Signatures of fractionalization in spin liquids from interlayer thermal transport

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Y. Werman, S. Chatterjee, S. Morampudi and E. Berg (arXiv:170x.xxxxx)
• **Traditional quantum magnetism**: *Ordered* ground states with broken symmetry (Eg: Antiferromagnet)

![Diagram of quantum spin liquids](image)

• Geometric frustration: **Additional possibilities**

• **Spin liquids**: Mott insulators with no broken symmetry due to quantum fluctuations
Quantum Spin liquids

• How can we define spin liquids more precisely?

• Long range quantum entanglement

• 4-fold g.s. degeneracy on a torus (topological order)

• Excitations which carry fractional quantum number \((S = \frac{1}{2} \text{ spinons})\) coupled to emergent gauge fields.

Detecting Quantum Spin liquids

- **Experimental signatures:**
  - No magnetic order down to very low temperatures
  - Can we probe fractionalization directly?
  - Previous work: Neutron scattering, spin injection, coherent tunneling into superconductors...

**This talk:** Temperature dependent anisotropy of thermal conductivity in gapless QSLs

• Why thermal transport:

• Many proposed QSLs are layered materials, with possibly gapless charge-neutral spinons

• $\kappa_c$ and $\kappa_{ab}$ show parametrically different behavior as a function of temperature

Detecting QSLs: Thermal transport

- Why thermal transport:
- Contrast with an anisotropic metal having non-fractionalized excitations (electrons)

At low temperatures, \( \frac{\kappa_{ab}}{\kappa_c} \rightarrow \text{const} \gg 1 \)

Figures: E. Berg, U. Chicago
Detecting QSLs: Thermal transport

- Model and results:
  Weakly coupled stacks of Kitaev’s honeycomb model


- TRS preserved: Dirac cones
- TRS broken: Fermi surface

Distinguishing feature: Time reversal symmetry

Figures: E. Berg
Model and results:

Weakly coupled stacks of Kitaev’s honeycomb model

TRS disorder acts as random vector potential

<table>
<thead>
<tr>
<th></th>
<th>In-plane</th>
<th>c-axis</th>
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<tbody>
<tr>
<td></td>
<td>Clean</td>
<td>Disordered</td>
</tr>
<tr>
<td>$Z_2$ Dirac</td>
<td>$T$</td>
<td>$[1]$</td>
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<tr>
<td>$Z_2$ FS</td>
<td>$\infty$</td>
<td>$T$</td>
</tr>
<tr>
<td>$U(1)$</td>
<td>$T^{1/3}$</td>
<td>$[2]$</td>
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Parametrically different in-plane vs interplane thermal transport can be a valuable probe of fractionalization in layered spin liquids.

Thank you for your attention!