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Effective S=1/2 Hamiltonians and the Quantum Spin Ice Ground State of $Yb_2Ti_2O_7$

BRUCE D. GAULIN, Department of Physics and Astronomy, McMaster University

New neutron scattering instrumentation offers unprecedented opportunities for mapping out the full dispersion and dynamic susceptibility of magnetic materials. In turn, these measurements can be exploited to determine their microscopic spin Hamiltonians in great detail. We've used these techniques to examine the exotic quantum spin ice ground state of $Yb_2Ti_2O_7$, a pyrochlore magnet, which can be thought of in terms of spins decorating a network of corner-sharing tetrahedra. In this environment, Yb^{3+} displays a ground state crystal field doublet which is very well separated from its excited states, resulting in an effective S=1/2 description for the Yb moments. It's positive Curie-Weiss constant of ~ 0.5 K indicates net ferromagnetic interactions and it displays a g-tensor with XY anisotropy. However strong spin orbit effects give rise to an anisotropic exchange Hamiltonian, which can be understood in quantitative detail by modeling time-of-flight neutron scattering in a high field polarized state with spin wave theory using anisotropic exchange. The resulting Hamiltonian shows strong coupling between local z-components of spin, as in spin ice, but also substantial terms that encourage quantum fluctuations. Armed with the microscopic spin Hamiltonian, the mean field phase diagram and a range of physical properties can be calculated and compared with experiment. We see that any possible ordering is strongly suppressed relative to mean field theory by the presence of geometrical frustration, quantum fluctuations, or both; and the low temperature bulk properties are well accounted for by the effective S=1/2 Hamiltonian we determine.

[1] K.A. Ross, L. Savary, B.D. Gaulin and L. Balents, Phys. Rev X, 1, 021022, 2011.