Experimental report

12/02/2016

Proposal: 4-03-1705 **Council:** 10/2014

Title: Investigation of the out of plane Q-dependence of the triplet magnetic excitations in SrCu2(BO3)2

Research area: Physics

This proposal is a new proposal

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Samples: SCBO

Instrument	Requested days	Allocated days	From	To
IN8	4	4	23/07/2015	27/07/2015

Abstract:

This proposal concerns SrCu2(BO3)2, a realization of the Shastry-Sutherland model, which is of particular interest in frustrated quantum magnetism. We started a study of the effect of the interlayer coupling (~8K) on the localized single triplet excitations (~3meV) as well as on the multi-triplon continuum at higher energy transfers and observed a pronounced intensity variation with Ql. We therefore wish to use IN8 to completely understand the dependence in Ql of the excitations by performing Q-scans along Ql at constant energy transfers 3 meV, 5meV and 11 meV. These measurements are paramount not only to complete our Ql investigations, but also to allow quantitative analysis of a large amount of TOF data (obtained with scans with varying Ql value). We ask for 4 days of beamtime in order to complete the study of the Ql dependence of the magnetic excitations in SrCu2(B03)2

SCBO is a realization of the Shastry-Sutherland model, which is of particular interest in quantum magnetism due to frustration driven localization of triplet excitations, correlated hopping, magnetization plateaus and has been proposed as a realization of the conjectured “supersolid” phase. The Shastry-Sutherland model has an "exact" dimer ground state (a direct product of spin singlets on the nearest neighbor bonds) as the S=1/2 moments of the Cu2+ ions are arranged in a 2D lattice of strongly coupled dimers (J=85K for SCBO). The inter-dimer coupling (J'=54K) is geometrically frustrated, leading to a singlet ground state of almost isolated dimers, with a 3meV spin gap to localized triplet excitations. At higher energy transfers (~5meV, ~9meV and higher) multiple-triplet excitations are also present and we observe a multi-triplon continuum. INS and ESR measurements have established that the perfect frustration is in fact weakly lifted by an anisotropic Dzyaloshinskii-Moriya (DM) interaction and that there is an interlayer coupling of J"=8 K. This averaged value was derived from bulk magnetic susceptibility. A theoretical study using the method of perturbative continuous unitary transformations estimates a higher interlayer coupling of approx. 15 K. Strictly speaking, due to the buckling of the CuBO3 plane, two types of interlayer interaction are necessary, although only the averaged value could be estimated from mean field approximations. Thus a precise modeling of SCBO must also take into account the DM interaction as well as the interlayer coupling.

The goal of this experiment was to complete the investigation of the out of plane Q-dependence of triplet excitation in the compound SrCu2(BO3)2 (SCBO) using the IN8 spectrometer, using the preliminary results obtained on the cold triple axis TASP and the thermal triple axis EIGER in PSI,Switzerland.

The sample was a 3g single crystal of SCBO with (110) x (001) in scattering plane held on an Al sample holder, inserted in an orange cryostat and cooled to 1.5 K. On IN8, we used the Si monochromator, the PG analyser with fixed k_f=2.662, and no collimation.
Based on the EIGER experiment, we focused on Q=(1 1 L) and Q=(1.5 1.5 L), and we first performed constant-Q scans in order to identify the energy of the modes, and check consistency with previous results, shown in Figure 1.

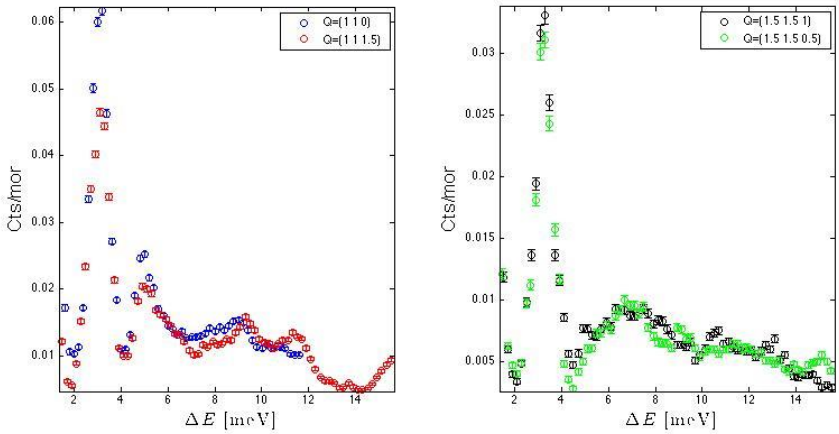

Fig 1: Energy scans at Q=(11L) (left) for L=0 and 1.5 and Q=(1.5 1.5 L) (right) at L=0.5 and 1

