FIRST REPORT OF A HOMOGENEOUS INTERNAL FIELD IN HIDDEN-ORDERED URu_2Si_2

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Introduction

URu_2Si_2 is a heavy-fermion superconductor (T_c=1.2 K) that undergoes a puzzling "hidden order" phase transition at ambient pressure below 17.5 K.[1-3] It also exhibits a complex phase diagram at high fields (30-50 T).[1,2] Our ^{29}Si NMR experiments provide microscopic evidence for the development of internal fields as the material undergoes the hidden order transition.

Experimental

Representative single-crystal ^{29}Si NMR spectra and corresponding spectral parameters are shown in Fig.1 (a)-(c) as functions of T. The field was perpendicular to the crystal c-axis and kept constant at the value H_0 = 9.4 T, while the entire line was irradiated by narrow rf pulses in a Carr-Purcell-Meiboon-Gill sequence. We used the 15 T superconducting magnet system at the NHFML Condensed Matter NMR facility.

Results and Discussion

The main result of our measurement is the T-dependent shift of the entire spectrum as shown in Fig. 1 (a). Other features of the spectra follow. Two lines are observed above T_0: Main Line (narrow and tall) and Line **x** (broad and short—not fully understood yet). The lines cannot be resolved below T_0, where an overall linewidth enhancement takes over (see the low-T spectrum). We have fit the data to a two-gaussian line spectrum keeping the half-width-at-half-maximum (HWHM) of Line **x** at its high-T value (5.3 G). The remaining parameters are plotted in Fig. 1 (b) and (c). [The hidden order effects appear to develop well below T_0 because the high power rf pulses (~50/shot) in the CPMG sequence induce rf heating in the single crystal and a T-calibration error. In practice T_0 = 17.5 K was obtained from magnetization data taken at the NHMFL using the same sample as for NMR (not shown).] Figure 1 (b) gives the T dependence of the center field, relative to the applied field H_0 for both the Main Line and Line **x** as indicated. The lines are found to shift up field [4 G (Main Line), 8 G (Line **x**)] as T is decreased below T_0. The presence of these shifts reflects homogeneous local field changes for the entire line; a strong indication of time-reversal symmetry breaking.[2] Finally, Fig 1 (c) shows that there is a linewidth enhancement as reported for the oriented powder,[3] but the absolute size is smaller here: 3.8 G (extracted in quadrature) as compared with about 10 G.[3]

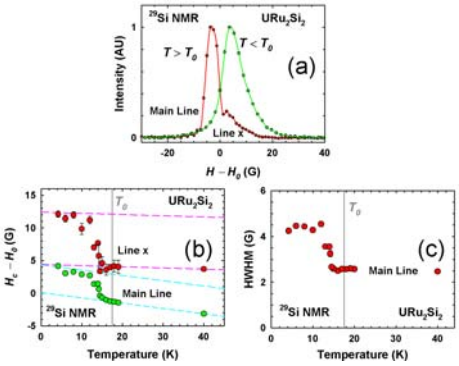

Figure 1, (a) Spectra at T = 40 and 4.2 K. (b) Average line positions relative to H_0. Dashed lines: overall shift magnitudes. (c) HWHM of Main Line vs. T.

Conclusions

Our NMR measurements in single crystal URu_2Si_2 represent the first piece of compelling evidence associating an internal field with the hidden order parameter. Further experiments ought to allow the test of prevailing theories by a quantitative comparison between predicted fields and what we might actually observe by our NMR experiments.

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References

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