Experiment Proposal

Experiment Number: 810289

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Experiment Title	Search for Magnetic Monopoles in Spin Ice

Instrument	**MUSR**	**Days Requested:** 5
Access Route	Direct Access - New	**Previous RB Number:** -
Science Areas	Physics	
Sponsored Grant	No	**Sponsor:** -
Grant Title	-	
Grant Number	-	
	Start Date: -	**Finish Date:** -
EU Access?	No	
Similar Submission?	No	

Abstract

In recent work Moessner and colleagues have shown that defects in spin ice behave as emergent magnetic monopoles (article to appear in Nature). We suggest that a signature of these objects may be found by measuring magnetic relaxation as a function of field and temperature. We propose a pulsed field Muon spin relaxation experiment to do this, using the muons as a magnetometer (i.e. implanting muons outside the sample) as well as the more conventional method of internal implanation. We previously used this method with great effect to study a similar material Tb2Ti2O7 and showed that it can assist in interpreting conventional MuSR as well as providing a useful contrast to bulk magnetization measurements.

Publications

Pinch points and Kasteleyn transitions in kagome ice, T. Fennell et al., Nature Physics, 3, 566 (2007).

ISIS Sample record sheet

Principal contact	Dr S R Giblin, s.r.giblin@rl.ac.uk, Tel: 0191 374 2114
Instrument	MUSR, 5 days, preferred contact is Giblin, S R (s.r.giblin@rl.ac.uk)
Special requirements	pulsed magnetic field <200G, dilution fridge

SAMPLES

Material	HoTi2O7
Formula	HoTi2O7
Forms	Solid
Volume	-
Weight	1000 mg
Container / substrate	-
Storage requirements	-
Xtal details	

SAMPLE ENVIRONMENT

Equipment	T < 0.3K cryostat
Temperature range	0.05-4 K
Pressure range	-
Magnetic field range	0-200 gauss
Special equipment	pulsed magnetic field box and coils (<200G)

SAFETY

Hazards	-
Hazard details	-
Sample sensitivity	-
Experimental hazards	-
Sample prep hazards	-
Equipment hazards	-
Prep lab needed	No
Special equip reqs	-
Sample will be	Removed By User

1. Background

In spin ice materials like $Ho_2Ti_2O_7$ and $Dy_2Ti_2O_7$ [1] the Ising-like rare earth spins are analogous to hydrogen displacement vectors in water ice. Spin ice shares with water ice the Pauling "zero point" entropy and shows several interesting properties in applied magnetic field, including liquid-gas type transitions a so-called Kasteleyn transition and a giant entropy spike (see, for example [2]). Chemical modifications of spin ice include the "Berry phase" anomalous Hall effect material, $Nd_2Mo_2O_7$ [3], while an alternative approach to spin ice behaviour has utilised nanomagnetic arrays [4].

