Title
Magnetic Field-Induced Quantum Critical Point in CeAuSb2

Journal
AIP Conference Proceedings, 850(1)

ISSN
0094-243X

ISBN
9780735403475

Authors
Balicas, L
Nakatsuji, S
Lee, H
et al.

Publication Date
2006-09-07

DOI
10.1063/1.2354899

Magnetic Field-Induced Quantum Critical Point in $CeAuSb_2$

L. Balicas,[1] S. Nakatsuji,[2] H. Lee,[3] P. Schlottmann,[1] T. P. Murphy,[1] and Z. Fisk[3]

[1]*National High Magnetic Field Laboratory, Florida State University, Tallahassee-FL 32306, USA*
[2]*Department of Physics, University of Kyoto, Kyoto 606-8502, Japan*
[3]*Department of Physics, University of California Davis, Davis, California 95616, USA*

Abstract. Transport, magnetic and thermal properties at high magnetic fields (*H*) and low temperatures (*T*) of the heavy fermion compound $CeAuSb_2$ 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 *TlnT* 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, $YbRh_2Si_2$ and $Sr_3Ru_2O_7$, 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, $CeAuSb_2$, exhibiting a field-tuned QCP with unusual transport and thermodynamic properties. $YbRh_2Si_2$, $Sr_3Ru_2O_7$ and $CeAuSb_2$ 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 $CeAuSb_2$, 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.K^2. Hence, $CeAuSb_2$ can be considered a system of relatively light heavy-fermions. Above T_N, on the other hand, ρ(T) displays a T^α dependence with $\alpha \leq 1$ and, C_e/T has a *-lnT* 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 $(H\text{-}H_c)^{-1}$. 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 *-lnT*. At higher fields, $H >> H_c$, an unconventional T^3-

CP850, *Low Temperature Physics: 24th International Conference on Low Temperature Physics;*
edited by Y. Takano, S. P. Hershfield, S. O. Hill, P. J. Hirschfeld, and A. M. Goldman

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 $CeAuSb_2$ at H=5 T, and for its isostructural non-magnetic analog $LaAuSb_2$ at H=0 T. The large peak for $CeAuSb_2$ 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 $-lnT$ 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 $T \to 0$ increases considerably as $H \to H_c$, although it remains finite. Because of the AFM order the effective mass cannot be defined precisely. In the PM phase the $-lnT$-dependence does not continue to very low T. This is similar to the behavior of the specific heat of $Sr_3Ru_2O_7$, 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.

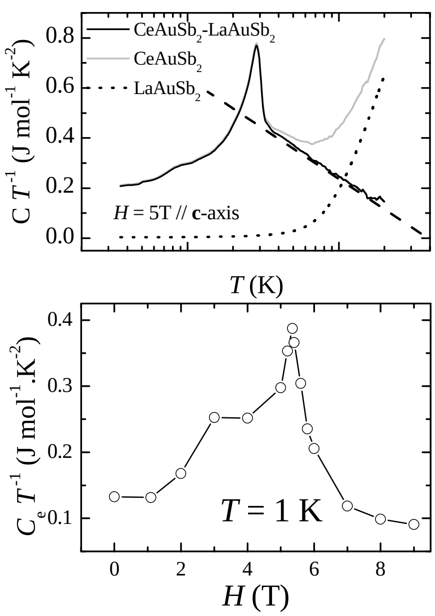

FIGURE 1. Upper panel: Heat capacity divided by temperature C/T vs. T down to 0.38 K for $CeAuSb_2$ with H=5 T applied along the c-axis (blue line), as well as for $LaAuSb_2$ at H=0 T (black line). The difference is the magnetic contribution to the heat capacity C_e/T (in magenta), which shows a lnT-dependence. 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 $n \cong \partial ln(\rho(T) - \rho(0)/\partial lnT$ 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 $YbRh_2Si_2$ and $Sr_3Ru_2O_7$. The FL state (in green) is recovered below the Néel temperature but is gradually suppressed as $H \to H_c$. 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 Ts.

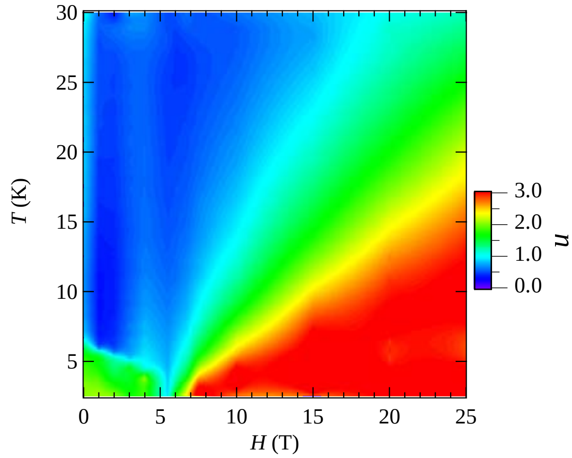

FIGURE 2. Exponent n of $\rho(T)$ in the T - H plane.

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.

ACKNOWLEDGEMENTS

This work is sponsored by the National Nuclear Security Administration under the Stewardship Science Academic Alliances program through DOE grant DE-FG03-03NA00066 and was performed at the NHMFL which is supported by NSF through DMR-0084173 and the State of Florida. LB acknowledges support from the NHMFL in-house program, SN from Grants-in-Aids for Scientific Research from JSPS and for the 21st Century COE Center for "Diversity Universality in Physics" from MEXT of Japan, and PS by grants (DOE) DE-FG02-98ER45707 and (NSF) DMR01-05431..

REFERENCES

1. S. Sachdev, *Quantum Phase Transitions*, Cambridge: Univ. Press, 1999.
2. A. J. Millis, A. J. Schofield, G. G. Lonzarich, and S. A. Grigera, *Phys. Rev. Lett.*, **88**, 217204 (2002).
3. G. R Stewart, *Rev. Mod. Phys.*, **73**, 797 (2001).
4. K. Heuser, E. W. Scheidt, T. Schreiner, and G. R. Stewart, *Phys. Rev. B*, **57**, R4198 (1998).
5. A. Thamizhavel, *et al.*, *Phys. Rev. B*, **68**, 054427 (2003).