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Authors
Marcenat, C.
Fisher, R.A.
Phillips, N.E.

Publication Date
1988-07-01

LBL-25763

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Materials & Chemical Sciences Division

Presented at the Sixth International Conference on Crystal-Field Effects and Heavy-Fermion Physics, Frankfurt, FRG, July 18–24, 1988, and to be published in the Journal of Magnetism and Magnetic Materials

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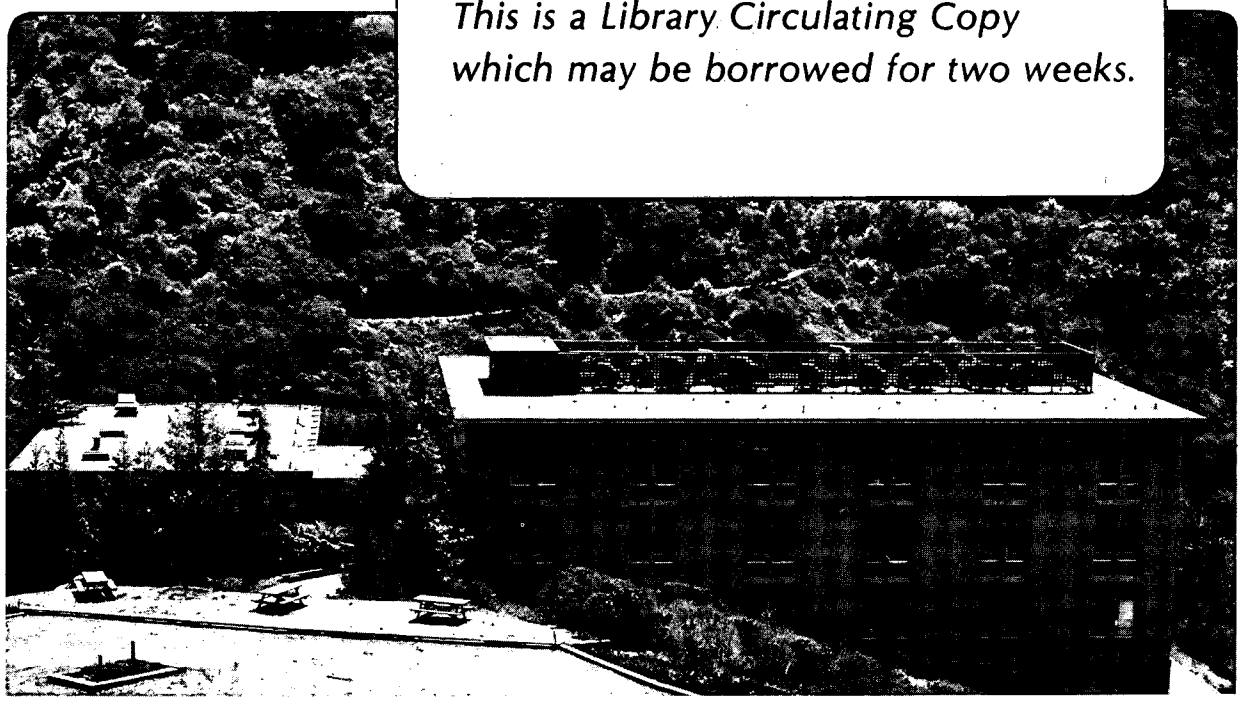
C. Marcenat, R.A. Fisher, N.E. Phillips, and J. Flouquet

July 1988



Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098.

DISCLAIMER

Comparison of the specific heat of heavy fermion cerium compounds

C. MARCENAT
D.P.M.C., 24 Quai Ernest-Ansermet
1211 Geneve 04, SWITZERLAND

R. A. FISHER and N. E. PHILLIPS
Materials and Chemical Sciences Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720, USA

J. FLOUQUET
C.R.T.B.T. - C.N.R.S., B.P. 166X
38042 Grenoble Cedex, FRANCE

ABSTRACT

Specific heat data obtained on magnetically ordered heavy fermion cerium compounds (HFC) $CeAl_2$, CeB_6, $CeIn_3$ and $Ce_{0.9}La_{0.1}Ru_2Si_2$ are compared to those obtained on archetype HFC $CeAl_3$, $CeRu_2Si_2$ and $CeCu_6$. Special emphasis is given to the occurrence of a maximum in C/T and on the field dependence of the mass enhancement.

