Experimental report

02/10/2018

Proposal: **4-01-1589** **Council:** 4/2018

Title: Pseudo-Goldstone magnon in the single-domain state of Sr3Fe2O7

Research area: Physics

This proposal is a new proposal

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Samples: Sr3Fe2O7

Instrument	Requested days	Allocated days	From	To
IN5	4	4	28/06/2018	03/07/2018

Abstract:

In a recent experiment on IN5, we discovered a pseudo-Goldstone mode in the low-energy spectrum of the frustrated cubic spinel ZnCr2Se4. This soft spin-wave branch appears gapless within linear spin-wave theory (LSWT), but develops a small energy gap of 0.17 meV due to nonlinear corrections arising from quantum fluctuations. This offers a possibility to estimate the weak effects related to spin-wave scattering processes and to compare them with theory on a quantitative level. However, the complex unit cell of the pyrochlore sublattice formed by S=3/2 magnetic Cr3+ ions in the spinel structure leads to multiple spin-wave modes that complicate the calculations. It is therefore important to repeat the same experiment on a helimagnetic compound with a simpler tetragonal structure, with only one magnetic atom per unit cell. The perfect candidate material for this study is Sr3Fe2O7, which we already investigated earlier. Here we suggest to study the field-cooled single-domain state of Sr3Fe2O7, looking at the pseudo-Goldstone magnon that emanates from the suppressed magnetic reflection. We will measure its low-energy dispersion and spin gap that will be later compared with theory.

Introduction

The bilayer perovskite $Sr_3Fe_2O_7$ is a helimagnetic material with an incommensurate spin-spiral ground state. The Fe^{4+} ions (electron configuration $3d^4$) with classical spins $S = 5/2$ form the tetragonal magnetic sublattice [1]. Following from the symmertry there are two possible magnetic domains with helixes pointing along $(\xi\xi 0)$ and $(\xi\bar{\xi}0)$ structurally equivalent directions. In our recent study of the other symmetric helimagnet $ZnCr_2Se_4$ we discovered the presence of the so-called pseudo-Goldstone magnons [2] – soft magnon modes at the wave vectors orthogonal to the propagation vector of the helix. The theoretical description of this mode was complicated by the complex unit cell of the pyrochlore sublattice. Unlike this, $Sr_3Fe_2O_7$ with its tetragonal lattice serves an ideal playground for the experimental and theoretical investigation of the pseudo-Goldstone magnons. The idea of the experiment was to choose the single magnetic domain by cooling down the sample in a magnetic field and investigate the low energy magnetic excitations in this material. The greatest interest was to measure the low-energy dispersion and detemine the spin gap of the pseudo-Goldstone modes.

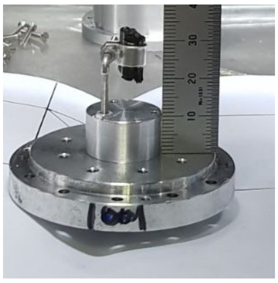

Fig. 1: $Sr_3Fe_2O_7$ single crystal on the aluminium holder.

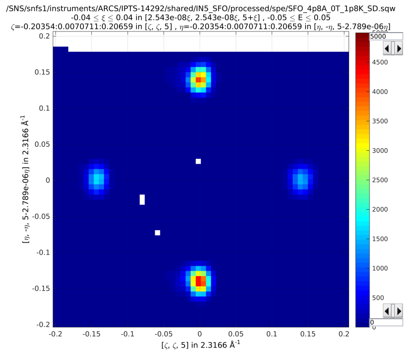

Fig. 2: Elastic cut through the $(H+K, H-K, L)$ plane containing both selected and suppressed Bragg peaks.

