Experimental report

19/03/2019

Proposal: **4-05-647** **Council:** 4/2016

Title: Polarization of the continuum in the pyrochlore magnet Yb2Ti2O7

Research area: Physics

This proposal is a new proposal

Main proposer: **Julien ROBERT**

Experimental team: Elsa LHOTEL
Julien ROBERT
Sylvain PETIT

Local contacts: Stephane RAYMOND

Samples: Yb2Ti2O7

Instrument	Requested days	Allocated days	From	To
IN3	0	1	01/06/2016	02/06/2016
THALES	7	0		
IN12	0	7	06/06/2016	13/06/2016

Abstract:

The proposed experiment is part of our systematic experimental studies of geometrical frsutration in various pyrochlore R2M2O7 (R = Rare earth, M an element like Ti, Sn, Zr). Here, we plan to study the polarization of the magnetic excitations of the pyrochlore ferromagnet Yb2Ti2O7 on the THALES spectrometer. Despite its long range ordering, this remarkable material shows a broad spectrum that persits up to high temperature and that is tentatively interpreted in terms of a continuum. This feature likely originates from competing ferromagnetic and antiferromagnetic instabilities. The polarization analysis of this continuum is expected to give new insight into the origin of this feature.

Experimental report on Exp 4-05-647
Polarization of the continuum in the pyrochlore magnet $Yb_2Ti_2O_7$

This proposal aims at investigating the spin dynamics in the pyrochlore material $Yb_2Ti_2O_7$. It has aroused a lot of interest in the last years in the context of spin ice and quantum spin ice [1-6].

This compounds shows a crossover from a paramagnetic to a correlated regime around a few Kelvin (θ_{CW} ~ 1 K), followed by a first order transition towards a canted ferromagnetic order at Tc = 240 mK [7-9]. In this structure, the spins are slightly tilted away from their local easy plane in order to minimize the rather strong ferromagnetic exchange energy (see Fig. 1). This transition, not always reproducible because of the crystalline quality of the samples [10] has however been observed at Tc = 175 mK in our single crystal by magnetic susceptibility and specific heat measurements. Furthermore, our spin dynamics investigations have revealed an unconventional spectrum, which takes the form of a continuum characterized by a very broad and roughly flat profile extending up to 1-2 meV (figure 2) [11], on top of a quasi-elastic response which takes the form or "rod" scattering in reciprocal space (see the inset in Figure 2). An applied magnetic field induces a robust magnetic ordered state and rearranges this spectrum to eventually form classical spin waves. This important feature allows a standard analysis based on linear spin wave theory. Bases on such analysis, we could determine the (anisotropic) exchange tensor at play. This work explains quite well the polarization of the rods determined by Chang et al [6]. Furthermore, at variance with previous reports, claiming that $Yb_2Ti_2O_7$ might be a quantum spin ice candidate, our conclusion is that $Yb_2Ti_2O_7$ is extremely close to an antiferromagnetic phase (see [11] and [12]).

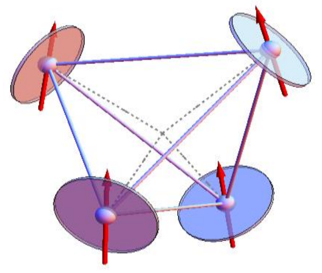

Figure 1: sketch of the canted ferromagnetic state observed in $Yb_2Ti_2O_7$.

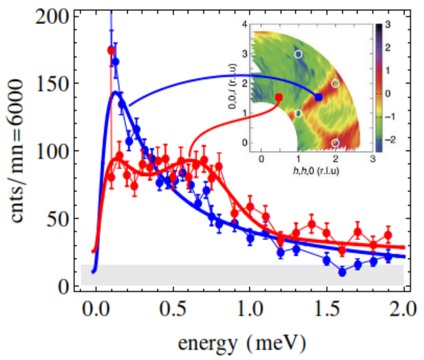

Figure 2 (4F2, LLB): the spin excitation spectrum in $Yb_2Ti_2O_7$ takes the form of a broad continuum extending up to about 1.5 meV. The figure shows the dynamical response at two different Q points.

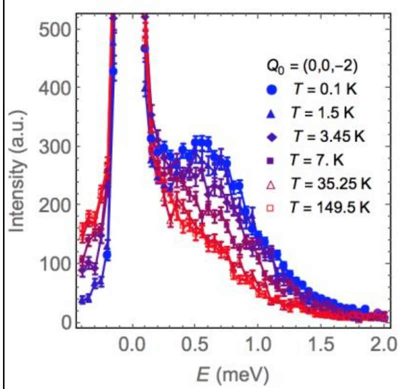

Figure 3 : (Thales) Energy scans at Q=(0,0,-2) at different temperatures. The data were taken with a final wavevector kf=1.15A $^{-1}$.

