Evidence for a Nematic Component to the Hidden Order Parameter in URu_2Si_2 in High Magnetic Fields

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Introduction

URu_2Si_2 is an unconventional, heavy fermion superconductor with T_c ~1.5 K; however, prior to the onset of superconductivity, the material undergoes a phase transition to a novel "Hidden Order" state which has defied comprehensive understanding for over 30 years. Ongoing experimental efforts have focused on studying the nature of the Hidden Order parameter (which can be suppressed with chemical substitution, pressure, and magnetic field) and characterizing its symmetry.

With a novel piezo actuator technique, our previous zero field measurements used the differential elastoresistance (a quantity which relates normalized resistivity changes to applied strain) to probe the nematic susceptibility of URu_2Si_2, revealing that the Hidden Order parameter is a two-component vector that breaks four-fold rotational symmetry and couples to nematic fluctuations in the [110] direction [1]. Our most recent experiments at the Magnet Lab explore the extent to which these nematic fluctuations persist in high field, particularly in the quantum critical regime where the Hidden Order state is suppressed to 0 K (H_c ~35.1 T).

Experimental

Magnetotransport measurements under strain were performed in the 31 T resistive and 45 T hybrid magnets at the NHMFL in a He^4 refrigerator.

Results and Discussion

The temperature dependence of the differential elastoresistance in the [110] direction at different magnetic fields is presented in Fig. 1b, which are extracted from the slope of the normalized change in resistance to strain (Fig. 1a). There are two salient features of these data: 1) a pronounced downward anomaly at the Hidden Order transition temperature T_{HO}, which shifts downward in increasing field and scales as the heat capacity singularity; and 2) an extended regime above T_{HO} for which there is a large susceptibility which persists even as the phase transition goes from second to first order. The elastoresistance also diverges at fixed temperature while sweeping field (Fig. 1c)—the elastoresistance in orthogonal directions is large and opposite in sign for $H<H_c$, diverges at the critical field, and is essentially unresolvable at higher fields (high uncertainties due to the material's very small magnetoresistance in this field range). These data reveal that four-fold rotational symmetry is broken at the Hidden Order thermal phase transition even in a magnetic field. Furthermore, the nematic susceptibility appears to diverge towards the quantum phase transition.

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References

[1] Riggs, Scott C., *et al*., to be published in *Nature Comm.* (2014). ArXiv: 1405.7403

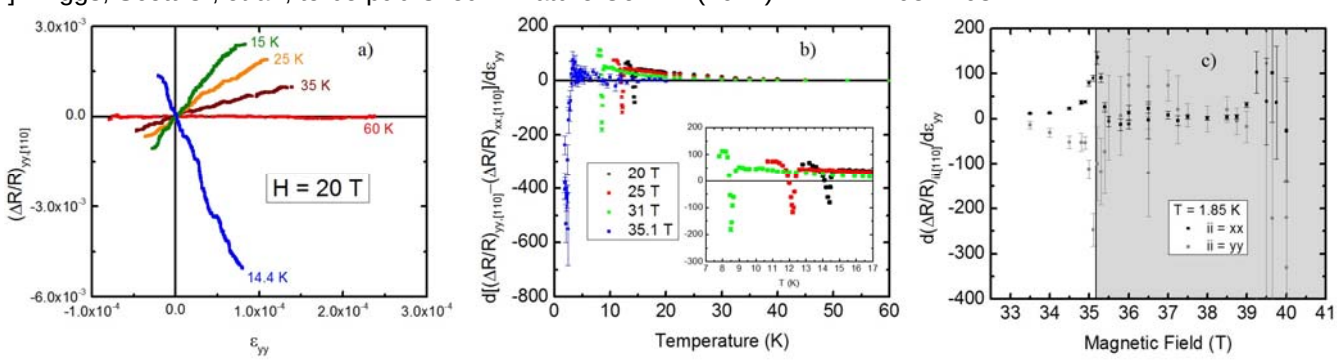

Fig.1 a) Temperature dependence of the resistive response to strain at H = 20 T. The slopes increase with decreasing temperature but then abruptly change sign at T_{HO}. b) Temperature dependence of the differential elastoresistance at different magnetic fields. Inset: Expanded view near the Hidden Order anomaly, which scales as the heat capacity singularity. c) Field dependence of the elastoresistance at 1.85 K. The resistive response diverges from below at the critical field. Vertical line marks the critical field associated with the quantum phase transition. Data for fields greater than H_c suffer from a poorer signal to noise due to the smaller magnetoresistance in this regime, but the divergence of the elastoresistance for $H<H_c$ is clear.