Experimental report

24/03/2021

Proposal:	**4-05-771**	**Council:**	10/2019

Title: Threshold effect and the continuumof spin excitations in the octupolar quantum spin ice Ce2Sn2O7

Research area: Physics

This proposal is a new proposal

Main proposer: **Romain SIBILLE**

Experimental team: Markus APPEL
Elsa LHOTEL

Local contacts: Markus APPEL

Samples: Ce2Sn2O7

Instrument	Requested days	Allocated days	From	To
IN16B Si 111 BATS	5	3	01/03/2021	04/03/2021

Abstract:

Our recent measurements on the pyrochlore magnet Ce2Sn2O7 demonstrate that a quantum liquid of magnetic octupoles develops below about 1 K in this material. This exotic state is qualitatively new and was revealed by experiments using thermal neutrons, in which a liquid-like signal appears at high momentum transfer due to the peculiar form factor of higher-rank multipoles. Our current understanding of this remarkable phase of matter is that spin excitations have a dipolar character and thus should be measurable using low-energy inelastic spectroscopy. This indeed appears to be the case based on a short test experiment on IN5. We propose to measure the excitation spectrum of Ce2Sn2O7 in greater details using IN16B, in order to gain energy resolution. In particular, we will finely characterise the lower edge of the continuum, for which precise theoretical predictions are newly available and indicate that a 'threshold' effect should be observed in quantum spin ices. We expect these results will complement our existing data and will contribute to provide a 'smoking-gun' signature of a 3D quantum spin liquid - a rare opportunity in general, and a great one for backscattering!

Experiment # 4-05-771: Threshold effect and the continuum of spin excitations in the octupolar quantum spin ice Ce2Sn2O7

A large powder sample of $Ce_2Sn_2O_7$, placed in a copper can, was mounted on a dilution fridge. The can was filled with few bars of He in order to have as efficient cooling as possible without bringing additional difficulties to the experiment. Once base temperature of the dilution fridge reached, additional time was needed so as to thermalize the sample. This step took a few hours due to the powder nature of the sample. The actual temperature of the sample was estimated based on fits performed on the inelastic spectrum of the sample using two Lorentzian functions weighted by the Bose factor. Meanwhile, two instrumental resolutions were chosen to carry out the experiment. First one with an energy resolution of 2μeV over a window from -0.15 to 0.2 meV (res6, “high” flux). The second one with a resolution of 0.5 μeV from -0.16 to 0.3 meV (res4, “low” flux). After complete stabilization of the inelastic signal, the sample’s temperature was found to be about 200mK. Spectra were collected at base temperature, 0.4, 0.8, 1.2 and 5 K using the res6 configuration. Additional spectra were measured using the res4 configuration at base temperature, 0.8 and 5 K.

Data sets were reduced using a Mantid routine, summing over the different detectors. Subsequently, the spectrum measured at 5K was subtracted from the others in order to recover the imaginary part of the dynamic spin susceptibility (assuming no magnetic correlation/order at 5 K, which is reasonable judging from previous measurements). The signal was also corrected for the Bose factor. Resulting signals in the positive energy exchange channel were subsequently fitted using a Lorentzian, as can be seen in Figure 1, providing useful information such as the energy gap (~0.045 meV) and the “width” of the signal (~0.02 meV). Furthermore, the Q-dependence of the signal is under consideration. The res6 configuration showed additional intensity at very low energy transfer (Figure 1). This could be better resolved using the res4 configuration (Figure 2). This signal seems to be located at around 0.023 meV, thus very close to the elastic line. An even higher energy resolution would be required to further characterize this yet unidentified low energy excitation.

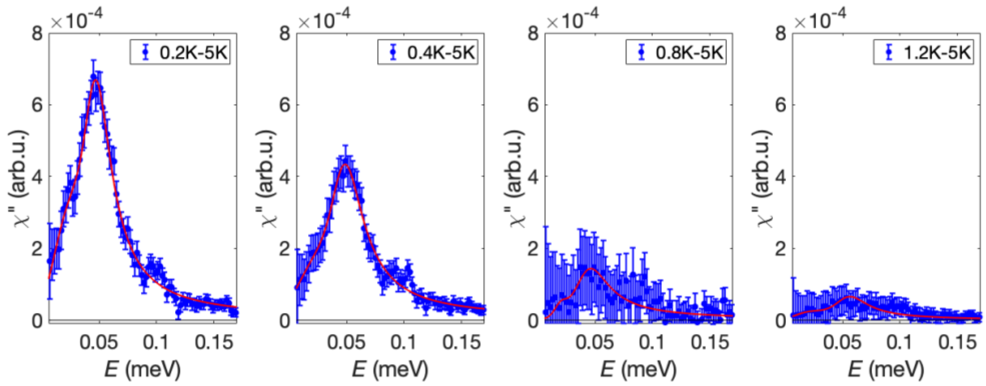

Figure 1: Imaginary part of the dynamic spin susceptibility obtained by subtracting data recorded at 5K to data obtained at lower temperatures in the correlated regime. The above data were collected with the res6 configuration. The main excitation was fitted using a Lorentzian function. The fit of the low energy one was attempted using a Gaussian function. Additional intensities around 0.1 meV might stem from the sample environment and would thus require correction using vanadium and empty scans (performed but yet to be applied).

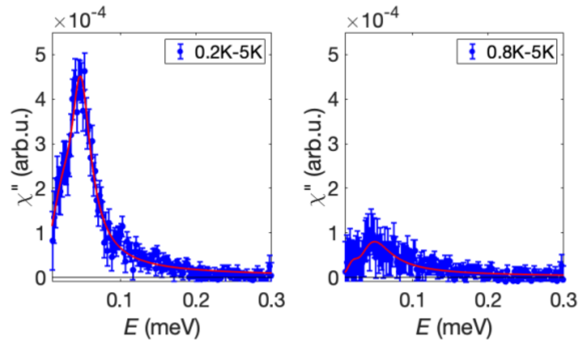

Figure 2: Imaginary part of the dynamic spin susceptibility obtained by subtracting data recorded at 5K to data obtained at lower temperatures in the correlated regime. The above data were collected with the res4 configuration. Data were re-binned to improve statistics and fitted using the same method than for data measured with the res6 configuration.