

Origin of the large thermal Hall effect in the pseudogap phase of cuprates

Background

In hole-doped cuprates, a large negative thermal Hall conductivity κ_{xy} appears when the doping p is lowered below the critical doping p^* at which the pseudogap phase ends. The signal persists, and is in fact largest, in the undoped Mott insulator (e.g. La_2CuO_4), where mobile charge carriers are absent. At low temperature $|\kappa_{xy}|/T$ reaches values of order $0.5 \text{ mW K}^{-2} \text{ m}^{-1}$ in a field of 15 T, far larger than expected from magnons of a conventional Néel state or from electrons in this regime.

Measurements with the heat current along the c axis, where magnon and electron transport is negligible, show a comparable κ_{zy} , which indicates that phonons carry the signal. Phonons are neutral and have no intrinsic Hall response, so they must acquire chirality through coupling to some other degree of freedom.

The open question

What microscopic mechanism gives phonons in the cuprate pseudogap phase and Mott insulator a thermal Hall response of the observed sign and magnitude: skew scattering by defects or impurities, coupling to spin fluctuations of the antiferromagnetic background, or a coupling to a symmetry-breaking order of the pseudogap phase itself?

What would settle it

A microscopic model that reproduces the sign, the magnitude and the temperature and doping dependence of κ_{xy} and κ_{zy} , tested against controlled changes in disorder (irradiation or substitution) and against isotope substitution; or an experiment that cleanly separates the extrinsic (defect) from the intrinsic (spin or order-parameter) contribution.

References

1. G. Grissonnanche *et al.*, Giant thermal Hall conductivity in the pseudogap phase of cuprate superconductors, *Nature* **571**, 376 (2019).
2. G. Grissonnanche *et al.*, Chiral phonons in the pseudogap phase of cuprates, *Nature Physics* **16**, 1108 (2020).
3. M.-E. Boulanger *et al.*, Thermal Hall conductivity in the cuprate Mott insulators Nd_2CuO_4 and $\text{Sr}_2\text{CuO}_2\text{Cl}_2$, *Nature Communications* **11**, 5325 (2020).