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Frustrated Quantum Spin Ice and a Nematic Quantum Spin Liquid

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Spin ices are famous for their "magnetic monopole" excitations and algebraic spin correlations. Quantum fluctuations should enrich this scenario, leading to a U(1) quantum spin liquid (QSL) state described by emergent quantum electrodynamics. The search for an experimental "quantum spin ice" has revealed several candidate materials showing tantalising hints of the QSL state. Meanwhile, there has been great progress in theoretical studies of quantum spin ice with unfrustrated transverse exchange interactions, for which Quantum Monte Carlo (QMC) simulations are not subject to the sign problem. However, much less is known for the case of frustrated transverse interactions which is likely to be the more relevant case experimentally.

In this talk, I will describe a multi-faceted study of the ground state phase diagram of quantum spin ice with frustrated transverse exchange. A combination of cluster mean field theory, variationalwave functions, finite temperature series expansions and insights from the classical limit reveals a rich phase diagram with competing U(1) spin liquid phases. The limit of strong, frustrated, transverse exchange is of particular interest, hosting an exotic phase in which the emergent gauge fields and fractional quantum numbers of a spin liquid are combined with nematic symmetry breaking. This work thus reveals new phases of matter arising from frustration and suggests new approaches for frustrated systems where QMC is impractical.