Rare Earth Pyrochlores with Anisotropic Exchange Interactions – Spin Ice Goes Quantum ?

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"Spin ice" is one of the great success stories of modern condensed matter physics. In the rare-earth magnets $Ho_2Ti_2O_7$ and $Dy_2Ti_2O_7$, competetition between strong Ising anisotropy and weak ferromagnetic interactions gives rise to an infinite number of possible magnetic ground states. At low temperatures, these ground states combine to give "spin ice", a classical spin-liquid in near-perfect correspondence with water ice. Spin ice offers a beautiful realization of classical magnetostatics, and the first experimentally-verified example of magnetic monopoles.

Quantum effects, however, are hard to observe, since any tunnelling between different spin ice ground states in $Ho_2Ti_2O_7$ or $Dy_2Ti_2O_7$ is restricted to extremely low temperatures.

In this talk I review some of the recent progress in understanding "quantum spin ice" materials - rare earth pyrochlores with chemistry similar to $Ho_2Ti_2O_7$ and $Dy_2Ti_2O_7$, but smaller moments, and highly ansiotropic exchange interactions.

Stops on this tour will include dimensional reduction in $Yb_2Ti_2O_7$ [1], the selection of an ordered ground state by quantum fluctuations in $Er_2Ti_2O_7$ [2,3], a spin-liquid with exotic magneto-elastic excitations in $Tb_2Ti_2O_7$ [4], and the tantalizing theoretical possibility of realizing a "quantum ice" - a quantum spin-liquid with magnetic "photon" excitations [5,6].

[1] K. Ross et al., Phys. Rev. Lett. 103, 227202 (2009)

[2] L. Savary et al., Phys. Rev. Lett. 109, 167201 (2012)

[3] M. Zhitomirsky et al. Phys. Rev. Lett. 109, 077204 (2012)

[4] T. Fennell et al., arXiv:1305.5405

[5] N. Shannon et al., Phys. Rev. Lett. 108, 067204 (2012)

[6] O. Benton et al., Phys. Rev. B 86, 075154 (2012)