Experimental report

04/04/2016

Proposal: **4-01-1452** **Council:** 10/2014

Title: Spin dynamics in Yb2Ti2O7

Research area: Physics

This proposal is a new proposal

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Samples: Yb2Ti2O7

Instrument	Requested days	Allocated days	From	To
THALES	0	5	18/06/2015	23/06/2015
IN12	7	0		

Abstract:

We propose to measure the magnetic excitations in Yb2Ti2O7. This highly frustrated magnet shows a transition towards a ferromagnetic state, recently interpreted as a Higgs transition from a magnetic Coulomb liquid to a ferromagnet. Recent data collected at LLB provide evidence for unconventional excitations, very broad in energy, reminiscent of a continuum rather than well defined spin-wave-like excitations. Actually, theoretical predictions argue that such spectra could be the signature of a spinon continuum with a signature in the <S+S-> response function. We propose to carry out a polarized neutron study to check this prediction.

Experimental report on Exp 4-01-1452 @THALES

"Polarization of the continuum in the pyrochlore magnet $Yb_2Ti_2O_7$"

Geometrical magnetic frustration often suppresses the usual thermal magnetic ordering in favor of more original and "disordered" states of matter such as spin ices and spin liquids, characterized by complex structures and fractional excitations. In this context, the rare earth pyrochlores $R_2Ti_2O_7$, constructed on the basis of tetrahedra connected by their vertices, are model systems and form the archetype of geometric frustration in three dimensions [1]. Depending on the crystal field scheme of the rare earth (leading to Ising, XY, or Heisenberg anisotropies) and the spin-pair interactions (dipolar and/or exchange), different ground states are stabilized.

$Yb_2Ti_2O_7$, at the heart of this proposal, exhibits an peculiar behavior: a crossover from paramagnetic to a correlated regime first occurs around few Kelvin (note that θ_{CW} ~ 1 K). This regime is followed by a first order transition towards a canted ferromagnetic order at Tc = 240 mK [6-9]. In this former structure, the spins are slightly tilted from their easy plane in order to minimize the rather strong ferromagnetic exchange energy (see Fig. 1b). This transition, not always reproducible because of the crystalline quality of the samples [6-10], has however been observed at Tc = 175 mK in our own single crystals by magnetic susceptibility and specific heat measurements [12]. To puzzle out this behavior, the (anisotropic) exchange tensor has then been determined by comparing the excitation spectrum measured in applied magnetic fields H = 2 and 5 T to RPA and/or linear spin wave calculations [11,12] (the magnetic field inducing a robust magnetic ordered state with well-defined spin-wave excitations). These parameters succeed in reproducing the zero-field first-order transition toward the ferromagnetic order observed experimentally [13,14], but place $Yb_2Ti_2O_7$ extremely close to an antiferromagnetic phase, and, in any case, far from the canonical quantum spin liquid state [12]. These results suggest that the unconventional ground state of $Yb_2Ti_2O_7$ is governed by strong quantum fluctuations arising from the competition between those phases [12].

Spin dynamics measurements carried out on the 4F2 triple-axis spectrometer (LLB, Saclay) have shown that the inelastic response is a "continuum" characterized by a very broad and almost flat dynamical response which extends up to 1−1.5 meV, coexisting or not with a quasi-elastic response depending on the wave-vector (see Figs. 2 and [12]). **To get more insight into this problem, we proposed to measure the full polarization of these spectra at THALES by means of a polarized neutron study in the paramagnetic, short-range correlated and ordered regimes. The set-up was however not available and we had to go back to a "standard" measurement as a function of temperature.**

The outcome of the present experiment is that, while the inelastic component of this dynamical response smoothly disappears along with the correlations above T ~ 4 K, the broad QE component persist up to at least 150 K (Fig. 3). Moreover, this QE signal is not consistent with classical spin dynamics simulations and cannot be understood as simple paramagnetic fluctuations [12], since the exchange tensors determined in [11,12] predict a $FWHM_{QE}$ ~ 0.6 meV, versus 1-1.5 in the neutron experiments.

The initial experiment with polarization analysis has been submitted again for this call.

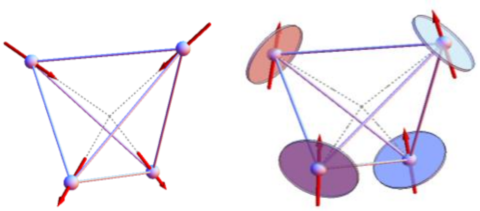

Fig1 : 2-in 2-out ice rule (left) and canted ferromagnetic state (right) on one tetrahedron

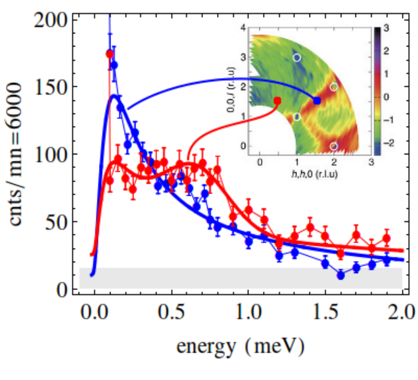

Fig. 2 : (4F2) Energy scans at ***Q*** = (1.5,1.5,1.5) (blue) and (0.5,0.5,1.5) (red) obtained at *T* = 200mK and *kf* = 1.15 A-1. Plain lines : Fit considering a QE signal (blue) and a guid to the eye (red) since many model could fit the corresponding data (see text). Inset : diffuse scattering in the (*h,h,l*) plane from ref. [10].

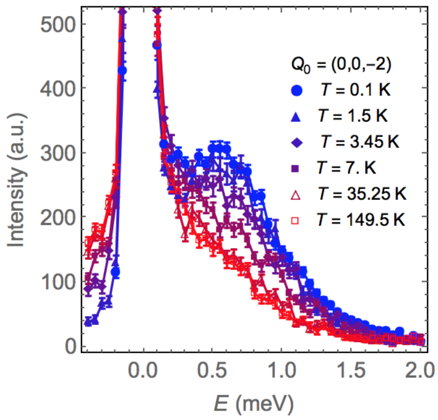

Fig. 3 : (Thales) Energy scans at Q=(0,0,-2) at different temperatures and kf=1.15A-1

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