Experimental report

03/04/2024

Proposal: **4-01-1820** **Council:** 10/2023

Title: Completing our investigation of magnon band-sticking in a non-symmorphic crystal

Research area: Physics

This proposal is a new proposal

Main proposer: **Tobias WEBER**

Experimental team: Tobias WEBER

Local contacts: Paul STEFFENS

Samples: CU2OSEO3

Instrument	Requested days	Allocated days	From	To
THALES	5	4	18/03/2024	22/03/2024
ORIENTEXPRESS	1	1	11/03/2024	12/03/2024

Abstract:

The combination of a non-symmorphic and time-reversal symmetry in a material can lead to nodal planes, planar band degeneracies (so-called "band-sticking") at the boundary of the Brillouin zone. Similar to point-like degeneracies, these nodal planes can be assigned topological invariants and will lead to protected surface states. An external magnetic field allows to break time-reversal symmetry, allowing to lift the nodal plane degeneracy and thereby adjust the material¿s topological properties in a controlled way.

We wish to finish our investigation into field-polarised magnon band degeneracies in the skyrmion host Cu2OSeO3, for which we already have a working theoretical spin-wave model and almost full experimental data, but still need to resolve anomalies discovered during a previous experiment.

(Note that Niclas Heinsdorf (MPG, Germany), Andreas Schnyder (MGP, Germany), and Marc Wilde (TUM, Germany) are also co-proposers, but were not listed in the user database.)

Nodal Planes in the Magnons of a Chiral Magnet

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(Dated: April 3, 2024)

The lack of an inversion symmetry for compounds crystallising in the $P2_13$ space group has led to the theoretical prediction of energetic degeneracies in their electron and magnon band structures, so-called "band-sticking" or "nodal planes" [1]. This effect has been predicted to be centred around the corner R = (0.5 0.5 0.5) of the cubic Brillouin zone [1]. Performing de Haas-van Alphen measurements of the magnetisation, Wilde *et al.* very recently confirmed the appearance of electronic band degeneracies around the R point of the chiral magnet MnSi [2]. They could influence and lift these degeneracies by changing the angle of the applied external magnetic field.

For the present experiment we continued our investigation on possible nodal planes manifesting themselves as field-dependent magnon degeneracies in a Cu_2OSeO_3 crystal. We had already performed previous experiments at *Thales* [3], *IN8* [4], and *TAX* [5].

The Cu_2OSeO_3 single-crystal was cooled to $T = 10$ K and the experiment was performed around its (220) Bragg reflection. (220) was selected for its large nuclear structure factor and its wave vector being low enough for a sufficiently strong magnetic form factor as well as a strongly diminished phonon intensity. The crystal was oriented in the (hhl) plane, and we applied a horizontal field of magnitude $B = 0.4$ T along the [001], the [110], as well as the [111] directions for three scan series, respectively, using an *Oxford* cryomagnet [6]. For each field direction we also investigated non-reciprocal effects by flipping the field polarity. To rule out any possible hysteresis effects, we warmed the crystal to $T = 80$ K before each change of field.

Fig. 1 shows the (1.5 1.5 l) dispersion along an edge of the Brillouin zone with the magnetic field oriented along [110] and $[\bar{1}\bar{1}0]$, respectively. Here, the dispersions and spin-spin correlation functions are the same for both field polarisations, the differences in the measurements are instrumental resolution effects.

Fig. 2 shows the same (1.5 1.5 l) dispersion as Fig. 1, but with the field along [001] and $[00\bar{1}]$, respectively. In this case, the dispersion differs dramatically for the two field polarisations with the branches changing from non-crossing to crossing.

The solid lines in Figs. 1 and 2 were determined using a convolution fit between the linear spin-wave theory [7] and the instrumental resolution function [8]. For that, we used the theoretical spin-wave model from [9], and fitted the exchange parameters and Dzyaloshinskii-Moriya vectors simultaneously to all our data. A single global intensity scaling parameter was used for all scans.

As our main result we found that the two pairs of dispersion branches for $B \parallel [110]$ collapse into two branches when turning the field towards $B \parallel [001]$. This suggests that the magnon band sticking in Cu_2OSeO_3 occurs along the edge(s) of the Brillouin zone, not in the corner as for the electronic bands in MnSi [2]. Additionally, we could experimentally verify the strong non-reciprocal nature of the $B \parallel [001]$ dispersion branches, which manifests itself in the dispersions changing from a non-crossing "O" shape to a crossing "X" shape (Fig. 2, top left) when flipping the polarisation of the field.

Experiment conducted at *Thales* [3] by T.W., with P.S. as local contact; DOI: 10.5291/ILL-DATA.4-01-1820.

