Title
COEXISTENCE OF SPIN FLUCTUATIONS AND SUPERCONDUCTIVITY IN UPT3

Permalink
https://escholarship.org/uc/item/9tn6w1t4

Journal
PHYSICA B & C, 127(1-3)

ISSN
0378-4371

Authors
STEWART, GR
FISK, Z
WILLIS, JO
et al.

Publication Date
1984

License
CC BY 4.0

Peer reviewed
Correlation of Spin Fluctuations and Superconductivity in UPt₃

G.R. Stewart, Z. Fisk, J.O. Willis and J.L. Smith

Materials Science and Technology Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

Heat capacity measurements on the heavy fermion superconductor UPt₃, in an 11 T magnetic field show that above approximately 7 K, UPt₃ behaves like the spin fluctuation compounds UA₃ and TbBe₂. Magnetoresistance measurements on UPt₃ at 1.3 K also yield results similar to UA₃, in contrast to the other heavy fermion superconductors, CeCu₂Si₂ and UBe₁₁, which show a magnetoresistance effect of opposite sign. Thus, experimental results permit continued speculations of triplet superconductivity in UPt₃.

Since our report on the superconductivity of UPt₃ [1], which was already known to be a candidate for spin fluctuations [2], other workers have confirmed those results and measured the superconducting critical field [3, 4, 5]. Interest is high in UPt₃ because it has joined CeCu₂Si₂ and UBe₁₁ in the small family of heavy fermion superconductors [6], which have electron mass enhancements of about 200, but also because of its differences from them, particularly the T³ ln T term in its heat capacity. Speculation is rampant on the possibility of a triplet paired superconducting state in all of these compounds [7, 8]. For a recent review of heavy fermion systems, see ref. [9]. However, UPt₃ is unique in the similarity of its heat capacity to that of ⁴He at much lower temperatures, which may make it the most likely candidate for p-state pairing [10]. Whatever the outcome of this particular speculation, the extreme properties of these compounds will remain a source of controversy for a while. For this reason we report here an extension of our earlier heat capacity work [1] to heat capacity in an applied magnetic field of 11 T and on magnetoresistance measurements.

Fig. 1 shows the effect of the applied magnetic field on the heat capacity of UPt₃. Above about 7 K, the data are consistent with the point of view that spin fluctuations are depressed by the field. This is the same as the results on UA₃ [11] and TbBe₂ [12], which are the only previously known compounds that showed a T³ ln T term in their heat capacities. At lower temperatures the two data sets cross. It is not clear how this might be interpreted. However, two points should be made. In the neighborhood of 7 K the thermal energy and the magnetic energy of the electrons in 11 T are comparable, which obscures a spin-fluctuation interpretation. Second, until there are candidates for a proper description (including anisotropy) of this Fermi liquid state that the heat capacity shows is developing below about 10 K, we can only say that it is not unexpected to observe that a field modifies that state.

Fig. 2 shows the effect of applied magnetic fields on the electrical resistivity of UPt₃ at 1.2 K as measured with a standard 4-wire ac technique. As in the heat capacity case, there is little theoretical guidance, but the data may be compared to those for related compounds. For UA₃ the power law for the field has exponents of 1.45 (2 T to 15 T) and 1.3 (above 15 T) [13]. We measured an exponent of 1.25 (2 T to 11 T) which suggests either that UPt₃ has a larger paramagnon contribution to the resistivity than does UA₃ or that there are band structure effects. In contrast, the other heavy fermion superconductors show a negative magnetoresistance. For the same temperature and field UBe₁₁ shows a -34% change and CeCu₂Si₂ shows approximately a -4.5% change, [14] compared to the UPt₃ results in fig. 2 of +41%. So magnetoresistance suggests that UPt₃ is more like the other spin fluctuators than like the other heavy fermion superconductors.

The results shown in the figures confirm that UPt₃ is unique amongst spin fluctuators and heavy fermion superconductors in that it is a member of both small groups. Because these

0378-4363/84/$3.00 © Elsevier Science Publishers B.V.
(North-Holland Physics Publishing Division)
Fig. 1. Heat capacity of UP\textsubscript{3} from 2 to 17 K in zero and 11 T magnetic fields. The $c$-axis of the samples was perpendicular to the field.

Fig. 2. Magnetoresistance of UP\textsubscript{3} in magnetic fields up to 11 T. The current was parallel to the $c$-axis, which was perpendicular to the field.

Fluctuators are considered to show a ferromagnetic spin coupling, the experimental data suggest that UP\textsubscript{3} remains the best current candidate for triplet superconductivity.

Acknowledgment

This work was performed under the auspices of the U.S. Department of Energy.

References