Experimental configuration

The sample on the aluminium holder (Fig.1) was aligned in the (HHL) scattering plane, with its $(1\bar{1}0)$ axis pointing vertically along the field direction. It was mounted in the 2.5 T cryomagnet. In this configuration, field cooling had to result in the selection of the $(\xi\bar{\xi}1)$ magnetic domain, whereas the $(\xi\xi 1)$ domain had to be suppressed. The sample is air-sensitive so all alignment was performed in the helium atmosphere. The measurements were done with 3.15, 3.8 and 4.7 Å wavelengths at the base temperature of 1.8 K.

Experimental results

The sample was cooled down in the magnetic field of 2.5 T. After reaching the base temperature, the magnetic field was switched off, and data was collected in the vicinity of both wave vectors. To confirm the domain selection we have made the constant energy cut through the $(H+K, H-K, 5)$ plane (Fig. 2) to compare the magnetic Bragg intensities at the two wave vectors. It is clearly seen that the intensity of the suppressed Braggs is just three times smaller compared to the selected peaks. It indicates that 2.5 T field is not enough for the complete domain selection in this sample.

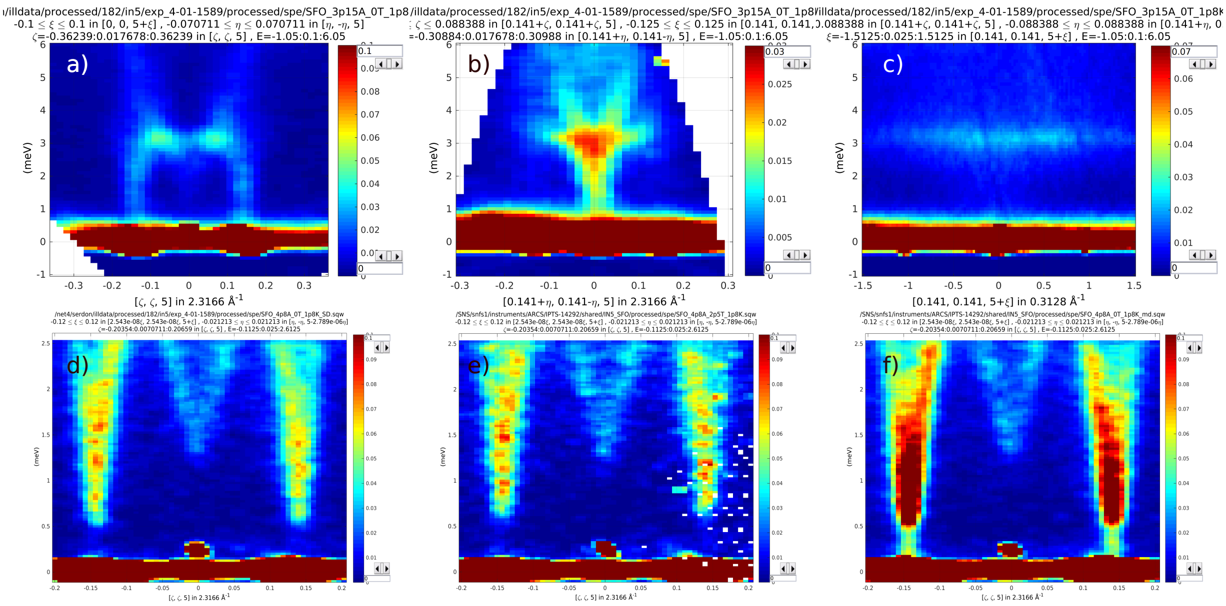

Fig. 3: Energy-momentum cuts through the partially suppressed Bragg peaks. a), b), c) $\lambda = 3.15$ Å, B = 0 T cuts along $(HH5)$, $(H\bar{H}5)$, $(00L)$ directions correspondently. d)$\lambda = 4.8$ Å, B = 0 T cut along $(HH5)$ direction. e) $\lambda = 4.8$ Å, B = 2.5 T cut along $(HH5)$ direction. f) $\lambda = 4.8$ Å, B = 0 T cut along $(HH5)$ direction in the multi-domain state.

