Experimental report

16/09/2024

Proposal:	**5-41-1233**	**Council:**	4/2023
Title:	New topological magnetic textures of enantiopure B20 chiral helimagnets at low temperatures		
Research area:	Physics		

This proposal is a resubmission of 5-41-1201

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Samples: MnSi
Fe1-xCoxSi (x=0.25)

Instrument	Requested days	Allocated days	From	To
D22	2	0		
D33	3	2	25/09/2023	27/09/2023

Abstract:

By using careful ac susceptibility measurements at low temperature, we determined the magnetic phase diagrams of oriented crystals of MnSi and Fe1-xCoxSi where a new unexpected B-phase appears.
The general aim of this proposal is to observe in MnSi and Fe1-xCoxSi (x = 0.25) homochiral crystals the large-scale magnetic textures (SANS) to clarify the nature of the new magnetic phase (¿B-phase¿) at low temperatures near Hc, and to see if also the skyrmionic ¿A-Phase¿- like could exist at low temperatures, as predicted, in the macroscopic magnetic phase diagram of MnSi and Fe1-xCoxSi (x = 0.25).

This proposal was well evaluated the last round but did not receive beam time due to the application of the National balance reduction.

Report of experiment 5-41-1233

New topological magnetic textures of enantiopure B20 chiral helimagnets at low temperatures

Helimagnetic structures, in cubic or uniaxial magnets, driven by anti-symmetric Dzyaloshinskii-Moriya (DM) interaction, have been paid attention due to the emergence of unique magnetic textures such as skyrmion lattices (SkL) and chiral magnetic soliton lattices (CSL). These magnetic textures are expected to exhibit attracting new phenomena, which can be applied for spintronic and magnonic purposes. In fact, the presence of a SkL has been described in the B20 cubic helimagnets MnSi and Fe1-xCoxSi just below Tc, the so called “A-phase” [1].

This SkL phase just below Tc in the magnetic field-temperature (B-T) phase diagram of MnSi have been investigated in detail in [2-8]. Recently, we suggested theoretically that at low T the conical (CH) and forced-ferromagnetic (FM) phases in cubic helimagnets like the B20, are not connected but are separated by another SkL, which could be metastable, and a new phase of “unknown” nature just below the critical field Hc at low temperature [9]. The theoretical prediction of the new SkL phase at low T is in good agreement with the experiments reported in [6-8]. On the other hand, by using careful ac susceptibility measurements at low temperature, we determined the magnetic phase diagrams of oriented crystals of MnSi [10] and Fe1-xCoxSi (x=0.25), where a new unexpected B-phase appears.

In order to clarify the nature of this new B-phase at low temperature near Hc, SANS experiments are necessary to see the magnetic satellites peaks with B $\perp$ ki or B // ki configurations, to confirm that the new B-phase is different from the typical A-phase. Therefore, the general aim of this proposal was to observe in MnSi and Fe1-xCoxSi homochiral crystals the large-scale magnetic textures (SANS) to clarify the nature of the new magnetic phase (“B-phase”) at low temperatures near Hc, and to see if also the skyrmionic “A-Phase”- like could exist at low temperatures, as predicted, in the macroscopic magnetic phase diagram of MnSi.

Experimental setup:

Several measurements were performed on a single crystal of MnSi. Next, the crystal was glued to the sample holder such that the [111] direction was in the horizontal axis and the magnetic field was perpendicular to the neutron beam. The setup was further optimized to reduce background noise by attaching cadmium strips above and below the sample.

Methodology and Measurements:

Magnetic field sequence:

$\overrightarrow{\boldsymbol{k_\iota}} \parallel [\mathbf{1\bar{1}0}] \perp \overrightarrow{\boldsymbol{B}} \parallel [\mathbf{111}]$ **(ω = 0º, san = 0º):**

Measurements were conducted at 2 K from 0 T to 0.7 T in steps of 0.01 T, and then back from 0.7 T to 0 T, with a scan range of -3.5º to 3.5º.

These scans were followed by additional measurements at various temperatures: 3.5 K, 5 K, 15 K and 28 K. For these temperatures, fields were increased from 0 T to 0.7 T in steps of 0.02 T. After each temperature was finished, we went back to 40 K and performed a demagnetization of the field (it oscillated around 0), so that we were sure to start each time with the same history.

