

## Thermal Hall Effect in Ferromagnetic Insulators

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It is commonly believed that the Hall effect and thermal Hall effect are limited to systems of charged particles since they are driven by the Lorentz force. However, neutral quasi-particles such as phonons and magnons can carry heat current and potentially be responsible for the thermal Hall effect without resorting to the Lorentz force. We show both theoretically and experimentally that magnons exhibit the anomalous Hall effect in insulating ferromagnets with the Dzyaloshinskii-Moriya (DM) interaction, which acts as a vector potential for magnons.<sup>1,2</sup> We study various types of insulating ferromagnets, including a pyrochlore ferromagnet  $\text{Lu}_2\text{V}_2\text{O}_7$ , and find that the observed temperature and magnetic-field dependence of the thermal Hall conductivity can be well explained by the analytic expression for it derived from the theory based on the Berry curvature in momentum space.

<sup>1</sup>H. Katsura, N. Nagaosa, and P.A. Lee, *Phys. Rev. Lett.* **104**, 066403 (2010).

<sup>2</sup>Y. Onose, T. Ideue, H. Katsura, Y. Shiomi, N. Nagaosa, and Y. Tokura, *Science* **329**, 297 (2010).