Experimental Report

Proposal: **4-01-1301** **Council:** 10/2012

Title: Neutron spin echo study of the spin dynamics of the geometrically frus trated pyrochlore Er2Ti2O7 in themagnetically ordered state.

This proposal is continuation of: 4-03-1693

Researh Area: Physics

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Samples: Er2Ti2O7

Instrument	Req. Days	All. Days	From	To
IN11	15	12	11/03/2013	21/03/2013
			21/03/2013	23/03/2013

Abstract:

The geometrically frustrated magnets on a pyrochlore lattice are attracting a lot of attention. In these systems where the magnetic ions sit on a lattice of corner sharing tetrahedra, a large variety of exotic magnetic states is observed. The reason is rooted in the different possible crystal-electric-field anisotropies and the large degeneracy of the ground state energy which is favored by the geometry of the lattice. The actual ground state depends on the balance of several types of magnetic interactions. The compound of interest here is the planar antiferromagnet Er2Ti2O7 which shows magnetic order, but an unexpected dynamical component in the nanosecond time range is inferred by muon spin relaxation measurements deep in the ordered state. This unconventional coexistence of static and dynamical components in the ordered state was previously found for the Ising-like Tb2Sn2O7. In our initial high-resolution measurement on IN11, we have evidenced spin dynamics in the ordered state of Er2Ti2O7 by the neutron spin-echo technique. We now propose to go further into this study to shorter spin-echo times and lower temperatures to complete this study to produce publishable results.

Neutron spin echo study of the dynamics of the geometrically frustrated pyrochlore $Er_2Ti_2O_7$

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Geometrically frustrated systems have received much attention from experimentalists and theorists alike [1]. Among these systems the pyrochlore structure compounds $R_2M_2O_7$ (R is a trivalent rare earth metal and M a tetravalent diamagnetic element like Ti or Sn) where the R ions form a sublattice of corner sharing regular tetrahedra, are particularly prone to frustration [2]. Exotic magnetic ground states have been found for these insulators such as the spin-ice state for $Dy_2Ti_2O_7$, $Ho_2Ti_2O_7$, or $Ho_2Sn_2O_7$, and a magnetic analogue of the gas-liquid transition in ordinary matter for $Yb_2Ti_2O_7$. The compound of interest for the present study is the titanate $Er_2Ti_2O_7$. It displays a second order phase transition at $T_N \simeq 1.2$ K. The magnetic moment of an Er^{3+} ion is perpendicular to its local [111] axis with a saturation value of $3.25\,(9)\,\mu_B$ [3, 4]. The moments order in a non-collinear magnetic structure with a propagation vector $\mathbf{k} = (0, 0, 0)$. Recently we have inferred from μSR measurements [5] the presence of spin fluctuations in its magnetically ordered state. The main purpose of the current experiment was to pursue the characterisation further by neutron spin echo (NSE). A preliminary study [6] shows fast relaxation in both the paramagnetic and the ordered phases. Furthermore the dynamics of the magnetic correlations depend strongly on the Q wavevector investigated. However, the intermediate scattering function $S(Q, t)$ could not be fully characterised. The purpose of the continuation of this experiment was to use a smaller wavelength to probe shorter times.

The measurements were performed on IN11C at a wavelength $\lambda = 4.1$ Å. A 5 g powder of $Er_2Ti_2O_7$ filled an annular copper sample holder. A ^{3}He-^{4}He dilution fridge was used to reach temperature down to 80 mK. The resolution calibration was done at T=2 K with a magnetically "frozen" sample $Ho_{1.3}Y_{0.7}Ti_2O_7$ of the same annular geometry as our $Er_2Ti_2O_7$ sample. We measured the dynamics of the magnetic correlations for two positions of the detector at 20° and 50° covering respectively the wavevector ranges $0.13 \leq Q \leq 0.92$ Å^{-1} and $0.92 \leq Q \leq 1.65$ Å^{-1}.

The left panel of Fig.1 displays $S(Q, t)$ normalised by the elastic signal integrated in the range $0.13 \leq Q \leq 0.92$ Å^{-1} at $T = 0.08$ and 1.9 K, i.e. deep into the ordered phase and in the paramagnetic phase. A strong decay is observed in both states with a characteristic time of fluctuations $t_c \approx 5$ ps. While fast dynamics is expected above the transition temperature, this is more surprising to observe magnetic fluctuations with a similar time scale in the ordered phase.

