Physica 127B (1984) 448–449
North-Holland, Amsterdam

COEXISTENCE OF SPIN FLUCTUATIONS AND SUPERCONDUCTIVITY IN UPt_3

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Heat capacity measurements on the heavy fermion superconductor UPt_3 in an 11 T magnetic field show that above approximately 7 K, UPt_3 behaves like the spin fluctuation compounds UAl_2 and $TiBe_2$. Magnetoresistance measurements on UPt_3 at 1.2 K also yield results similar to UAl_2, in contrast to the other heavy fermion superconductors, $CeCu_2Si_2$ and UBe_{13}, which show a magnetoresistance effect of opposite sign. Thus, experimental results permit continued speculation of triplet superconductivity in UPt_3.

Since our report on the superconductivity of UPt_3 [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 UPt_3 because it has joined $CeCu_2Si_2$ and UBe_{13} 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 $T^3 \ln T$ 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, UPt_3 is unique in the similarity of its heat capacity to that of ^3He 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 on 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 UPt_3. 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 UAl_2 [11] and $TiBe_2$ [12], which are the only previously known compounds that showed a $T^3 \ln T$ 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 UPt_3 at 1.2 K as measured with a standard 4-lead, 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 UAl_2 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 UPt_3 has a larger paramagnon contribution to the resistivity than does UAl_2 or that there are band structure effects. In contrast, the other heavy fermion superconductors show a negative magnetoresistance. For the same temperature and field UBe_{13} shows a −34% change and $CeCu_2Si_2$ shows approximately a −4.5% change, [14] compared to the UPt_3 results in fig. 2 of +41%. So magnetoresistance suggests that UPt_3 is more like the other spin fluctuators than like the other heavy fermion superconductors.

The results shown in the figures confirm that UPt_3 is unique amongst spin fluctuators and heavy fermion superconductors in that it is a member of both small groups. Because these

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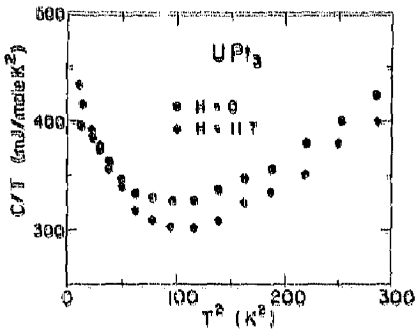

Fig. 1. Heat capacity of UPt_3 from 2 to 17 K in zero and 11 T magnetic fields. The c-axis of the samples was perpendicular to the field.

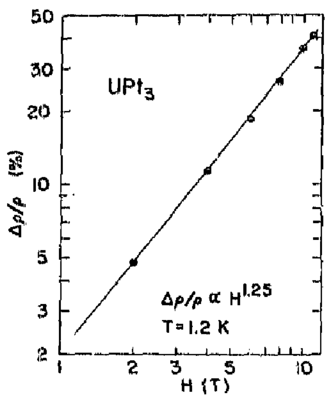

Fig. 2. Magnetoresistance of UPt_3 in magnetic fields up to 11 T. The current was parallel to the c-axis, which was perpendicular to the field.

fluctuators are considered to show a ferromagnetic spin coupling, the experimental data suggest that UPt_3 remains the best current candidate for triplet superconductivity.

Acknowledgment

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

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