Experimental report

04/04/2016

Proposal: 4-01-1448 **Council:** 10/2014

Title: Spin Dynamics Under magnetic fieldin Pr2Zr2O7

Research area: Physics

This proposal is a new proposal

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Samples: Pr2Zr2O7

Instrument	Requested days	Allocated days	From	To
IN5	7	6	05/05/2015	12/05/2015

Abstract:

The pyrochlore compound Pr_2 Zr_2 O_7 is very likely a “quantum spin ice” candidate, with similar physics as encountered in the celebrated Tb_2 Ti_2 O_7. Recently, neutron experiments using applied magnetic field along the [1-10] direction have provided clues to understand the magnetic behavior of the zirconate sample. Together with these observations, the study of the magnetic excitations under a magnetic field applied in the [111] direction would lead to a more complete analysis of Pr_2 Zr_2 O_7 including the calculation of the exchange parameters of the Hamiltonian. In this context we would like to carry out a 7 days experiment on IN5 (with the dilution fridge and a cryomagnet).

Experimental report on Exp. 4-01-1448

In this proposal we asked for beam time at IN5 to study the spin excitation in $Pr_2Zr_2O_7$ under a magnetic field applied along [111]. Treatments had been applied to "clean" the sample as much as possible, especially eliminating Pr4+, and eventually providing a beautiful green transparent single crystal. However, it also became very fragile; unfortunately it broke during the preparation of the experiment. We had to change our position, and decided to study another member of the family $Nd_2Zr_2O_7$. In the meantime, a new high quality single crystal has been grown by our collaborators from Warwick University. The sample is available for the next round.

It is worth noting, in addition, that the experiment on $Nd_2Zr_2O_7$ was quite successful, as we have discovered in this particular material a novel fractionalization mechanism called "fragmentation". The results have been published in Nature Physics (DOI **10.1038/nphys3710**).

Observation of magnetic fragmentation in spin ice

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(accepted in Nature Physics, see also http://arxiv.org/abs/1603.05008)

Abstract: Fractionalised excitations that emerge from a many body system have revealed rich physics and concepts, from composite fermions in two-dimensional electron systems, revealed through the fractional quantum Hall effect, to spinons in antiferromagnetic chains and, more recently, fractionalisation of Dirac electrons in graphene and magnetic monopoles in spin ice. Even more surprising is the fragmentation of the degrees of freedom themselves, leading to coexisting and *a priori* independent ground states. This puzzling phenomenon was recently put forward in the context of spin ice, in which the magnetic moment field can fragment, resulting in a dual ground state consisting of a fluctuating spin liquid, a so-called Coulomb phase, on top of a magnetic monopole crystal. Here we show, by means of neutron scattering measurements, that such fragmentation occurs in the spin ice candidate $Nd_2Zr_2O_7$. We observe the spectacular coexistence of an antiferromagnetic order induced by the monopole crystallisation and a fluctuating state with ferromagnetic correlations. Experimentally, this fragmentation manifests itself via the superposition of magnetic Bragg peaks, characteristic of the ordered phase, and a pinch point pattern, characteristic of the Coulomb phase. These results highlight the relevance of the fragmentation concept to describe the physics of systems that are simultaneously ordered and fluctuating.