Experimental report

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Proposal: **4-01-1338** **Council:** 4/2014

Title: Magnetic order and softening of excitations in the nematic phases of $Sr_3Ru_2O_7$ for in-plane fields

Research area: Physics

This proposal is a new proposal

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Samples: $Sr_3Ru_2O_7$

Instrument	Requested days	Allocated days	From	To
IN12	8	7	25/11/2014	02/12/2014
IN3	0	3	22/11/2014	25/11/2014

Abstract:

Metamagnetic materials are those which exhibit a field-induced transition from a low- to high-magnetization state. A very topical metamagnetic system is the layered oxide metal $Sr_3Ru_2O_7$. This material may be prepared in high purity form and shows several metamagnetic features which are believed to be due to the underlying electronic structure, anisotropies therein, and anisotropies in the magnetic exchange interactions. For B parallel to the crystallographic c-axis, $Sr_3Ru_2O_7$ shows kinks in the magnetic isotherms and peaks (anomalies) in the susceptibility. These features have been used to map out various phases including the famous "electron nematic phase". We have recently shown that this phase coincides with a dramatic softening of the magnetic excitations and the occurrence of incommensurate magnetic order. Here we propose to search for a similar softening and the occurrence of magnetic order for B applied perpendicular to the c-axis. Anomalies in the susceptibility have also been observed for this field direction.

Magnetic order and softening of excitations in the nematic phases of $Sr_3Ru_2O_7$ for in-plane fields

Introduction

$Sr_3Ru_2O_7$ is a unique layered oxide metal which features several field-induced first-order transitions from a low magnetization (LM) to high-magnetization (HM) state (metamagnetism) [1]. Previous neutron diffraction measurements have established that for a field applied along the c-axis (**B||c)** $Sr_3Ru_2O_7$ goes from LM to HM polarized states via an intermediate state with broken translational symmetry due to two incommensurate spin-density-wave ordered phases [2]. The SDW order causes anomalies in the in-plane resistivity [3] and AC susceptibility. The phase diagram determined by these anomalies is shown in Fig.1 [4].

The SDW phases occur in the critical point of a metamagnetic transition, but the role of critical fluctuations in stabilising the SDW order is unknown. In this IN12 experiment, we sought to investigate the excitations and order away from the metamagnetic critical region, achieved by applying a magnetic field along the a-axis. Transport measurements show another region of anomalous resistivity for this field direction (Nematic Region 2) [3] but there is no evidence that the region is bounded by first-order transitions [4].

Results

The experiment on IN12 was performed with a 6.6 g array of co-aligned single-crystals. The sample was mounted in an 8.5 T vertical magnet with dilution insert capable of reaching a base temperature of 120mK. The sample array was mounted with the field direction along the a-axis [i.e. the scattering plane was (0KL)]. A Be filter was used with k_f=1.15 Å^{-1} to eliminate higher-order contamination.

Constant energy scans of the elastic line showed SDW order propagating along the b-axis (perpendicular to the field) with $\boldsymbol{q}_{SDW}$ = (0,0.195,0) (see Fig.2), in a narrow field region centred on a first-order metamagnetic transition at ~5T (H_1 in Fig.1). This order was also associated with soft excitations (see Fig.3). No order was found in nematic phase 2 (onset at 5.7 T) and the low energy fluctuations at this field have less spectral weight than at 5T (see Fig.3).

References

[1] Mackenzie, A. P., et al. *Physica C: Superconductivity* 481 (2012): 207-214.

[2] Lester, C., et al. *Nature materials* 14.4 (2015): 373.-378.

[3] Borzi, R. A., et al. *Science* 315.5809 (2007): 214-217.

[4] Grigera, S. A., et al. *Physical Review B* 67.21 (2003): 214427

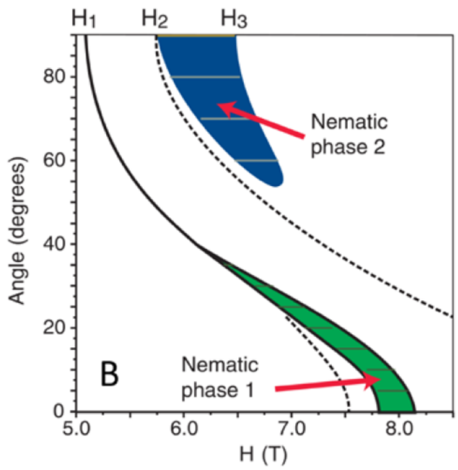

Fig.1: Phase diagram of so-called "nematic regions" from resistivity [3] and susceptibility measurements [4] at low temperature as a function of magnetic field and angle of the field from the c-axis (θ). Adapted from [1].

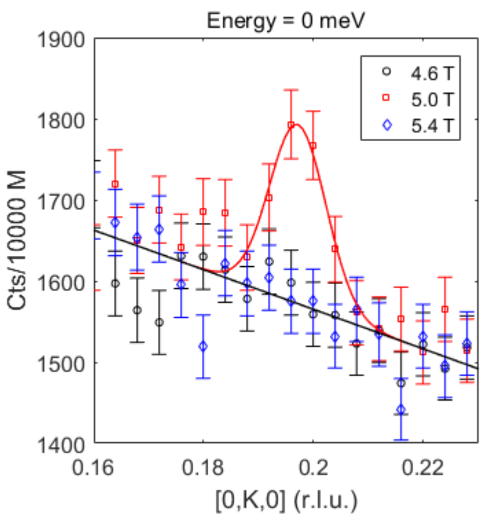

Fig.2: Raw data from the IN12 experiment. Elastic scattering along [0,K,0]. The magnetic Bragg peak occurs at 5 T (but not at 4.6 T or 5.4 T).

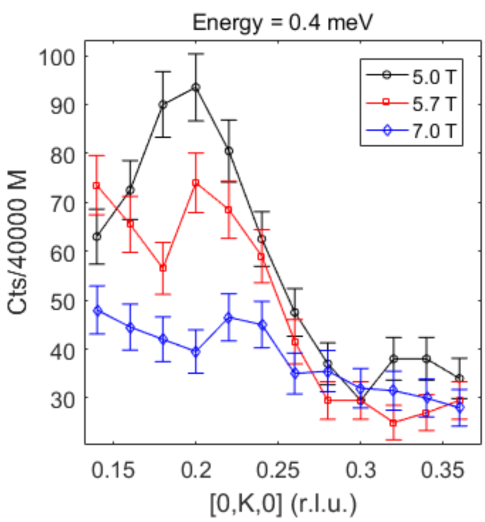

Fig.3: Constant energy scan at 0.4meV with Q along [0,K,0]. The spectal weight of the low-energy magnetic fluctuatuations is largest at 5T where order occurs. There is still significant spectral weight at 5.7 T at the onset of Nematic phase 2.