The same experimental procedures were repeated with different orientations of the magnetic field respect to the crystal axis and neutron beam:

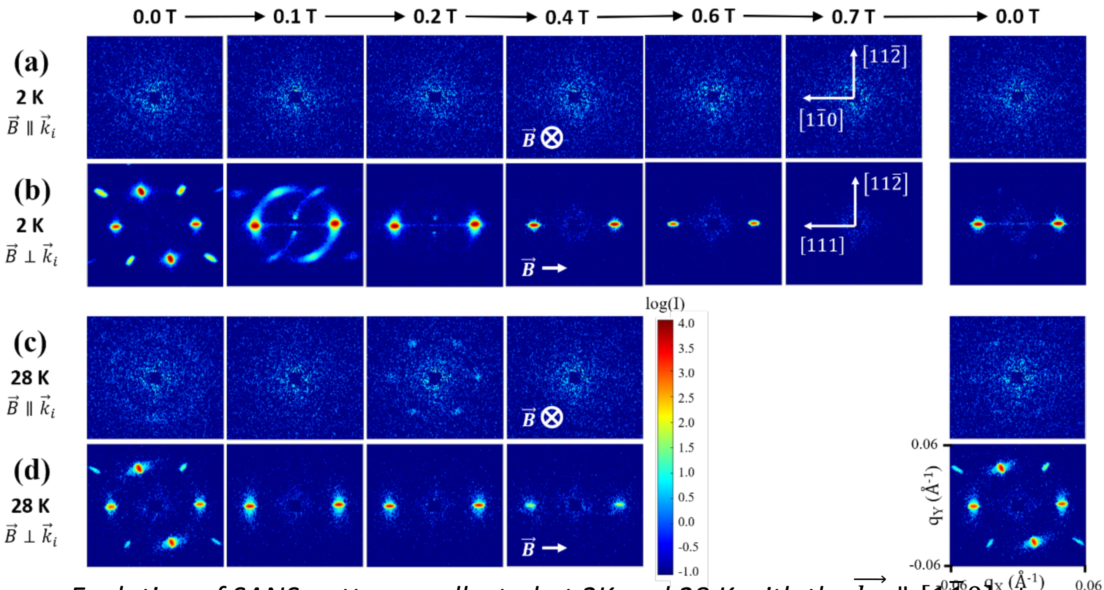
$\overrightarrow{k_i}$ ∥ $[111]$ ⊥ $\vec{B}$ ∥ $[1\bar{1}0]$ (ω = -90º, san = 0º):

Measurements were conducted at 2 K, 15 K and 28 K from 0 T to 0.7 T in steps of 0.02 T, and then back from 0.7 T to 0 T, with a scan range of -3.5º to 3.5º.

$\overrightarrow{k_i}$ ∥ $[111]$ ∥ $\vec{B}$ (ω = 0º, san = 90º) ; $\overrightarrow{k_i}$ ∥ $[1\bar{1}0]$ ∥ $\vec{B}$ (ω = -90º, san = 90º):

Measurements were conducted at 2 K and 28 K from 0 T to 0.7 T in steps of 0.02 T, and then back from 0.7 T to 0 T, with a scan range of -3.5º to 3.5º.

Attempts were also made to observe metastable skyrmion phases by fast cooling from 28 K to 2 K in a 0.2 T field. These measurements aimed to stabilize the skyrmion lattice phase. No clear evidence of such phases was observed.



Evolution of SANS patterns collected at 2K and 28 K with the $\overrightarrow{k_i}$ ∥ $[1\bar{1}0]$ ⊥ $\vec{B}$ ∥ $[111]$ and $\overrightarrow{k_i}$ ∥ $[1\bar{1}0]$ ⊥ $\vec{B}$ ∥ $[111]$ configurations.

References:

[1] S. Muhlbauer et al., Science 323, 915 (2009).
[2] L. J. Bannenbert et al., Phys. Rev. B 96, 184416 (2017).
[3] C. Pappas et al., Phys. Rev. Lett. 119, 047203 (2017).
[4] L. J. Bannenberg et al., Phys. Rev. B 98, 184430 (2018).
[5] L. J. Bannenberg et al., Phys. Rev. B 98, 184431 (2018).
[6] H. Oike et al., Nat. Phys. 12, 62 (2016).
[7] T. Nakajima et al., Sci. Adv. 3, e1602562 (2017).
[8] T. Nakajima et al., Phys. Rev. B 98, 014424 (2018).
[9] V. Laliena and J. Campo: Phys. Rev. B 96, 134420 (2017).
[10] M. Ohkuma et al., APL Mater. 10, 041104 (2022).