Experimental report

28/08/2024

Proposal: **4-01-1790** **Council:** 4/2023

Title: Magnons at the skyrmion-conical phase transition in MnSi

Research area: Physics

This proposal is a new proposal

Main proposer: **Tobias WEBER**

Experimental team: Tobias WEBER

Local contacts: Arno HIESS
Paul STEFFENS

Samples: MnSi
MnSi 2
Modification - not using polarisation analysis anymore. Consequently there will be a ca. 10-fold increase of beam intensity

Instrument	Requested days	Allocated days	From	To
THALES	4	4	30/10/2023	03/11/2023

Abstract:

We wish to continue our study of the transition of magnetic dynamics from the conical to the skyrmion phase in MnSi whose latest measurements we recently conducted at TASP (PSI proposal 20220901).

Skyrmion dynamics show very different behaviour depending on whether reduced momentum transfer is parallel or perpendicular to the applied field direction. The first leads to asymmetric parabolic modes, the second to very closely spaced Landau levels.

The comparison of the asymmetric modes between skyrmion and conical dynamics we could successfully conduct at TASP. For the very weak Landau levels and conical bands, on the other hand, we require the high flux at Thales to have enough statistics for a clear distinction of the two phases.

Based on our past measurements in the skyrmion phase, we have calculated optimal scan positions and instrument configurations for this study.

[Note: J. Waizner and M. Garst are also co-proposers, but are not in the user database.]

Magnons at the skyrmion-conical phase transition in MnSi

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(Dated: August 28, 2024)

The itinerant-electron compound MnSi features several magnetically ordered phases below temperatures of ca. 29 K. These are the helical [1], conical [2], the field-polarised ferromagnetic [3], and the skyrmion phase [4, 5].

The goal of the present experiment was to compare the magnon spectra of the skyrmion to the adjacent conical phase. The measurements were conducted using a horizontal collimation of 30 minutes after the MnSi crystal. The sample was placed in a horizontal Oxford magnet [6], providing a field of $B = 190\,\mathrm{mT}$ along the $[\bar{1}\bar{1}0]$ axis. In order to remove higher-order contamination, a cooled Beryllium crystal was used in the instrument's k_f axis.

The left panel of Fig. 1 shows transverse elastic scans around $(1\bar{1}0)$. Here, the two magnetic satellites are visible in the conical phase. The right panel of Fig. 1 shows longitudinal elastic scans. The six magnetic satellites in the skyrmion phase, namely at $0.98\,\overline{0.98}\,0$ and $1.02\,\overline{1.02}\,0$, as well as four out-of-plane peaks, two each at $0.99\,\overline{0.99}\,0$ and $1.01\,\overline{1.01}\,0$, are visible.

Fig. 2 shows the theoretical dispersion curves for magnons propagating along $(1\bar{1}0) - [hh0]$ for both the conical and the skyrmion phase at the brink of their shared phase boundary, namely at 27.6 K and 28.4 K, respectively. Crossing the phase transition, the three discrete modes centred around the nuclear and the two magnetic Bragg peaks for the conical phase fan out into the plethora of modes in the skyrmion phase. While the overall structure of the two dispersions is similar within the typical resolution of neutron spectrometers, the starkest contrast arises from the non-spin-flip mode, which is expected to be much more pronounced in the conical phase.

Fig 3 depicts the unpolarised measurements at the positions marked by the grey vertical bars labelled (i) in Fig. 2. The solid lines are (preliminary) convolutions of the instrumental resolution function and the respective theoretical models [7] for both the conical and the skyrmion phase. The expected difference in intensity for the non-spin-flip mode is indeed observed, with the conical magnons showing a stronger intensity around 0.5 meV, albeit not quite as pronounced as the convoluted theory curve suggests. This might be due to additional line broadenings at these higher-energy positions that are not yet taken into account. Furthermore, both the conical and the skyrmion theory curves seem to be slightly shifted towards higher energies compared to the measured data. The reason could be that the sample might actually have been at a slightly higher temperature than the thermometer recorded. A higher temperature would mean a lower transition field B_{c2} of the phase diagram, and thus a shift of the theoretically expected magnon branches towards lower energies.

The experiment was conducted at *Thales* [8] by T.W., with A.H. as local contact. The crystal was grown and provided by A.B. and C.P. The theory was derived by M.G. and J.W. [7]. DOIs: 10.5291/ILL-DATA.4-01-1790 (experiment) and 10.5281/zenodo.5718363 (model source codes).

