# Experimental report

22/03/2020

**Proposal:** **4-05-770**

**Council:** 10/2019

**Title:** Spin excitations of a quantum liquid of octupoles

**Research area:** Physics

**This proposal is a resubmission of 4-05-747**


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**Samples:** $Ce_2Sn_2O_7$

| Instrument | Requested days | Allocated days | From | To |
|---|---|---|---|---|
| IN5 | 3 | 3 | 03/02/2020 | 06/02/2020 |


## Abstract:

Our recent measurements on the pyrochlore magnet $Ce_2Sn_2O_7$ demonstrate that a quantum liquid of magnetic octupoles develops below about 1 K in this material. This exotic state is qualitatively new - at least experimentally - 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 cold neutron inelastic spectroscopy. This indeed appears to be the case based on a short test experiment on IN5, which we need to extend by measurements at several temperatures. We propose to measure the excitation spectrum of $Ce_2Sn_2O_7$ using IN5. We expect these results will complement our existing data and contribute to an important discovery.

**Experiment # 4-05-770: Spin excitations of a quantum liquid of octupoles**

A large powder sample of $Ce_2Sn_2O_7$ (~30g), 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 base on fits performed on the inelastic spectrum of the sample using various models (single Lorentzian, double Lorentzian, damped harmonic oscillator). Meanwhile, an incident wavelength of 10 Angstrom was chosen to carry out the experiment. After complete stabilization of the inelastic signal (~12h), the sample's temperature was found to be about 200mK.
After measuring at this base temperature, the remaining time was divided into six segments including measurements at five temperatures (400mK, 800mK, 1.2K, 2.3K, 5K) as well as an empty copper can. This was performed in such a way that different data sets will have similar statistics, allowing for a meaningful data analysis involving subtraction of data sets.
After careful study of the raw data, selected data sets of each temperature were carefully reduced through a Mantid routine. Figure 1 shows the evolution of the inelastic signal upon temperature change, which, as expected for this compound, takes the shape of a continuum of excitations. Data sets were then subtracted to each other, taking into account the impact of the Bose factor. Resulting signals in the positive energy exchange channel were subsequently fitted using a Lorentzian, as can be seen in figure 2-6, providing useful information such as the energy gap and the "width" of the signal. Furthermore, the Q-dependence of the signal is under consideration.