We then did a series of QL scans for L=-4 to 4 at constant energy ΔE= 3, 4.85 and 9 meV for Q=(1 1 L), ΔE=3, 4.85, 7 and 11 meV for Q=(1.5 1.5 L), at 1.5K. There appeared to be a lot of spurious signal on top of our magnons. Not all are identified, but some might be coming from Al phonons. We chose the cleanest scans and improved statistic.
In order to separate phonons from our magnons, we did similar sets of scans at 15K (at this temperature the magnons should be completely damped out) , in order to use the result as background for our base temperature data. Figure 2 shows the result of this analysis.

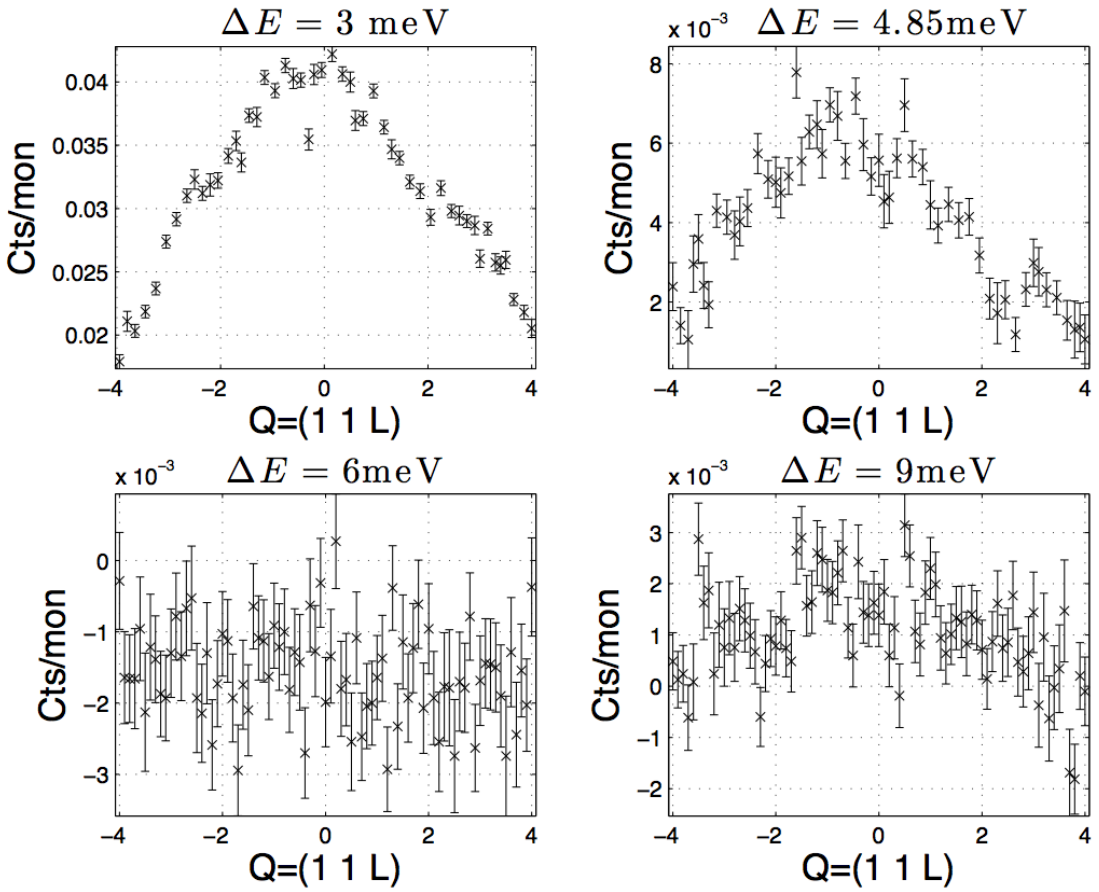

Figure 2: Difference between the 1.5K and 15K QL scans at ΔE=3, 4.85 6 and 9 meV

In order to confirm the absence of magnon at 15K, and to separate phonons from spurions, we also went well above the magnons' critical temperature with 150K, and did a set of energy scans at constant Q=(1 1 0), Q=(1 1 1.5) and Q= (1.5 1.5 0.5). The 9 meV mode clearly seemed to have a phononic component, which explains that the intensity varyiation as a function of QL does not follow the magnetic form factor dependence. However, the 3meV and 4.85 meV mode seem to phonon free and to show a behavior consistent with a 2D system.