Experimental report

07/09/2022

Proposal: **5-32-901** **Council:** 10/2019

Title: Magnetic PDF of a new potential spin liquid

Research area: Physics

This proposal is a new proposal

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Samples: $CuSb_2O_6$

Instrument	Requested days	Allocated days	From	To
D4	5	3	23/02/2020	26/02/2020

Abstract:

The frustration of triangular antiferromagnets with isotropic interactions leads to a variety of ground states even for classical spins. In regions where several classical phases are degenerate, quantum spins may realize a quantum ground state with lower energy. From symmetry analysis, 15 different types of quantum spin liquid ground states have been classified for the triangular lattice, symmetric spin liquids as well as chiral spin liquids. Due to the lack of suitable highly symmetric compounds, such spin liquids are experimentally not much explored.
Recently a new spin-1/2 triangular AFM has been synthesized, $CuSb_2O_6$ in rosiaite ($PbSb_2O_6$) structure, space group P-31m. There was no evidence of long-range order down to 1.5K, however a very steep dispersion was observed at several characteristic wave-vectors on the inelastic spectra. Since there is no long-range order in $CuSb_2O_6$ compound, we would like to approach the investigation of short-range magnetic correlations by the better suited magnetic PDF (mPDF) analysis. The mPDF will give us directly (without any modelling) an ensemble average (not a time average) of quasi-instantaneous local magnetic correlations.

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MOTIVATION

Recently a new spin 1/2 triangular antiferromagnet has been synthesized [1], $CuSb_2O_6$ in rosiaite ($PbSb_2O_6$) structure, space group P$\bar{3}$1m. In this highly symmetric structure, the spin 1/2 carrying Cu^{2+} sit on sites 1a [0,0,0] with site symmetry $\bar{3}$m, all Cu-O bonds have the same length. Contrary to $CuSb_2O_6$ in tetragonal form which distorts into a monoclinic structure already above room temperature and displays long-range order at low temperature [2], the metastable trigonal $CuSb_2O_6$ remains trigonal to low temperatures without a magnetic or structural phase transition down to 1.5 K [1]. However, when Cu is replaced by Co or Ni, the trigonal crystals again display long-range antiferromagnetic order at low temperature [1].
The antiferromagnetic (AF) Heisenberg model on the triangular lattice is an example of two-dimensional geometrically frustrated magnets. With only AF nearest-neighbor interaction the ground state of this system is the three-sublattice 120° structure, which is commensurate to the underlying lattice. With further-neighbor interactions spin liquid or skyrmion phases can be realized [3-5].
The absence of long-range order, the isotropy of the Cu^{2+}, no glassy freezing of spins, the presence of sizable antiferromagnetic interactions could imply a quantum (S=1/2) spin liquid scenario.

EXPERIMENTAL DETAILS

We have performed a powder neutron diffraction experiment at D4 instrument with the incident neutron wavelength of 0.5 Å. The advantage of using D4 instrument is high incident energy $E_i > 300$ meV. The diffraction patterns were measured at $T = 4$ K (base and stable temperature of D4 instru- ment), and at several higher temperatures $T = 20$, 30, and 40 K. No difference was observed between those high temperature data, hence, we have merged them into one data-set (Fig.1).

