Optical Signatures for Fractional Excitations in Quantum Liquid Candidate $Ba_4Ir_3O_{10}$

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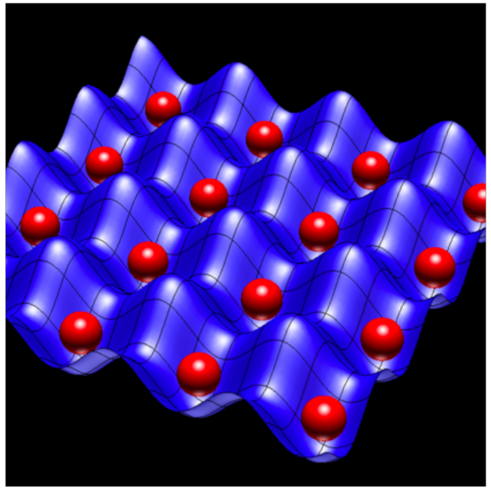
Defining Magnetic Insulators

- Hubbard model
  - Nearest neighbor tunneling
  - On site repulsion
- 2nd order perturbation in (t/U) gives effective spin Hamiltonian
- Usually (e.g. square lattice) magnetically orders
- Platforms: optical lattices, crystals, etc.

$$H = -t \sum_{\langle i,j \rangle \sigma} (c_{i\sigma}^\dagger c_{j\sigma} + h.c.) + U \sum_i n_{i\uparrow} n_{i\downarrow}$$

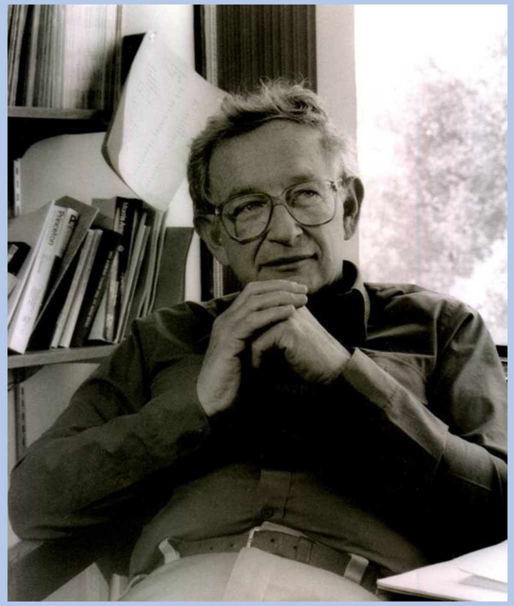
$$H_{\text{eff}} = J \sum_{\langle i,j \rangle} \mathbf{S}_i \cdot \mathbf{S}_j$$



NIST

Magnetic insulators can avoid magnetic ordering via exotic *quantum liquid* phases

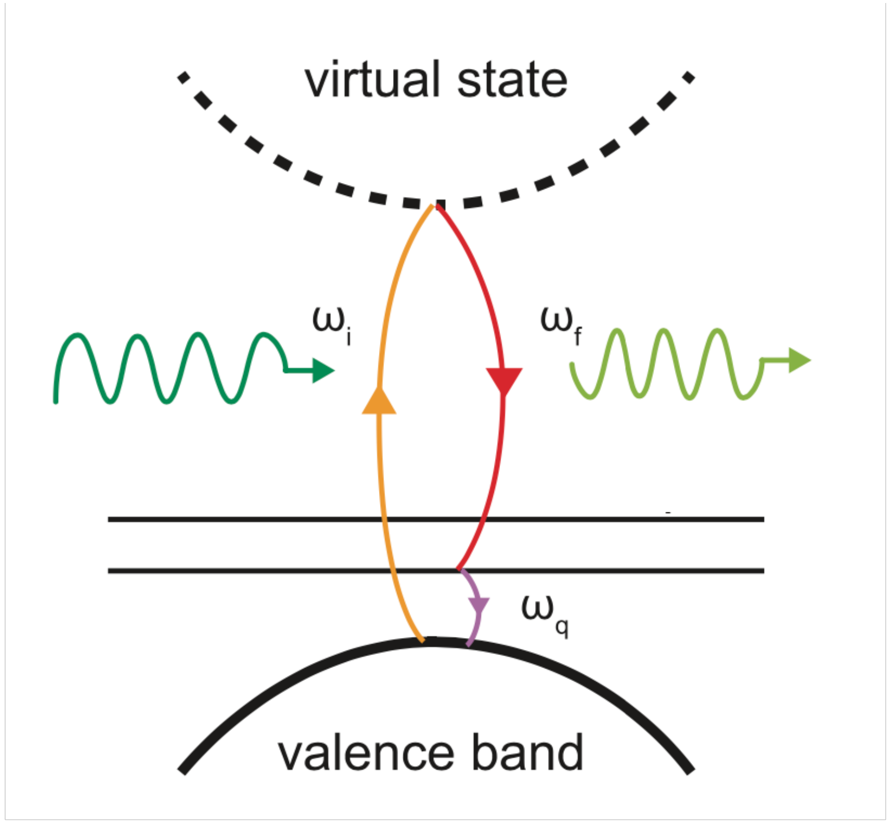
- High degree of many-body entanglement
- Continuum of nonlocal fractional excitations: half integer spin (not S = 1 spin flips)
- Proposed emergence of high-T_C superconductivity via doped quantum liquid
- Beyond lack of ordering, positive signatures for quantum liquid state are difficult to access



