Quantum metric and nonlinear magnetotransport from spin-momentum locking

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Quantum materials are characterized by electromagnetic responses that are directly related to the geometry and topology of electronic wavefunctions. These properties are encoded in the Berry curvature and quantum metric, which constitute the real and imaginary parts of the quantum geometric tensor, respectively. Berry curvature-mediated transport effects, including the anomalous Hall [1] and nonlinear Hall effect with time-reversal symmetry [2], have been observed in various magnetic and nonmagnetic materials. However, transport effects governed by the quantum metric remain limited to topological antiferromagnets [3-4]. Here [5], we show that spin-momentum locked electronic bands, which are commonly found at the surfaces and interfaces of materials with substantial spin-orbit coupling, are characterized by a nontrivial quantum metric that activates a nonlinear and nonreciprocal magnetoresistance. We observe the occurrence of this phenomenon and its gate-tunability in 111-oriented $LaAlO_3/SrTiO_3$ interfaces. The additional presence of the Berry curvature-mediated anomalous planar Hall effect further allows us to sense, for the first time and in a single nonmagnetic material, both components of the quantum geometric tensor. Our findings extend the application of quantum geometry to a vast class of materials and provide new strategies for designing electronic functionalities based on the geometric properties of electronic wavefunctions.

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