Experimental report

28/09/2021

Proposal: **DIR-239**

Council: 4/2021

Title: Coupling between a magnon and a triplon lattice in SeCuO3

Research area: Physics

This proposal is a continuation of 4-01-1295

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Samples: SeCuO3

Instrument	Requested days	Allocated days	From	To
IN8 Flatcone	5	5	25/08/2021	30/08/2021
IN20 Flatcone	5	0		

Abstract:

The Cu-based quantum magnet hosts three types of magnetic excitations : triplons, magnons and spinons. Their behaviour has been nicely explained by a model based on two decoupled magnetic sublattices. The first one is formed by non-interacting dimers while LRO emerges on the second one. However, previous INS measurements showed multiple evidence of a weak coupling between both sublattices, which would be suppressed by the strong dimer interaction within a dimer unit. This energy scale difference effectively reduces the dimensionality of the system.

The present experiment proposes to characterise the interaction responsible for the coupling between both sublattices by mapping out the dimer excitation at low- and high-temperature. It would then open the way to a theoretical treatment of multi-type excitations systems.

Coupling between a magnon and a triplon lattice in $SeCuO_3$

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This experiment is a direct continuation of our work on $SeCuO_3$[1]. We claimed that the excitations in the system could be accurately described by two decoupled systems : dimer units formed by Cu_1 atoms and spin waves emerging on the Cu_2 magnetic lattice. However, despite the effective decoupling, there is clear evidence of a coupling between the two sublattices. The aim of the experiment is to quantify this coupling through careful analysis of the high energy excitation (26 meV) that we associated with a singlet to triplet transition in the appropriate energy range above and below the Néel temperature ($T_{\mathrm{N}} \sim 8$ K). One expects to recover a perfect [2] dimer behaviour above T_{N} when LRO disappears, while things get more interesting at lower temperature.

We obtained 5 days of beamtime on IN8 (ILL) with the FlatCone option. We used a 0.2 g sample oriented in the (HK0) scattering plane that has already been measured in a previous experiment. The final wave vector was fixed at 3 Å^{-1}. We performed two main series of measurements. The first one, below T_{N}, consists in A3 scans of a portion of the reciprocal space at different energies in order to extract peaks corresponding to the magnetic excitations. The second one, above T_{N}, is energy scans at selected positions in reciprocal space due to lower statistics. I comment that no in depth analysis has been made yet, but the interested scientist can use the `nplot` Matlab tools that can be found online [3]. The command for multi analysers measurements reads `plotmultiple scan_number_with_0`. An example of script can be found in my personal folder (`results_2K.m` and `results_40K.m`).

Low temperature

We decided to go for a partial mapping of the reciprocal space covering regions of interest $\mathrm{dA}_3 = 1.5°$, ΔE from 24 meV to 30 meV with dE = 0.25 meV, and with approximately 140 s of measurement time per A3 step. The following figure confirms the presence of a dispersive magnetic excitation that follows a symmetric pattern. Two regions are particularly interesting. The first one is located around (0,3,0) while the second one is formed by the four peaks pattern on (2,4,0), (3,5,0), (2,6,0) and (1,5,0). Energy scans and thus the

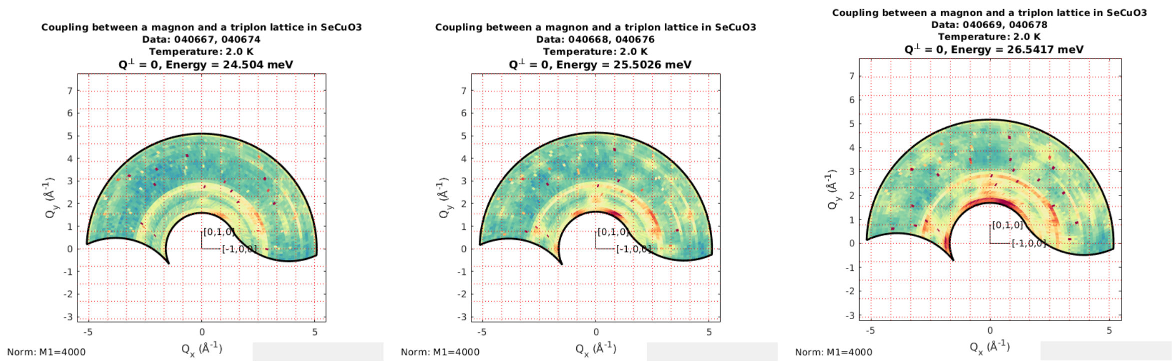

Figure 1: 180° mapping of the reciprocal space for different energy transfer values

dispersive maps $E(\omega)$ can easily be extracted along all directions (see example in `results_2K.m`). The next figure shows an example along the $[0, k, 0]$ direction. A clear dispersion is present despite the presence of really strong Aluminium peaks. I add that the asymmetric behaviour of the peak has also been observed in a scan along the elastic line (#040685) and might be due to a small misalignment of the sample (too high in the beam). This will have to be considered in the analysis.