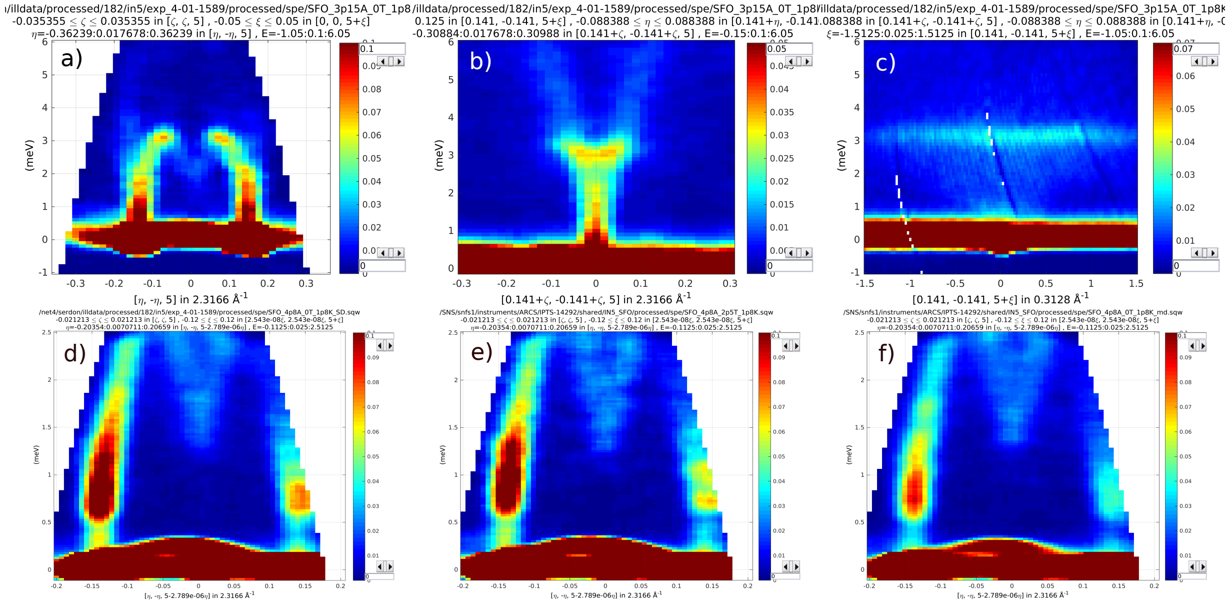

Fig. 4: Energy-momentum cuts through the selected Bragg peaks. a), b), c) $\lambda = 3.15$ Å, B = 0 T cuts along $(HH5)$, $(H\bar{H}5)$, $(00L)$ directions correspondently. d)$\lambda = 4.8$ Å, B = 0 T cut along $(HH5)$ direction. e) $\lambda = 4.8$ Å, B = 2.5 T cut along $(HH5)$ direction. f) $\lambda = 4.8$ Å, B = 0 T cut along $(HH5)$ direction in the multi-domain state.

Nevertheless we performed a series of measurements in this "partially single domain state" as well as in the multi-domain state as a reference. The quality of the data still enable us to separate the signal from the single domain and perform the analysis.

On the Fig. 3 and Fig. 4 there are typical cuts through the positions of the suppressed and selected Bragg peaks correspondently. The preliminary measurements were done with incoming neutron wavelength of 3.15 Å (Fig. 3, 4, panels a, b, c). In order to better resolve the details of the magnon dispersion we performed measurements with 4.8 Å wavelength. The correspondent energy-momentum cuts are presented on the Fig. 3, 4, panels d, e, f. To have a reference we also collected the data in the multi-domain state (Fig. 3, 4 panel e) and in the field of 2.5 T (Fig. 3, 4 panel f).

[1] J. -H. Kim *et al.*, Phys. Rev. Lett. **113**, 147206 (2014).

[2] Y. V. Tymoshenko *et al.*, Phys. Rev. X **7**, 041049 (2017).