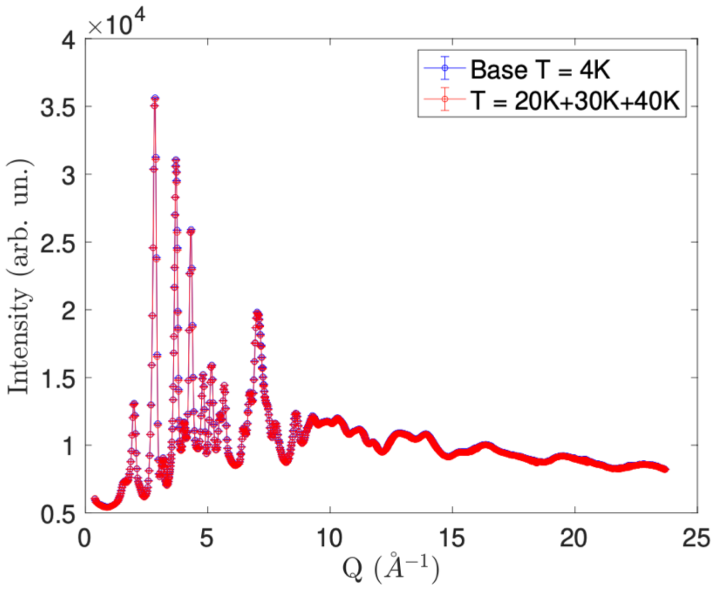

Fig.1. Diffraction patterns measured at D4 instrument at T = 4 K (blue) and at T = 20, 30 and 40 K, which were merged into one data-set (red).

PRELIMINARY RESULTS

Simple subtraction of these two data-sets is shown in Fig.2. Interestingly that we could observe very weak but significant intensities at the same characteristic vectors $Q = 0.65$ Å^{-1}, 1 Å^{-1}, and 1.5 Å^{-1}, as were captured previously at IN5 and LET TOF instruments. Diffraction experiment is actually the same spectroscopy method but without analyzing final energies. The main aspect of the diffraction experiment is that all final energies are integrated, hence all excitations (lattice and magnetic) are integrated and ultimately contribute to the diffraction pattern. Therefore, despite the fact that we have integrated IN5 and LET data in a certain energy range excluding elastic line, we can extrapolate that range to 0 meV, since we have detected those features in difference diffraction pattern, and determine the energy integrated inelastic signal as S(Q), which then can be used as input for SPINVERT.

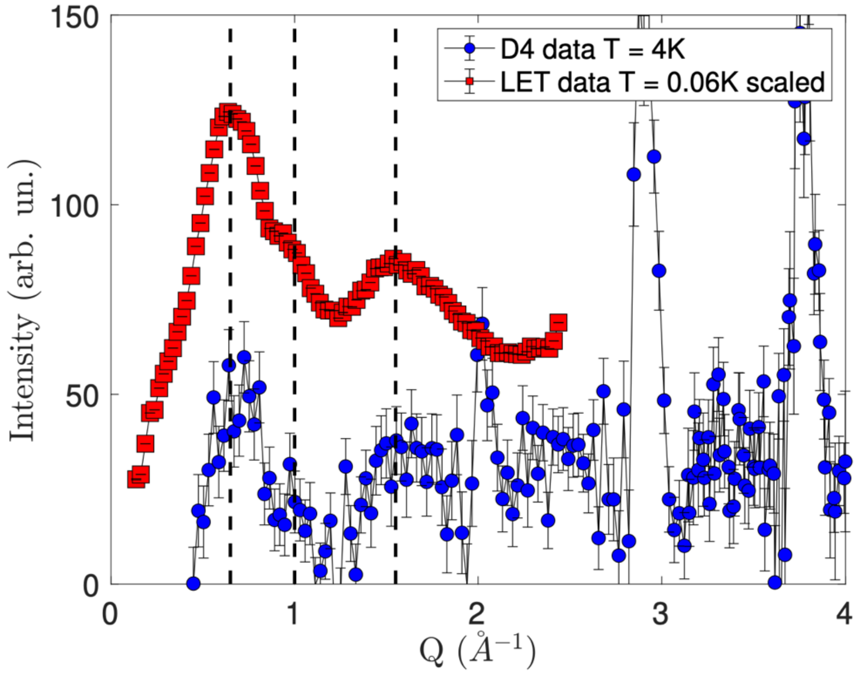

Fig.2. Difference diffraction pattern measured at D4 (blue) and integrated LET signal (red) in $0.4 < E < 3$ meV energy range. Dashed lines are the guides to the eye depicting common characteristic wave-vector features.

ONGOING ANALYSIS

Since the sample is only in powder form, we are limited in the information, which could be extracted from the experimental data. With the reverse Monte Carlo method implemented in SPINVERT software, one can reconstruct spin pair correlation function by fitting powder diffuse magnetic scattering independently of Hamiltonian. This work is currently in progress.

REFERENCES

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