Title
Observation of antiferromagnetic correlations in UBe13

Journal
Solid State Communications, 60(8)

ISSN
0038-1098

Authors
Neumann, KU
Capellmann, H
Fisk, Z
et al.

Publication Date
1986-11-01

DOI
10.1016/0038-1098(86)90259-0

Solid State Communications, Vol.60,No.8, pp.641-643, 1986.
Printed in Great Britain.

0038-1098/86 $3.00 + .00
Pergamon Journals Ltd.

OBSERVATION OF ANTIFERROMAGNETIC CORRELATIONS IN UBe_{13}

K.U. Neumann*, H. Capellmann*, Z. Fisk**, J.L. Smith**, K.R.A. Ziebeck*

* Institut Laue-Langevin, 156X, 38042 Grenoble Cedex, France

**Center for Material Science, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

Received 22 August 1986 by E.F. BERTAUT

The wavevector and energy dependence of the paramagnetic response in the normal phase of the Heavy Fermion system UBe_{13} has been investigated between 10 K and 300 K using polarized neutrons and polarization analysis. At 10 K the response was found to be enhanced at non zero wavevectors indicating the presence of strong antiferromagnetic correlations. The peaks in the scattering occurred at positions expected for incipient type G antiferromagnetism of the simple cubic uranium sublattice. At room temperature the spatial correlations completely disappeared and the response was wave vector independent. Constant Q scans carried out at 10 K confirmed the Lorentzian dependence proposed by Goldman et al. [1].

Introduction

Since the discovery of the first superconducting Heavy Fermion system $CeCu_2Si_2$ by Steglich et al.[2] other compounds containing uranium e.g. UPt_3 [3], UBe_{13} [4] have also been found to exhibit heavy electron behaviour as well as a transition to superconductivity at low temperatures i.e.< 1 K. Of these compounds UBe_{13} was found to have the largest specific heat coefficient (γ=1.1 J/mol K^2). Between 150 K and room temperature the static susceptibility is Curie-Weiss with a proposed [5] effective moment of 3.08 μ_B. Below 150 K the susceptibility deviates from a Curie-Weiss behaviour.

Neutron measurements by Goldman et al.[1] using a powder sample at 10 K were analysed using a Lorentzian relaxation function yielding a width Γ of 13 meV. The measurements did not reveal the presence of a narrow f resonance expected on the basis of the large γ value.

Presented here are the results of a polarized neutron investigation between 10 K and room temperature concerning the wave vector dependence of the paramagnetic scattering which is important for establishing the presence of spatial correlations. In addition constant Q scans extending up to 80 meV have been carried out at several wave vectors.

Experimental

Powder neutron diffraction patterns of UBe_{13} were obtained at 10 K and 100 K using the high resolution diffractometer D2B located at the thermal source of the HFR in Grenoble. The two diffraction patterns confirmed that the sample was single phased and had the cubic $NaZn_{13}$ structure. A refinement of the structure using the two data sets yielded crystallographic parameters which were in agreement with those obtained by Goldman et al.[6].

The paramagnetic response was investigated using polarized neutrons and polarization analysis as provided by the triple axis spectrometer D5 located on the hot source at the ILL. The experimental arrangement of the spectrometer was similar to that previously described [7], in which the final wavelength was held fixed at .84 Å (E_f=112 meV). The sample of volume ~9 c.c. was mounted in an Al can attached to a Displex closed cycle refrigerator.

A clean measurement of the paramagnetic response was obtained by measuring the difference of the spin flip scattering cross section observed with the incident neutron polarization parallel and perpendicular to the neutron scattering vector [8].

Measurements were carried out at 10K, 100K and 300K. At each temperature constant energy scans centered on E=0 with an energy width $\Delta E= \pm 19$ meV were performed. The results of these measurements are shown in Fig.1-3. At 10 K the response was found to be peaked at non zero wave vectors remote from the position of nuclear Bragg peaks suggesting the presence of spatial correlations of antiferromagnetic nature. From the position of the enhanced scattering it was concluded that the fluctuations were consistent with incipient type G antiferromagnetism associated with the simple cubic uranium sublattice.

Constant Q scans were carried out at Q=1.06 $Å^{-1}$, Q=2.56 $Å^{-1}$ which corresponded to positions of enhanced scattering and at Q=1.56 $Å^{-1}$ where a minimum of the scattering was observed. The energy profiles could be characterized by a Lorentzian relaxation function as proposed by Goldman et al.[1]. Although the scattering was peaked at low energy transfers the tail of the response extended beyond 80 meV the highest energy transfer employed in the experiment.

