

# Experimental report

26/08/2024

**Proposal:** 4-01-1762

**Council:** 10/2022

**Title:** Investigation of the longitudinal fluctuations in the skyrmion phase of MnSi

**Research area:** Physics

**This proposal is a new proposal**

**Main proposer:** Tobias WEBER

**Experimental team:** Tobias WEBER

**Local contacts:** Paul STEFFENS

**Samples:** MnSi  
MnSi (large crystal)

Instrument	Requested days	Allocated days	From	To
THALES	5	5	21/06/2023	26/06/2023
ORIENTEXPRESS	1	2	31/03/2023 16/06/2023	01/04/2023 17/06/2023

## Abstract:

While we recently published a comprehensive investigation on skyrmion dynamics resulting mainly from experiments at Thales, see Science 375, 1025 (2022), there still remains an open question on the origin of certain low-energy modes that we could not answer so far. We estimate these modes to be non-linear longitudinal spin fluctuations related to either Landau damping or magnon-magnon interactions in the skyrmion phase. In the paper they were not included in our quantitative linear spin-wave theory comprising only transverse fluctuations, but instead treated phenomenologically. Here we propose to systematically measure them and identify the underlying mechanism.

# Investigation of the longitudinal fluctuations in the skyrmion phase of MnSi

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The itinerant-electron compound MnSi features several magnetically ordered phases below temperatures  $T$  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 experiment was twofold: First, to investigate the low-energy assumed longitudinal fluctuations seen before [5]. Second, as part of a long-running investigation, to compare these and the magnon spectra to the adjacent conical phase.

The experiment was conducted using linear polarisation analysis and a horizontal collimation of 30 minutes after the MnSi crystal. The sample was placed in a horizontal Oxford magnet [6], providing a field of  $B = 200$  mT along the [110] axis. In order to remove higher-order contamination, a cooled Beryllium crystal was used in the instrument's  $k_f$  axis. Unfortunately, the beamtime was riddled with problems with the Beryllium filter's cryostat: A leak heated up the Beryllium crystal and thus lead to changing neutron intensities making comparisons between scans difficult. The scans shown in this report are the ones that are only weakly affected by this.

Fig. 1 shows the predictions calculated from the theoretical linear spin-wave models [2, 5, 7] of the conical and the skyrmion phase close to their mutual phase boundary, both including higher-order correction terms [1]. So close to the boundary, the two dispersion relations share similar features, with the discrete branches of the conical dispersion fanning out into a multitude of closely-spaced branches when transitioning into the skyrmion phase.

Fig. 2 shows the measured magnon modes for adjacent conical and skyrmion phases at a position of  $Q = (1.1\ 1\ 0)$ . The solid lines correspond to (preliminary) convolutions of the instrument's resolution function and the theoretical models for the conical and the skyrmion phase [2, 5, 7]. The  $Q$  position was chosen as a middle ground between the easier to measure dispersions that form longitudinally to the field direction and the more difficult transverse dispersions. At this position, strong components of presumed longitudinal fluctuations are found for the skyrmion phase, which are already present in the adjacent conical phase, albeit with a weaker intensity. They are only seen in one of the spin-flip channels and are not visible in the convoluted lines as the theory only models transverse fluctuations. Additionally, the intensity of the magnons in the skyrmion phase at ca. 0.75 meV is overestimated by the theory for spin-flip channel 1. This may be explained by an additional line broadening for this mode, which is not yet taken account of in the present simulation.

The results also confirm the close relation of skyrmion and conical magnetic dynamics that is predicted by the theory: Transitioning from the skyrmion phase to the conical one, the complicated internal details of the skyrmion dispersion disappear and merge into the simpler conical dispersion branches. At the phase boundary, this leads to the observed smooth transformation from one type of dispersion to the other.

The experiment was conducted at *Thales* [8] by T.W., with P.S. as local contact. The crystal was grown and provided by A.B. and C.P. The theory was derived by M.G. *et al.* [7]. DOI: [10.5291/ILL-DATA.4-01-1762](https://doi.org/10.5291/ILL-DATA.4-01-1762).

