Investigation of the Field Dependence of Kondo Lattice Coherence as Probed by NMR Knight Shifts

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Introduction

Heavy fermions are metals that typically contain a lattice of either Ce or U ions, in which localized lanthanide (4f) or actinide (5f) electrons weakly interact with the itinerant conduction electrons of the material. Hybridization between these two sets of electrons gives rise to a number of unusual properties, such as a large effective mass of the carriers as well as unusual ground state orders such as antiferromagnetism or unconventional superconductivity. The behavior of these systems is often described in the context of a Kondo lattice, in which the spins of the local moments interact with the spins of the conduction electrons. At sufficiently low temperature and for sufficiently large density of states, the conduction electrons can screen out the local moments and form singlets. On the other hand, the conduction electrons can also mediate RKKY interactions between the local moments leading to long range order. All such materials undergo a crossover at a temperature T* where the local moments change from independent to some form of collective behavior. This crossover is clearly evident in Nuclear Magnetic Resonance (NMR) Knight shift experiments as a breakdown of the linear relationship between the Knight shift and the bulk magnetic susceptibility. In order to investigate the microscopic nature of this crossover we have conducted experiments to investigate the magnetic field dependence of T*.

Experimental

In order to investigate the field dependence, we measured the Knight shift of the In(1) and In(2) sites in $CeIrIn_5$ at several fields between 24 T and 30 T in Cell 2 at the NHMFL in Tallahassee, and compared the results to our previous measurements in 12 T. T* ~ 35K in $CeIrIn_5$, and there are two distinct crystallographic Indium sites that can be discerned in the NMR spectra. For T > T*, we find at all fields that K(1) and K(2) are both proportional to the bulk susceptibility, χ, and to one another. By plotting K(1) versus K(2), one can directly measure T* from the point where the linear relationship breaks down. This enabled us to extract the crossover data at high fields without the need for an independent measure of χ in these fields.

Results and Discussion

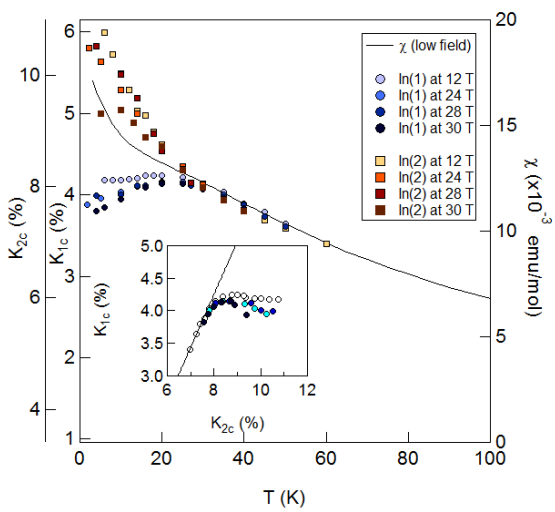

Figure 1: In Knight shift in $CeIrIn_5$ versus temperature and field.

The Knight shift of both the In(1) and In(2) sites is shown in **Figure 1** as a function of both temperature and field. T* is clearly evident at 35 K where the data sets diverge from one another at lower temperature. Below T* the Knight shifts of both sites are suppressed with increasing field. Surprisingly, however, T* does not appear to change with field. In the context of the two-fluid model [1,2], these results imply that χ_{cf} is unaffected by the field, but χ_{ff} is. On the other hand, the fields involved are too small to significantly affect the local moment magnetism at these temperatures.

Conclusions

The Knight shift becomes field dependent below T*, which clearly implies that the field is affecting coherence in the Kondo lattice. Further theoretical work is necessary to understand the fundamental behavior of the various susceptibilities below the coherence temperature in high fields.

Acknowledgements

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References

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[2] Shirer, K, *et al.*, Proc. Nat. Acad. Sci. **109** E3067-E3073 (2012).