Experimental report

13/04/2026

Proposal: CRG-3069 **Council:** 10/2023

Title: Origin of a peculiar magnetic ground state in a kagome-like lattice

Research area: Physics

This proposal is a new proposal

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Samples: Cu2OSO4

Instrument	Requested days	Allocated days	From	To
IN5	5	0		
IN12	7	2	04/03/2024	06/03/2024
ORIENTEXPRESS	1	1	10/03/2024	11/03/2024

Abstract:

Cu2OSO4 can be considered as a playground where significant perturbations to the kagome lattice can help quantify the effects of fluctuations and strong magnetic frustration, and provide better understanding of their experimental and theoretical effects on the quantum spin-liquid state. We desire to improve the coverage of the excitation spectrum in the ab-plane to identify all the relevant magnetic couplings and develop a fully quantum model able to describe spin excitations in any direction, within the Kagome plane. Furthermore, we want to address the dimensionality of the system and investigate the nature of the magnetic excitations by applying a magnetic field. This may advance the understanding of the physics in systems dominated by magnetic frustration and of the delicate balance between long-range order and quantum fluctuations.

Di-copper oxide sulfate (Cu_2OSO_4) [1] is a realisation of a kagome-like lattice of Cu ions where one of the three corners of the conventional triangle is replaced by a dimer, whose Cu atoms reside slightly out-of-plane. The crystal structure is show in Fig. 1(a), while the kagome plane formed by the Cu atoms is illustrated in Fig. 1(b). This system provides a platform to study how deviations from the perfect kagome lattice influence the magnetic ground state and the excitation spectrum.

Our experiment on IN12 was designed to complement previous inelastic neutron scattering data collected in the kagome (*ab*) plane on CAMEA (SINQ) (Fig. 1(c)). Those measurements revealed two spin-wave modes centred at approximately 2 and 8 meV, respectively. On IN12, the *bc** plane was instead chosen as the horizontal scattering plane. In accordance with the original beamtime proposal, we tracked the L-dispersion of the two modes at their respective minima.

The data collected for the lower mode show a non-negligible dispersion along the L direction, with a bandwith of about 0.8 meV, supporting the presence of superexchange pathways between different Cu planes mediated by SO_4 groups. Measurements at higher energy revealed that the upper mode actually consists of 2 modes, dispersing in a similar fashion. We also investigated the avoided crossing observed at K = 1 and around 3 meV in the CAMEA data. The IN12 results show that the hybridization weakens as one moves away from the kagome plane, until the two features merge when approaching L = 0.5. IN12 energy scans are presented in Figs. 1(d–f), where