Keywords: Specific heat, heavy fermion

Presented at the Sixth International Conference on Crystal-Field Effects and Heavy-Fermion Physics, July 1988, Frankfurt, FRG and to be published in J. Magn. Magn. Mat. (special issue).

In heavy fermion systems, the occurrence of a maximum in the ratio of the specific heat (C) to the temperature (T) has been interpreted as a fingerprint of the entrance into a coherent state [1]. In $CeAl_3$, this maximum occurring at T~400 mK was attributed to the opening of a pseudo-gap due to the hybridization of the conducting band with f-electrons [2]. When Gd is added, this maximum does not disappear, which gives rise to doubts about such an explanation [3]. Furthermore, compounds like $CeCu_6$ or $CeRu_2Si_2$ display only a continuous increase on cooling. Therefore, it is tempting to reconsider the existence of this maximum in C/T in the light of recent transport [4], muon [5] and NMR [6] experiments which show that $CeAl_3$ is magnetically ordered below $T_N \sim 1.6$ K. The difficulty in observing associated effects in C is directly related to the weakness of the ordered magnetic moment ($m_0 \sim 0.05\ \mu_B$) as pointed out by the following simple energy balance which provides an upper limit to the static ordered moment m_0 (if it exists) at T=0. Within a molecular field framework, one can relate m_0 of a simple up and down antiferromagnet to the specific heat and the susceptibility χ at T_N by [7]:

$$m_0^2 = 2\chi(T_N) \int_{T_N}^{0} C(T)dT. \qquad (1)$$

Numerical values obtained by integration of the total electronic specific heat are given in Table 1. The first five compounds $CeAl_2$, $CeAl_3$, $CeIn_3$, CeB_6 and $Ce_{0.9}La_{0.1}Ru_2Si_2$ are magnetically ordered and the calculated values are not too different from the measured ones. The discrepancy found for $Ce_{0.9}La_{0.1}Ru_2Si_2$ must be related to the fact that this compound is close to a magnetic-non magnetic transition [8]. In the case of $CeRu_2Si_2$ and $CeCu_6$, considered not to be magnetically ordered, we find, indeed, very small moments by taking reasonably characteristic temperatures.

The recent specific heat experiments performed on $Ce_{0.9}La_{0.1}Ru_2Si_2$ in magnetic fields (see Fig. 1) lead also to a better understanding of the behaviour of $CeAl_3$. At H=0, the ordering at T_N gives rise only to a sharp increase of C/T as observed for a weakly itinerant ferromagnetic such as Sc_3In [9]. For fields lower than the metamagnetic field (H_M), $H_M = 37.7$ kOe, a maximum in C/T is clearly observed. Its amplitude increases with field while its position, T_M, decreases, reflecting unambiguously the magnetic (H,T) phase diagram. However, T_M does not necessarily coincide with the Neel temperature

as determined by a molecular field treatment based on the resonant level model [10]. On the contrary, for $H > H_M$, the maximum of C/T shifts to higher temperature as H increases, due to the Zeeman decoupling of narrow spin-up and spin-down bands. The possible occurrence of drastic field changes of the electronic specific heat of $CeAl_3$ is emphasized in Fig. 2 which represents the strong field dependence of the effective mass m* derived from the field variation of the T^2 coefficient of the resistivity for $CeAl_3$ and CeB_6; the dashed line is a direct measurement of m* of CeB_6 by specific heat.

Thus, we suggest that specific heat experiments on a single crystal of $CeAl_3$ will lead to similar phenomena showing that the intersite magnetic coupling drives the temperature and field behaviour of heavy fermion compounds.

Work at Berkeley supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Department of Energy under Contract DE-AC03-76SF00098.

