Tuning the electron-skyrmion interaction: topological Hall effect and beyond

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Topological solitons such as skyrmions hold great promise to build ultra-high density magnetic racetrack memory because they can be reduced down to the nanoscale[1] and be moved with low-density current[2]. Achieving such a device can only be realized by a deep understanding of the interaction between the skyrmion and electrons. So far these interactions, such as the topological Hall effect (THE), have only been described in the complex framework of the Berry phase theory. Recently, a new energy term coupling the angular momentum of light with a magnetic moment has been shown to be able to re-derive complex magneto-electric effects such as the spin current model[3] in multiferroics, the anomalous Hall effect[4], inverse Rashba-Edelstein effect[5], anisotropic magnetoresistance and planar Hall effects[6]. However, no rigourous proof of this Angular MagnetoElectric (AME) coupling was given.
In this work, we demonstrate the existence of this coupling starting from the Dirac equation, and are able to re-derive the THE.

In addition, we are able to show that, under the application of electric fields, the force applied on the skyrmion could be finely tuned. Furthermore, the direct relationship between the transverse Hall conductivity and the skyrmion radius could allow the study of dynamical excitation of the skyrmion such as e.g., breathing modes. The AME coupling also allows for the prediction of novel magnetoelectric effects in metals hosting skyrmions.

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