[1]Testa *et. al.* Phys. Rev. B **103**, L020409
[2]J. T. Haraldsen *et. al.* Phys. Rev. B **71**, 064403
[3]https://github.com/nplot

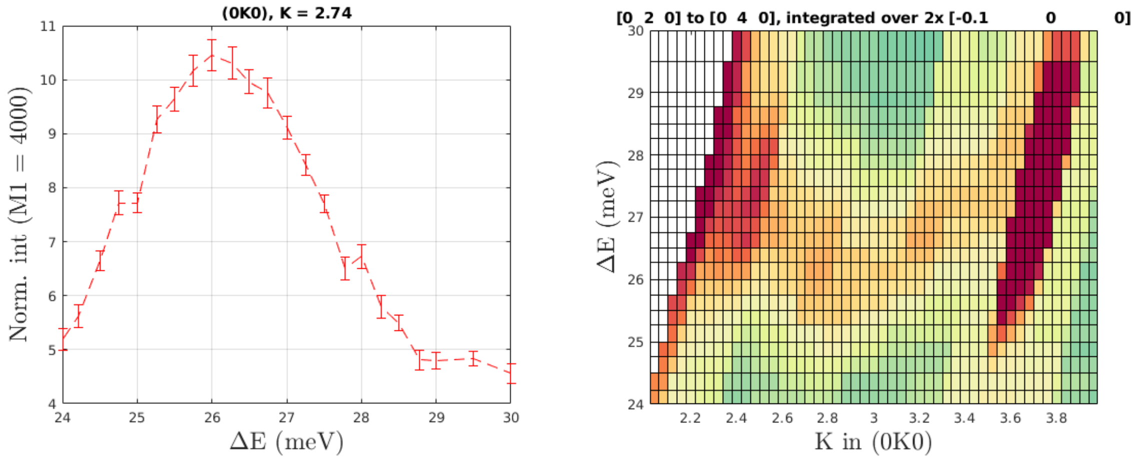

Figure 2: The dispersion can be extracted from a series of energy scans at different positions

High temperature

Similar measurements have been made at high temperature ($T = 40$ K) in a smaller portion of the reciprocal space that covers the points described previously. Unfortunately, the excitations are not as well defined as they are below the transition.

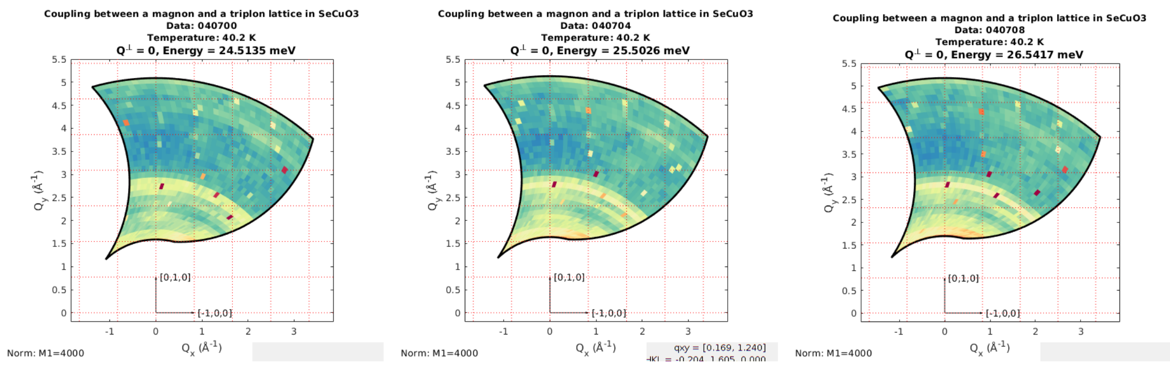

Figure 3: Mapping of the reciprocal space for different energy transfer values at 40 K

It is much harder to follow it as can be seen on the following constant-q energy scans.

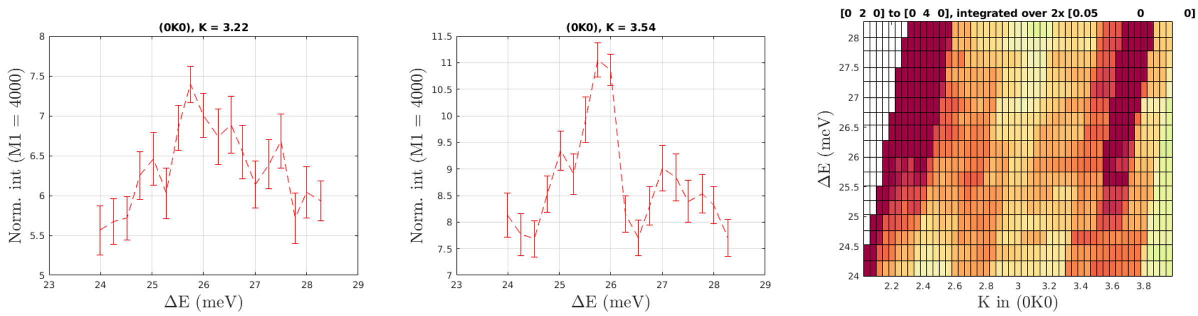

Figure 4: Selected energy scans at high temperature and associated dispersion along $[0, k, 0]$.

