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Author(s):
A. Lacerda
T. Graf
M.F. Hundley
J.D. Thompson
D. Gajewski
P.C. Canfield
Z. Fisk

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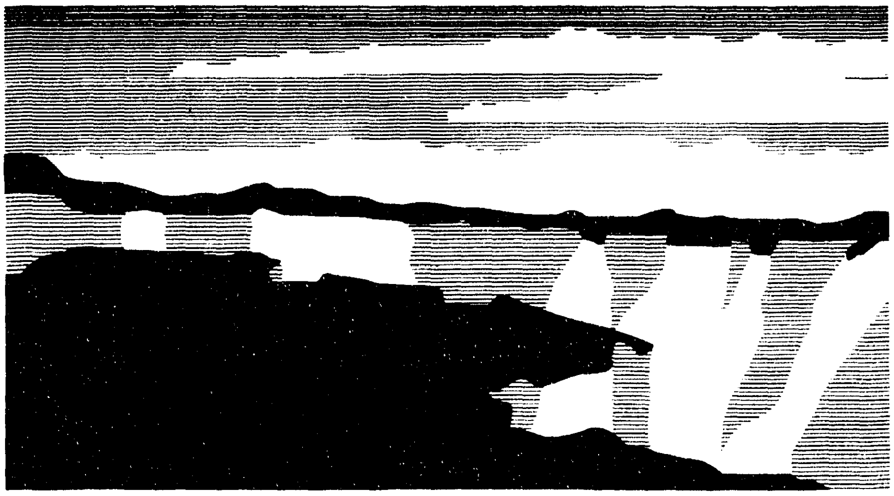

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High Field Magnetotransport and Specific Heat in $YbAgCu_4$

A. Lacerda [a], T. Graf [a,b], M.F. Hundley [b], J.D. Thompson [b], D. Gajewski [c], P.C. Canfield [d] and Z. Fisk [b,c]

a) National High Magnetic Field Laboratory, Pulse Facility, Los Alamos, NM 87545
b) Los Alamos National Laboratory, Los Alamos, MM 87545
c) University of California, San Diego, Department of Physics, La Jolla, CA 92093
d) Ames Laboratory, Ames, IA 50011

Abstract

The electrical resistivity (ρ) and magnetoresistance of polycrystalline $YbAgCu_4$ have been measured at temperatures between 25 mK and 300 K, and at magnetic fields (B) to 18 T. The magnetoresistance $(\rho(B)-\rho(0))/\rho(0)$ is positive at all temperatures below 200 K and reaches its maximum of 60% at 18 T and 25 mK. The field- and temperature-dependent resistivity does not scale in a simple way. The opposite magnetoresistance behaviors at ambient and high pressure can be explained qualitatively by crystal-field effects lifting the degeneracy of the J=7/2 groundstate. The linear coefficient of specific heat (γ) measured at fields to 10 T shows a quadratic field dependence. We do not find a linear relation between γ^2 and A, the T^2-coefficient of the temperature-dependent resistivity, with field as the implicit parameter.

contact address: Alex Lacerda
National High Magnetic Field Laboratory, Pulse Facility, Los Alamos
Mail Stop: E536
Los Alamos, NM 87545, USA
Fax: (505) Tel: (505)

$YbAgCu_4$ is one of the few Yb-based intermetallic compounds with a large linear coefficient of specific heat $\gamma = 245$ mJ/mole K^2 [1]. Its temperature-dependent magnetic susceptibility and specific heat are described well by the Coqblin-Schrieffer model with J=7/2 and a characteristic energy scale $T_0 \approx 160$ K [1, 2]. Inelastic neutron scattering [3] finds no evidence for well-defined crystal-field excitations, consistent with the susceptibility results. Application of pressure causes a rapid decrease in T_{max}, the temperature at which the resistivity is a maximum, and an increase of the T^2-coefficient of resistivity (A) [4, 5], suggesting that $\partial T_0/\partial P < 0$. At sufficiently high pressures, it is distinctly possible that T_0 becomes much less than crystal-field splitting of the J-multiplet, the ground state degeneracy is at least partially lifted and spin fluctuations increasingly dominate electrical transport at low temperatures. This possibility could provide a partial explanation for the significantly different magnetoresistive behavior of $YbAgCu_4$ at low and high pressures: at ambient pressure the magnetoresistance is positive for $T < 20$ K and fields less than 10 T [4] but for pressures greater than 70 kbar, the magnetoresistance is strongly negative [5]. To explore in more detail the origin of these opposite behaviors at low and high pressure (at large and small T_0, respectively) we have measured the specific heat (C), of $YbAgCu_4$ in fields to 10 T for temperatures $4 \leq T \leq 10$ K and the electrical resistivity at fields to 18 T and temperatures between 25 mK and 300 K.

