**Quantum Spin Liquids**

**Phases without order**

Landau’s paradigm: ordering at low T

Quantum spin liquid and geometric frustration. No broken symmetry nor order even at zero T

**Quantum Spin Liquids**

**Fractionalized particles**

Emergent Majorana fermions with fractional statistics

Topological order reflected in the ground state degeneracy and long-range entanglement
Fractionalization

Spin wave vs fractionalized excitation by density matrix renormalization group (DMRG)


Future Work

Entanglement in QSL

Transport in QSL (spin and energy conductivities)

Kitaev spin liquids

Gapless $\mathbb{Z}_2$ QSL, Gapped $\mathbb{Z}_2$ QSL

Frustration from bond-dependent interactions