LBL-30903
Preprint

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Materials & Chemical Sciences Division

Submitted to Physica C

Specific Heat of UPt_3 in the Vicinity of the Antiferromagnetic Ordering at 5 K

R.A. Fisher, B.F. Woodfield, S. Kim, N.E. Phillips,
L. Taillefer, A.L. Giorgi, and J.L. Smith

June 1991

LOAN COPY
Circulates
for 4 weeks
Bldg. 50 Library.
LBL-30903
Copy 2

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

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

SPECIFIC HEAT OF UPt_3 IN THE VICINITY OF THE ANTIFERROMAGNETIC ORDERING AT 5K

R.A. Fisher, B.F. Woodfield, S.Kim and N.E. Phillips

Materials and Chemical Sciences Division, Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

L. Taillefer

Laboratoire de Magnetisme Louis Néel
Centre National de la Recherche Scientifique, BP 166X
38042 Grenoble-CEDEX, France

A.L. Giorgi and J.L. Smith

Los Alamos National Laboratory, Los Alamos, New Mexico 87545

June, 1991

To be published in Physica C

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

SPECIFIC HEAT OF UPt_3 IN THE VICINITY OF THE ANTIFERROMAGNETIC ORDERING AT 5K

R.A. Fisher, B.F. Woodfield, S. Kim, N.E. Phillips, L. Taillefer,[†] A.L. Giorgi,[§] and J.L. Smith[§]

Material Sciences Division, LBL, Berkeley, California 94720, USA
[†]Laboratoire de Magnetisme Louis Néel, CNRS, BP 166X, 38042 Grenoble-CEDEX, France
[§]Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

Specific-heat data in the 0.3 to 20K region for two high-quality UPt_3 samples are analyzed with emphasis on the 4-10K region. It is concluded that no effect associated with antiferromagnetic ordering has been observed, and an upper limit of the order of 0.1% for such an effect is deduced. The results are compared with earlier measurements in the vicinity of the Néel temperature, 5K.

Antiferromagnetic ordering in UPt_3 is of particular interest in relation to the splitting of the superconducting transition[1] with its implication of unconventional superconductivity and the possibility that the magnetic properties influence the nature of the superconducting transition. Weak antiferromagnetic ordering in UPt_3 at a Néel temperature $T_N \sim 5K$ was first observed in μSR measurements.[2] Subsequent neutron-diffraction measurements have shown the presence of ordered moments with a magnitude of the order of $10^{-2}\mu_B$ /U-atom in some, but not all, UPt_3 samples[3]. As a contribution to establishing a better understanding of the magnetic properties of UPt_3, we report here measurements of the specific heat, C, on two high-quality samples in the vicinity of the Néel temperature. Although the results show qualitative similarities to earlier measurements, including measurements[4] on one of the same samples, they are interpreted differently. In particular, it is concluded that, to within a precision of approximately 0.1%, there is no intrinsic feature in the specific heat near the antiferromagnetic ordering. (In Ref. 4 it was concluded that the anomalies in C near 7K were intrinsic, but it was noted that the sample independence of the

anomaly made its association with the antiferromagnetic ordering questionable.)

Measurements of C on the same two samples in the vicinity of the critical temperature for superconductivity, T_c ~0.5K, have been reported elsewhere[1], and all measurements reported here between 4 and 10K were made with the same high-sensitivity thermometer. The samples, number 1 and number 2, are identified by the same numbers here and in Ref. 1, and information on sample preparation and other properties is given in Ref. 1 and in references cited there. Sample 1 was also one of a group of three studied earlier[4] in the vicinity of T_N, but was designated sample 3 in that work.