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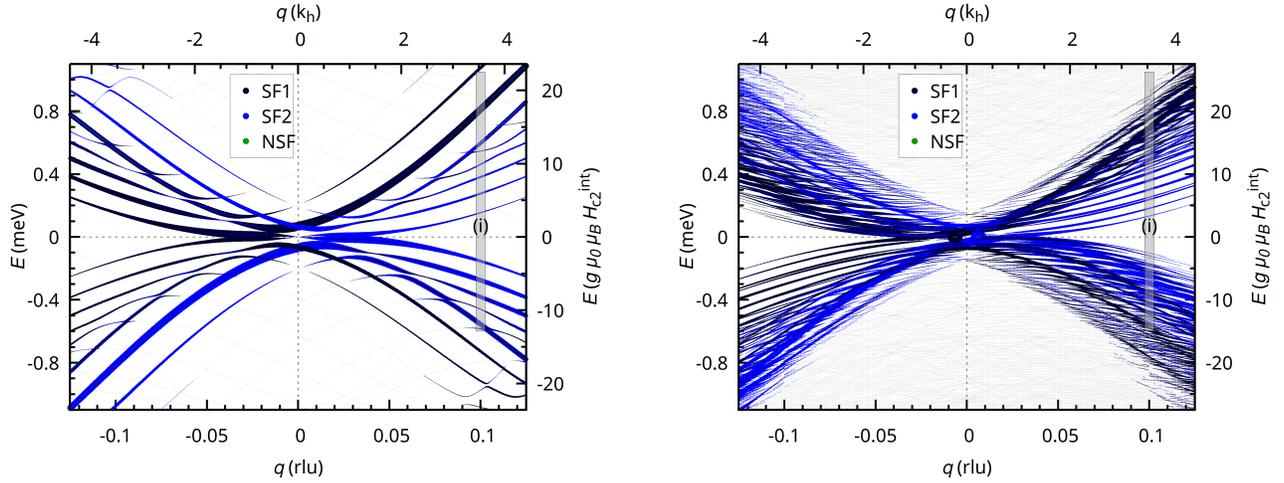


Figure 1. Left: Theoretical linear-spin wave dispersion for the conical phase in the  $(110) + [q00]$  direction. Right: Theoretical linear-spin wave dispersion for the skyrmion phase in the  $(110) + [q00]$  direction. The position of the scans and their ranges are marked as grey boxes labelled (i). Near the phase boundary, the two dispersions are very similar, with the skyrmion one appearing as a complicated version of the conical one. The thickness of the lines correspond to the spectral weights of the magnons, i.e. their spin-spin correlation functions. The oscillations at high  $q$  values are artefacts at the border of the validity of the linear spin-wave approximation. Both models are described in [7].

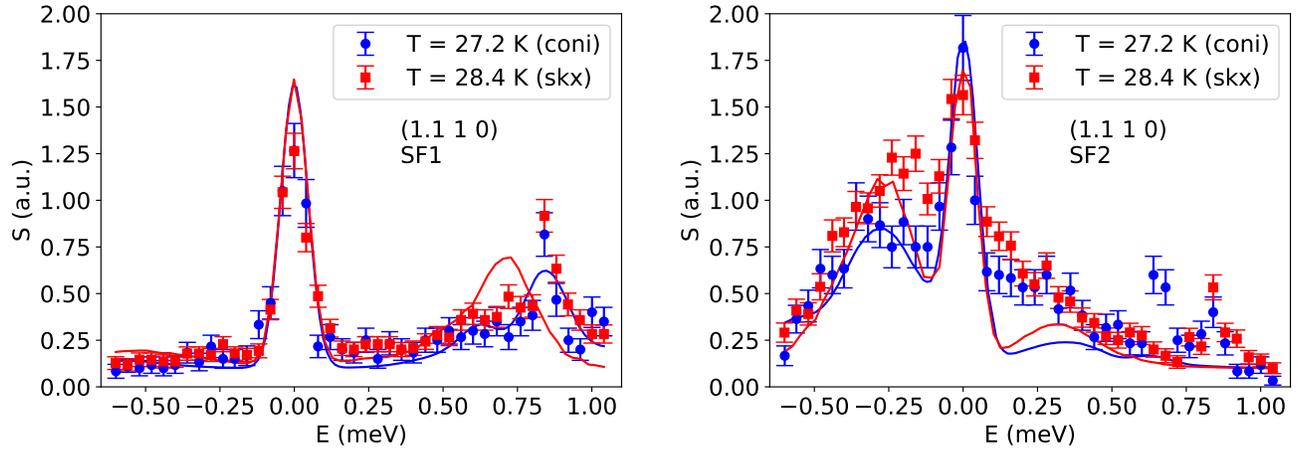


Figure 2. Adjacent conical and skyrmion magnon dispersions at the “diagonal” position  $(1.1\ 1\ 0)$ . The solid lines are preliminary resolution-convolutions with the respective models [7] shown in Fig. 1. The left and right panels show the two respective spin-flip channels. The data points have been merged from several individual shorter scans over the same position. The strong peak at ca. 0.85 meV, which appears in both channels, consists partly of a spurious leaking over from a very strong peak in the non-spin-flip channel (not shown).

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