Experimental report

11/03/2021

Proposal: **4-01-1709** **Council:** 10/2020

Title: Localized high-energy excitations in the Cu_2GaBO_5 ludwigite

Research area: Physics

This proposal is a new proposal

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Samples: $Co_3Sn_2S_2$
Cu_2GaBO_5

Instrument	Requested days	Allocated days	From	To
IN8 Flatcone	6	5	18/02/2021	24/02/2021

Abstract:

The frustrated low-dimensional quantum magnet Cu_2GaBO_5 with the ludwigite crystal structure features strong site disorder on the magnetic Cu^{2+} sublattice. Nevertheless, in zero magnetic field it exhibits a sharp magnetic transition at $T_N=4$ K into a complex long-range-ordered noncollinear antiferromagnetic (AFM) state with a propagation vector $q_m=(0.45\ 0\ \&\ -0.7)$, according to our single-crystal neutron diffraction measurements. External magnetic field broadens the transition and drastically reduces the magnetic correlation length, leading to a field-induced magnetically disordered (spin-glass-like) state. On the one hand, our recent cold-neutron INS measurements at PANDA (MLZ, Garching) revealed quasielastic diffuse scattering in the vicinity of the magnetic ordering vector with typical energy scales of < 1 meV. On the other hand, first-principles calculations predict strong antiferromagnetic coupling within dimer and trimer units on much higher energy scales of the order of 10 meV, implying that most of the INS spectral weight should be contained in quasi-localized triplon-like excitations at higher energies.

Experiment Title

Localized high-energy excitations in the Cu_2GaBO_5 ludwigite (#4-01-1709, 18–24 February, 2021)

Proposer

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Report

Introduction

The frustrated low-dimensional quantum magnet Cu_2GaBO_5 with the ludwigite crystal structure features strong site disorder on the magnetic Cu^{2+} sublattice. Nevertheless, in zero magnetic field it exhibits a sharp magnetic transition at $T_N \approx 4$ K into a complex long-range-ordered noncollinear antiferromagnetic (AFM) state with a propagation vector $\mathbf{q}_m = (0.45\ 0\ -0.7)$, according to our single-crystal neutron diffraction measurements. External magnetic field broadens the transition and drastically reduces the magnetic correlation length, leading to a field-induced magnetically disordered (spin-glass-like) state. On the one hand, our recent cold-neutron INS measurements at PANDA (MLZ, Garching) revealed quasielastic diffuse scattering in the vicinity of the magnetic ordering vector with typical energy scales of <1 meV [1]. On the other hand, first-principles calculations predict strong antiferromagnetic coupling within dimer and trimer units on much higher energy scales of the order of 10 meV [1], implying that most of the INS spectral weight should be contained in quasi-localized triplon-like excitations at higher energies. To verify this theory, we proposed to search for these higher-energy excitations on IN8 using the Flatcone multianalyzer.

Scientific background

Ludwigites are oxyborate compounds with the general formula $Me_2^{2+}Me^{3+}(BO_3)O_2$. Their structure consists of low-dimensional zigzag walls with triangular motifs, making them an interesting playground for the realization of magnetic frustration on quasi-low-dimensional lattices [2, 3]. Of particular interest are copper ludwigites, in which the divalent transition-metal ion is Cu^{2+}, carrying a quantum spin 1/2, whereas the trivalent ion is nonmagnetic. First large single crystals of these compounds were recently grown by Y. Moshkina (Institute of Physics, Kransoyarsk, Russia), and our present goal is to understand their magnetic properties by combining the results of complementary experimental probes such as

