Experimental report

30/09/2016

Proposal: **5-42-409**

Council: 4/2015

Title: Frustrated skyrmions in reentrant spin glasses: checking the Skyrmionlattice by SANS

Research area: Physics

This proposal is a new proposal

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Samples: Ni0.78Mn0.22
(Fe1-XMnX)0.75P0.16B0.06Al0.03, x=0.235, isotopic 11B
Ni0.81Mn0.19

Instrument	Requested days	Allocated days	From	To
D33	5	5	17/10/2015	22/10/2015

Abstract:

Skyrmions are considered as the possible building blocks of future electronics. These vortex-like spin textures mostly observed in chiral magnets, are now searched for in frustrated magnets, but not observed yet. Actually, similar spin textures have been seen in the eighties in metallic reentrant spin glasses. We propose to study these frustrated Skyrmions with a new geometry of the magnetic field, perpendicular to the scattering plane, by comparing the scattering in amorphous [Fe(1-x)Mnx]0.75P0.16B0.06Al0.03 (x=0.235) hereafter called a-FeMn and in Ni0.81Mn0.19 single crystal. We will check the possibility of the frustrated SK lattice in NiMn, and confirm the isotropy of the vortex structure in a-FeMn. We will also check the presence of scaling laws governing the vortex size in a field range (up to 4T) not explored before. This information is important to evaluate the structure factor of these "frustrated skyrmions" in comparison with the "magnetic skyrmions" observed in chiral magnets such as MnSi.

Experimental report- Proposal 5-42-409: Frustrated skyrmions in reentrant spin glasses: checking the Skyrmion lattice by SANS by I. Mirebeau *et al.*

Frustrated ferromagnets called reentrant spin glasses show vortex like structures [1], with strong similarities with the "skyrmions" textures recently observed in itinerant helical magnets of the B20 family (MnSi, FeGe). The purpose of the experiment was to check the possible presence of a skyrmion lattice in a NiMn single crystal, and study the vortex texture in more details in NiMn and amorphous a-FeMn reentrant spin glasses. We studied a Ni0.81Mn0.19 single crystal (T_C=250K), with two configurations of the magnetic field. The amorphous a-$Fe_{0.78}Mn_{0.22}P_{0.16}B_{0.06}$ $Al_{0.03}$ (T_C=310K) was also studied in the second geometry (B). We focus here on the single crystal results.

A) H// neutron beam: checking the skyrmion lattice.

As shown for helical magnets and superconductors, a lattice of field induced topological defects such as vortex or skyrmions can be evidenced in this configuration by well-defined Bragg-like peaks related to the periodicity of the lattice. In contrast the patterns measured in NiMn (x=0.19) single crystal show ***an isotropic ring*** in the detector plane in the whole field (0<H<2T) and temperature ((1.5K<T<30K) range where the vortices are the best defined. A typical spectrum is shown in Fig 1-a. A small hysteresis is observed when decreasing the applied field. The patterns remain basically unchanged when the sample is cooled either in zero or in applied field, the cooling field behaving as an additional magnetic field due to the field induced DM anisotropy. This result clearly shows that ***the vortex-textures induced by the applied field do not form a regular lattice, but rather a liquid-like texture, even when the sample is in single crystal state.***

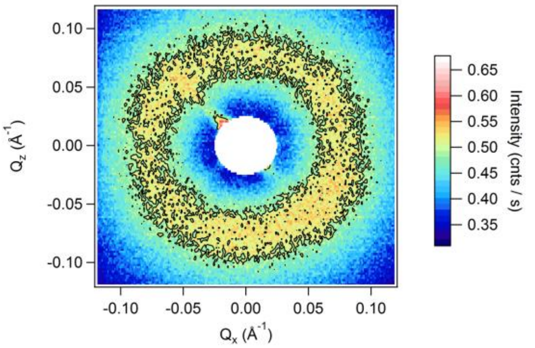

Fig 1: $Ni_{0.81}Mn_{0.19}$ single crystal; typical SANS pattern measured on D33 for H// neutron beam.

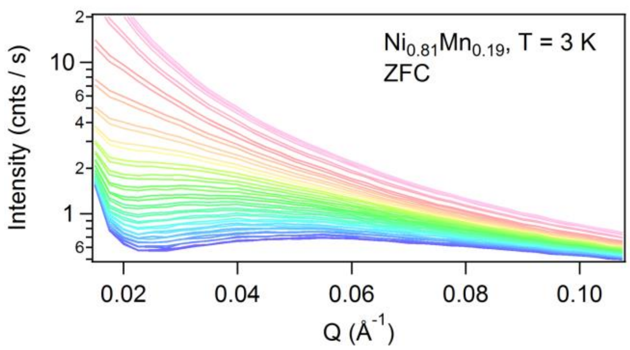

Fig 2: $Ni_{0.81}Mn_{0.19}$ single crystal; isotropic average of the intensity. Evolution of the magnetic structure with increasing and decreasing magnetic field (from 0 to 2T and back) , showing a small hysteresis.

B) H in the detector plane: checking the shape of the topological defect: "vortex *or* skyrmion?"

