Geometric Frustration on the $SrHo_2O_4$ Honeycomb Lattice

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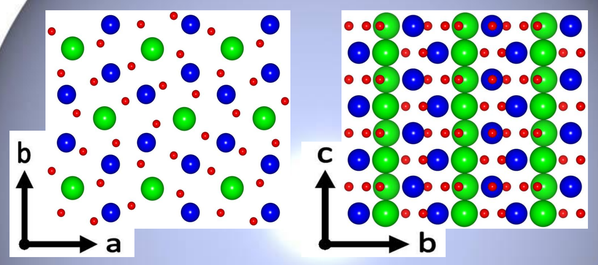
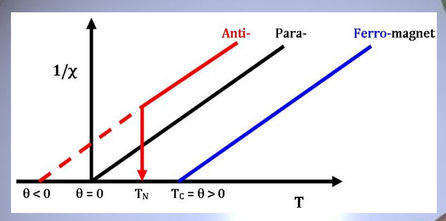
Background shows a unit cell of $SrHo_2O_4$, with colours representing Strontium (Green), Holmium (Blue) and Oxygen (Red) atoms – not to scale!



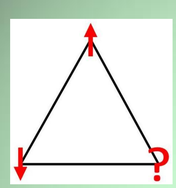
Crystal structure of $SrHo_2O_4$ (VESTA):

- *ab* plane - honeycomb arrangement of the Ho atoms (blue).
- *bc* plane - triangular arrangement of Ho gives rise to geometric frustration.



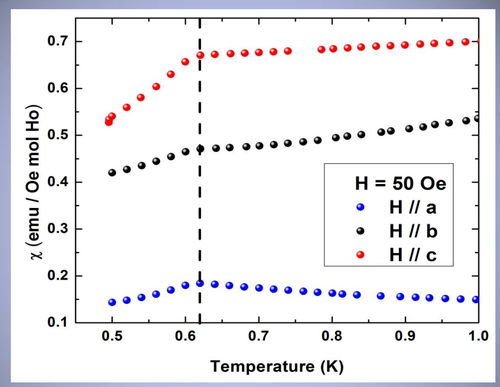
Magnetic order set by the scale of interactions appears at $T_N \approx |\theta_{CW}|$. In geometrically frustrated compounds like $SrHo_2O_4$ the paramagnetic phase exists over a wider range, and $T_N << |\theta_{CW}|$.

Introduction

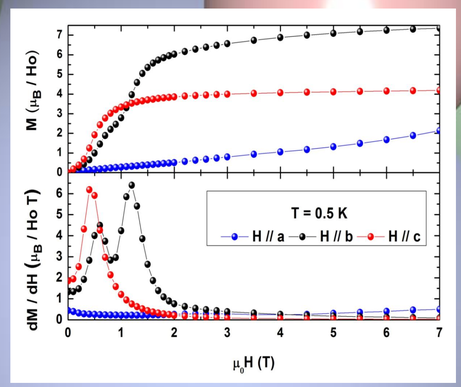


Incompatibility of antiferromagnetic exchange interactions with triangular lattices gives rise to geometric frustration.

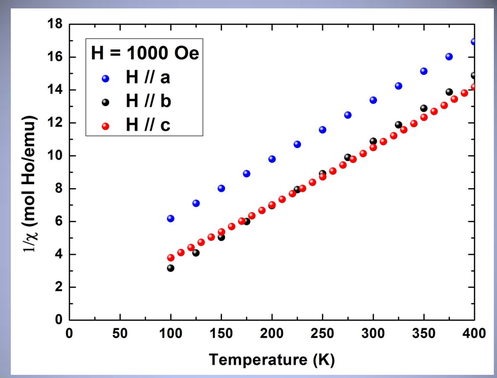
A variety of degenerate low temperature states are formed due to residual entropy when $T \rightarrow 0$ K [1]. Karunadasa *et al.* [2] reported on a series of compounds with the formula $SrLn_2O_4$ (where *Ln* = Ho, Er, etc). The crystal structure allows the magnetic *Ln* ions to be linked in a network of triangles and hexagons forming a distorted honeycomb lattice.