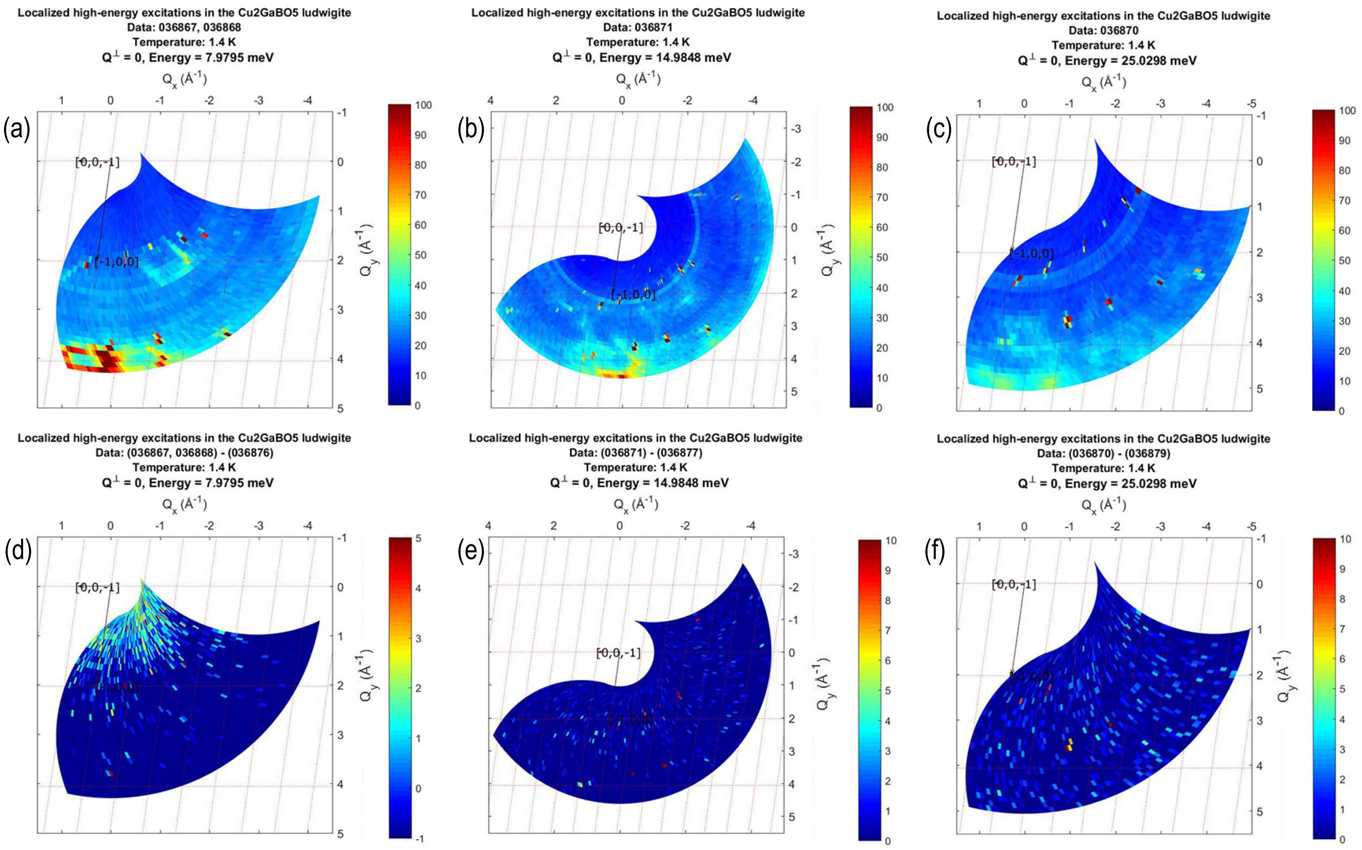

Fig. 1: (a),(b), and (c) are **Q** maps at 1.4 K for 8, 15, and 25 meV, respectively. (d),(e), and (f) are differences of **Q** maps at 1.4 and 70 K for 8, 15, and 25 meV, respectively.

neutron scattering, μSR, NMR, and thermodynamic measurements, supported by first-principles calculations that are done by O. Janson (IFW Dresden) to estimate the exchange parameters. It is worth noting that the structurally related [4] mineral malachite has not been grown so far in the form of synthetic single crystals, and therefore recent investigations of its low-temperature magnetic properties had to be performed on either natural crystals or synthetic powders [5]. In this respect, ludwigites look much more promising due to their large chemical variability and the availability of sizable isotope-enriched single crystals suitable for INS measurements.

Experimental configuration and results

Our ludwigite mosaic with total mass of ∼1.8 grams was measured by thermal neutron three-axis high-flux spectrometer IN8 at ILL, France, in the Flatcone configuration using Si(111) monochromator. The sample was mounted in $(H0L)$ scattering plane. We were interested in the low-temperature measurements below 4 K. For this purpose we used the "orange" cryostat. The goal of the past experiment was to map out the higher-energy part of the magnetic excitation spectrum in Cu_2GaBO_5. We performed several constant-energy maps at 8, 15, and 25 meV at various temperatures between 1.4 and 70 K, some of which are shown in Fig. 1(a–c). We use datasets at 70 K as background. Without subtraction of high-temperature datasets, we see phonon branches around the $(\bar{1}02)$ and $(\bar{2}00)$ Bragg positions from the minority twin at 8 and 15 meV. No magnetic signal can be observed in the whole measured energy range. This also follows from the continuous energy scan presented in Fig.2. After subtraction of background at 8 meV, we see the very weak diffuse magnetic signal at low **Q**, which is shown in Fig. 1(d). No such signal is present at energies above 8 meV [Fig. 1(e,f)]. Given the weakness of the signal and the fact that it surrounds the direct beam, rather than the magnetic ordering vector, its magnetic origin is doubtful. In summary, our experiment did not confirm the theoretically predicted localized high-energy excitations in Cu ludwigites.

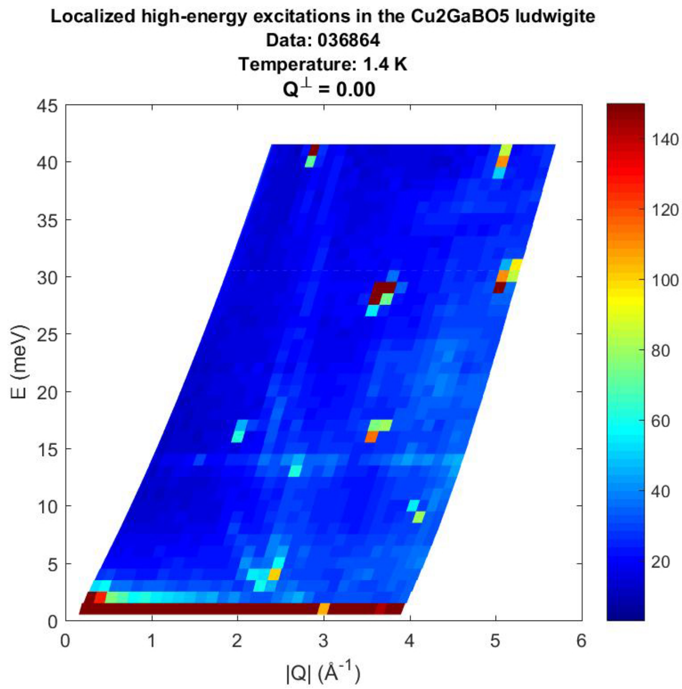

Fig. 2: Energy momentum cut.

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[4] F. Girgsdies & M. Behrens *et al.*, Acta Cryst. B **68**, 107 (2012).
[5] E. Canévet *et al.*, Phys. Rev. B **91**, 060402(R) (2015).