A Magnetic Neutron Reflectometry Study of the Spin Ice $Dy_2Ti_2O_7$

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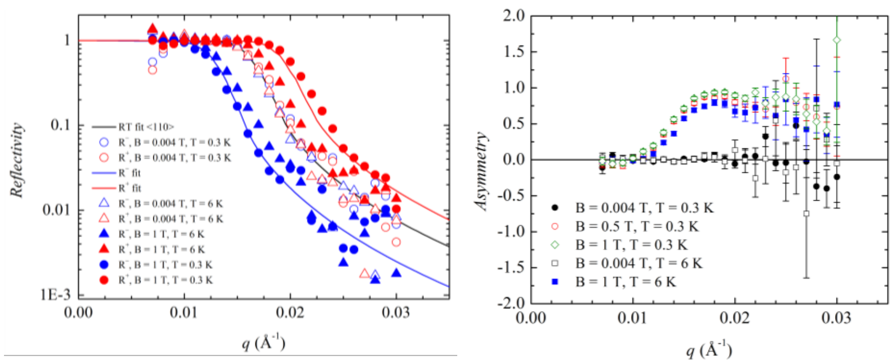
Spin ices, typically rare earth based titanate pyrochlores such as $Ho_2Ti_2O_7$ and $Dy_2Ti_2O_7$, are an interesting family of magnetic materials. Spin ices are formed from a corner-sharing tetrahedral network of ferromagnetically interacting rare earth cations. Strong crystal field effects mean that the spins of the rare earth cations are Ising-like and are constrained to point along the crystallographic [111] axis, which is directed along the body diagonal of each tetrahedron. The spin ice ground state has two spins pointing in towards and two spins pointing outwards from the centre of each tetrahedron. The magnetic structure of spin ice is inherently frustrated due to the enormous number of possible two-in two-out spin configurations within a macroscopic sample. As such, spin ices are able to evade long range magnetic order down to the lowest measurable temperatures by fluctuating between the manifold of different spin ice configurations.

This ferromagnetic near neighbour model of spin ice well describes many of the observed properties of spin ice materials. However, there remain several unresolved questions about this magnetic state. It is known from neutron scattering studies that long range dipolar interactions must be taken into account in order to quantitatively understand the neutron data. It has since been suggested that this dipolar interaction should in fact lift the degeneracy of the spin ice state to give long range magnetic order. We performed the first magnetic reflectometry study of the spin ice material $Dy_2Ti_2O_7$ using the D3 Reflectometer at the Canadian Neutron Beam Centre with the M5 ^3He Cryomagnet. We tested the hypothesis that the surface properties of spin ice may differ from the bulk by truncating the long range dipolar interactions known to be important in the spin ice state, which may induce magnetic order. We also began to investigate the field dependent properties of the [110] surface of $Dy_2Ti_2O_7$ which is considered to be a good model of an Ising chain system. There does not appear to be any magnetisation at the [110] surface in 0.004 T as there is no detectable asymmetry in the spin-up and spin-down neutron reflectivities, R^+ and R^-, respectively. A large effect is observed when stronger fields are applied to the sample, the largest asymmetry is observed when a field of 1 T is applied to the sample at 0.3 K, however the temperature and field dependence of the asymmetry within the range of our study is small.



(Left) polarised neutron reflectivity data and (right) asymmetry for the [110] surface of $Dy_2Ti_2O_7$.