Correlated Quantum Tunneling of Monopoles in Spin Ice

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The spin ice materials Ho2Ti2O7 and Dy2Ti2O7 are by now perhaps the best-studied classical frustrated magnets. A crucial step towards the understanding of their low temperature behaviour- both regarding their unusual dynamical properties and the possibility of observing their quantum coherent time evolution- is a quantitative understanding of the spin-flip processes which underpin the hopping of magnetic monopoles. We attack this problem in the framework of a quantum treatment of a single-ion subject to the crystal, exchange, and dipolar fields from neighboring ions. By studying the fundamental quantum mechanical mechanisms, we discover a bimodal distribution of hopping rates that depends on the local spin configuration, in broad agreement with rates extracted from experiment. Applying the same analysis to Pr2Sn2O7 and Pr2Zr2O7, we find an even more pronounced separation of timescales signaling the likelihood of coherent many-body dynamics.

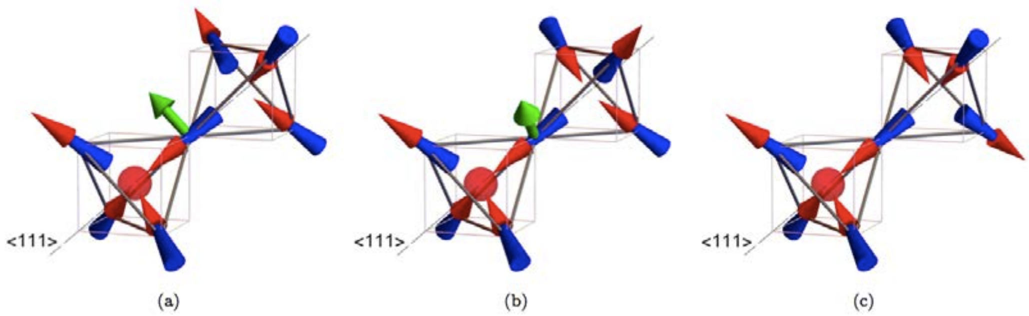

Figure 1: (a-c) The 3 inequivalent low-energy configurations of a 2-tetrahedron system hosting only one monopole (red sphere). Effective fields on the central site due to its n.n.spins are purely transverse (green arrows) to the axis of anisotropy in (a) and (b), and identically null in (c).