Philip Anderson

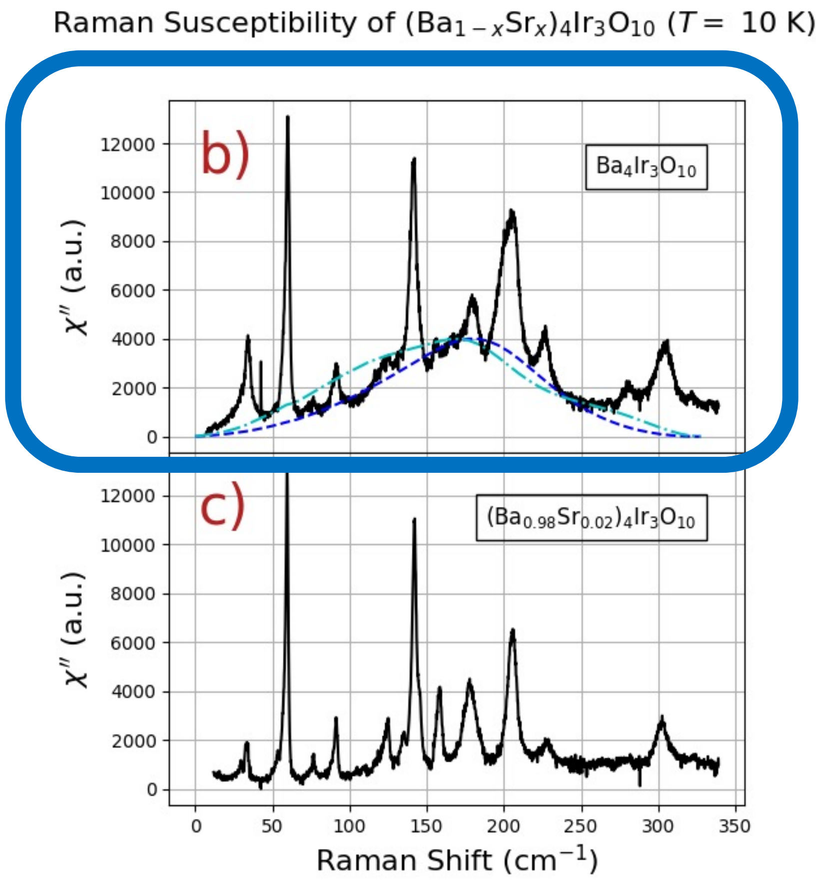
Inelastic Raman spectroscopy optically probes magnetic and vibrational excitations

- Incident photon excites a virtual state
- Virtual state decays into emitted photon and magnetic/vibrational modes (e.g. spinons/phonons)
- Can Raman spectroscopy identify a quantum liquid phase?



Raman response of $Ba_4Ir_3O_{10}$ is consistent with a fragile quantum liquid phase