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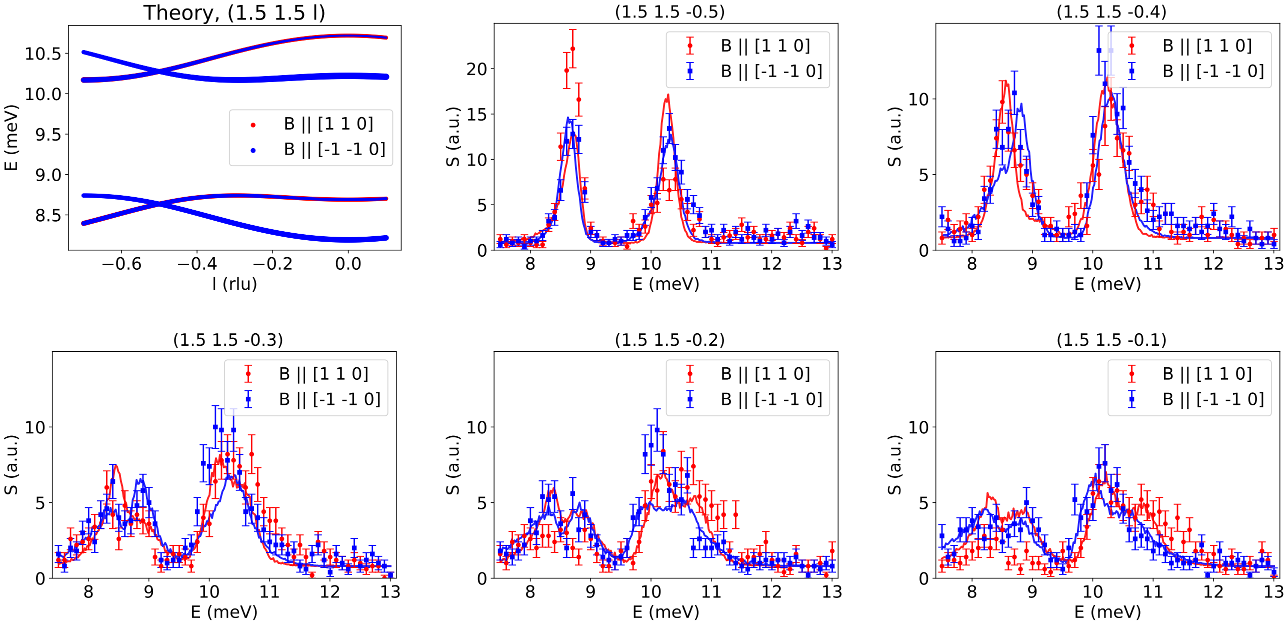

Figure 1. (1.5 1.5 l) dispersion branches with $B \parallel [110]$ (red) and $B \parallel [\bar{1}\bar{1}0]$ (blue) measured at *Thales* (points). The solid lines show a preliminary resolution-convolution [8] of the spin-wave model adapted from [9].

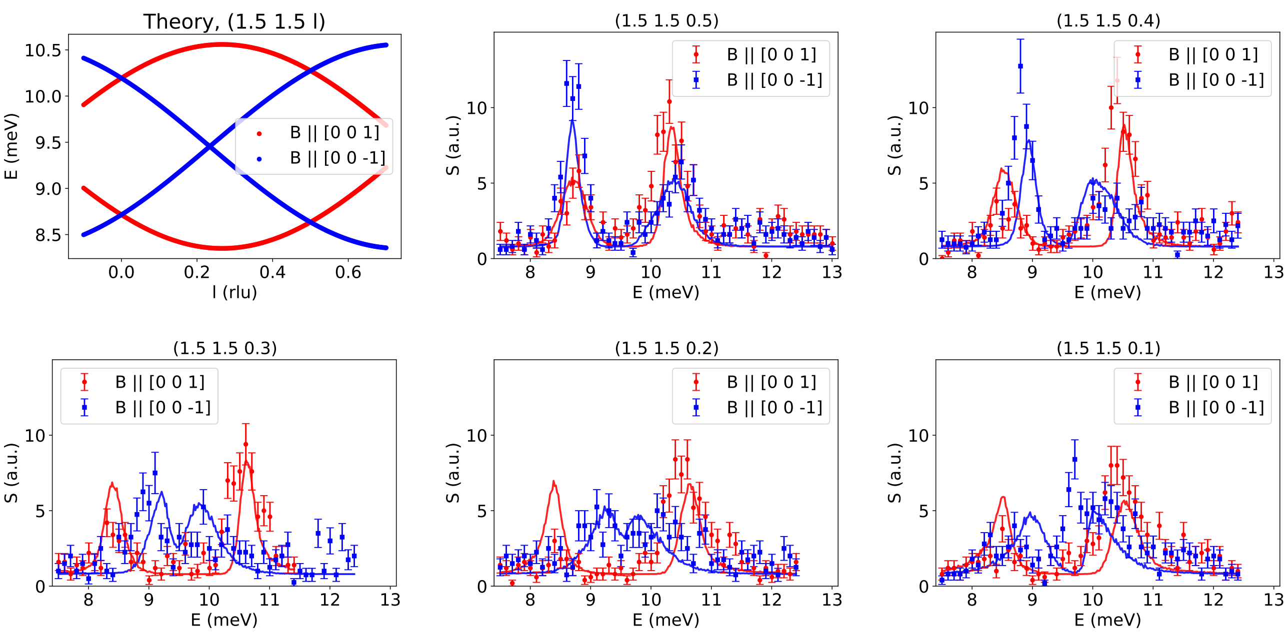

Figure 2. (1.5 1.5 l) dispersion branches with $B \parallel [001]$ (red) and $B \parallel [00\bar{1}]$ (blue) measured at *Thales* (points). The solid lines show a preliminary resolution-convolution [8] of the spin-wave model adapted from [9].