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The many faces of order-by-disorder in rare-earth pyrochlore magnets

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Order-by-disorder (ObD) is a concept of central importance in the field of frustrated magnetism. Saddled with large accidental degeneracies, a subset of states, those that support the largest quantum and/or thermal fluctuations, may be selected to form true long-range order. More formally, one often begins describing a system in terms of some order parameter m with the low-energy description framed in terms of an effective action $\Gamma(m)$. In each ObD scenario, one starts from an artificial limit where there is an accidental degeneracy; that is the effective action at this point, $\Gamma_0(m)$, has an accidental symmetry. One may then view ObD phenomena as cases where the corrections to $\Gamma_0(m)$ arise through some form of fluctuation corrections, may they be thermal, quantum or virtual, towards an enlarged higher energy Hilbert space. In the rare-earth pyrochlore oxides, of formula $R_2M_2O_7$, the trivalent magnetic rare-earth ions R^{3+} (e.g R =Gd, Er, Yb; M =Ti, Sn is non-magnetic) reside on a three-dimensional pyrochlore lattice of corner-sharing tetrahedra. This architecture is prone to a high degree of magnetic frustration, with the $R_2M_2O_7$ pyrochlore materials having been found over the past twenty years to display a gamut of exotic phenomena. In this talk, I will discuss three such phenomena: (i) the intermediate partially-ordered multiple-k state between 0.7K and 1K in the $Gd_2Ti_2O_7$ Heisenberg antiferromagnet [1], (ii) the ordered ψ_2 state selection in the XY $Er_2Ti_2O_7$ antiferromagnet [2] and (iii) the puzzling high sample sensitivity of the $Yb_2Ti_2O_7$ "quantum spin ice" candidate [3]. I will argue that in all three cases, some form of fluctuation corrections to their simplest $\Gamma_0(m)$ description play a significant role in the state selection and experimentally observed behaviors.

[1] PRL **114**, 130601 (2015)
[2] arXiv:1510.04292
[3] arXiv:1505.05499