For the last days of measurements, we thus decided to perform E-scans at fixed positions (practically, only **one** of the 31 detectors has fixed-Q, the rest forms a sort of helix in $(\mathbf{Q}, \omega)$ space). Here are a few E-scans at (0,3.1,0), (0,3,0) and (0,2.9,0). We expect to have higher statistics and thus to simplify the analysis but we unfortunately restricted the measurements to a much lower of positions.

Hopefully a consistent analysis combining both experimental approaches will lead to a conclusion.

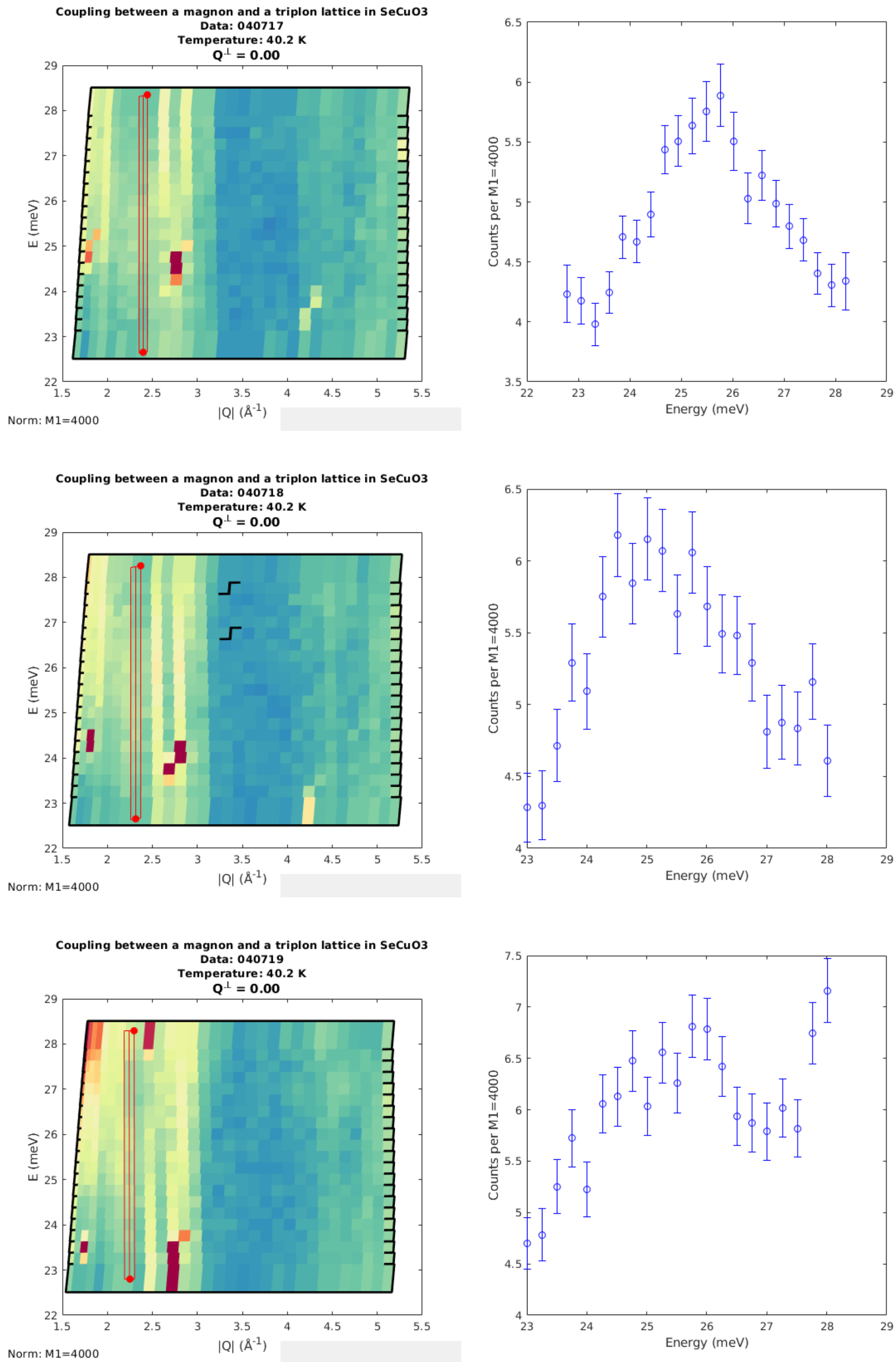

Figure 5: "Dispersion" and E-scans at fixed Q for different positions along $[0, k, 0]$.