The right panel of Fig.1 displays results of measurements performed with a linear time step to probe more efficiently the shorter times in the range $0.13 \leq Q \leq 0.92$ Å^{-1} at $T = 0.08$ and 1.9 K. The main unexpected result lies in the presence of damped oscillations in both sides of the magnetic transition.

In Fig.2 is displayed the Q-dependence of $S(Q, t)$ at 0.08 K (left panel) and 1.9 K (right panel). Oscillations are progressively damped as Q increases in both cases. At low temperature and high Q values, the signal does not go to 0 in the available time range: a static component appears which could be explained by the presence of a Bragg peak. In the paramagnetic phase, a slowing down of the magnetic fluctuations is observed as Q increases with a characteristic time $t_c \approx 0.02$ ns at $Q = 1.58$ Å^{-1}.

To conclude, finite energy excitations modes were evidenced from the presence of oscillations in both the ordered and paramagnetic phase. Furthermore, several relaxation channels are involved as the observed decay of $S(Q, t)$ is not purely exponential and strongly depends on the wavevector.

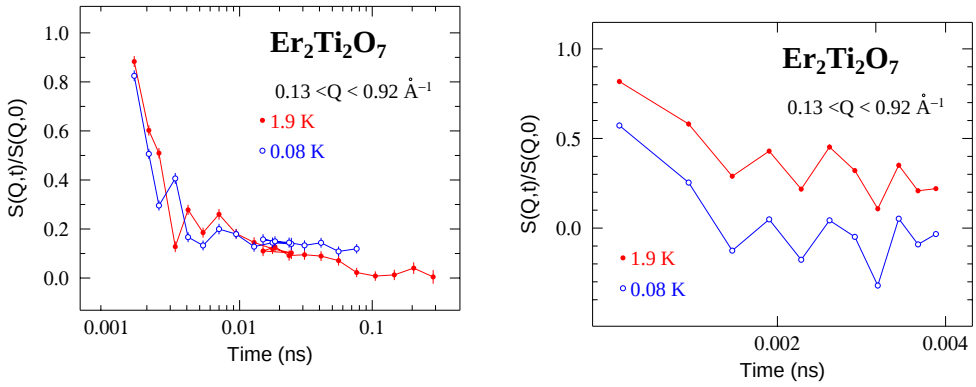

Figure 1: *Normalised intermediate scattering function $S(Q,t)$ measured by NSE on $Er_2Ti_2O_7$ recorded in both sides of the transition temperature at T=0.08 and 1.9 K with a wavevector integration range $0.13 \leq Q \leq 0.92$ Å^{-1}, and displayed in the logarithm (left) and linear (right) time scale to evidence respectively the full depolarisation of the signal and the damped oscillations at short times.*

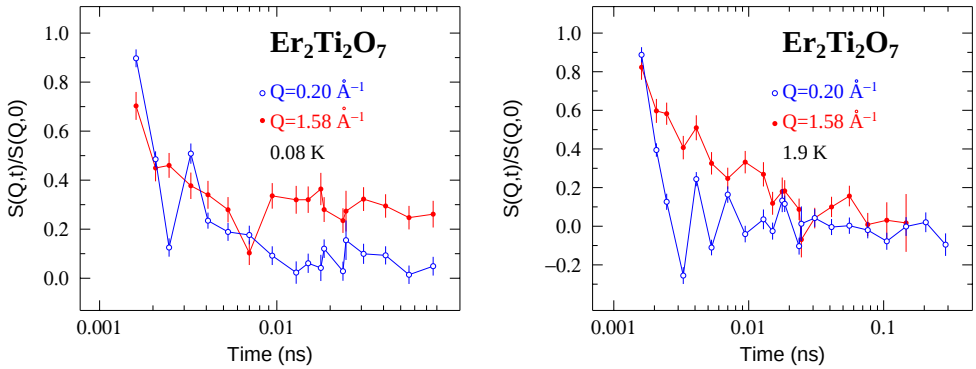

Figure 2: *Q-dependence of the normalised intermediate scattering function $S(Q,t)$ measured by NSE on $Er_2Ti_2O_7$ for $Q = 0.20$ Å^{-1} (integration range $0.13 \leq Q \leq 0.27$ Å^{-1}) and $Q = 1.58$ Å^{-1} (integration range $1.51 \leq Q \leq 1.65$ Å^{-1}) at $T = 0.08$ K (left panel) and $T = 1.9$ K (right panel).*

References

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