Since the temperature scale used for the measurements reported here is known to include irregularities that can produce spurious structure of the order of several tenths of a percent in C, it is necessary to consider the possibility that the structure reported in Ref. 4 is related to temperature-scale error and does not reflect an intrinsic property of the sample. One way of distinguishing between these two possibilities is by comparison with the values of C for a reference material such as Cu measured with the same thermometer. Such a test is illustrated in Fig. 1: the expression $C = \gamma T + \delta T^3 \ln T + \varepsilon T^3$, which is known to give a reasonable approximation to C for UPt_3 in this temperature interval, was used to make separate fits to the 4-10K data for each UPt_3 sample in each field; 4-10K, zero-field data for a high-purity Cu sample were also fitted by the 3-parameter expression appropriate to Cu in that temperature interval, $C = \gamma T + B_3T^3 + B_5T^5$. The fractional deviations from each of the 5 fitting expressions are compared as functions of temperature in Fig. 1. The striking similarity of the deviations and the field independence of the measurements is convincing evidence that they arise from temperature-scale error rather than intrinsic properties of the samples.

Further evidence bearing on the origin of the structure in C is provided by consideration of the nature of the temperature scale -- an R-T relation that gives the temperature, T, as a function of the resistance, R, of the thermometer -- and its relation to the calculated C. In this case, the temperature scale has two components that correspond to two stages in its development. The first is an R-T equation of the form $T^{-1}=\Sigma A_n(\ln R)^n$, that approximates the calibration data to within a few percent in the 2-30K region. The second component is a "difference curve" that is used to correct values of T calculated from the equation. Inclusion of the difference curve in the calculation of T provides a significant increase in the overall accuracy of the derived values of C. However, particularly since C depends on the temperature derivative of errors in the temperature scale, errors in the curve that are within the uncertainty of the calibration data can produce small errors in C that change sign in short temperature intervals. To demonstrate that the difference curve can produce structure in C similar to that evident in Fig. 1, two calculations, one with and one without a difference curve, of the 4-10K, zero-field data for sample 1 are compared in Fig. 2. The open circles represent the calculation with the complete R-T relation including the difference curve, but in Fig. 2 C/T has been divided by a+bT, which is a linear approximation to C/T in that temperature interval, to permit display on an expanded scale. For comparison the solid squares represent $C^*/T^*(a^*+b^*T^*)$ in which the corresponding quantities are all calculated from a three-term equation that approximates the R-T relation in the 4-10K temperature interval, but without the use of a difference curve. Furthermore, the coefficients of the terms in the R-T equation were forced to be positive to avoid systematic alternation in the sign of the deviations from the fit which could also produce structure in $C^*(T^*)$. On average, the open circles are certainly a better approximation to

C, but they do show structure introduced by the difference curve that is not apparent in the solid squares.

On the basis of the measurements reported here, and the comparisons described above, we conclude that, for both sample 1 and sample 2, there is no structure in C in the 4-10K region that cannot be understood as arising from temperature-scale irregularities. Since sample 1 was also one of a group of three samples that showed essentially identical structure in other measurements[4], and since that structure was qualitatively similar to (although greater in magnitude than) that reported here, we suggest that all of the observed structure in C originates in temperature-scale irregularities. Since both samples 1 and 2 showed antiferromagnetic order[2,5], this interpretation of the data implies an upper limit of approximately 0.1% for the effect of antiferromagnetic ordering on C (see Fig. 1).

The work at Berkeley and Los Alamos was supported by the Director, Office of Energy Research, Office of Basic Energy Science, Division of Materials Sciences of the U.S. Department of Energy (at Berkeley under contract No. DE-AC03-76SF00098).

REFERENCES

1. R. A. Fisher, et al., Phys. Rev. Lett. **62**, 1411 (1989).
2. R. H. Heffner, et al., Phys. Rev. B**39**, 11345 (1989).
3. G. Aeppli, et al., Phys. Rev. Lett. **60**, 615 (1988); P. Frings, et al., Physica B **151**, 499 (1988).
4. J. Odin, et al., J. Magn. Magn. Mat. **76 & 77**, 223 (1988).
5. L. Taillefer, et al., J. Magn. Magn. Mat. **90-91**, 623 (1991).

FIGURE CAPTIONS

Figure 1. Deviations from appropriate 3-parameter fits.

Figure 2. Two different calculations of the same zero-field data for sample 1.

