Dipolar spin correlations in classical pyrochlore magnets.

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AND

Power-law spin correlations in pyrochlore antiferromagnets.

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Recommended and a commentary by Subir Sachdev, Yale University.

Emergent gauge excitations have played a key role in the study of quantum antiferromagnets in the past decade. They are a very useful tool for characterizing correlations in the `disordered' or paramagnetic phase, without long-range magnetic order. It has become clear that far from being featureless, phases in which all correlations decay exponentially have subtle multiple-spin correlations which are captured by effective gauge field theories. These correlations play an important role in determining the spin excitation spectrum, which can be measured in neutron scattering experiments. However, a direct experimental detection of the gauge excitations has remained elusive, as it likely requires probes sensitive to the spin zero sector.

The papers above show that an emergent gauge structure is actually already present in certain frustrated classical antiferromagnets, and that it has a simple experimental signature which agrees well with simulations and existing experiments. They highlight an early observation by Youngblood and Axe (Phys. Rev. B 23, 232 (1981)) that certain antiferromagnets in which the spins obey a local `ice rule' have dipolar power-law spin correlations in their `disordered' phase. In particular, they focus on antiferromagnets on the pyrochlore lattice. This is a lattice of corner-sharing tetrahedra, and at low temperatures the spin configurations must be such that the sum of the spins on each tetrahedron is zero. The ensemble of states obeying this rule has a macroscopic entropy and preserves all symmetries of the Hamiltonian. The local spin constraint can be translated to a zero divergence condition on a discrete `polarization' vector field defined on the dual lattice. Indeed, we can interpret this vector field as a 3-dimensional electromagnetic field, and the zero divergence condition as a Maxwell equation. After assuming a direct coarse-graining to a continuum gauge field theory, the dipolar spin correlations are easily derived. These correlations lead to a characteristic pinch-point singularity in the spin structure factor.

A natural next question is whether violations of the ice rule (which are exponentially rare at low temperature) would lead eventually to an exponential decay of spin correlations. It is plausible that such violations correspond to magnetic monopole sources in the gauge theory, that these could lead to the Polyakov confining phase of 3-dimensional gauge theory.