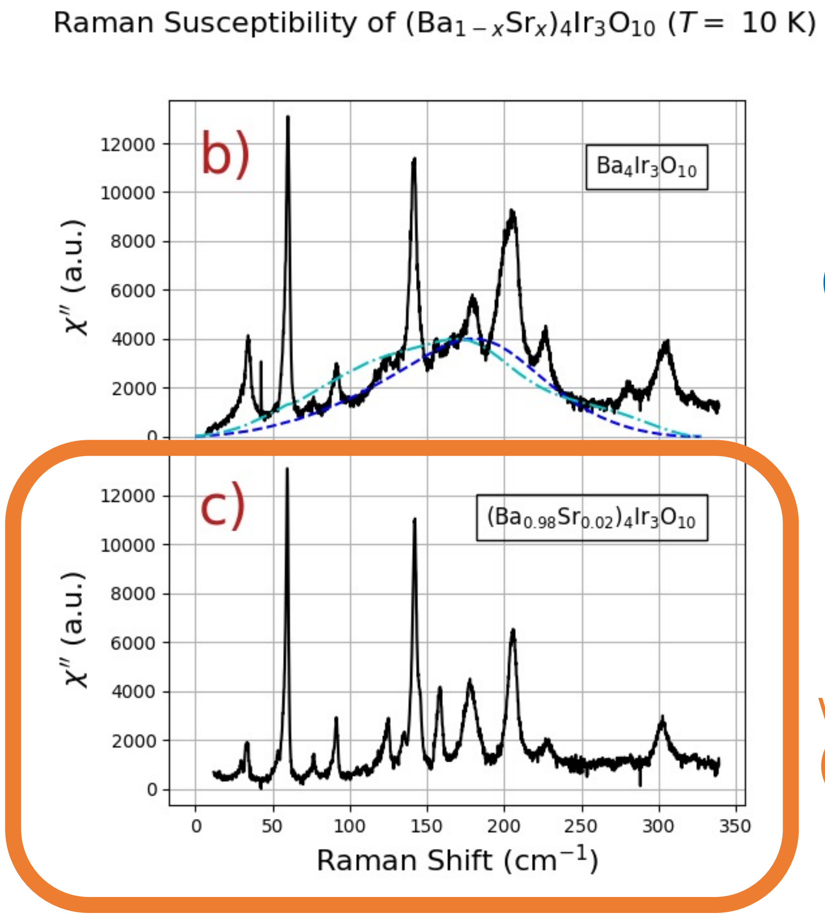
- Large bandwidth hump (dashed) suggests a continuum of excitations
- Broad phonon peaks indicate short phonon lifetime



Pure sample (no magnetic order)

Raman response of $Ba_4Ir_3O_{10}$ is consistent with a fragile quantum liquid phase

- Large bandwidth hump (dashed) suggests a continuum of excitations
- Broad phonon peaks indicate short phonon lifetime
- 2% nonmagnetic impurity destroys hump & counterintuitively increases phonon lifetime

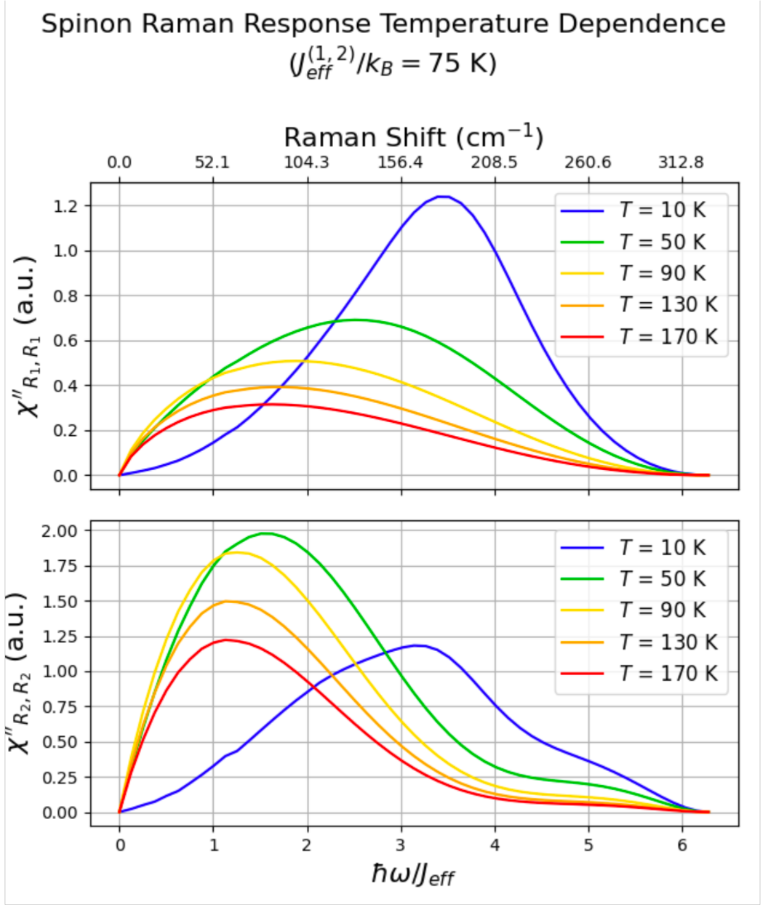


Pure sample (no magnetic order)