The preparation of polycrystalline samples has been described previously [5]. Electrical resistivity was measured using a four lead ac resistance bridge (LR-400) operating at 17 Hz.. The magnetic field was applied perpendicular to the current (transverse geometry) and was generated by a 20 T superconducting magnet at the National High Magnetic Field Laboratory, Los Alamos Facility. The specific heat was measured in a small mass calorimeter utilizing a relaxation method.

Figure 1(a) shows the temperature-dependent resistivity ρ of $YbAgCu_4$ in magnetic fields from 0 to 18 T. For $T < 15$ K, the curves can be fit to $\rho(T, B) = \rho_0(B) + A(B)\, T^2$, which is shown explicitly in the inset of Fig. 1(a). The magnetoresistance $(\rho(B)-\rho(0))/\rho(0)$ is positive for all temperatures less than 200 K and reaches its maximum of 60 % at 18 T and 25 mK. The monotonic evolution of the magnetoresistance with increasing temperature is shown in Fig. 1(b). At each temperature $\Delta\rho/\rho(0) \propto B^{\alpha}$, with $\alpha \approx 1.5$. The data shown in Fig. 1(a) do not scale in any simple way, contrary to what has been found for pressure-induced changes in the resistivity [6]. For example, plots of ρ/ρ_ι vs. T/T_ι, where ρ_ι and T_ι are the resistivity and temperature where $\partial\rho/\partial T$ is a maximum, do not scale the curves, nor does plotting the data in a Kohler-form $\Delta\rho/\rho(0) = f(B/\rho(0))$, or as ρ vs. $T\sqrt{A}$.

The specific heat divided by temperature is plotted in Fig. 2 as a function of T^2 for various applied fields. Solid lines are least squares fits to the data and yield the linear coefficients γ, which are shown in Fig. 3 to increase linearly with B^2. With the usual assumption that $\gamma \propto 1/T_O$, this implies that T_O is inversely proportional to B^2. From the linear relation $\gamma \propto \sqrt{A}$ found [7] for several heavy fermion compounds at zero field, we would expect A to increase as B^4. Figure 3 shows the measured change in A as a function of B^2. Though A(B) increases superlinearly in B^2 for $B \leq 12$ T, at higher fields A varies approximately as B^2. The inset of Fig. 3 clearly demonstrates the absence of a linear correlation between and γ and $\sqrt{A}$ for $B \leq 10$ T. This is contrary to what is found [8] when pressure is the implicit variable.

Qualitatively we can understand the different field responses of $YbAgCu_4$ at zero and high pressures as follows. Okiji and Kawakami [9] have shown for the J=5/2 Coqblin-Schrieffer model that γ increases approximately quadratically with field for $B < 0.4\ T_O$ ($B < 95$ T for $T_O = 160$ K). We expect a similar situation to hold for J=7/2, i.e. $YbAgCu_4$ at ambient pressure. From the usually assumed relationship between γ and A, we ,therefore, would expect A to increase with B, as found at ambient pressure. On the other hand, for J=1/2, γ decreases strongly with field [9, 10] and we should find A decreasing with field as well, as observed at high pressures [5]. Although, a change in groundstate degeneracy appears to account qualitatively for observations at ambient and high pressure, there remain quantitative questions to be addressed. The 10 % increase in γ at 10 T is larger than predicted, at least for J=5/2. The large change in ρ_O in applied field, for either ambient or high pressures, lacks a simple explanation, as does the field dependence of A and, more generally, of $\rho(T)$. Additional high field measurements on heavy fermion systems would be helpful to identify to what extent these features are general.

