Experimental Report

15/10/2013

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Title: Study of magnetism and its dynamics in the geometrically frustrated magnet Nd2Sn2O7 by the backscattering technique

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Research Area: Physics

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Samples: Nd2Sn2O7

Instrument	Req. Days	All. Days	From	To
IN16	5	5	07/03/2013	12/03/2013

Abstract:

In the pyrochlore lattice systems the magnetic ions sit on a lattice of corner sharing regular tetrahedra. A large variety of ground states is observed due to geometrical frustration effects. The actual ground state depends on the balance between several types of interactions, e.g. exchange interactions between nearest and further neighbours, the dipolar interaction and the single ion anisotropy. This balance turns out to be extremely subtle since for instance the actual ground states observed in Tb2Ti2O7 and Tb2Sn2O7 are very different while only the Ti ion is substituted for Sn which are both non-magnetic.

In the series of the pyrochlore stannates, Nd2Sn2O7 has so far been the object of few investigations. It presents a well marked thermodynamic phase transition at 0.91 K. A neutron powder scattering is scheduled at ILL in order to determine its magnetic structure. Here we propose to study this system by the backscattering technique in order to determine its dynamical properties. This will help in finding out the key parameters which are relevant to explain the nature of the actual ground state adopted by a geometrically frustrated magnet.

Study of magnetism and its dynamics in the geometrically frustrated magnet $Nd_2Sn_2O_7$ by the backscattering technique.

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Geometrically frustrated magnetic systems have received great attention both from experimentalits and theorists [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].

In this experiment, we have studied the compound $Nd_2Sn_2O_7$, which displays a magnetic order seen by neutron diffraction and a persistence of the spin dynamics down to the lowest temperature, using the high-resolution backscattering spectrometer IN16 (neutron wavelength of 6.28 Å). We used 9.7 g of powder sample in annular geometry. The resolution of the spectrometer was determined using a vanadium sample of the same geometry.

In the left panel of Fig.1 are diplayed some spectra recorded at different temperatures. In the ordered phase, i.e. $T \leq 0.91\ K$, we observe a splitting of the nuclear levels as the incoherent cross section of the isotope ^{143}Nd is non negligible and these nuclei possess a nuclear spin $I = \frac{7}{2}$. This splitting originates essentially from the Zeeman effect due to the hyperfine field B_{hyp} created by the electronic $4f$ shell and secondly, the quadrupolar interaction due to the electric field gradient acting on the nucleus. The measured $B_{\mathrm{hyp}}(0) = 211.4(7)$ T corresponds to a spontaneous magnetic moment $m_{\mathrm{sp}}(0) = 1.665(6)\ \mu_{\mathrm{B}}$ using the hyperfine constant $\mathcal{A}_{\mathrm{hyp}} = 20.9(3)$ mT [3, 4, 5]. This value is similar to one found by neutron diffraction ($m_{\mathrm{SP}} = 1.7\ \mu_{\mathrm{B}}$ at very low temperature). In the paramagnetic phase, we only observe a quasielastic peak analyzed with a Lorentzian function convoluted by the resolution function. In the right panel of Fig.1 is displayed the temperature dependence of the spontaneous magnetic moment measured by magnetic neutron diffraction and neutron backscattering. Surprisingly, $B_{\mathrm{hyp}}(T)$ does not track $m_{\mathrm{sp}}(T)$.

