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Universal thermal Hall conductivity of a kagomé antiferromagnet

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Abstract:

Searching for the ground state of a kagomé Heisenberg antiferromagnet (KHA) has been one of the central issues of condensed-matter physics, because the KHA is expected to host many unknown spin-liquid phases with exotic elementary excitations.

To study the elementary excitations, we investigate the longitudinal (κ_{xx}) and transverse (κ_{xy}) thermal conductivities of a new candidate of S = 1/2 kagomé antiferromagnet Ca kapellasite ($CaCu_3(OH)_6Cl_2 \cdot 0.6H_2O$) of which the spin Hamiltonian is suggested to be well approximated to be an ideal KHA [1].

We find a clear thermal Hall signal in the spin liquid phase of $T^* < T < J/k_B$ ($T^* \sim 7$ K is the magnetic transition temperature and $J/k_B \sim 66$ K is the effective spin interaction energy). The temperature dependence of κ_{xy}/T shows a peak at $k_B T \sim J/3$, which is followed by a rapid decrease below T^*. We find that κ_{xy} is well reproduced, both qualitatively and quantitatively, by the Schwinger-boson mean-field theory with the Dzyaloshinskii-Moriya interaction of $D/J \sim 0.1$ [2]. Most remarkably, both κ_{xy} of Ca kapellasite and that of another kagomé antiferromagnet volborthite [3] are found to converge to one single curve of our Schwinger-boson calculation only by choosing J and D as fitting parameters. We further find that κ_{xy} of another kagomé compound Cd kapellasite [4] with smaller J shows a similar temperature dependence with a peak at lower temperature as expected by the Schwinger-boson calculation. This excellent agreement demonstrates not only that the thermal Hall effect in these kagomé antiferromagnets is caused by spins in the spin liquid phase, but also that κ_{xy} is given by a simple scaling function $f(k_B T/J)$, unveiling the universal $\kappa_{xy}(T)$ of KHA.

References

[1] H. Yoshida *et al.*, J. Phys. Soc. Jpn. **86**, 033704 (2017).

[2] H. Lee, J. H. Han, and P. A. Lee, Phys. Rev. B **91**, 125413 (2015).

[3] D. Watanabe *et al.*, Proc. Natl. Acad. Sci. **113**, 8653-8657 (2016).

[4] R. Okuma *et al.*, Phys. Rev. B **95**, 094427 (2017).

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