Experimental report

09/01/2024

Proposal: **4-03-1761**

Council: 10/2022

Title: Low temperature dynamics in iron doped MnSi

Research area: Physics

This proposal is a new proposal

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Samples: Mn0.88Fe12Si

Instrument	Requested days	Allocated days	From	To
IN15	7	4	15/06/2023	19/06/2023

Abstract:

Under decreasing temperature, Skyrmions emerge in MnSi from the paramagnetic state via a weak crystallization process, where fluctuating skyrmion textures are observed already above the onset of static order. An open question concerns whether the correlation length and time of these textures is sufficient to support sizable topological Hall contributions. However, the narrow temperature range in which the fluctuating textures are observed in MnSi make direct measurements prohibitively challenging. Under substitutional doping with iron the magnetic ordering temperature of MnSi decreases and the skyrmion lattice is observed across a wider range in temperature. Additionally topological Hall contributions may persist above Tc where isotropic short-range helimagnetic correlations are reported down to low temperatures for iron concentrations above x*~0.11. These correlations vanish above xc ~0.17. A comprehensive study on the dynamic and topological properties in this regime is lacking to date. The energy resolution and large dynamic range of spin-echo spectroscopy makes it a uniquely suitable tool to study the dynamics in these samples.

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Instrumental Setup:

IN15 was setup in the paramagnetic spin-echo configuration, where the sample is used as a pi flipper. The sample environment used was a dilution setup in a classic orange cryostat.

Experiments performed:

We have studied two single crystals with different iron contents: $Mn_{1-x}Fe_xSi$ with x = 0.10 and x = 0.12. The measurements were performed at temperatures around the phase transition into the helical state.

Previously, it was found by us, that the sample with x = 0.10 exhibits static order at low temperatures, whereas the sample with x = 0.12 has not shown static order down to 50mK. These findings were in contradiction to what has been published by Pappas et al. [1], who found static order for a polycristalline sample with x = 0.14.

During the measurements performed during this beamtime at IN15, we found that the sample with x = 0.10, does indeed order statically for temperatures lower or equal than 5.8K (see figure 1).

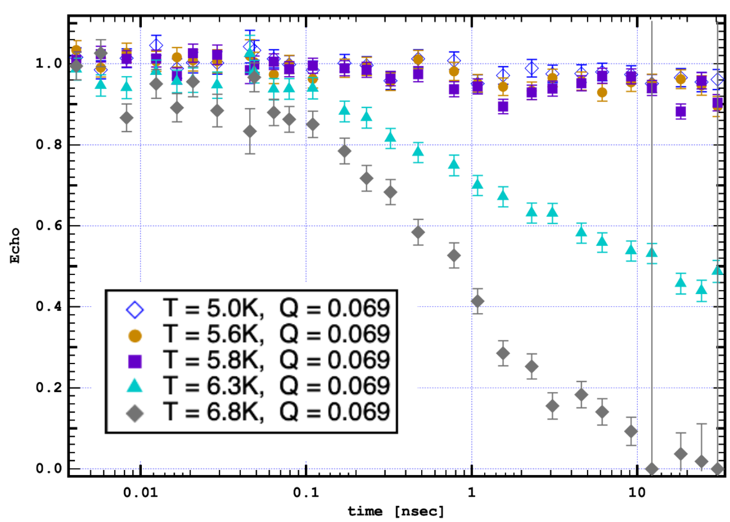

Figure 1: Intermediate scattering function (S(Q,t)) of $Mn_{0.9}Fe_{0.1}Si$. For temperatures lower or equal to 5.8K the system becomes static, indicated by the constant line in S(Q,t).

Similarly, we found that the sample with x = 0.12 orders statically as well (figure 2)

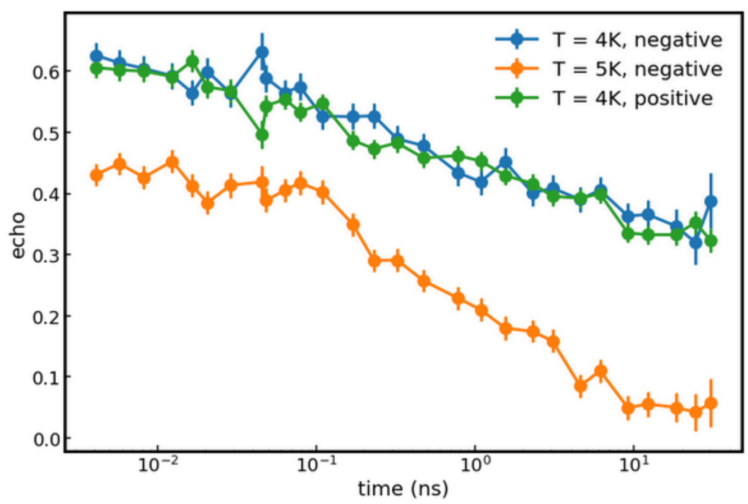

Figure 2: Intermediate scattering function (S(Q,t)) of $Mn_{0.88}Fe_{0.12}Si$ for different temperatures and measured at two Bragg peaks that occur at opposite angles in small angle scattering geometry (therefore the nomenclature positive and negative);

Encountered issues:

However, since $Mn_{1-x}Fe_xSi$ orders into a chiral magnetic structure at low temperatures, we have encountered a few issues when analyzing the data:

- It was very difficult to properly normalize the data.
- We found when investigating the flipping ratio of the sample at different Bragg reflections that possible chiral contributions to the dynamic behaviour of the sample can not be observed with paramagnetic spin-echo. Looking at Figure 2, the chiral contribution would add to the signal labelled “negative” while it would lead to a reduction of the signal labelled “positive”. However, considering the data match within experimental error, this contribution can not be observed.

Improvements and outlook:

To extract the chiral contributions to the dynamic behaviour of $Mn_{1-x}Fe_xSi$ it will be necessary to perform ferromagnetic spin-echo experiments rather than paramagnetic spin-echo.

[1] C. Pappas, A. O. Leonov, L. J. Bannenberg, P. Fouquet, T. Wolf, and F. Weber, “Evolution of helimagnetic correlations when approaching the quantum critical point of Mn 1 − x Fe x Si,” Phys. Rev. Res., vol. 3, no. 1, p. 013019, Jan. 2021, doi: 10.1103/PhysRevResearch.3.013019.