Experimental report

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Proposal: **5-42-464** **Council:** 4/2017

Title: Possible spin-spiral and (bi)skyrmion lattice phases in Co3Sn2S2

Research area: Physics

This proposal is a new proposal

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Samples: Co3Sn2S2

Instrument	Requested days	Allocated days	From	To
D33	4	3	22/06/2018	25/06/2018

Abstract:

Topologicaly stable particle-like objects, so-called magnetic skyrmions attract much attention due to their remarkable properties that include ultra-low current driven motion, multiferroic coupling and emergent electrodynamics. Recent experiments show that skyrmion like states, such as biskyrmions or frustrated skyrmions can emerge in centrosymmetric compounds where, unlike for the skyrmions in the well-known chiral cubic materials like MnSi, the internal helicity and/or vorticity degree of freedom of the skyrmions can be controlled. Here, we aim to study Co3Sn2S2, which has a centrosymmetric crystal structure composed of Kagomé layers. Analogous with the chiral cubic skyrmion materials, this compound has a magnetic phase that is stable only in the vicinity of the magnetic phase transition, and low-fields induce a transition to the field polarized state. AC susceptibility also indicates that large magnetic structures are rearranged in this phase. The proposed SANS experiments can confirm the presence of modulated magnetic order and helps to resolve the spin texture in this anomalous phase.

Experimental report for proposal No. 5-42-464
Possible spin-spiral and (bi)skyrmion lattice phases in $Co_3Sn_2S_2$

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Introduction

The lattice of skyrmions, which are spin vortices with non-trivial topology, was discovered in cubic helimagnets using small-angle neutron scattering (SANS) [1]. Later, the real-space spin configuration of an individual skyrmion was unambiguously confirmed by Lorentz transmission electron microscopy (LTEM) [2]. In the case of the most studied cubic helimagnets, such as MnSi, (Fe0.5Co0.5)Si, Cu_2OSeO_3 (all with the chiral cubic spacegroup $P2_13$), a single-q helical ground state is realized due to a competition between the symmetric exchange and the Dzyaloshinskii-Moriya interaction (DMI), where the latter is allowed by the lack of inversion symmetry. The relative strength of these two interactions determines the length of the magnetic q-vector. The SkL, which can be described by three coupled q-vectors connected by a 3-fold symmetry (a triple-q state), is stabilized by finite temperature and magnetic field close to the paramagnetic phase boundary [1]. The present surge of interest in skyrmions is motivated by their use in possible spintronics applications, since these nanoscale spin whirlpools can be detected electrically via the topological Hall-effect [3], and they can be moved by low current densities in metallic skyrmion hosts [4, 5], or low electric fields in the hitherto only known insulating host Cu_2OSeO_3 [6].

Experiments in hexaferrites [7], layered manganites [8] and (Mn,Ni)Ga [9] show that bound pairs of skyrmions with opposite helicity, so-called biskyrmions, can be stabilized even in the presence of inversion symmetry. In these classes of compounds, instead of symmetry forbidden DMI, probably dipolar interactions stabilize the twisted magnetic structures, thus, the helicity degree of freedom is not frozen - this opens a new channel for data storage. The current-driven motion of biskyrmions has also been detected in these materials, which allows the possible use of biskyrmions in race-track type memories as dreamed for skyrmions. Although biskyrmion pinning is strong in the compounds tested so far, they carry larger topological charge which can enhance their topological Hall signal, and so their detectability. Moreover, theory predicts that proper skyrmion states can also emerge in centrosymmetric compounds from the competition of frustrated exchange interactions [10]. Since symmetry does not impose any restriction on the spin-swirling, the helicity and vorticity degrees of freedom can be manipulated on demand. However, such frustrated skymions have not been detected yet. The ideal candidate material should posses a lattice with frustrated interactions, at least one symmetry axis with high rotation symmetry Cn ($n \geq 3$) and an inversion center.

In a shandite compound, $Co_3Sn_2S_2$ (space group R-3m), where magnetic cobalt ions occupy 2D Kagomé layers, magnetic susceptibility measurements indicate the emergence of an extra magnetic phase beside the conventional ferromagnetic order [10]. Moreover, the magnetic relaxation process studied by AC susceptibility in the frequency range covering five orders of magnitude from 0.01 to 1000 Hz shows slow spin dynamics with characteristic relaxation times in the order of several seconds at the boarders of the anomalous phase [11]. These results suggest the rearrangement of large period magnetic structures. Therefore, we proposed to study the magnetic correlations in $Co_3Sn_2S_2$ by SANS.

Results

We performed SANS experiments on a single crystal of $Co_3Sn_2S_2$ at several temperatures (110 K, 150 K, 160 K) below the magnetic ordering temperature, T_c=174 K. Paramagnetic background was recorded at 200 K, which was subtracted from the low temperature images. In order to cover a broad q-range we collected SANS images with several settings of the D33 instrument.

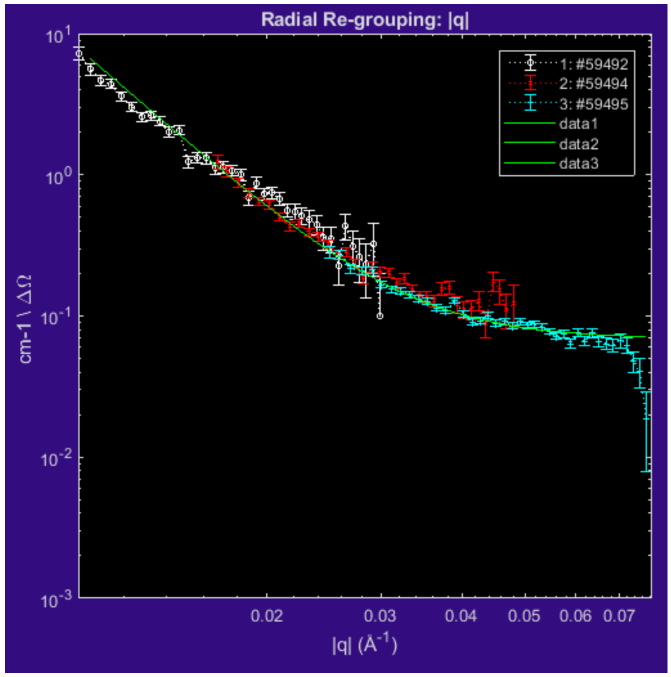

Figure 1 Radially integrated scattering intensity as function of the length of the scattering vector. The data is recorded at 150 K using several settings of the D33 instrument indicated by white, red and cyan symbols.

The radially integrated intensity as a function of the length of the scattering vector measured at 150 K is plotted in Fig. 1. Within the accuracy of the experiment we did not observed any peaks at finite q values. We only observed a broad continuum of scattering intensity, however, within the error of the measurement it is identical that of recorded at 200 K in the paramagnetic phase. No magnetic scattering was detected.

Conclusions

Although, magnetic susceptibility measurements and LTEM images measured on thin lamellas (~100 nm) indicated magnetic structures with large length scales, we did not find any magnetic scattering in our SANS experiment. In case of the LTEM lamellas the different sample geometry and the correspondingly larger demagnetization fields may be responsible for the observed skyrmion bubbles, that are absent in the bulk sample.

References

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