Acknowledgments

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Figure Captions:

Fig. 1(a). Resistivity ρ as a function of temperature T at magnetic fields of 0 (bottom curve), 6, 10, 14 and 18 T (top curve). Inset: Resistivity vs. temperature squared at the same fields. The lines are linear fits to the data. (b). Magnetoresistance $(\rho(B)-\rho(0))/\rho(0)$ as a function of magnetic field B at different temperatures.

Fig. 2. Specific heat C divided by temperature T as a function of T^2 at different magnetic fields (0, 2, 4, 6, 8, 10 T, from bottom to top). The lines are linear least squares fits.

Fig. 3. Linear coefficient of specific heat γ (left axis) and T^2-coefficient of resistivity A (right axis) as a function of magnetic field squared. Inset: γ vs. $A^{1/2}$ with field as the implicit variable.

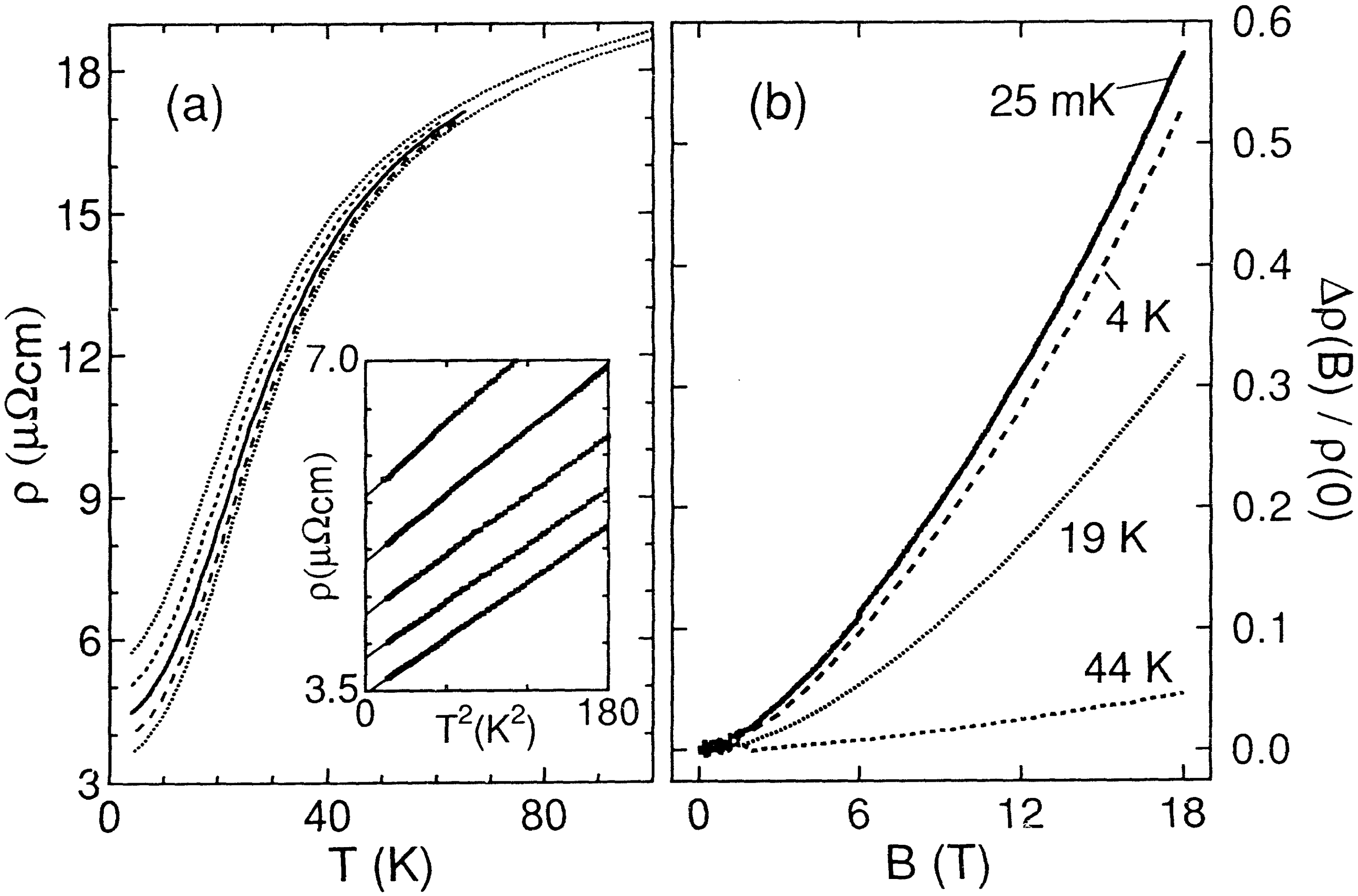

Fig. 1
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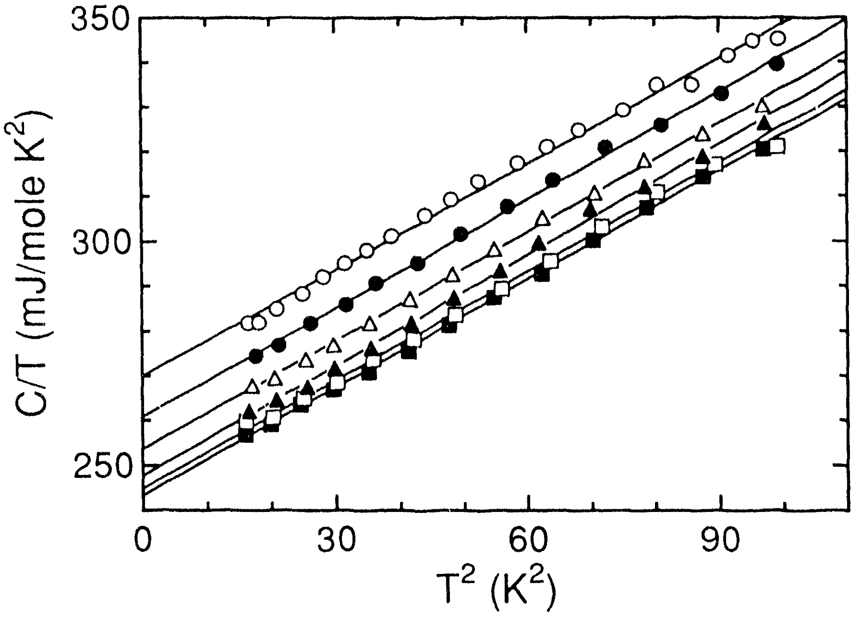

Fig. 2

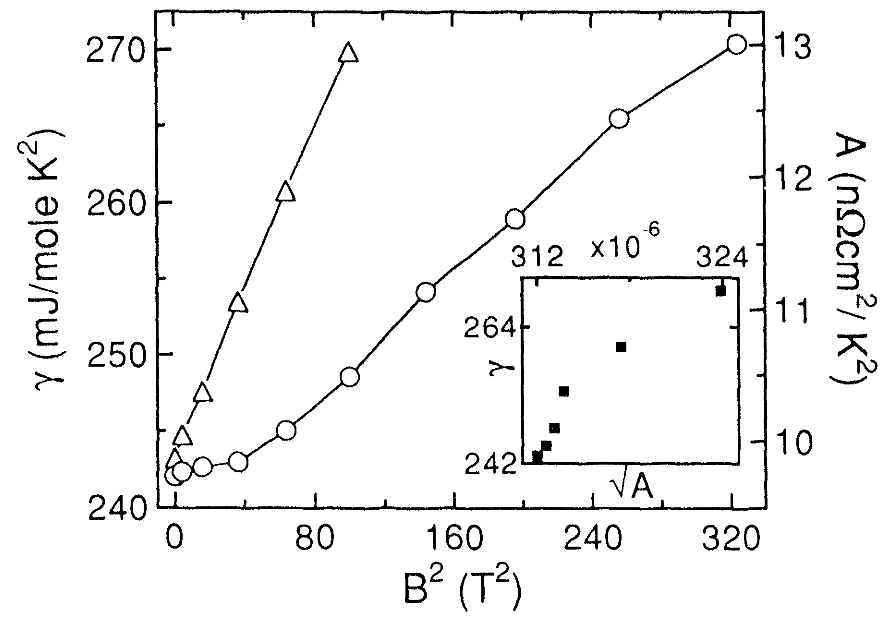

Fig. 3

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