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Frozen Spin Ice Ground States in the Pyrochlore Magnet $Tb_2Ti_2O_7$

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The ground state nature of the candidate spin liquid pyrochlore magnet $Tb_2Ti_2O_7$ has remained a puzzle for over 15 years. Despite theoretical expectations of magnetic order below ~ 1 K based on classical Ising-like Tb3+ spins, early μSR and neutron scattering experiments showed no long range order down to 50 mK [1,2]. This motivated two theoretical scenarios to account for the apparently disordered ground state: a quantum spin ice scenario in which the classical spin order is suppressed by virtual crystal field excitations that renormalize the antiferromagnetic exchange [3], or a scenario arising from a yet to be observed structural distortion creating a non-magnetic singlet ground state [4]. I will discuss our time-of-flight neutron scattering measurements on $Tb_2Ti_2O_7$ that reveal a glassy spin ice ground state, characterized by frozen antiferromagnetic short range order and the formation of a ~ 0.08 meV energy gap in its spin excitation spectrum at the (1/2,1/2,1/2) quasi-ordering wave vectors [5]. A new $H-T$ phase diagram for $Tb_2Ti_2O_7$ in [110] magnetic field will be presented[6]. I will further discuss recent experiments on slightly off-stoichiometric $Tb_{2+x}Ti_{2-x}O_{7-y}$ samples, which also display the same gapped spin ice correlations at (1/2,1/2,1/2) wave vectors.

[1] Gardner et al., PRL 82, 1012 (1999)
[2] Gingras et al., PRB 62, 6496 (2000)
[3] Molavian et al., PRL 98, 157204 (2007)
[4] Bonville et al., PRB 84, 184409 (2011)
[5] Fritsch et al., PRB 87, 094410 (2013)
[6] Fritsch et al., PRB 90, 014429 (2014)