In this geometry, the scattering is anisotropic in the detector plane due to the neutron selection rules. It is enhanced along the field direction, showing that it is mainly due to spin components perpendicular to the field. This is expected for a reentrant spin glass, where the field mostly aligns the longitudinal spin components, and the transverse components rotate to describe the vortex structure. We have performed 2d- fits in the detector plane, to extract the relative contributions of the transverse and longitudinal cross sections $S_T(Q)$ and $S_L(Q)$. Neglecting in a first step the isotropic background and nuclear contributions, much smaller than the magnetic one except in the low Q range (Q<0.02 Å^{-1}), the intensities are given by: $2S_T(Q)$ for Q//H and $S_T(Q)+S_L(Q)$ for Q $\perp$H . The $S_T(Q)$ cross section was fitted by a Lorentzian term (Fig3). A careful subtraction of the data along and perpendicular to the field allowed us to have access to the longitudinal cross section. Whereas the transverse cross section is clearly modulated in Q space, with a maximum related to the typical size of the topological object, the longitudinal cross section is very small, Q-independent within the accuracy of the measurement, and cannot be easily isolated from the incoherent background. This result was also observed in the amorphous system. We recall that the longitudinal magnetization which is the dominant term, only contributes to the Bragg peaks or to the amorphous structure factor, both invisible in this window. Therefore our result clearly shows that the field induced ***magnetic textures in reentrant spin glasses are vortices and not skyrmions***, at least in the conventional skyrmion picture where longitudinal and transverse spin components show coherent modulations in space.

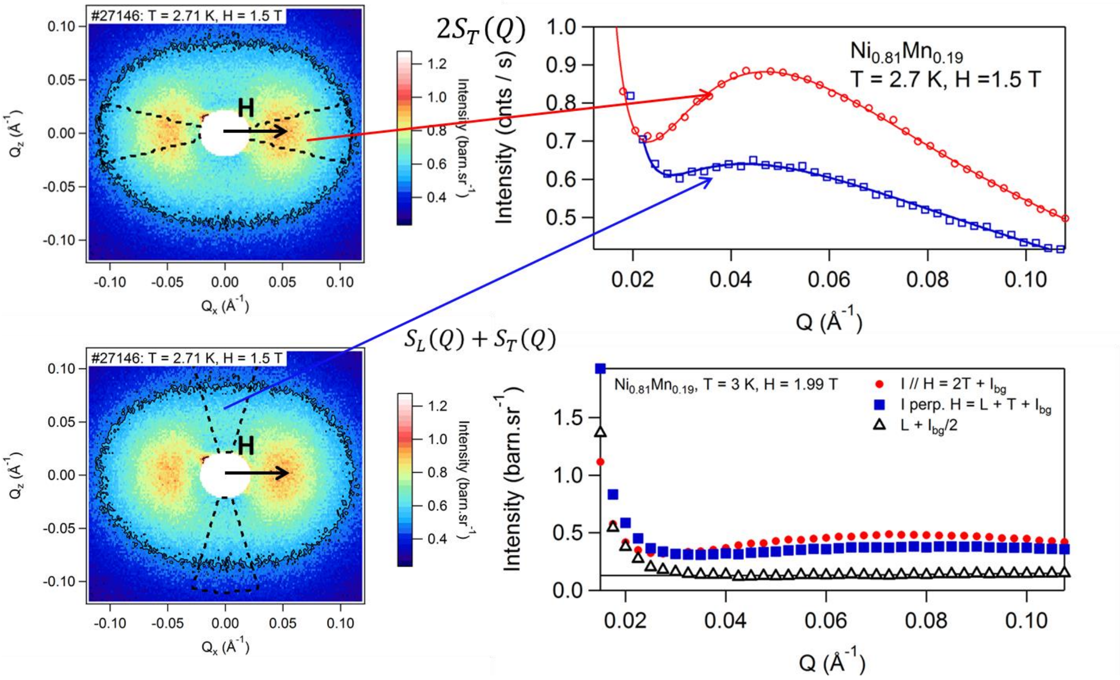

Fig 3: $Ni_{0.81}Mn_{0.19}$ single crystal ; left : typical SANS pattern measured on D33 for H in the detector plane; magnetic cross section for Q//H (red) and Q⊥H (blue), Yielding the transverse (T) and longitudinal (L) components.

C) Field dependence and scaling laws

With increasing the field, the vortex texture remains visible up to the maximum field of the experiment (2T), showing the liquid texture is robust in high applied field. This is consistent with the fact that the magnetization does not saturate up 30T (as shown by previous unpublished measurements), even at low temperature where the contribution of spin waves is negligible. The magnetic intensity decreases and the position of the maximum Q_{max} increases, following scaling laws ($Qmax \propto (H-H_c)^{\beta}$ with a critical exponent β~0.35-0.45, its precise value depending on the cooling conditions).These new data show that such scaling laws can be extended from the previous range (0.8T) to 2T at least. The exponent value is qualitatively consistent with Monte-Carlo simulations in a 2d system (β~0.37)[3]. This behavior means that the vortex size decreases with increasing field, so that the transverse spin components rotate on smaller and smaller scales. A more elaborate picture would require simulating the vortex form factor and density for different crystal, field and temperature states. This point is currently being discussed with theoreticians.

[1] M. Hennion, I. Mirebeau *et al.,* Europhys. Letters **2**, 393, (1986).

[2] Mulhbauer *et al.,* Science **323**, 915, (2009).

[3] H. Kawamura and M. Tanemura J. Phys. Soc. Jpn. **60**, 1092, (1991)