Experimental report

07/09/2022

Proposal: **5-32-899** **Council:** 10/2019

Title: Spin-spin pair correlation function 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
D7	4	4	12/08/2020	16/08/2020

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 so much explored. Recently a new spin 1/2 triangular antiferromagnet has been synthesized, $CuSb_2O_6$ in rosiaite ($PbSb_2O_6$) structure, space group P-31m. In this highly symmetric structure, the spin 1/2 is carrying by Cu^{2+}. Down to 1.5K there was no evidence of long-range order. In order to clearly separate magnetic scattering from the nuclear part, we would like to perform XYZ polarization analysis on D7. Further analysis of the data will be the key in the understanding of the interaction scheme in this compound. To prove spin liquid scenario we would like to go to the lowest possible temperature, thus we are additionally asking for dilution fridge.

Experimental report 5-32-899

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 polarized diffraction experiment at D7 instrument with the incident neutron wavelength of 3.1 Å, thus providing E_i =8.5 meV at T=0.06K. The main goal of this experiment was to separate magnetic scattering from the nuclear part because of possible disorder in the structure [1], thanks to XYZ polarization analysis on D7 instrument.

RESULTS

In Fig.1, we show comparison of the magnetic cross-section obtained in D7 experiment and magnetic cross-section in case of paramagnet $\left(\frac{d\sigma}{d\Omega}\right)_{mag} = \frac{2}{3}\left(\frac{\gamma_n r_0}{2}\right)^2 f^2(\boldsymbol{Q}) g_s^2 S(S+1)$. One can notice that experimental results are quite far from the theoretical curve, which could be explained either by crystal structure disorder (namely by lack of magnetic copper ions) or by Fig.2. In Fig.2, we show inelastic S(Q,w) spectrum measured previously at IN5 TOF spectrometer and parabolic trajections for D7 (black solid line) and D4 (red solid line) instruments according to their accessible angles and incident energies. As one can see, unfortunately D7 cuts out the significant part of the magnetic excitations at Q = 0.5 $Å^{-1}$, which could be a reason for lacking of the magnetic signal in Fig.1. In another words, incident energy of neutrons wasn't high enough to cover all the excitations present in the system -- excitations extend up to 7 meV, whereas the incident energy was only 8.5 meV. From the other hand, during this experiment we got the first evidence of absence of long-range order down to 60 mK.

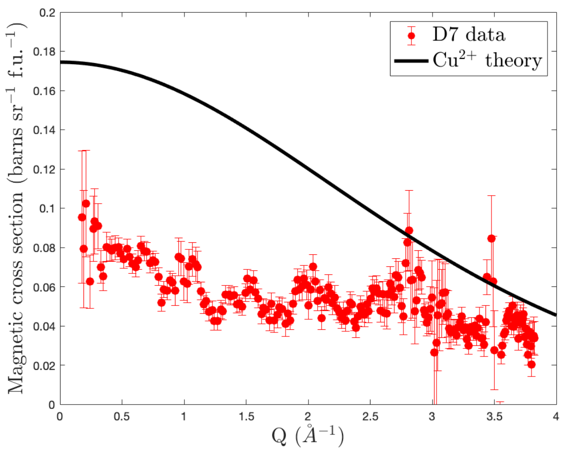

Fig.1. Red curve – experimental CuSb2O6 magnetic cross-section obtained as result of XYZ polarization analysis. Black – theoretical magnetic cross-section according to the formula mentioned above in case of paramagnet.

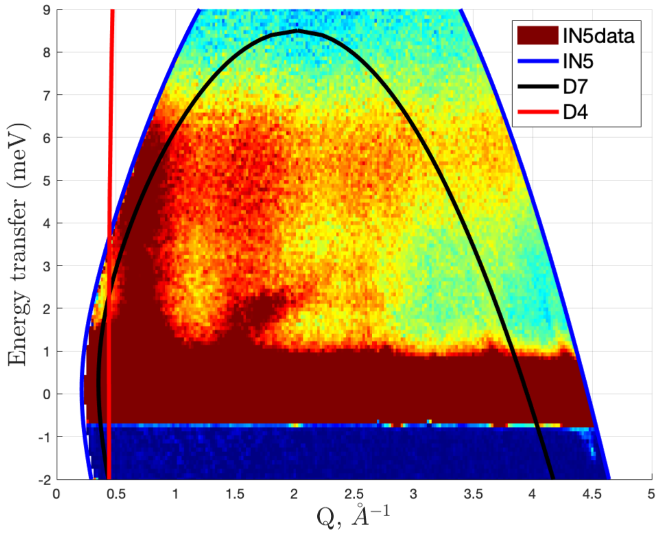

Fig.2. Inelastic S(Q,w) spectrum measured at IN5 at T = 1.6K. Black and red solid lines correspond to the parabolic trajectories of D7 and D4 instruments according to their accessible angles and incident energies (E_i = 8.5 meV and E_i = 300 meV, respectively).

REFERENCES

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