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Table 1

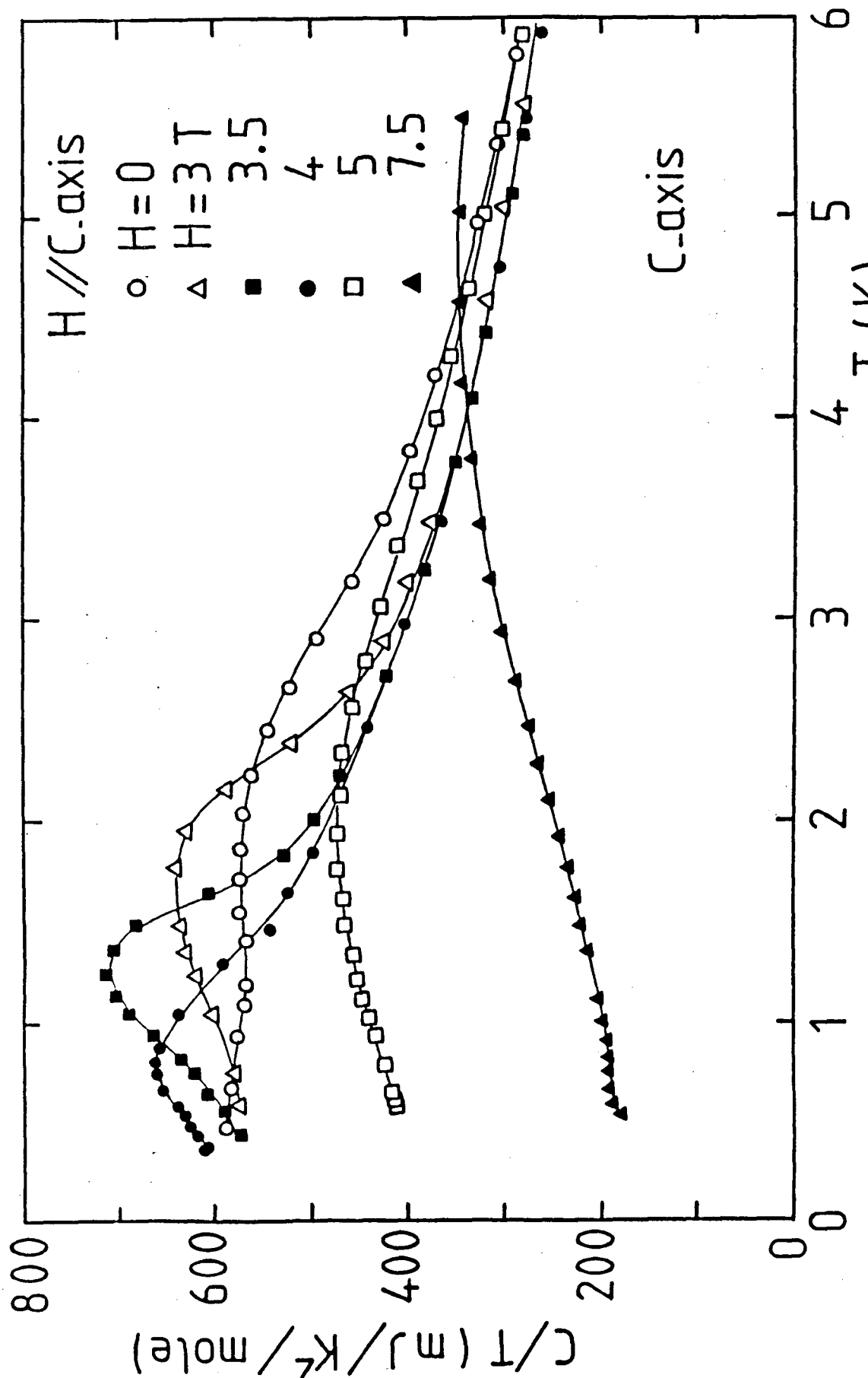
Numerical values derived from equation (1) for the ordered moment m_o (calc) compared to the experimental m_o(exp) for various Ce compounds.

Sample	$T_N(T^*)$ (K)	$\chi(T=T_N)$ (10^{-2} u.e.m)	ΔU ($J.mol^{-1}$)	m_o(calc) (μ_B)	m_o(exp) (μ_B)
$CeAl_2$	3.8	5.5	8.5	0.53	0.89
$CeAl_3$	1.6	4	1.4	0.17	0.05
$CeIn_3$	10	1.27	40	0.55	0.48
CeB_6	2.3	5	10	0.5	0.22
$Ce_{0.9}La_{0.1}Ru_2Si_2$	2.7	7	2	0.3	0.8
$CeRu_2Si_2$	~1	3.5	.18	0.06	-
$CeCu_6$	~0.25	3.3	0.05	0.03	-

Figure Captions

Fig. 1. Specific heat of $Ce_{0.9}La_{0.1}Ru_2Si_2$ in magnetic fields as C/T vs T.