To get more insight into this issue and understand this peculiar spin dynamics, new studies have been initiated:

i) In a further experiment at THALES, we could show that some signal persists up to at least 150 K (Fig. 3). This is not consistent with classical spin dynamics simulations and cannot be understood as simple paramagnetic fluctuations [11], since the amplitude of the exchange tensors are of the order of a few K.

ii) The present 4-05-647 experiment carried out at IN12 allowed us to determine the polarization of the flat spectrum. We measured the NSF and SF channels for different Q positions at 50 and 500 mK. These Q-positions were chosen to map out the "rods" as well as the regions in Q-space where the continuum is observed. These experiments confirm the strong anisotropy of the quasi-elastic rod-like correlations [6]. In contrast, to the accuracy of our experimental set-up, the inelastic spectrum appears isotropic, a feature observed at 50 and 500 mK. This is illustrated in Figure 4, which displays the response at a Q position away from the rods. Our analysis of exchange interactions [11] allows to understand quite well these observations, attributed to the effect of competing ferromagnetic and antiferromagnetic fluctuations.

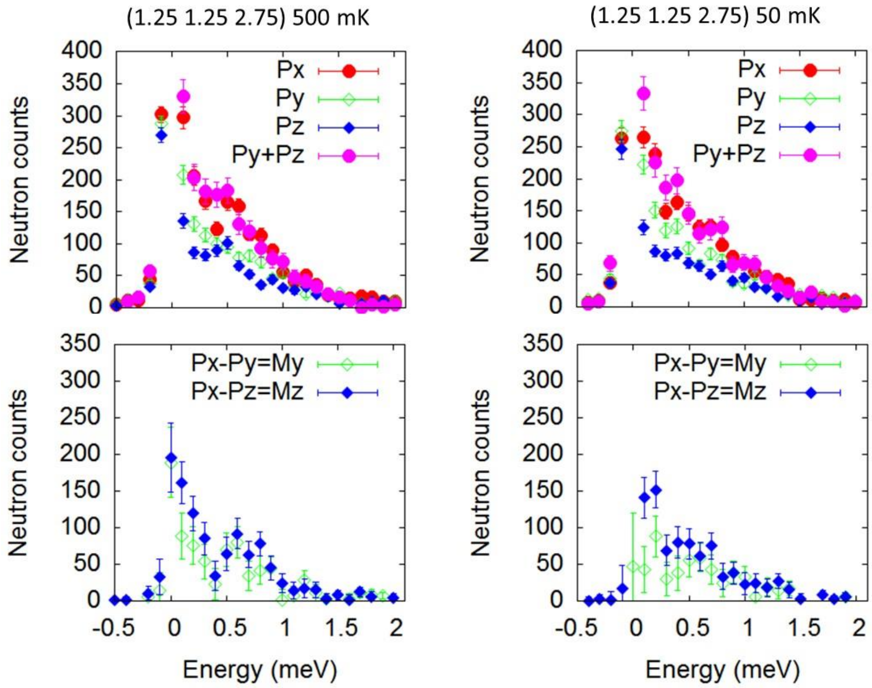

Figure 4 (IN12, 4-05-647 experiment): inelastic response measured at 50 and 500 mK at two Q positions away from the rods. "My" and "Mz" are very similar suggesting isotropic fluctuations.

To determine the origin of the persisting inelastic signal (Figure 3), we now aim at measuring in the high temperature range using polarization analysis and eventually check the magnetic nature of this signal.

[1] J. S. Gardner, M. J. P. Gingras, J. E. Greedan, Rev. Mod. Phys. **82**, 53 (2010).

[2] K.A. Ross et al. Phys. Rev. X, **1**, 021002 (2011)

[3] L. Savary et al. Phys. Rev. Lett. **109**, 167201 (2012).

[4] R. Applegate et al. PRL **109**, 097205 (2012)

[5] J. D. Thompson et al, PRL **119**, 057203 (2017)

[6] L. Chang et al, Nature Comm. DOI: 10.1038/ncomms1989 (2012)

[7] J.A. Hodges et al., J. Phys. Condens. Matter **13**, 9301 (2001).

[8] Y. Yasui et al., J. Phys. Soc. Jpn. **72**, 3014 (2003).

[9] H.W. J. Blöte, R. F. Wielinga, and W. J. Huiskamp, Physica (Amsterdam) **43**, 549 (1969).

[10] J Gaudet et al, Phys. Rev B **93**, 064406 (2016)

[11] J. Robert et al. PRB **92**, 064425 (2015)

[12] H. Yan et al., Phys. Rev B **95**, 094422 (2017)