On warming to 100 K the spatial correlations remained clearly visible. The scattering tended to increase slightly. The corresponding Q scans were similar to those observed at 10 K.

Finally at 300 K the spatial correlations were destroyed and the scattering became essentially wave vector independent.

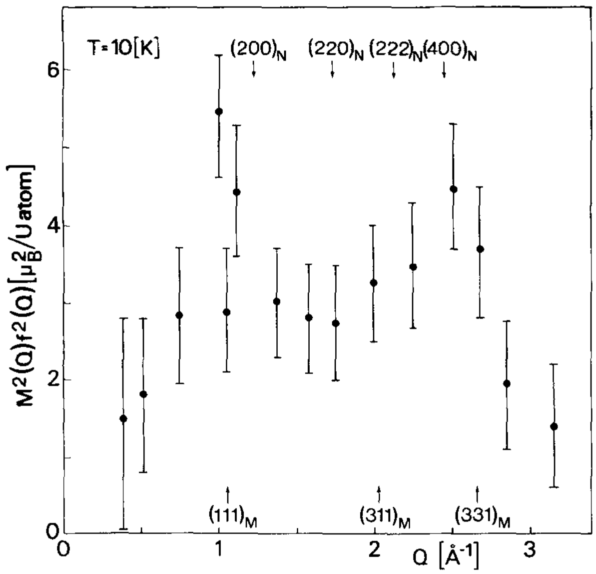

Fig.1:

The wave vector dependence of the paramagnetic scattering at the elastic position of the spectrometer with an energy width of ±19meV. The temperature at which the measurement was made was 10 K. The positition of nuclear Bragg peaks is indicated by $(\ )_N$ and the Bragg positions for type G s.c.c. antiferromagnetism of the uranium sublattice by $(\ )_M$.

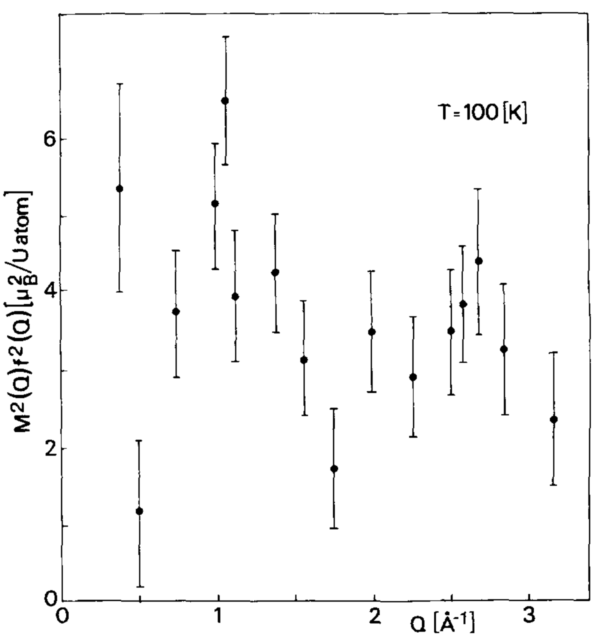

Fig.2:

Wave vector dependence of the paramagnetic scattering at 100 K.

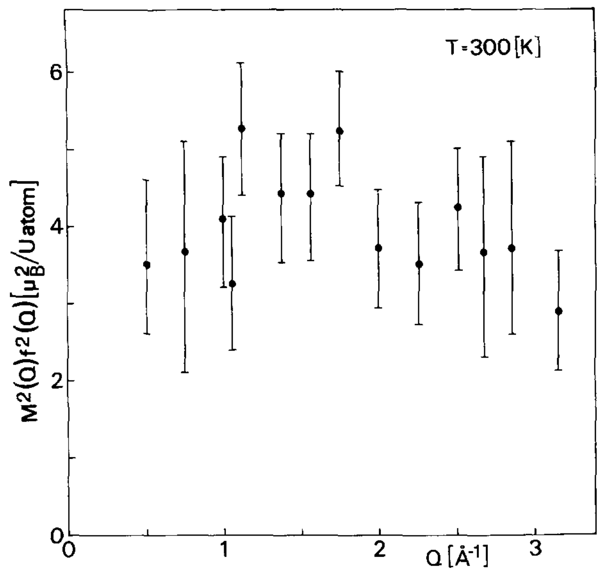

Fig.3:

The wave vector dependence of the paramagnetic scattering at 300 K.