Fig. 2. Field variation of the electronic mass m* for $CeAl_3$ and CeB_6.


H //C-axis
o H=0
Δ H=3 T
3.5
4
5
7.5
C-axis
C/T (mJ/K²/mole)
T (K)
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600
400
200
0
0
1
2
3
4
5
6

Fig. 1

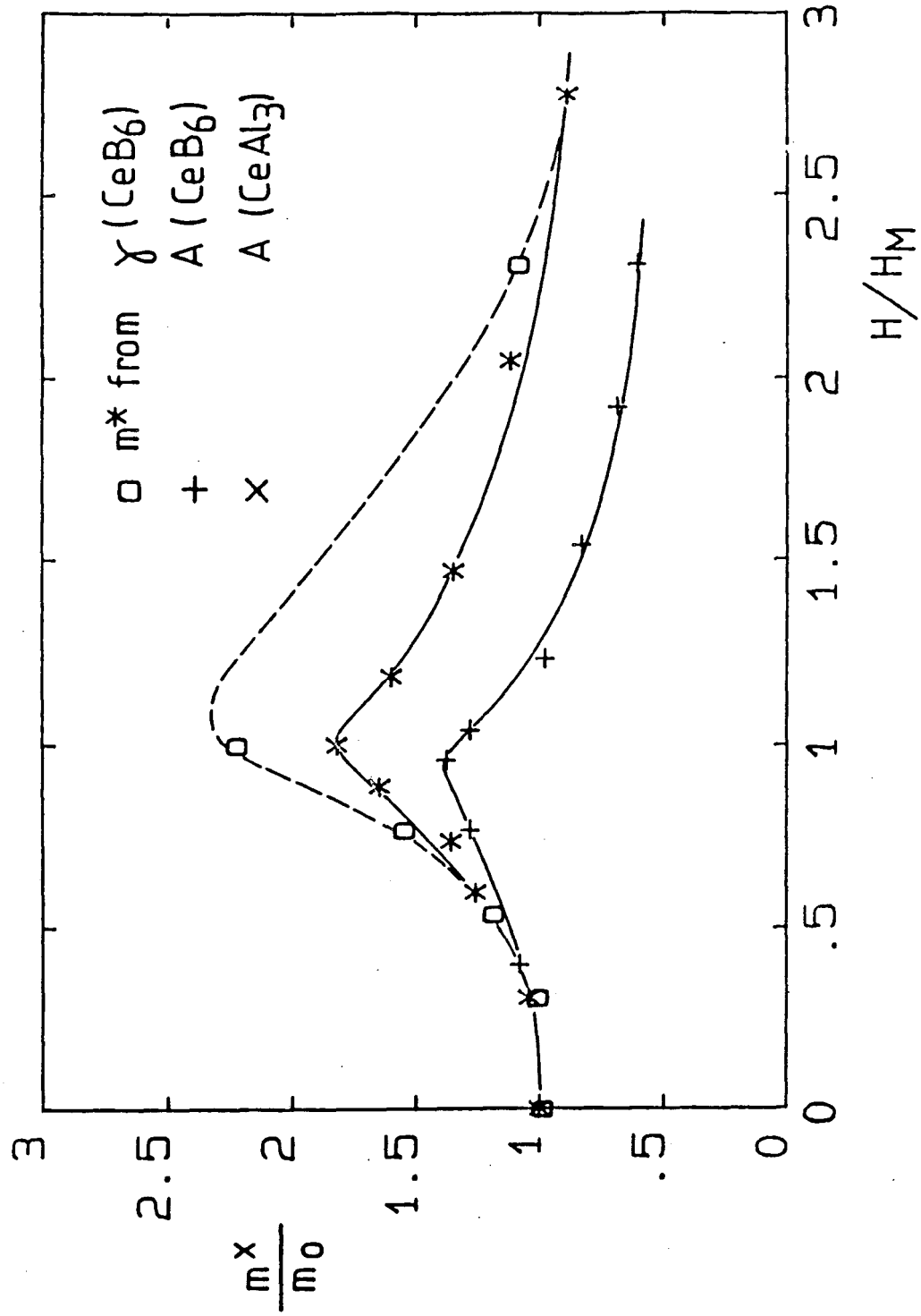

Fig. 2

LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720