Sister compound with impurity (magnetically orders)

Mean-field theory is consistent with observed broadband hump

- Fractional spinon excitations arise in our 1D model
- Spinon continuum from two equivalent mean-field theories reproduce experimentally observed hump



Spin-orbit coupling reduces phonon lifetime

- Spin-orbit coupling of Ir atoms connects spatial and spin degrees of freedom
- (Spatial) phonon excitations scatter off fractional (spin) excitations
- Scattering reduces phonon lifetime when spinons are present in the pure sample

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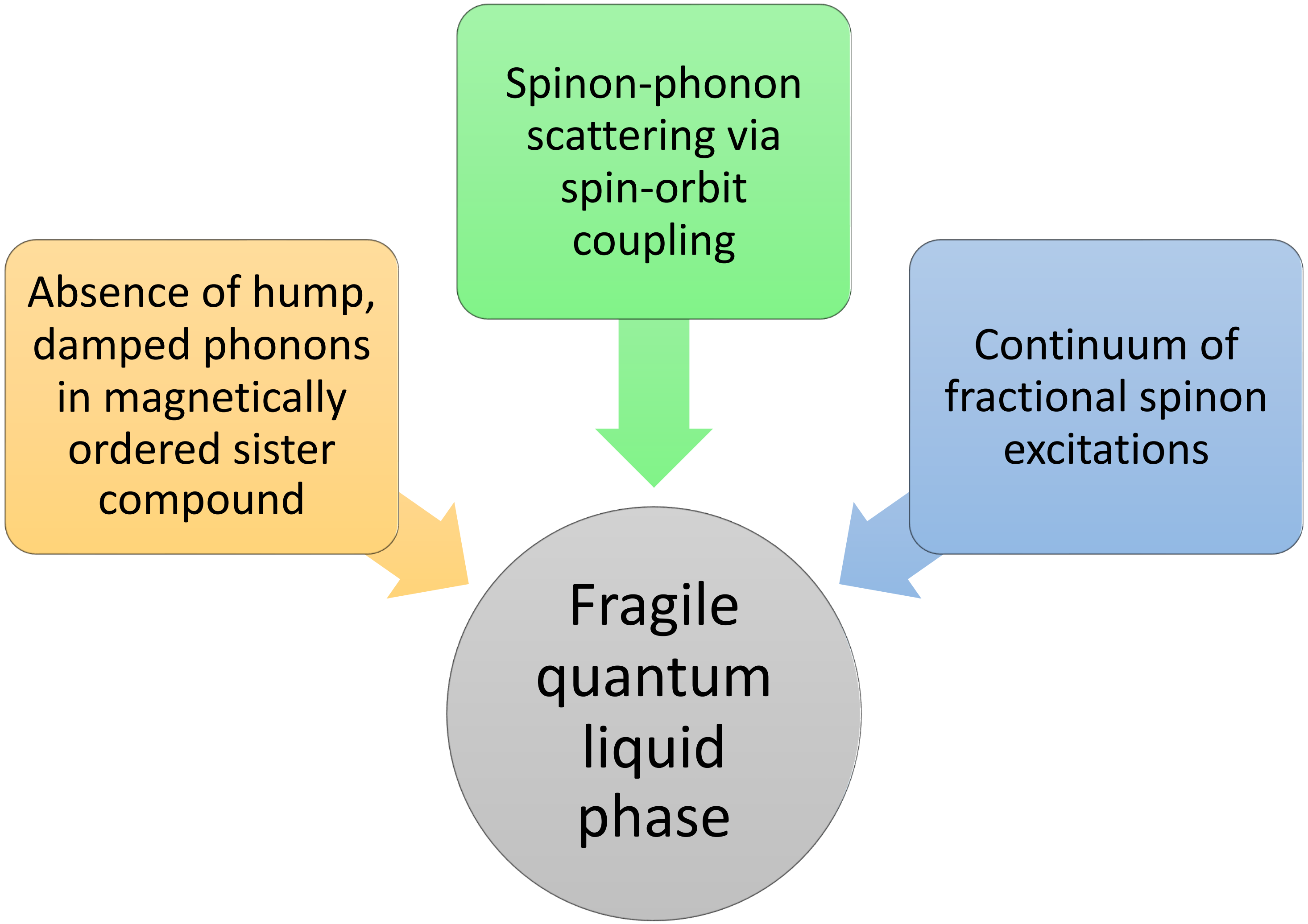

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