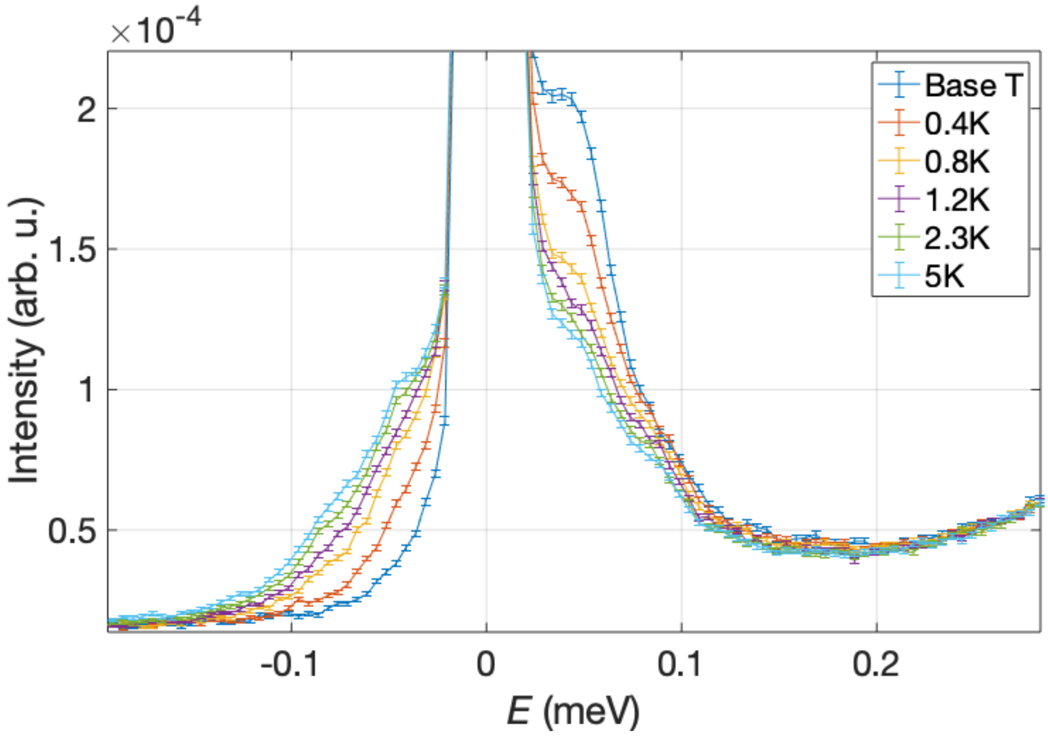


Figure 1: Evolution of the energy spectrum upon cooling. Incident energy was 0.81804meV (wavelength of 10 Angstrom).

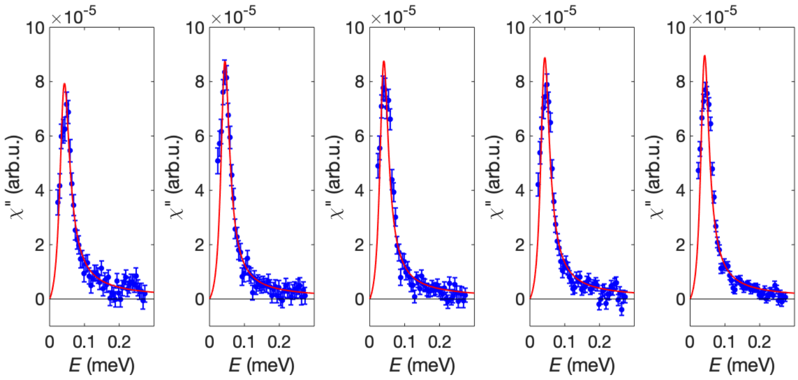


Figure 2: Imaginary part of the dynamic spin susceptibility obtained by subtracting data recorded at 5K to data obtained at 200mK. Different panels correspond to different Q-range: Q = 0.3 ± 0.1 Å$^{-1}$, Q = 0.5 ± 0.1 Å$^{-1}$, Q = 0.7 ± 0.1 Å$^{-1}$, Q = 0.9 ± 0.1 Å$^{-1}$, Q = 0.75 ± 0.25 Å$^{-1}$.

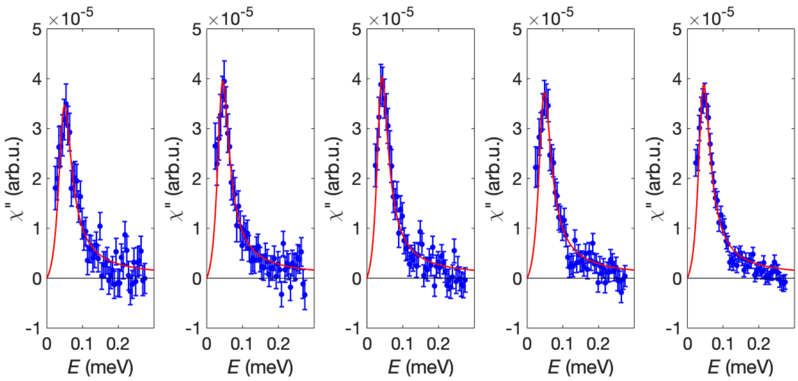


Figure 3: Imaginary part of the dynamic spin susceptibility obtained by subtracting data recorded at 5K to data obtained at 400mK. Different panels correspond to different Q-range: Q = 0.3 ± 0.1 Å$^{-1}$, Q = 0.5 ± 0.1 Å$^{-1}$, Q = 0.7 ± 0.1 Å$^{-1}$, Q = 0.9 ± 0.1 Å$^{-1}$, Q = 0.75 ± 0.25 Å$^{-1}$.

