Dear Editors of Physical Review X,

We are pleased to submit our manuscript entitled “Thermal Hall Transport in Extended Kitaev Models” for consideration for publication in Physical Review X.

Quantum spin liquids are exotic states of matter characterized by long-range entanglement and fractionalized excitations. The Kitaev model offers a paradigmatic platform for realizing such states, hosting itinerant Majorana fermions and localized fluxes. A key experimental signature of these excitations is the thermal Hall conductivity, which is predicted to exhibit half-integer quantization at zero temperature under a magnetic field. Remarkably, this quantization has been reported in the Kitaev candidate material α-RuCl₃, suggesting the realization of a topological Majorana Chern insulator. However, the experimental situation remains highly controversial and is currently the subject of intense debate. While some studies report quantized thermal Hall conductivity, others observe deviations, with possible contributions from phonons, magnons, or visons being proposed. These conflicting results raise fundamental questions about the nature of the heat-carrying quasiparticles and the validity of the topological interpretation, particularly at finite temperatures and in the presence of additional interactions beyond the ideal Kitaev model.

In this work, we investigate the thermal Hall conductivity in an extended Kitaev model that includes symmetric off-diagonal interactions, Γ and Γ′ terms, under magnetic fields. Using unbiased finite-temperature tensor network simulations, benchmarked by thermal pure quantum state methods, we find that the thermal Hall conductivity divided by temperature, κₓᵧ/T, exhibits a pronounced overshooting behavior beyond the half-integer quantized value, closely resembling experimental observations in α-RuCl₃. Furthermore, we show that the sign of κₓᵧ/T changes systematically with the direction of the applied magnetic field, in agreement with topological predictions from perturbation theory as well as experimental results. Importantly, these features persist even in the polarized regime beyond the quantum critical point, indicating that the topological Majorana fermion picture remains relevant across a wide range of magnetic fields and interaction strengths.

Our findings reveal that the thermal Hall effect in the extended Kitaev models is a rich finite-temperature phenomenon, with topological Majorana fermion excitations remaining robust even in regimes traditionally considered dominated by conventional magnons. By reproducing key experimental features, including the overshooting behavior and field-direction-dependent sign change, and offering a consistent topological interpretation, our study provides a pathway toward reconciling conflicting experimental observations. We expect these results to have a strong impact on the actively evolving research field, offering a solid framework for interpreting thermal transport and guiding the identification of topological phases in strongly correlated quantum materials.

We confirm that this manuscript has not been published elsewhere and is not under consideration by another journal. All authors have approved the manuscript and agree with its submission to Physical Review X.

Thank you for considering our work. We look forward to your response.

Sincerely,  
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