Experimental report

04/04/2016

Proposal: 4-02-440 **Council:** 10/2014

Title: Mechanism of the antiferromagnetictransition in the geometrically frustrated magnet Er2Ti2O7

Research area: Physics

This proposal is a new proposal

Main proposer: Sylvain PETIT

Experimental team: Elsa LHOTEL
Solène GUITTENY
Sylvain PETIT

Local contacts: Hannu MUTKA
Jacques OLLIVIER

Samples: Er2Ti2O7

Instrument	Requested days	Allocated days	From	To
IN5	5	6	15/07/2015	21/07/2015

Abstract:

We would like to study the evolution of the spin gap as a function of the temperature and of magnetic field in the geometrically frustrated pyrochlore Er2Ti2O7. The aim of the experiment is to determine the mechanism responsible for the stabilization of the long range order in this material. Indeed, recent reports claim that it might be "order by disorder", but the CEF small anisotropies might also be at play. We hope to be able to get a set of results allowing to discriminate between these two scenarii.

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Geometrical frustration and the associated strong degeneracy of the ground state manifold very often prevent the stabilization of standard magnetic phases. At this point, quantum or thermal fluctuations enter into play to select and stabilize a particular configuration (or a subset of configurations), a phenomenon called "order by disorder" [2]. It has been recently argued that the pyrochlore compound $Er_2Ti_2O_7$ is a model system to study these subtle effects [3,4,5] (in $Er_2Ti_2O_7$, the rare-earth magnetic moments are localized at the vertices of corner-sharing tetrahedra. They present a strong XY-like anisotropy, the XY planes being perpendicular to the local <111> ternary axes).

Actually, $Er_2Ti_2O_7$ undergoes a transition towards an antiferromagnetic k=0 Néel phase below T_N=1.2K [5,6,7,8]. This magnetic ordering was described in detail by neutron polarimetry (ψ2 vector in Γ5 representation), as a non-collinear antiferromagnetic structure, with magnetic moments, perpendicular to the local <111> axes, and aligned along <211> [9].

Several theoretical works have proposed that this peculiar ordering can be explained by a quantum order-by-disorder mechanism [10,11]. This model is based on a pseudo spin ½ Hamiltonian, spanning the ground crystal field doublet. It is characterized by an extensive degeneracy which is relieved by quantum zero point fluctuations contribution out of the ψ2 configuration. In a recent publication, we have proposed another mechanism called “order by virtual crystal field excitation” based on a mean field model written in terms of the actual Er^{3+} magnetic moment and taking into account the full CEF scheme (Ref [12,13]). Here, the ψ2 configuration is selected by a small anisotropy due to the exchange induced mixing between the CEF states. We have shown that the spin dynamics calculated in both models compare quite well with the neutron data recently collected at IN5 (see [13] as well as figure 1). Further, both models predict the opening of a spin gap at zone centers. The data of Ref [14] along with previous IN5 experiment confirm this prediction (see [13] and Figure 2), even if the experimental gap is larger, 43 µeV instead of 21 and 15 in the two above models.

Unfortunately, the two models remain quite difficult to distinguish. As a further possible test, we proposed in the present experiment to apply a magnetic field, and see how the spin gap evolves. With 8.5 Å the energy resolution was sufficient to observe the spin gap at the Q=(111) (see Fig. 4) between 0 and 1.5 T. The spin gap as a function of field measured at Q=(111) is then shown in Figure 3–left.

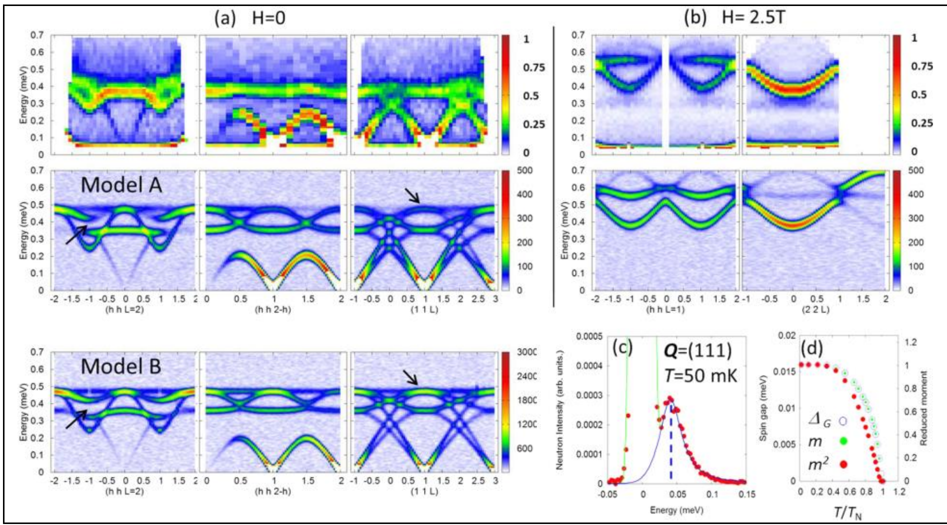

Figure 1: IN5 data taken at 50 mK along with spin-wave (Model B) and RPA calculations (Model A). Both models give similar dispersions and capture quite well the experimental observations

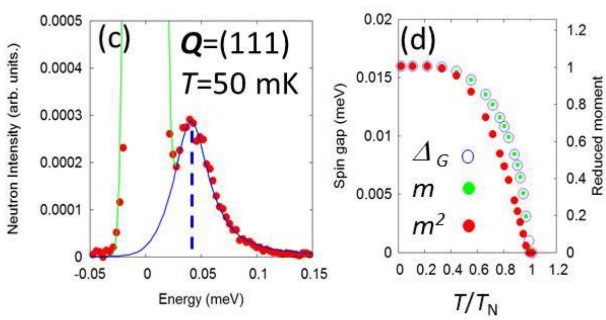

Figure 2 (from [13]) : (left), spin gap at Q=(111) (using the high resolution set-up, 8.5 Å), (right) evolution of the gap and order parameter in the framework of our model (A).

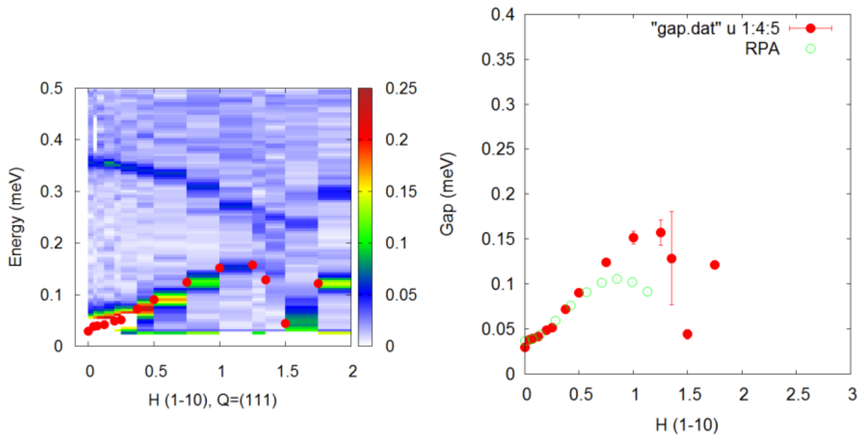

Figure 3: spin gap evolution as a function of magnetic field applied along (110).

The prediction of our model "order by virtual crystal field excitation" corresponds to the open green points in Figure 3-right. The interpretation of the data is still in progress.

References

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Figure 3 : raw data taken at 50 mK along (11L) for various fields.