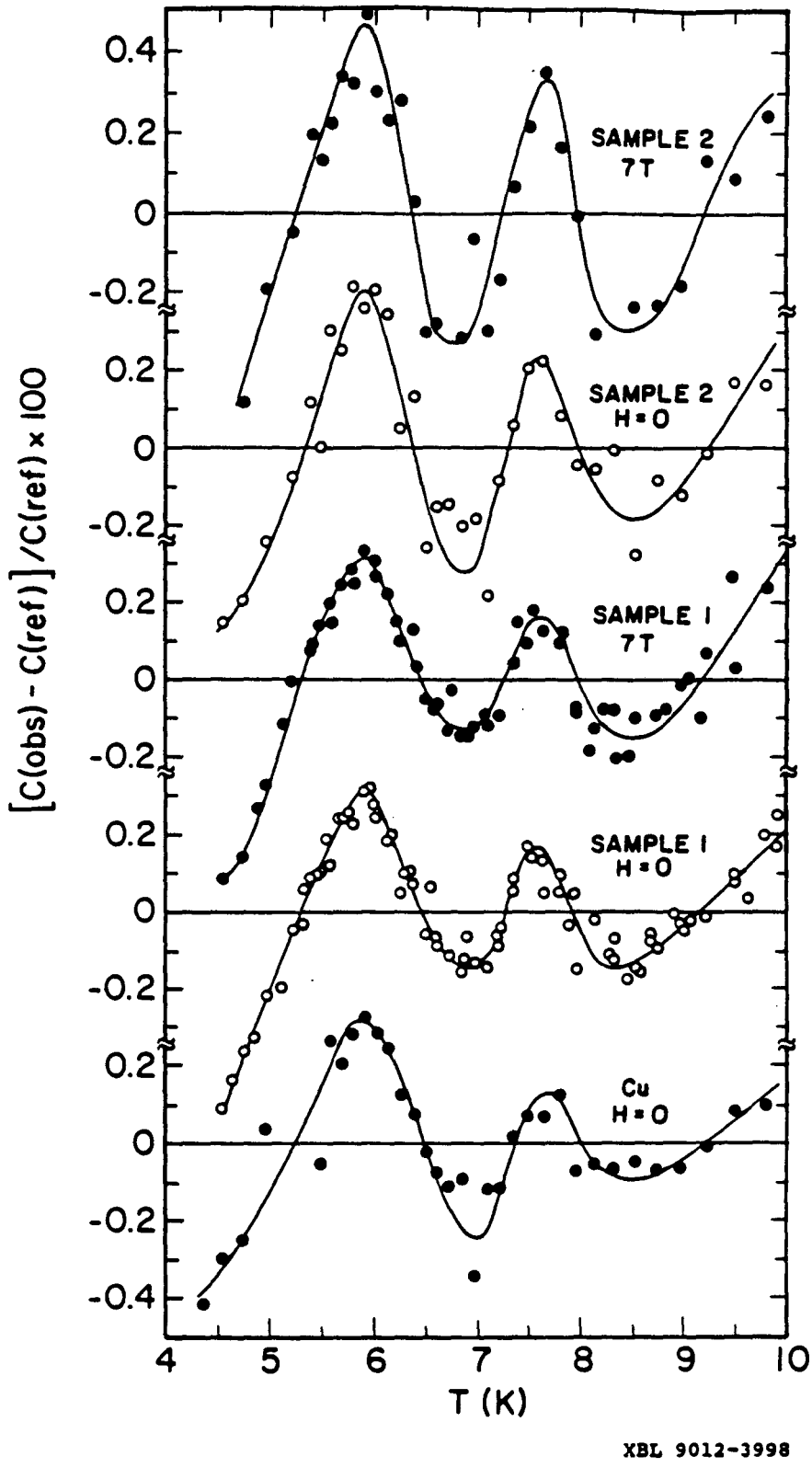
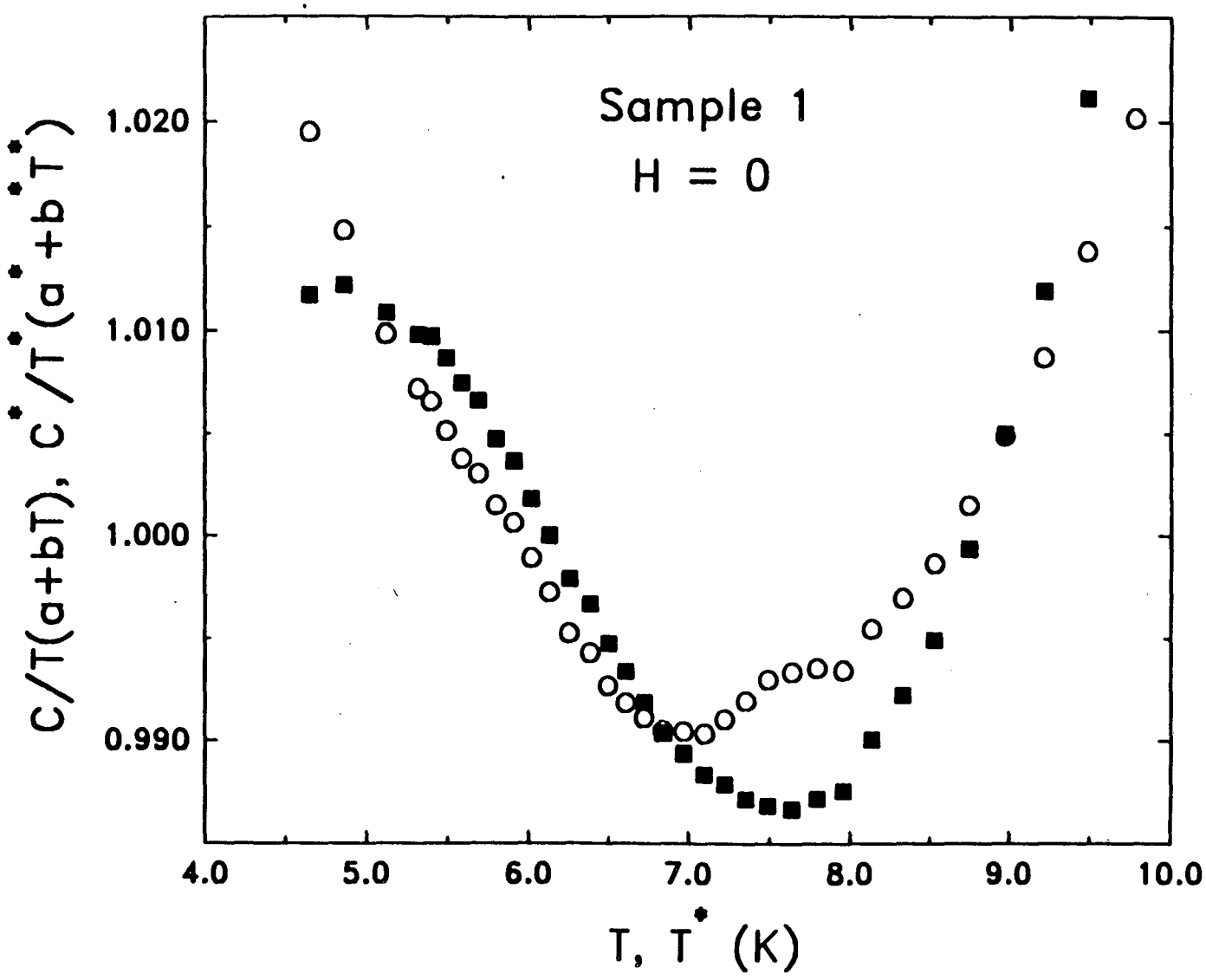

0.4
0.2
0
-0.2
0.2
0
-0.2
0.2
0
-0.2
0.2
0
-0.2
0.2
0
-0.2
-0.4
SAMPLE 2
7T
SAMPLE 2
H=0
SAMPLE 1
7T
SAMPLE 1
H=0
Cu
H=0
[C(obs) - C(ref)]/C(ref) x 100
4
5
6
7
8
9
10
T (K)
XBL 9012-3998

FIGURE 1



XBL 9012-4001

FIGURE 2

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