Quantum Materials: Full of Frustration and Correlations

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The pioneering work on geometrical frustration dates back to the 1920s, when Linus Pauling realized that the hydrogen bonds between H₂O molecules in ice can be allocated in multiple ways. A given oxygen atom in water ice is situated at the vertex of a diamond lattice and has four nearest-neighbor oxygen atoms, each connected via an intermediate proton according to the ice rule “two-in two-out”. Although these considerations used electric dipoles, Phil Anderson mapped them to a spin model possessing an extensive degeneracy of states.

Quantum spin liquids attract great interest due to their exceptional magnetic properties characterized by the absence of long-range order down to low temperatures despite the strong magnetic interaction. Commonly these compounds are strongly correlated electrons systems, and their electrodynamic response is governed by the Mott gap in the excitation spectrum.

Here we will summarize and discuss the optical properties of several two-dimensional quantum spin liquid candidates with different degrees of effective correlations. Placing organic molecules on a triangular lattice, a spin liquid ground state can be realized which allows us to investigate the genuine Mott state in the absence of magnetic order. Combining our optical data with pressure-dependent transport studies and theoretical calculations, we can construct a universal phase diagram of the correlation-controlled Mott insulator.

But how important is the coupling of the fluctuating magnetic moments? How important is disorder for the electronic properties? If this resembles a quantum phase transition, is there a superconducting phase found in the vicinity and what is the superconducting glue? Can our findings be generalized, when going to a kagome or hexagonal lattice, realized in Herbert-smithites or α-RuCl₃ for instance?

Reference:

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