Majorana-fermion origin for the planar thermal Hall effect in the Kitaev magnet α-RuCl$_3$

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The Kitaev quantum spin liquid has garnered attention due to the emergence of Majorana fermions and non-Abelian anyons resulting from the fractionalization of electron spins. The Kitaev model describes 1/2 spins on a 2D honeycomb lattice interacting through bond-dependent Ising ferromagnetic couplings. The spin-orbit Mott insulator α-RuCl$_3$ is a strong candidate Kitaev material. Several measurements, including specific heat, Raman scattering, and inelastic neutron scattering, provide evidence for the spin fractionalization in α-RuCl$_3$. Moreover, the half-integer quantized thermal Hall conductance includes evidence for forming a topologically nontrivial state consistent with the Kitaev model [1].

It has been shown that the half-integer quantized thermal Hall conductance appears even for a magnetic field with no out-of-plane components (planar thermal Hall effect, PTHE), providing further evidence for the Kitaev model [2]. However, an alternative scenario has been proposed; the topological bosonic magnon may account for the PTHE. To clarify the origin of the PTHE, we performed low-temperature measurements of high-resolution specific heat and planar thermal Hall conductivity with rotating in-plane fields[3, 4]. In the honeycomb bond direction, a distinct closure of the low-energy bulk gap is observed concomitantly with the sign reversal of the PTHE. This demonstrates that the topological transition is accompanied by the gap closing. Based on the general argument of topological bands, these results provide conclusive evidence for the fermion origin of the PTHE, ruling out the topological bosonic scenario. For the fermionic case, the thermal Hall conductivity should be quantized in principle.

We will also discuss the recent scanning tunneling microscopy measurements of monolayer α-RuCl$_3$ if time allows [5].

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