Experimental report

05/09/2022

Proposal: **4-01-1720** **Council:** 4/2021

Title: Magnetic interactions underpinningthe Skyrmion- and Hedgehog-latticephases in centrosymmetric SrFeO3

Research area: Physics

This proposal is a new proposal

Main proposer: **Darren PEETS**

Experimental team: Anton KULBAKOV
Yuliia TYMOSHENKO
Dmytro INOSOV

Local contacts: Jacques OLLIVIER

Samples: SrFeO3

Instrument	Requested days	Allocated days	From	To
IN5	6	4	03/09/2021	07/09/2021

Abstract:

SrFeO3 is one of only two known centrosymmetric compounds to host a Skyrmion-lattice phase, and the only centrosymmetric material known to host a three-dimensional hedgehog-lattice phase. Their unique helical propagation vectors make these the only two compounds in which the structure of helimagnetic excitations of a multiple-q structure can in principle be resolved. Studying the Gd material with neutrons would require ~20g of isotopically-enriched Gd metal, which would cost ~200 000 EUR¿, so in practice only SrFeO3 is accessible. The mechanism stabilizing these exotic multi-q phases is not known, and the required spin-wave theory has not been developed. Determining how such phases can arise in a centrosymmetric material will require characterizing the underlying exchange interactions, which are most directly accessible through neutron scattering, together with ongoing theoretical work (in an existing close collaboration). We intend to measure the excitation spectra in all low-field magnetically-ordered phases in SrFeO3, to determine these parameters and how they change among the phases, and to provide vital feedback for the theory.

Experimental Report #4-01-1720

Magnetic interactions underpinning the skyrmion- and hedgehog-lattice phases in centrosymmetric $SrFeO_3$

Proposer

Name: Darren Peets <darren.peets@tu-dresden.de>
Affiliation: Technische Universität Dresden, Germany
Co-proposers: Dmytro Inosov, Yevhen Onykiienko, Yuliia Tymoshenko (TU Dresden).

Report

Motivation

The fully-oxygenated cubic perovskites $SrFeO_3$ and $Sr_3Fe_2O_7$ (nominally Fe^{4+} $3d^4$) exhibit incommensurate helical order and 3D topological multi-**q** magnetic phases [1]. Contrary to chiral skyrmion-lattice systems where the helicity is driven by Dzyaloshinskii-Moriya interactions, in these centrosymmetric lattices the topological "hedgehog"-lattice phases are driven by competing exchange interactions and are characterized by larger incommensurability parameters. This enables studies of spin-wave excitations in multi-q phases that can be clearly resolved by conventional INS spectroscopy. The theoretical description of spin-wave excitations in noncoplanar multi-**q** spin structures is much more challenging than in conventional collinear magnets or helimagnets, and detailed measurements of such spectra with high energy resolution are required to provide reliable test ground for theoretical models.

Current results

In this experiment, we employed the cold-neutron TOF spectrometer IN5 at ILL to measure the low-energy spin-wave spectrum of $SrFeO_3$ with much higher energy resolution that what was previously available. A complementary dataset with the higher-energy part of the spectrum was measured by us earlier at the MERLIN spectrometer at ISIS. Here in Fig. 1 we show a cut through the IN5 dataset along the $(1+\zeta, 1-\zeta, \zeta)$ direction in reciprocal space, that is centered at the (110) zone center and passes through a pair of incommensurate magnetic reflections. According to Ref. [1], the dataset taken at the base temperature of 1.5 K in panel (a) corresponds to the double-**q** multidomain state (phase I), whereas the one at 100 K in panel (b) was taken in the quadruple-**q** state (phase II). One can clearly resolve thee spin-wave modes in the low-temperature dataset, whereas at higher temperatures there is an overall shift of spectral weight toward lower energies, accompanied by the broadening of the modes and softening of the peak positions. The interpretation of these data is still ongoing.

[1] S. Ishiwata *et al.*, Phys. Rev. B **101**, 134406 (2020).

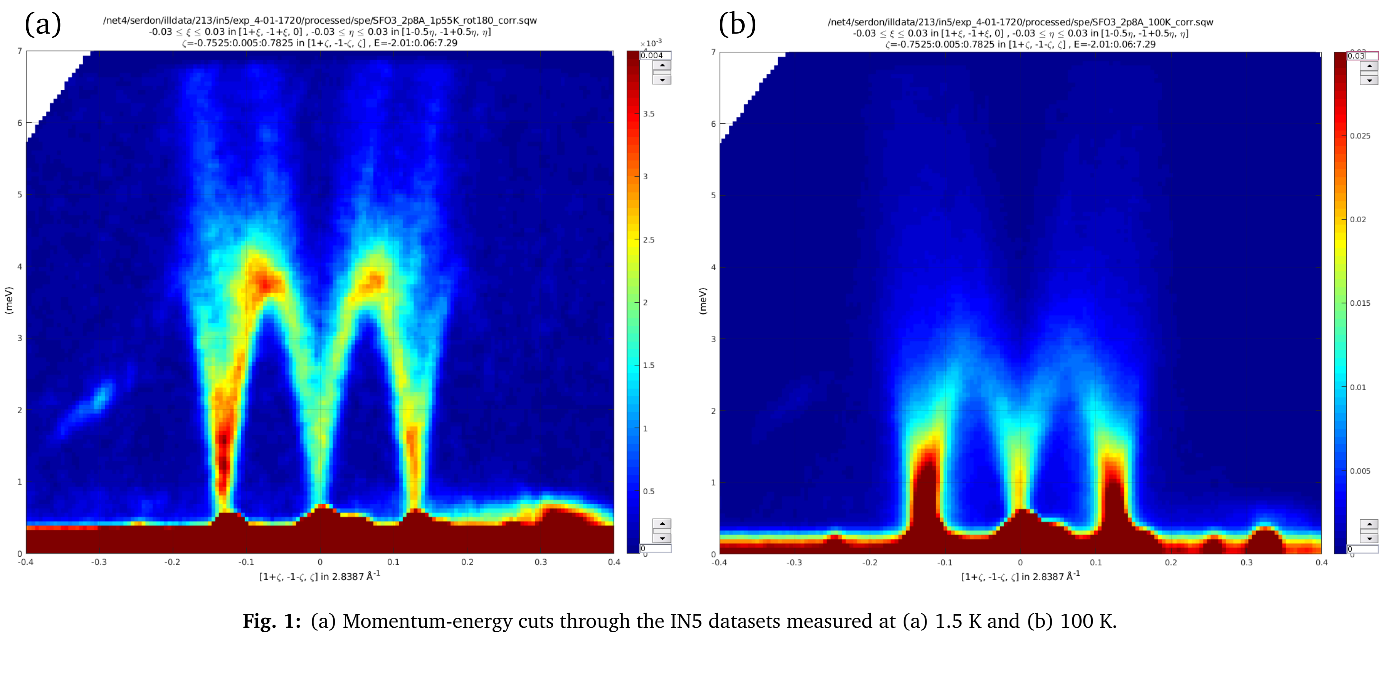

Fig. 1: (a) Momentum-energy cuts through the IN5 datasets measured at (a) 1.5 K and (b) 100 K.