Spin Ice Thin Films: Large-N Theory and Monte Carlo Simulations

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We explore the physics of highly frustrated magnets in confined geometries, focusing on the Coulomb phase of pyrochlore spin ices. As a specific example, we investigate thin films of nearest-neighbor spin ice, using a combination of analytic large-N techniques and Monte Carlo simulations. In the simplest film geometry, with surfaces perpendicular to the [001] crystallographic direction, we observe pinch points in the spin-spin correlations characteristic of a two-dimensional Coulomb phase. We then consider the consequences of crystal symmetry breaking on the surfaces of the film through the inclusion of orphan bonds. We find that when these bonds are ferromagnetic, the Coulomb phase is destroyed by the presence of fluctuating surface magnetic charges, leading to a classical Z_2 spin liquid. Building on this understanding, we discuss other film geometries with surfaces perpendicular to the [110] or the [111] direction. We generically predict the appearance of surface magnetic charges and discuss their implications for the physics of such films, including the possibility of an unusual Z_3 classical spin liquid. Finally, we comment on open questions and promising avenues for future research.

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