Axion coupling in magnetoelectric and topological materials

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I will provide an introduction to the theory of the Chern-Simons axion coupling, which is of growing interest in the context of magnetoelectric and topological materials. The axion coupling can be expressed in terms of a phase angle θ which plays a role in 3D analogous to that of the Berry-phase ϕ describing electric polarization in 1D. In particular, like the Berry phase, θ is only well defined modulo 2π. In ordinary magnetoelectric materials $\theta \ll 1$ and its branch choice is obvious. In some classes of topological materials, however, the symmetry is such that θ might be expected to vanish, but instead $\theta = \pi$ exactly. In such cases, a half-quantized anomalous Hall conductivity (AHC) is present at any gapped surface. This is the case for strong topological insulators, "axion insulators" (in which the topology is protected by inversion), antiferromagnetic topological insulators, and some topological crystalline insulators. In this talk I will give an overview of recent developments in this field, including some of our own recent work on a real-space decomposition of the anomalous Hall conductivity[1,2] and our use of this formalism to study the surface AHC for models of axion insulator.[3]

1. T. Olsen, M. Taherinejad, I. Souza, and D. Vanderbilt, *Surface theorem for the Chern-Simons axion coupling,* Phys. Rev. B **95**, 075137 (2017).
2. T. Rauch, T. Olsen, D. Vanderbilt, and I. Souza, *Geometric and nongeometric contributions to the surface anomalous Hall conductivity*, Phys. Rev. B **98**, 115108 (2018).
3. N. Varnava and D. Vanderbilt, *Surfaces of axion insulators,* arXiv:-1809.02853.