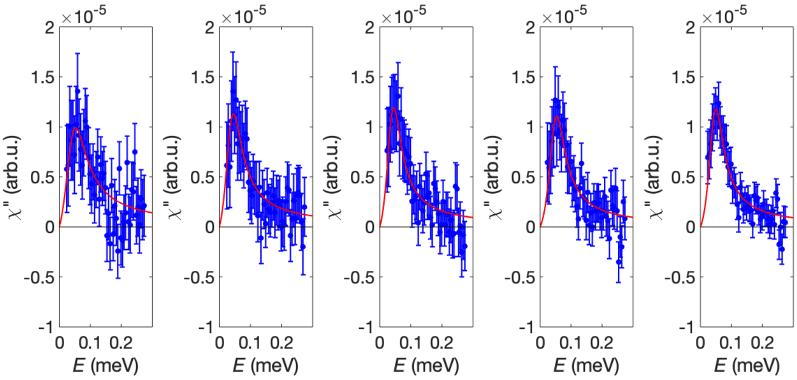

Figure 4: Imaginary part of the dynamic spin susceptibility obtained by subtracting data recorded at 5K to data obtained at 800mK. Different panels correspond to different Q-range: Q = 0.3 ± 0.1 Å$^{-1}$, Q = 0.5 ± 0.1 Å$^{-1}$, Q = 0.7 ± 0.1 Å$^{-1}$, Q = 0.9 ± 0.1 Å$^{-1}$, Q = 0.75 ± 0.25 Å$^{-1}$.

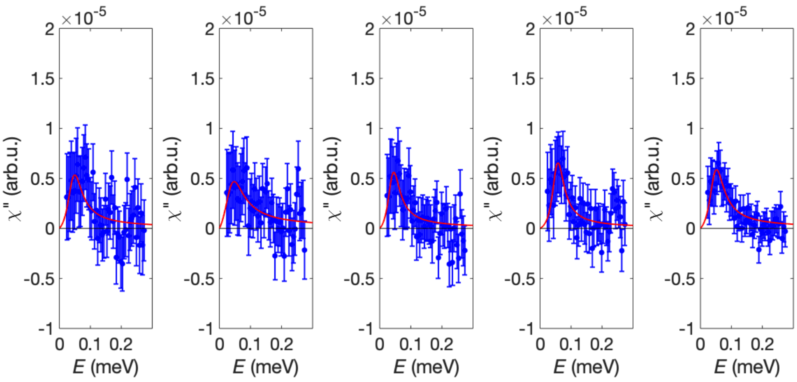

Figure 5: Imaginary part of the dynamic spin susceptibility obtained by subtracting data recorded at 5K to data obtained at 1.2K. Different panels correspond to different Q-range: Q = 0.3 ± 0.1 Å$^{-1}$, Q = 0.5 ± 0.1 Å$^{-1}$, Q = 0.7 ± 0.1 Å$^{-1}$, Q = 0.9 ± 0.1 Å$^{-1}$, Q = 0.75 ± 0.25 Å$^{-1}$.

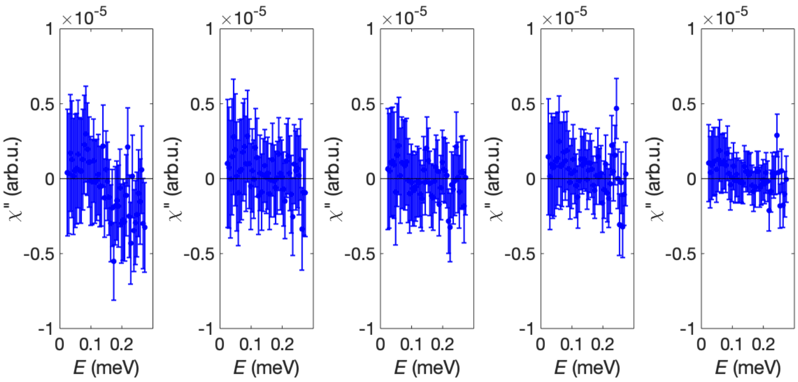

Figure 6: Imaginary part of the dynamic spin susceptibility obtained by subtracting data recorded at 5K to data obtained at 2.3K. Different panels correspond to different Q-range: Q = 0.3 ± 0.1 Å$^{-1}$, Q = 0.5 ± 0.1 Å$^{-1}$, Q = 0.7 ± 0.1 Å$^{-1}$, Q = 0.9 ± 0.1 Å$^{-1}$, Q = 0.75 ± 0.25 Å$^{-1}$.