Low temperature χ(T) for single crystal $SrHo_2O_4$.



$SrHo_2O_4$ magnetisation (top) and dM/dH (bottom).



χ^{-1} (T) for $SrHo_2O_4$ single crystal. Linear fits allow us to calculate θ_{CW} and μ_B/Ho from the Curie-Weiss Law:

$$\chi = C / (T + \theta_{CW}) \qquad C = \text{constant}$$

Fitting range: 100-400 K	θ_{CW}	μ_B /Ho
a	-73.75	10.57
b	21.31	10.10
c	-3.49	10.72
Average	-18.64	10.47
Expected Values	-16.9 (from [2])	10.4 (Hund's Rules)

A single crystal of $SrHo_2O_4$ was grown by the floating-zone method at Warwick [3].

χ(T) & M(H)

A peak in χ(T) at 0.62 K indicates the presence of a magnetic phase transition.

Highly anisotropic behaviour of the magnetisation is observed in the single crystal measurements. The minimum between the peaks seen in dM/dH (for H // *b*) at 0.8 T corresponds to a two spins up, one spin down, collinear magnetic order stabilised by an applied magnetic field.

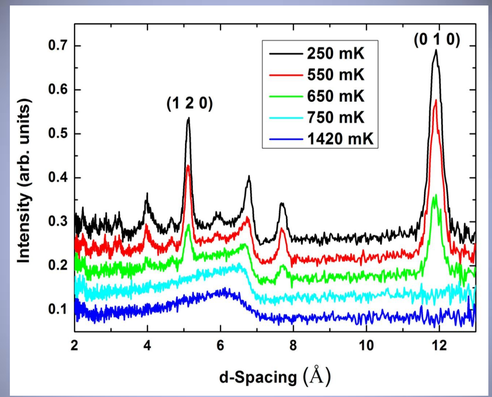
This suggests a rich H-T phase diagram for $SrHo_2O_4$.

Neutron Scattering

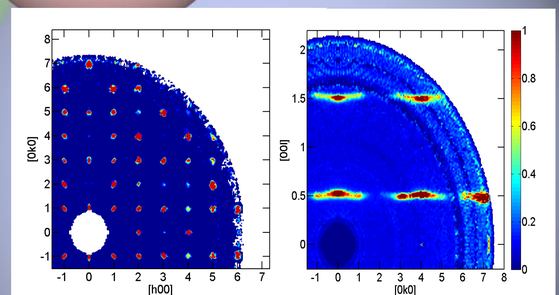
Below 0.7 K magnetic Bragg peaks can be seen indicating the presence of long-range order. Above T_N, short-range, temperature dependent correlations (incommensurate with the lattice) are also observed.

Analogously, in $SrEr_2O_4$ at low T, the diffuse scattering features correspond to "rods" in reciprocal space, suggesting the coexistence of both 3D and 2D magnetic order [5].

Single crystal diffraction experiments are planned at ILL to establish the magnetic structure of $SrHo_2O_4$.



Temperature evolution of the magnetic scattering from polycrystalline $SrHo_2O_4$ (GEM, ISIS) [4].



Magnetic intensity in the (*hk0*) (left) and (*0kl*) (right) scattering planes of $SrEr_2O_4$ at 60 mK (D7, ILL). Rod-like diffuse features along the *k*-direction suggest 2D correlations in the *ac* plane [5].

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References:

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[2] H. Karunadasa *et al.*, Phys. Rev. B **71**, 144414 (2005)
[3] G. Balakrishnan *et al.*, J. Phys. Cond. Mat. **21**, 012202 (2009)
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[5] T. J. Hayes *et al.*, (2011) in preparation; O. A. Petrenko *et al.*, ILL experimental report, 5-53-172 (2009)