NUCLEAR MAGNETIC RESONANCE STUDIES OF URu_2Si_2 IN HIGH FIELDS

N. J. Curro (Los Alamos National Laboratory); T. Caldwell (Los Alamos National Laboratory)

Introduction

URu_2Si_2 exhibits some of the most intriguing and mysterious forms of correlated electron behavior. This material undergoes a phase transition at T_0 = 17.5K in zero field, however the nature of the order parameter in this phase remains unknown even after nearly twenty years of intense research. Experimentally we know that the Fermi surface is gapped below this transition, and much of the data are consistent with an itinerant spin density wave order [1]. However, the size of the ordered moment (~ 0.03 μ_B) is too small to account for the entropy loss at the transition. Consequently several different scenarios have been suggested to explain this so-called hidden order phase. In particular, one candidate explanation is an incommensurate orbital antiferromagnetic phase arising from a Fermi surface instability [2]. Recently, Jaime and coworkers at the magnet lab in Los Alamos have investigated the behavior of the hidden order phase transition as a function of applied magnetic field up to 45 T. They found that the specific heat anomaly at T_0 is suppressed to $T = 0$ at 36 T; but surprisingly, for higher magnetic fields a second phase is manifest between 38 and 40 T, with a maximum transition temperature at 6K [3]. Further investigation by Harrision *et al.*, revealed a plethora of new phases at low temperatures in the vicinity of this re-entrant phase [4]; however all of the information about these new high field phases of URu_2Si_2 has been inferred solely from bulk measurements. To date, there have been no microscopic probes of any of these high field phases, yet such information is crucial to understanding not only the nature of these phases, but also may provide clues to the nature of the low field, hidden order phase. In order to shine light on this problem, we have performed ^{29}Si NMR as a function of temperature and fields up to 40 T.

Experimental

In October 2004, in collaboration with the Condensed Matter Physics NMR group at the National High Magnetic Field laboratory in Tallahassee, we measured the NMR on an aligned powder sample of URu_2Si_2 that was isotopically enriched with ^{29}Si to increase the signal to noise ratio using the resistive magnet in Cell 8.

Results and Discussion

Our original NMR studies of this material began some years ago at the NHMFL and in Los Alamos, and were focused on investigations of the unusual high field phases. However, in the process of investigating these phases, we discovered some rather unusual spin dynamics at intermediate fields, but we were unable to follow the behavior over a wide field range. Our current efforts are focused on tracking this behavior as a function of field. In particular, the Si nuclei are coupled to the conduction electrons via a hyperfine interaction. As a consequence, the NMR parameters such as the Knight shift and spin lattice relaxation rate are sensitive to the density of states at the Fermi surface. Any dramatic changes to the Fermi surface, such as the onset of a gap brought on by superconductivity or other Fermi surface instability are reflected in the spin lattice relaxation rate. By investigating the temperature and field dependence of these NMR parameters, we can probe the changes to the Fermi surface brought on by the high magnetic fields.

Our microscopic measurements of the spin dynamics reveal unusual behavior for fields greater than 20 T, but less than the critical field of 36 T where T_0 is suppressed to $T = 0$. However, these investigations are ongoing, and require further experiments at intermediate and high fields in order to develop any reasonable interpretation of our results. Further measurements are planned for next year.

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References

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