Experimental report

02/05/2022

Proposal: **4-01-1698** **Council:** 10/2020

Title: Field dependence of the magnetic soft modes in Sr3Fe2O7

Research area: Physics

This proposal is a new proposal

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Samples: Sr3Fe2O7

Instrument	Requested days	Allocated days	From	To
IN3	1	1	22/05/2021	23/05/2021
THALES	5	4	21/05/2021	25/05/2021

Abstract:

We propose to measure the field-dependence of the low-energy magnon spectrum of the helimagnet Sr3Fe2O7. The magnetic propagation vector is (q q 1) with q=0.142, which is doubly degenerate in the (effective) tetragonal symmetry, making this material an ideal candidate in which to study pseudo-Goldstone modes. These modes can only be observed once the helical order has been detwinned and only one of two allowed propagation vectors is populated, requiring cooling in a substantial magnetic field directed along the propagation vector we wish to select. Measurements can then be performed at lower fields. In a magnetically-detwinned sample, it is straightforward to separate the Goldstone modes near the favoured magnetic Bragg peak from pseudo-Goldstone modes, which we expect to find near the suppressed magnetic Bragg peak. Pseudo-Goldstone modes are crucial for the low-temperature properties, and in ZnCr2Se4 we discovered a field-driven closing of their gap leading to a quantum phase transition. We hope to find similar physics in Sr3Fe2O7.

Experimental Report on 4-01-1698:
Field Dependence of the Magnetic Soft Modes in $Sr_3Fe_2O_7$

This beamtime was intended to apply sufficient magnetic field to fully detwin the helical magnetic order in $Sr_3Fe_2O_7$, so that we could investigate pseudo-Goldstone modes at the forbidden magnetic Bragg peaks. We found similar soft modes previously in $ZrCr_2Se_4$, and such modes play a significant role in the low-temperature physical properties. Previous experiments on IN5 had only had access to fields of 3 T, leading to a ~3:1 ratio between the peaks corresponding to the favoured and suppressed magnetic Bragg positions. At THALES we had access to a 10 T magnet to ensure full detwinning of the magnetic order. The result was extremely illuminating.

The intensity in the suppressed magnetic Bragg peak as a function of temperature for several fields and field histories is shown in Fig. 1. This peak is reentrant, and the ratio of ~3:1 at base temperature is intrinsic, and does not change significantly with field above ~3.5 T. Around 65 K there is also a change in slope in the zero-field data. These data indicate that there are most likely three distinct magnetic phases, none of which are single-component helical order as previously thought, and that the previous data on IN5 were essentially detwinned despite appearances to the contrary. This also led us to reinvestigate the magnetization for more field histories, confirming these extra phase transitions.

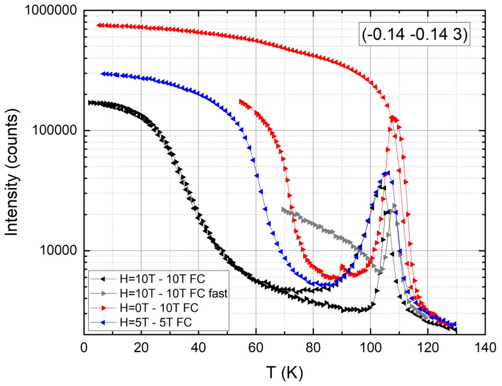

Fig. 1: Intensity in the suppressed magnetic Bragg peak for several fields and field histories.

The spin wave spectra shown in Fig. 2 indicate that suppression of the magnetic Bragg peaks leads to strong diffuse quasielastic scattering at the same wavevector, evidence for strong short-range dynamic correlations. These persist well above T_N. The temperature dependence of intensity in the gap in the inelastic spectrum is shown for two fields in Fig. 3.

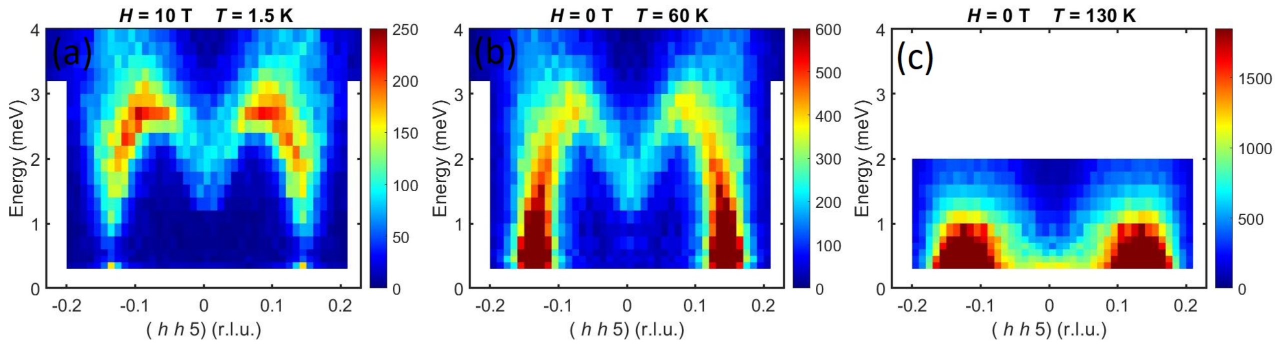

Fig. 2: Spin wave spectrum in magnetically-detwinned $Sr_3Fe_2O_7$ at several temperatures.

It was also possible during this beamtime to confirm that previously-observed superstructure peaks arising from charge order also involve shifts of the nuclei, and to track this intensity versus temperature. We found the same temperature dependence as in resonant x-ray data.

The surprising magnetic results have triggered considerable additional experimental effort, confirming and characterizing the new phases. We have also partnered with theorists to attempt to understand the meaning of the 3:1 ratio and what this state could look like. This remains in progress.

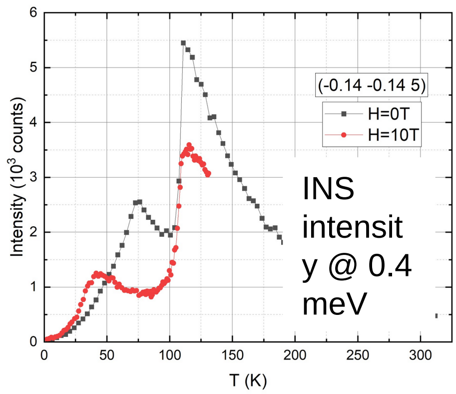

Fig. 3: Temperature dependence of the intensity in the gap in the excitation spectrum.