Using neutron scattering to measure spin chirality in Kagome lattices.

P. A. Lee and N. Nagaosa, arXiv.

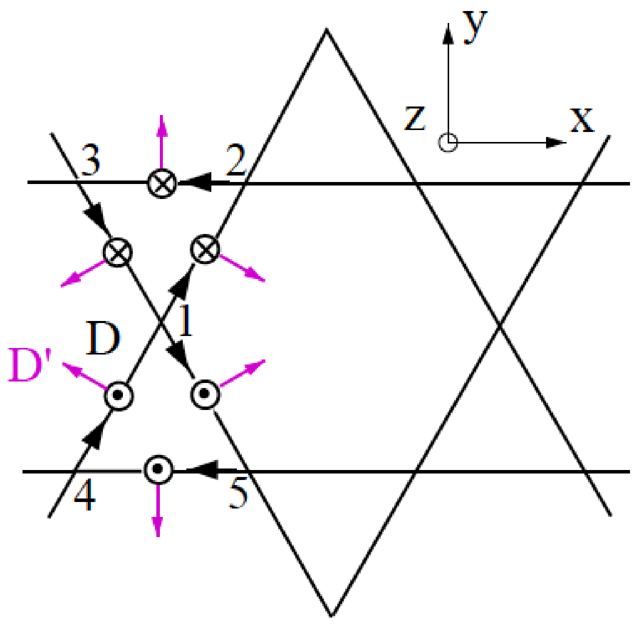
Gauge flux is proportional to scalar spin chirality. $\boldsymbol{S}_1 \cdot \boldsymbol{S}_2 \times \boldsymbol{S}_3$

How to measure its fluctuation spectrum?

Maleev, 1995 : neutron measurement of vector chirality.
Shastry-Shraiman, 1990: Raman scattering. Limited to small q.
Wingho Ko and PAL,2011, RIXS, limited energy resolution.

Savary and Balents PRL 2012, (also O. Benton, O. Sikora and N. Shannon, PRB 2012) showed that neutron scattering couples to gauge fluctuations in the spin ice problem, where spin-orbit coupling is dominant.

Can something similar work for the weak spin-orbit case?



$$\chi_1 = \boldsymbol{S}_1 \cdot \boldsymbol{S}_2 \times \boldsymbol{S}_3 + \boldsymbol{S}_1 \cdot \boldsymbol{S}_4 \times \boldsymbol{S}_5$$

$$\langle \boldsymbol{S}_2 \times \boldsymbol{S}_3 \rangle \ = \ \alpha \boldsymbol{D}_{23}$$
$$\langle \boldsymbol{S}_4 \times \boldsymbol{S}_5 \rangle \ = \ \alpha \boldsymbol{D}_{45} = -\alpha \boldsymbol{D}_{54} = \alpha \boldsymbol{D}_{23}$$

We expect that fluctuations of the z component of S1 contains information of the fluctuation of the scalar chirality.

A more formal argument:

$$S(q,\omega) = \sum_f |\langle f|S_z(\boldsymbol{q})|i\rangle|^2\,\delta(\omega - (E_f - E_i))$$

Let $|\alpha_\chi\rangle$ be a state which carries chirality and has no matrix element to couple to neutron scattering. To first order in DM, it becomes

$$|f_\chi\rangle = |\alpha_\chi\rangle + \sum_{\alpha\neq\alpha_\chi} \frac{\langle\alpha|H_{\mathrm{DM}}|\alpha_\chi\rangle}{E(\alpha_\chi) - E(\alpha)}|\alpha\rangle$$

$$\langle f_\chi|S_z(\boldsymbol{r}_1)|i\rangle = \sum_\alpha \left[\frac{\langle\alpha_\chi|H_{\mathrm{DM}}|\alpha\rangle\langle\alpha|S_z|0\rangle}{E(\alpha_\chi) - E(\alpha)} + \frac{\langle\alpha_\chi|S_z|\alpha\rangle\langle\alpha|H_{\mathrm{DM}}|0\rangle}{E(0) - E(\alpha)}\right]$$

Intermediate state is triplet. We assume triplet gap larger than singlet.

$$\omega = E(\alpha_\chi) - E(0) \ll E(\alpha) - E(0) \approx \Delta_t$$

$$\langle f_\chi|S_z(\boldsymbol{r}_1)|i\rangle = -\sum_{\langle jk\rangle} \frac{2D_{jk}}{\Delta_t}\langle\alpha_\chi|S_z(\boldsymbol{r}_1)\hat{z}\cdot\boldsymbol{S}(\boldsymbol{r}_j)\times\boldsymbol{S}(\boldsymbol{r}_k)|0\rangle$$

We predict that neutron scattering contains a piece which contains information on the scalar chirality fluctuations.

For example, for Dirac spin liquid, gauge propagator is:

$$\langle |b(q,\omega)|^2 \rangle \sim \frac{q^2\theta(\omega - vq)}{(\omega^2 - v^2q^2)^{1/2}}$$

Assumption of large triplet gap is not satisfied, but perhaps it can be replaced by the average triplet energy.

Does not work for the square lattice.