Discussion

These measurements represent an unambiguous confirmation of antiferromagnetic fluctuations in a Heavy Fermion system which does not order magnetically. It is remarkable that the spatial correlations extend up to at least 100 K (reminiscent of itinerant electron behaviour [9]) which is considerably higher than the region of Heavy Fermion behaviour. The results are particularly surprising since they have been obtained using a powder sample in which spatial correlations are averaged over a Debye Scherrer cone and therefore at finite Q only a part defined by the vertical divergence of the spectrometer is measured (for comparison see Cr[10]). From a consideration of the intensity it is probable that the fluctuations occur in or close to the (111) plane. Comparing these measurements to those of other heavy fermion systems it is found that the intensity within an energy range of 19 meV is substantially larger. Therefore the wave vector response may be determined more easily using D5.

Further measurements to investigate the role of the spin fluctuations in the superconducting state are planed.

Acknowledgments - The technical assistance of P.Agnes and the valuable support provided by J.Cockcroft on D2b are gratefully acknowledged.

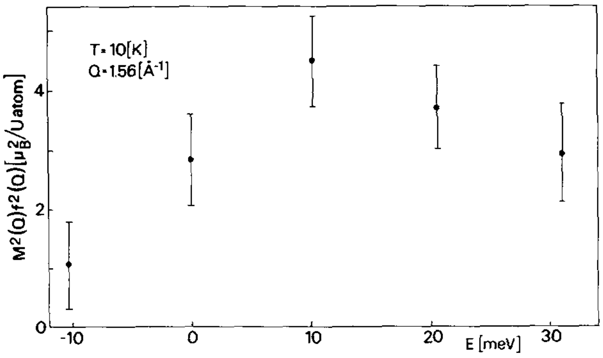

Fig.4:

Constant Q scan at T=10 K and Q=1.56Å^{-1}

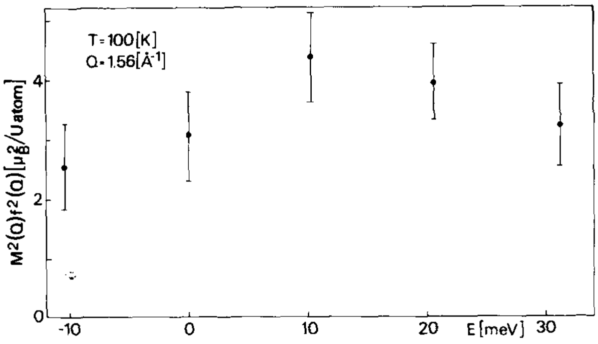

Fig.5:

Constant Q scan at T=100 K and Q=1.56Å^{-1}

References

1. A.I.Goldman, S.M.Shapiro, G.Shirane, J.L.Smith, Z.Fisk, Phys.Rev.B 33, 1627 (1986)
2. F.Steglich, J.Aarts, C.D.Bredl,W.Lieke, D.Meschde,W.Franz,J.Schaefer, Phys.Rev. Lett. 43, 1892 (1979)
3. G.R.Stewart, Z.Fisk, J.O.Willis, J.L.Smith, Phys.Rev.Lett. 52, 679 (1983)
4. H.R.Ott, H.Rudigier, Z.Fisk, J.L.Smith, Phys.Rev.Lett. 50, 1595 (1983)
5. H.R.Ott, H.Rudigier, Z.Fisk, J.O.Willis in:Moment Formation in Solids, edited by W.J.L.Buyers (Plemum, New York) (1984)
6. A.I.Goldman, S.M.Shapiro, D.E.Cox, J.L.Smith, Z.Fisk, Phys.Rev.B 32, 6042 (1985)
7. S.M.Johnson, A.Benoit, P.J.Brown, H.Capellmann, J.J.M.Franse, P.H.Frings, K.R.A.Ziebeck, Z.Phys.B 63, 335 (1986)
8. K.R.A.Ziebeck, P.J.Brown, J.Phys. F10, 2015 (1980)
K.R.A.Ziebeck,P.J.Webster, P.J.Brown, J.A.C.Bland, J.Magn.Magn.Mater.24, 258 (1981)
9. K.R.A.Ziebeck, J.G.Booth, P.J.Brown, H.Capellmann, J.A.C.Bland, Z.Physik B 48, 233 (1982)
10. K.R.A.Ziebeck, H.Capellmann, P.J.Brown, J.G.Booth, Z.Physik B 48, 241 (1982)