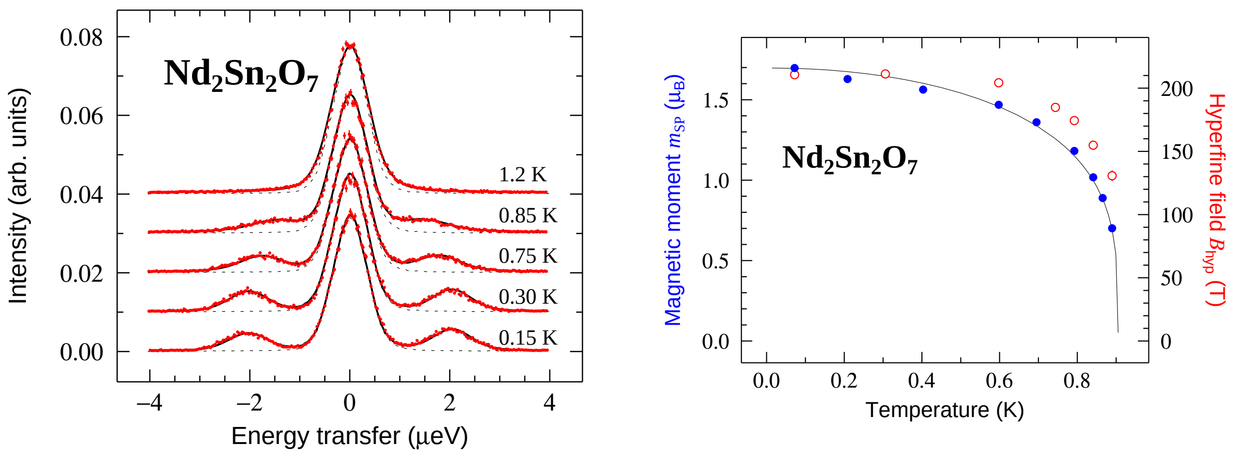
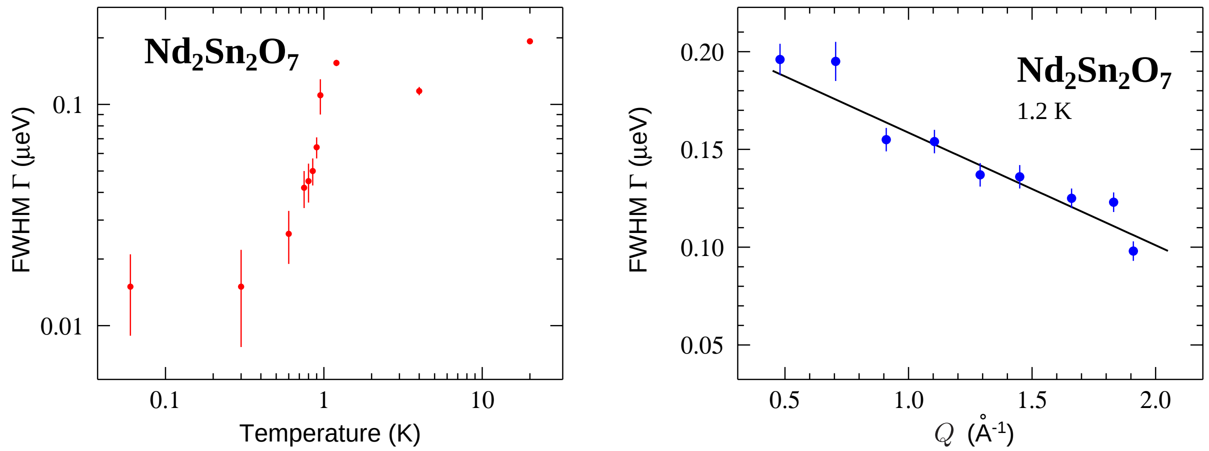


Figure 1: (Left) Neutron backscattering spectra recorded on IN16 at several temperatures in a 4 μeV energy window showing the temperature dependence of the nuclear splitting and the quasielastic signal in the paramagnetic phase. The black dashed line is the measured spectrometer resolution. The full black line is a fit of the data. (Right) Temperature dependence of the spontaneous magnetic moment m_{SP} inferred from the nuclear splitting measured by the backscattering technique (red circles) and from magnetic diffraction measurements at D1B (blue circles). The line is a guide to the eyes.

In the left panel of Fig.2, we report the temperature dependence of the quasielastic full-width at half-maximum $\Gamma(Q)$, showing a sharp decrease of the spins fluctuation time at the transition, whereas in the right panel of Fig.2, is displayed its wave-vector dependence measured at 1.2 K. It is too small to be estimated below T_c. A linear fit yields a proper description: $\Gamma(Q) = \Gamma(0) + a_Q Q$ with $\Gamma(0) = 0.21(1)$ μeV and $a_Q = -0.56(4)$ μeVÅ. To this $\Gamma(0)$ is associated a fluctuation time $\tau_0 = \hbar/\Gamma(0) = 3.1(1) \times 10^{-9}$ s.



(Left) Temperature dependence of the quasielastic width. The sharp decrease is indicative of the transition. (Right) Wave-vector dependence of the quasielastic full-width at half-maximum (FWHM) Γ in the paramagnetic phase at 1.2 K as deduced from the backscattering spectra. The solid line results from a linear fit described in the main text.

References

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