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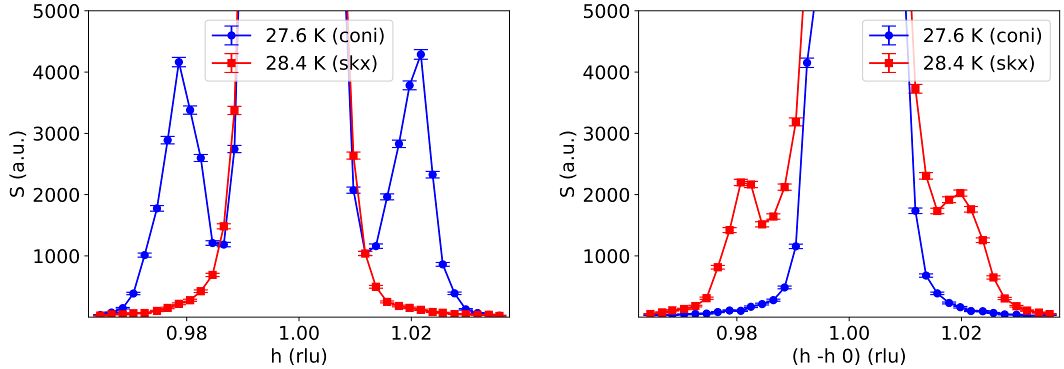

Figure 1. Elastic scans around $(1\bar{1}0)$ show the conical (left) and the skyrmion (right) satellite peaks.

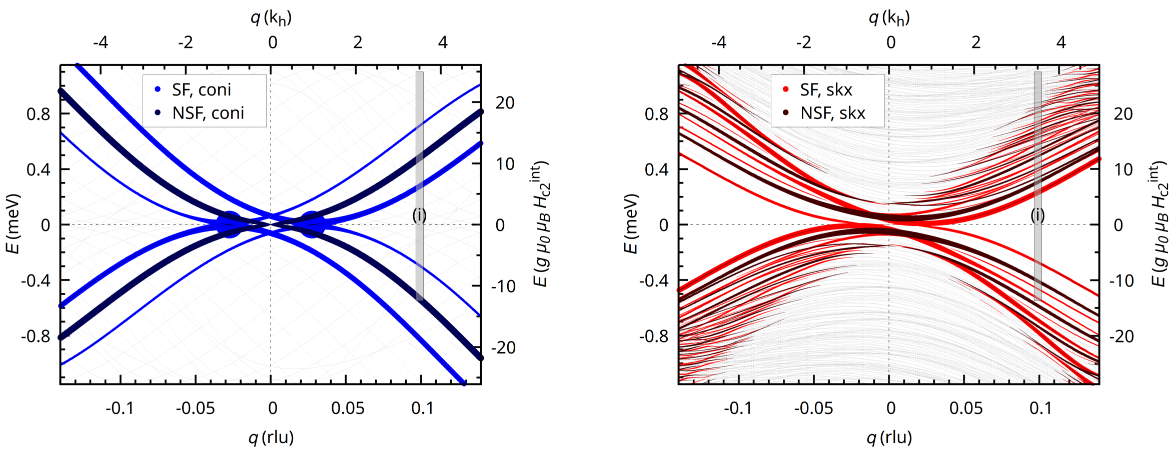

Figure 2. Linear spin-wave model [7] for the conical (left panel, at 27.6 K) and the skyrmion order (right panel, at 28.4 K) close to their mutual phase boundary. The plots show the magnon modes propagating along $(1\bar{1}0) - [hh0]$. The grey bar labelled (i) marks the position of the scan in Fig. 3.

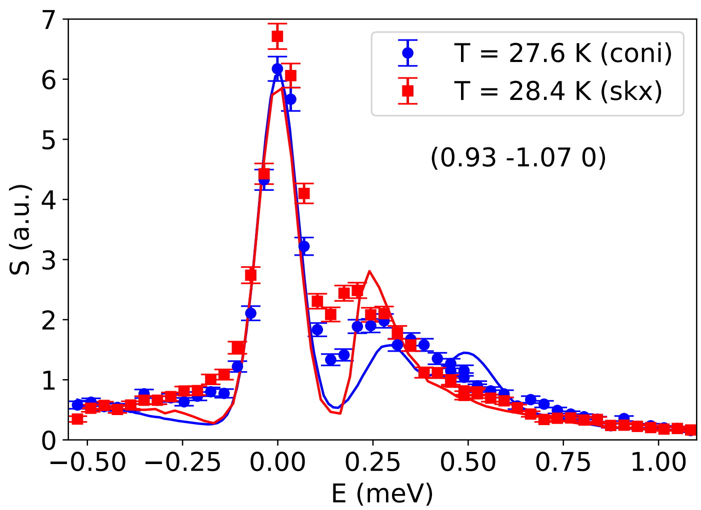

Figure 3. Measurements comparing the magnon branches for the conical and the skyrmion phase at $\left(0.93\,\overline{1.07}\,0\right)$, at temperatures close to their mutual phase boundary. The solid lines are (preliminary) resolution-convolutions of the theoretical models [7].