Experimental report

15/03/2021

Proposal: **5-41-1038** **Council:** 10/2019

Title: Exploring the emergent spin texture in the bulk van der Waals ferromagnet Fe3GeTe2

Research area: Physics

This proposal is a new proposal

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Samples: Fe3GeTe2

Instrument	Requested days	Allocated days	From	To
D11	3	2	17/09/2020	19/09/2020

Abstract:

Magnetism in van der Waals (vdW) materials is a trending area in condensed matter. These compounds not only possess the rich magnetic and electronic properties that are intrinsic to the state of matter in two-dimension, but also hold the revolutionary potential for spintronics devices due to their easy cleavage / exfoliation performance. Very recently, the skyrmion lattice, i.e. magnetic whirls protected by topology, has been reported in the vdW ferromagnet Fe3GeTe2. While these observations were made in a thin film sample, there exists studies, both experimental and theoretical, that support the appearance of magnetic textures in bulk. Here, we propose an experiment to extend the search of topological spin textures, e.g. skyrmions, to the bulk form of Fe3GeTe2 using small-angle neutron scattering.

Experimental Report
Instrument: D11
Experiment Number: 5-41-1038&1039

Title: Exploring the emergent spin texture in the bulk van der Waals ferromagnet Fe_3GeTe_2

Experiment Date: 17/09/2020 – 21/09/2020

Experimental Team: Lingjia Shen, Elizabeth Blackburn (Lund University), Safe-Ur-Rahman Khan, Hidekazu Kurebayashi (University College London), Nina-Juliane Steinke (Institut Laue Langevin)

Local Contact: Nina-Juliane Steinke

Introduction

Magnetic van der Waals (vdW) materials have gained much attention recently [1]. In close analogy with graphene, a vdW magnet is crystallized by weakly coupled atomic layers, delivering a new avenue for exploring the exotic physical properties in two-dimension. For example, some vdW systems, e.g. $Fe_{3-x}GeTe_2$, CrI_3, $Cr_2Ge_2Te_6$, have been found to host magnetic skyrmions [2-4], which can be engineered for spintronics, valleytronics, and magnetic tunnel junction switches. The observations of topological spin textures in materials of this class have been based on surface sensitive probes. In this experiment, we aimed to use small-angle neutron scattering (SANS) to search for an ordered skyrmion lattice in a bulk $Fe_{3-x}GeTe_2$ sample.

Sample Details and Instrumental Configurations

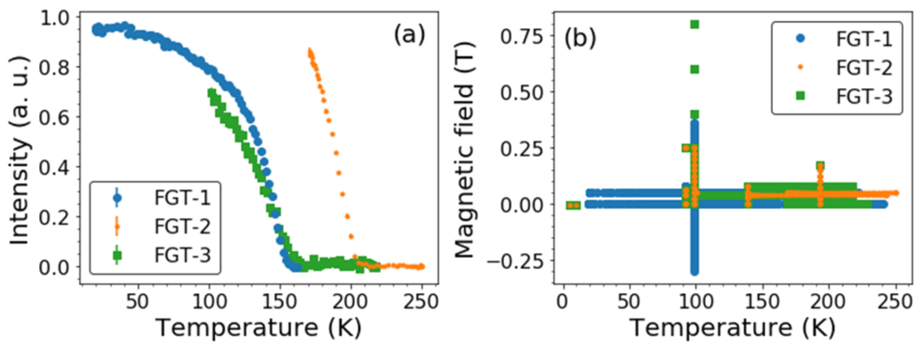

Figure 1 (a) Zero-field SANS intensity versus temperature curves. The scattering comes from the ferromagnetic domains, which disappear at T_C. (b) Summary of our measurements. The solids mark the positions in the temperature-field space that have been probed.

Three single crystalline $Fe_{3-x}GeTe_2$ thin flakes were studied. They were co-mounted on an Al thin plate so that we were able to selectively measure them using the vertical translation motor. These samples will be labelled as FGT-*i* (*i* = 1, 2, 3) below. Because of the Fe deficiencies, they possess different ferromagnetic Curie temperatures (T_C) [5], as can be seen from the temperature dependencies of the SANS intensity in Figure 1a.

