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Spin-Orbit Coupled Quantum Magnetism

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Quantum magnetism refers to magnetic phases with physical properties that are determined by strong quantum fluctuations. These include phases in which spins are long range entangled, as in the large number of theoretically predicted Quantum Spin Liquid (QSL) phases, from which exotic fractionalized quasi-particle excitations (spinons) are expected to arise. The QSL phases have previously been sought in spin only magnetic materials with isotropic interactions, and a few candidates have emerged, but an experimental smoking gun for the positive identification of such QSLs is still lacking. However, recently a new wave of quantum phases, including QSLs that would provide smoking gun experimental signatures, are being discovered in models with anisotropic interactions, which are physically realizable in materials where the spin and orbital angular momenta of the unpaired electrons are intimately linked by spin-orbit coupling (SOC). I will discuss the strong SOC pyrochlore material $Yb_2Ti_2O_7$ and show how inelastic neutron scattering was used to quantitatively determine its anisotropic interactions. This direct determination makes $Yb_2Ti_2O_7$ one of the first SOC quantum magnets with a quantitatively-known Hamiltonian, and provides a theoretical starting point for understanding its unusual dynamical properties which have long-evaded explanation in terms of conventional magnetism.