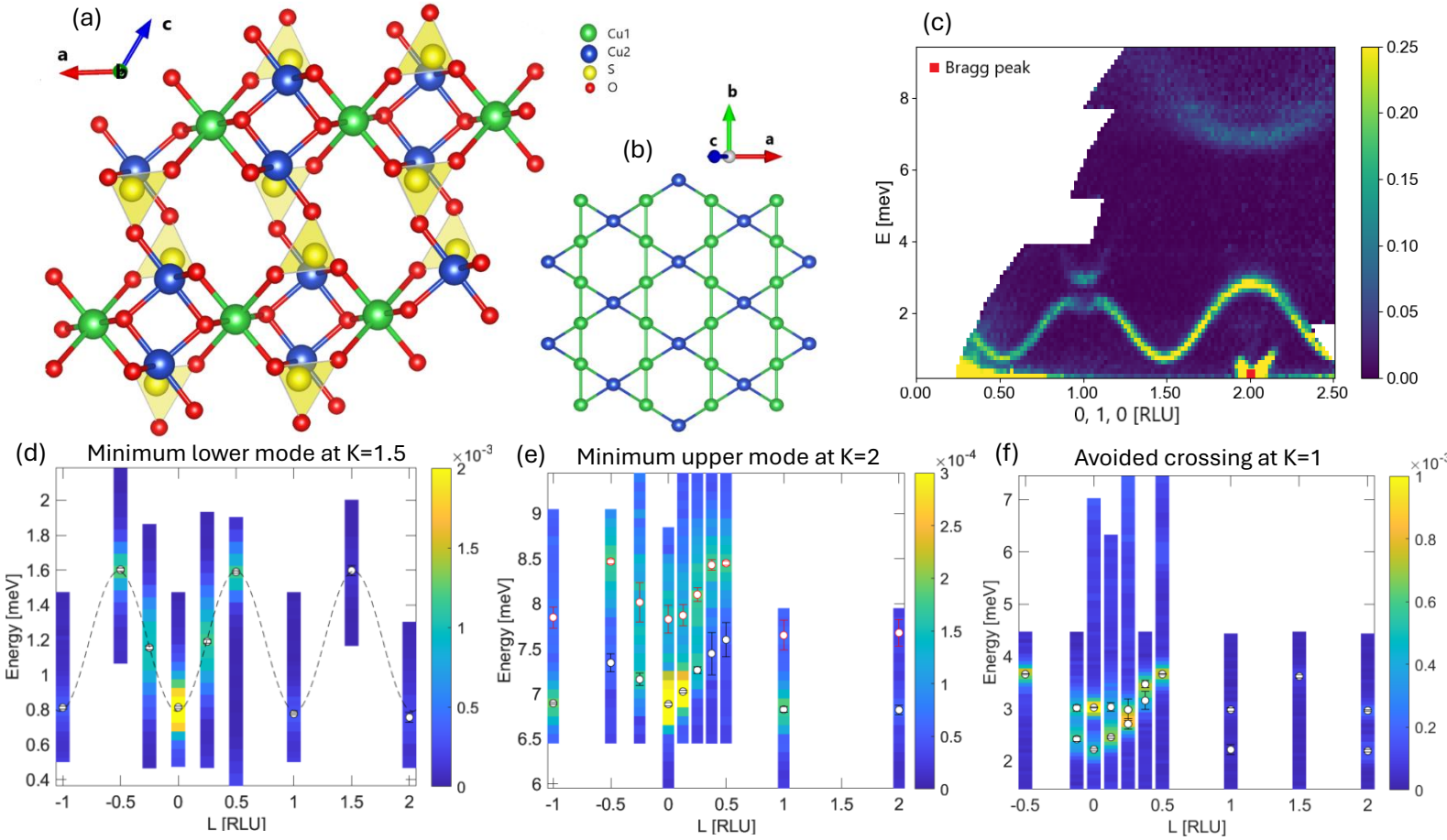


Figure 1 (a) Cu_2OSO_4 crystal structure. (b) The kagome-like plane realised by the Cu network. (c) (K, E)-plane collected on CAMEA (SINQ). Two spin-waves mode centred at 2 and 8 meV are visible. At K = 1rlu the lower mode displays an avoided crossing with another mode. (d) Dispersion of the lower mode along [0, 1.5, L], which is well describe by a sinusoidal curve (dashed line). (e) Dispersion of the upper mode along [0, 2, L]. (f) Dispersion of the avoided crossing modes along [0, 1, L].

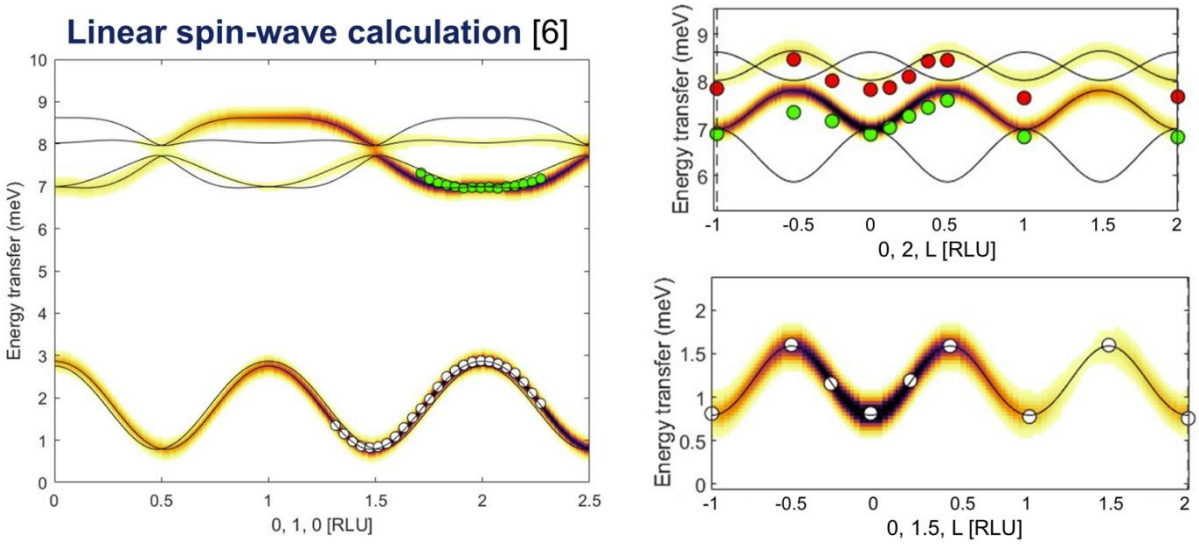


Figure 2 Linear spin-wave calculation performed with our model Hamiltonian along the reciprocal space directions (a) [0, K, 0], (b) [0, 2, L] and (c) [0, 1.5, L]. Solid lines represent the simulation, whereas white, green and red points are the energy centres of the fitted modes in CAMEA and IN12 data.

each intensity map rectangle corresponds to an energy scan at the specified reciprocal space point.

The magnetic excitations have been fitted and used to extract a model Hamiltonian for this system. In Fig. 2(a–c), we show how our model, simulated using spinW [2], reproduces the experimental data along selected reciprocal-space directions. We are currently working on refining the model by incorporating recent measurements performed under an applied magnetic field.

References

[1] V. Favre et al., Phys. Rev. B 102, 094422 (2020).

[2] S. Toth and B. Lake, J. Phys.: Condens. Matter 27, 166002 (2015).