Based on Ref. 2, the lattice parameter of the skyrmions are estimated to be 200-400 nm. Accordingly, the neutron wavelength, sample-detector-distance and collimation were configurated at 10 Å, 38.95 m and 40.5 m, respectively, covering the momentum transfers between 9×10^{-4} Å^{-1} and 9×10^{-3} Å^{-1}. The ORTF cryostat was used to get access to the temperature – field region of interest. The measurements were summarized in Figure 1b.

Results

As demonstrated in Fig. 1b, we have mainly performed field scans at 100 K (chosen to match the conditions in Ref. 2), as well as at the temperatures close to the T_c of the sample being measured. At each field, we have performed rocking scans using the SAN motor. In order to optimize our observations, we have also employed various magnetic field training protocols, including a field-cool from above T_c, wiggling the magnetic field at a fixed temperature and tilting the magnetic field away from the surface normal. In Figure 2, we show the data measured at 100 K and 0.1 T for all three samples. While there exist some sample and angular dependent SANS features pending further investigation, no skyrmion diffraction spot could be unambiguously observed.

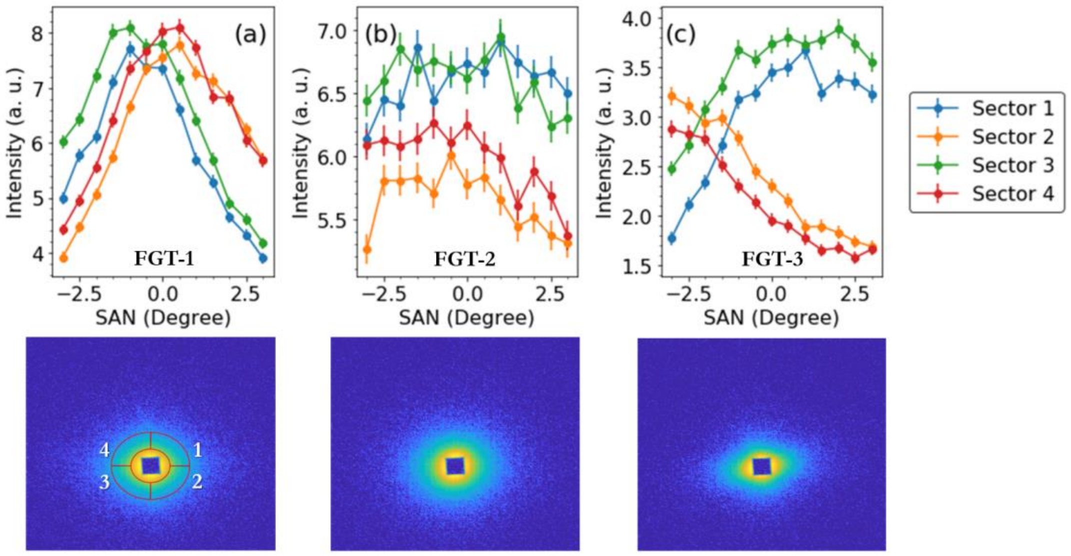

Figure 1 Rocking curves (upper panel) and 2D detector image (lower panel) of (a) FGT-1, (b) FGT-2 and (c) FGT-3. The four sectors are described in (a), enclosing a momentum transfer region between 1.2×10^{-3} Å^{-1} and 2.4×10^{-3} Å^{-1}. These measurements were performed at 100 K and 0.1 T.

Conclusions

We were not able to observe an ordered skyrmion lattice in all three samples. Due to the large parameter space (Fig. 1b), it could be that we have not located the `sweet spot’. Another plausible scenario is that the skyrmion lattice in these materials is a surface effect. A third scenario is that the skyrmions are disordered; whether the observed SANS signal in an external magnetic field comes from the disordered skyrmions is still under investigation.

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