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Magnon thermal Hall effect in antiferromagnetic insulators

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概要

The Hall effect is traditionally associated with the motion of charged particles subjected to an external magnetic field via the Lorentz force. Beyond this classical picture, Hall responses can also arise without an external magnetic field. In magnetic insulators, magnons, charge-neutral bosonic quasiparticles, can exhibit the thermal Hall effect through an emergent gauge field, without relying on the Lorentz force [1]. The thermal Hall effect is of fundamental importance as it provides a powerful probe of charge-neutral carriers and emergent gauge fields in quantum magnets.

In this seminar, I will discuss the realization of the magnon thermal Hall effect in two classes of systems where it was previously thought to be absent or strongly suppressed.

First, I will discuss the realization of this effect in edge-shared lattices, such as square and triangular lattices. The conventional $U(1)$ gauge-field picture imposes a no-go condition that precludes the thermal Hall effect in these geometries [2,3]. We overcome this limitation by introducing a non-Abelian gauge-field picture, in which the noncommutativity of gauge fields generates an additional emergent magnetic flux [4,5]. This flux breaks effective time-reversal symmetry and enables the magnon thermal Hall effect even in edge-shared lattices.

Second, I will discuss the thermal Hall effect in a spin-gapped system: $1/3$ -plateau phase of a kagome antiferromagnet. Spin-gapped systems are generally expected to suppress low-energy transport due to the absence of mobile excitations. We demonstrate that this picture breaks down in the presence of strong geometric frustration. We observe the coexistence of two distinct types of quasiparticles: localized, magnetically neutral modes that contribute to longitudinal heat transport, and mobile magnetic excitations with topologically nontrivial bands, giving rise to a sizable thermal Hall effect [6].

[1] Y. Onose *et al.*, *Science* **329**, 297 (2010)

[2] H. Katsura *et al.*, *Phys. Rev. Lett.* **104**, 066403 (2010)

[3] T. Ideue *et al.*, *Phys. Rev. B* **85**, 134411 (2012)

[4] H. Takeda*, M. Kawano* *et al.*, *Nat. Commun.* **15**, 566 (2024)

[5] M. Kawano, *Phys. Rev. B* **112**, L060403 (2025)

[6] H. Takeda*, M. Kawano* *et al.*, submitted

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