Peer Review Report

Interface-driven topological Hall effect in $SrRuO_3$–$SrIrO_3$ bilayer

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Summary. The manuscript reports an anomalous Hall resistivity component observed in $SrRuO_3$–$SrIrO_3$ bilayers and attributes it to a topological Hall effect (THE) originating from Néel-type skyrmions stabilized by an interfacial Dzyaloshinskii–Moriya (DM) interaction. While the experimental observations are interesting and the interfacial physics is potentially rich, the identification of the Hall anomaly as a topological contribution relies on a sequence of phenomenological assumptions that are not demonstrated to be necessary or uniquely selected. As a result, the central physical interpretation is not established at a demonstrative level.

1. Identification of the topological Hall effect. The topological Hall signal is obtained by subtracting an anomalous Hall contribution inferred from Kerr rotation measurements. This procedure implicitly assumes that the anomalous Hall effect is fully captured by the net magnetization. However, non-collinear spin textures, inhomogeneous magnetic states, and multi-domain dynamics can modify the Hall response without producing a proportional Kerr signal. Consequently, the residual Hall component obtained by subtraction is not a unique observable and cannot be unambiguously identified with a topological Hall effect. Since THE is defined here by model-dependent subtraction rather than by a directly invariant quantity, its interpretation remains non-unique.

2. Phenomenological treatment of the DM interaction. The model Hamiltonian introduces a DM interaction confined to a single interfacial layer. This assumption is not derived from a microscopic calculation and is not supported by *ab initio* analysis. In itinerant $4d$–$5d$ oxide heterostructures, spin–orbit coupling and orbital hybridization are inherently non-local, making a strictly interface-confined DM term physically questionable. The large effective DM strength required to reproduce the data (of order 10–15 meV) significantly exceeds values reported for metallic and oxide interfaces and is not quantitatively justified. The DM interaction therefore acts as an adjustable parameter rather than an emergent physical quantity.

3. Use of emergent-field formalism outside its regime of validity. The conversion from skyrmion density to Hall resistivity is performed using a relation valid in the strong adiabatic coupling limit. $SrRuO_3$ is a multi-band itinerant ferromagnet with substantial disorder and scattering, and no evidence is provided that the adiabatic regime applies. Applying the emergent-field formula without establishing its validity regime introduces an additional uncontrolled assumption into the analysis.

4. Absence of variational closure. The proposed skyrmion configuration is not shown to arise as a stationary solution of a global variational functional. Key parameters are introduced phenomenologically, and alternative magnetic configurations compatible with the experimental data are not excluded. Within a variationally closed framework, physical configurations must be selected uniquely by a stationarity condition. Here, the skyrmion interpretation is one possible narrative among several, but its physical necessity is not demonstrated.

Conclusion. The manuscript presents a genuine and interesting Hall anomaly in $SrRuO_3$–$SrIrO_3$ bilayers. However, the attribution of this anomaly to a topological Hall effect generated by interfacial Néel-type skyrmions is not uniquely supported by the analysis. The interpretation relies on model-dependent assumptions, phenomenological parameter choices, and indirect subtraction procedures that lack variational and topological uniqueness. The results should therefore be interpreted as evidence for unconventional interfacial magnetotransport rather than as a demonstrated realization of a topological Hall effect.

References

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