Heisenberg antiferromagnet on the pyrochlore lattice: order from distortion

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The Heisenberg antiferromagnet on the pyrochlore lattice is an example of a highly frustrated system with a large degeneracy of the ground state. The classical model with nearest-neighbor interactions shows no signs of magnetic order down to very low temperatures. The quantum analog, with short enough spins, was considered a prime candidate for a quantum-disordered ground state, such as a valence-bond liquid or solid. At the same time, the large degeneracy makes this magnet susceptible to a variety of nominally small perturbations. A spin-lattice coupling leads to a spin-Peierls-like distortion of the lattice. In contrast to spin chains, the spin-Peierls distortion in a pyrochlore antiferromagnet occurs for any spin length $S$ remaining robust even in the classical limit. A recent experimental characterization of the $S = 3/2$ prototype $\text{CdCr}_2\text{O}_4$ \cite{Chung2005} provided a test for the theoretical model. This antiferromagnetic spinel exhibits a tetragonal lattice distortion with an elongated unit cell $a = b < c$ and a weakly incommensurate spiral magnetic order with ordered moments in the $ac$ plane and a magnetic Bragg peak at $(0, \delta, 1)$, where $\delta \ll 1$. We show \cite{Chern2006} that the observed structural and magnetic orders are consistent with one of the spin-Peierls scenarios described previously. The distortion, caused by an odd phonon doublet $E_u$, breaks the inversion symmetry. The magnetic order is collinear to a first approximation. The broken parity makes the crystal structure chiral. The handedness of the lattice is transferred to the magnetic order resulting in a long-period spiral that agrees in detail with observations.


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