1. Introduction

- Recent experiments have provided strong evidence in favor of quantum-disordered ground states for certain Mott insulators.
- Conjectured ground states include quantum spin liquid states with no broken symmetry, fractionalized spin-half excitations, and topological order.
- Experiments till date: Thermal conductivity, thermal and electric transport, NMR, inelastic neutron scattering, etc. Several puzzles remain.

2. Probing via spin-currents

- Recent advances in the field of spintronics has enabled transmission of electric signals across insulators using spin-currents.
- Create a non-equilibrium accumulation of spin at metal-insulator boundary using the spin-hall effect.
- Inject spin into insulator at equilibrium.
- Use the inverse spin-hall effect to detect the spin-current at the right metallic reservoir.
- Measure spin-currents by measuring electrical voltages or currents.

3. Model and formalism

- Hamiltonian for the insulator Brillouin zone.
- Use Fermi’s Golden rule to evaluate spin-flip scattering at the boundary.
- Spin-current related to the dynamic structure factor $S_{\omega}(q,\omega)$ of the boundary spins.
- Simplifies in the limit of strongly peaked structure factors at well-separated momenta in the insulator Brillouin zone.

4. Application to AF

- Long range Neel-ordered cubic lattice antiferromagnetic insulator.
- Contributions from both inelastic scattering by static moments, and inelastic scattering by magnons:
  \[ I_{\text{spin}} = \frac{V}{c V^4} \]

5. Insulators without magnetic order

- Valence bond solid (VBS) states with broken lattice symmetries but unbroken SU(2) symmetry.
- Excitations are $S=1$ triplons, which can hop around.

6. Conclusion and Outlook

- Obtain the spin-current by simply measuring electrical voltages or currents.
- Can predict spinon gap and dispersion, and get more information about spinon-bands from the spin-current!
- In absence of spin-orbit coupling/random-field impurities, the spin-current does not degrade.

Open Questions:
What is the effect of coupling of spinons to non-spin carrying degrees of freedom in the spin liquid (like visons)?

How does presence of disorder at the boundary affect the spin-current?