho(T)$ has the typical AT^2 dependence of a FL and extrapolating C_e/T to $T=0$ yields $\gamma \sim 0.1$ J/mol.K². Hence, CeAuSb₂ can be considered a system of relatively light heavy-fermions. Above T_N , on the other hand, $\rho(T)$ displays a T^α dependence with $\alpha \leq 1$ and, C_e/T has a $-\ln T$ dependence, both characteristic of NFL behavior due to a nearby QCP. A magnetic field along the inter-plane direction leads to two subsequent MM transitions and the concomitant continuous suppression of T_N to $T=0$ at $H_c = 5.3 \pm 0.2$ T. As the AF phase boundary is approached from the paramagnetic (PM) phase, γ is enhanced and the A coefficient of the resistivity diverges as $(H-H_c)^{-1}$. When T is lowered for $H \sim H_c$, the T -dependence of ρ is sub-linear and the one of C_e/T is approximately $-\ln T$. At higher fields, $H \gg H_c$, an unconventional T^3 -

dependence emerges in ρ and becomes more prominent as H increases.

The upper panel of Fig. 1 shows $C(T)/T$ as a function of T for CeAuSb₂ at $H=5$ T, and for its isostructural non-magnetic analog LaAuSb₂ at $H=0$ T. The large peak for CeAuSb₂ signals the AF transition. The subtraction of both curves yields the magnetic contribution to the heat capacity $C_e(T)/T$. For $3 < T < 20$ K, $C_e(T)/T$ displays a $-\ln T$ NFL-like dependence. The lower panel of Fig. 1 shows $C_e(T)/T$ as a function of H at $T=1$ K which clearly indicate that the effective mass of the quasi-particles, as given by $C_e(T)/T$ for $T \rightarrow 0$ increases considerably as $H \rightarrow H_c$, although it remains finite. Because of the AFM order the effective mass cannot be defined precisely. In the PM phase the $-\ln T$ -dependence does not continue to very low T . This is similar to the behavior of the specific heat of Sr₃Ru₂O₇, where the $-\ln(T)$ dependence does not continue to very low T and there is a cross-over to a constant C/T at the lowest T .

FIGURE 1. Upper panel: Heat capacity divided by temperature C/T vs. T down to 0.38 K for CeAuSb₂ with $H=5$ T applied along the c-axis (blue line), as well as for LaAuSb₂ at $H=0$ T (black line). The difference is the magnetic contribution to the heat capacity C_e/T (in magenta), which shows a $\ln T$ -dependence. Lower panel: C_e/T vs H at $T=1$ K. Notice the pronounced enhancement of C_e/T as H approaches H_c .

Fig. 2 depicts a qualitative sketch of the H - T phase diagram. It shows the dependence of the exponent $n \equiv \partial \ln(\rho(T)) / \partial \ln T$ on H and T . Here different values of ρ_0 were used in the PM and AF phases. The PM phase is indicated by the blue region which is

influenced by the QCP leading to the anomalous NFL value $n \leq 1$. This is analogous to the behavior of YbRh₂Si₂ and Sr₃Ru₂O₇. The FL state (in green) is recovered below the Néel temperature but is gradually suppressed as $H \rightarrow H_c$. A FL-like $n=2$ exponent is obtained above H_c but only over a limited range of T . Instead a value $n=3$ is observed in the spin polarized PM phase at higher fields and lowest T s.

FIGURE 2. Exponent n of $\rho(T)$ in the T - H plane.

In conclusion, the field-tuned QCP systems represent a remarkable challenge from both the experimental and the theoretical perspectives, since the different compounds revealing some common aspects do *not* seem to belong to the same universality class.

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