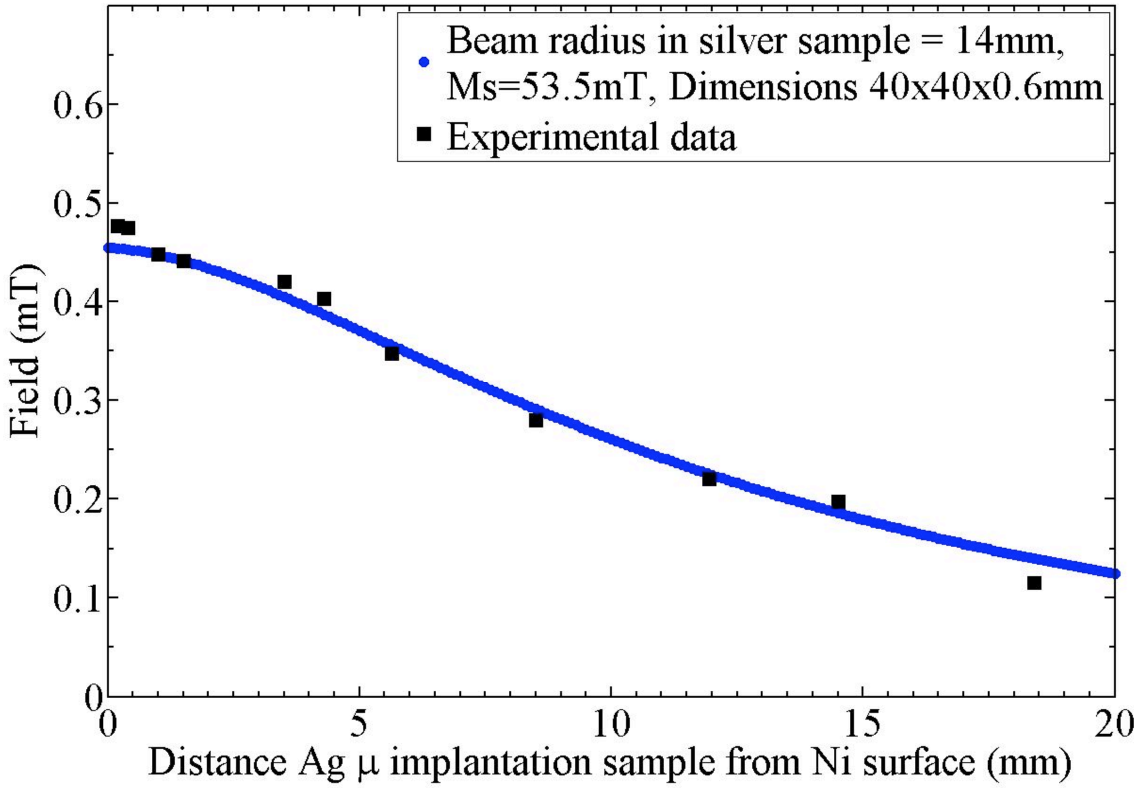
The latest twist in the story of spin ice is the recent discovery by Moessner, Castelnovo and Sondhi (to appear in *Nature*) that defects in the spin ice state behave as unbound magnetic monopoles. These are an emergent material property (monopoles in the H-field) rather than elementary cosmic particles (monopoles in the B-field), but from a practical point of view they are expected to behave just like magnetic charges, confined in the material samples. As a pragmatic guide to understanding their behaviour, one of us (STB, in preparation) has argued that the application of a magnetic field to spin ice in the very low field region should increase the rate of creation of monopoles: this in turn leads to an increase in monopole current and an increase in magnetic relaxation rate. This prediction is quantitative, so the key to experimental detection of monopoles is to observe changes in magnetic relaxation rate as a function of field.

2. The Proposal

We envisage a two pronged attack on the problem, using both bulk magnetometry at microTesla fields (Giblin & Terry, U. of Durham) to measure magnetic relaxation directly, and using MuSR to access a different time window and to make a contrast between the relaxation of the local and the global magnetic field produced by the sample. In the Muon experiment we will use the muons in a conventional way (implantation in the sample) and as a sensitive magnetometer (implantation in silver positioned near to the sample). In recent work on $Tb_2Sn_2O_7$ (RB620576), a closely related material, we have shown that this comparison gives a crucial extra handle on the problem of interpreting MuSR in frustrated magnets. This is because it gives a bulk measure of field distributions, with the exactly the same frequency characteristics as the conventional local measure, as well as providing a control experiment against sample perturbation by the muons. To illustrate that we can measure stray fields accurately we show in the Figure the field derived from the precession frequency of muons implanted in silver at various distances from a magnetized block of nickel, versus the exact theoretical expression for the stray field distribution in the silver (arising from the nickel: some parameters were adjusted within acceptable bounds to get the precise fit).

3. Experimental Details

The plan is to do pulsed field MuSR in red/green mode, which is magnetic pulse on, magnetic pulse off, thus giving a differential measurement. When the field is removed the monopoles on the surface (like surface charges) start to relax back to magnetic dipoles and then disappear, suggesting not only a bulk relaxation of the magnetization, but also an effect on the local field sensed by implanted muons. Using ISIS muons we will probe the time scale 50ns to 32 μs: a recent MuSR study of $Dy_2Ti_2O_7$ [6] detected spin relaxation on this time scale, with a temperature dependence consitent with ac-susceptibility measurements, but with a relaxation time much faster than that found in bulk measurements [7,8]. Our method will identify the cause of this discrepency, which is important to understand in the present context.



We will first perform a magnetic susceptibility measurement i.e Ag in front of sample. Next we will implant the muons into the bulk and watch relative changes in the relaxation with respect to the depth of muon implantation: here the muons act as a local probe. We will use a single crystal in the temperature range 0.05 - 5 K and the field range 0 - 0.2 T (the field direction will be parallel to [110], an unimportant detail at these low fields where the susceptibility tensor is isotropic).

[1] Bramwell and Gingras, *Science* **16**, 1495 (2001). [2] Moessner and Sondhi, *Phys. Rev. B* **68** 064411 (2003). [3] Taguchi et al., *Science* **291**, 2573 (2001). [4] Wang et al., *Nature*, **439**, 303 (2006). [5] Lago *et al.,. Phys.: Condens. Matter* **19** 326210. [6] Snyder *et al*., *Phys. Rev. B*, **69** 064414 (2004). [7] Orendac *et al*., *Phys Rev. B* **75** 104425 (2006).