Spin dynamics of "frozen" Spin Ice

S. R. Dunsiger[1], R. F. Kiefl[2,3], S. T. Bramwell[4], K. H. Chow[5], J. S. Gardner[6], J. Lago[7], G. D. Morris[3], A. N. Price[8] and J. E. Sonier[9]

[1]*Physik Department E21, Technische Universität München, D-85748 Garching, Germany.*
[2]*Dept of Physics and Astronomy, University of British Columbia, Vancouver BC, Canada.*
[3]*TRIUMF, 4004 Wesbrook Mall, Vancouver, BC, Canada.*
[4]*Department of Chemistry, University College London, United Kingdom.*
[5]*Department of Physics, University of Alberta, Edmonton, Alberta, Canada.*
[6]*NCNR, National Institute of Standards and Technology, Gaithersburg, MD, USA.*
[7]*Dipartimento di Fisica "A. Volta", Univ of Pavia and Unità CNR-INFM, I-27100 Pavia, Italy*
[8]*Physikalisches Institut III, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany*
[9]*Department of Physics, Simon Fraser University, British Columbia, Canada V5A 1S6*

An Ising model of spins on a pyrochlore lattice of corner sharing tetrahedra, combined with ferromagnetic nearest-neighbour exchange interactions and local $\langle 111 \rangle$ anisotropy is known to give rise to *geometrical frustration*, such that it is not possible to energetically satisfy all interactions simultaneously. Two of the spins on the vertices of any given tetrahedron are constrained to point in toward the centre of the tetrahedron, while the remaining two point outwards. The statistical mechanics governing the low temperature spin configuration in this so called "spin ice" mimics that of H disorder in water ice, exhibiting a macroscopic degeneracy.

A remarkable feature of many geometrically frustrated systems is the great sensitivity to an applied magnetic field, giving rise to a wealth of behaviour. For example, such a field applied along the [001] direction of a spin ice makes an angle of 54° with all the spins on a tetrahedron, raising the degeneracy and inducing "Q=0" long range order. Similarly, two coexisting magnetic structures consisting of ferromagnetic spin chains are formed on applying a [110] magnetic field. The pyrochlore lattice may be viewed as a series of kagomé and triangular planes stacked alternately along the [111] direction. Applying a field along this threefold axis, the stable "kagomé ice" spin configuration is the ice-rule 2-in 2-out state; with increasing field the ice rule breaks down through a first order phase transition of the liquid-gas type.

Spin ice models have been enormously successful in describing the experimentally observed *static* spin structures in the field-induced long range ordered phases, which have been extensively investigated. However, to date the nature of the spin excitations, while exciting a great deal of theoretical interest [1], has remained largely unexplored experimentally. The pyrochlore oxide $Ho_2Ti_2O_7$ is one of the most well known experimental realisations of spin ice systems. I discuss our progress using muon spin relaxation to explore the phase diagram of this model magnetic system, as well as the low energy excitations.

[1] C. Castelnovo, R. Moessner and S. L. Sondhi, Nature **451** 42 (2008)