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Topological BF field theory description of topological insulators

JOEL E. MOORE, University of California, Berkeley and Lawrence Berkeley National Laboratory, GIL YOUNG CHO, University of California, Berkeley — Topological phases of matter are described universally by topological field theories in the same way that symmetry-breaking phases of matter are described by Landau-Ginzburg field theories. We propose that topological insulators in two and three dimensions are described by a version of abelian BF theory. For the two-dimensional topological insulator or quantum spin Hall state, this description is essentially equivalent to a pair of Chern-Simons theories, consistent with the realization of this phase as paired integer quantum Hall effect states. The BF description can be motivated from the local excitations produced when a π flux is threaded through this state. For the three-dimensional topological insulator, the BF description is less obvious but quite versatile: it contains a gapless surface Dirac fermion when time-reversal-symmetry is preserved and yields "axion electrodynamics", i.e., an electromagnetic $E \cdot B$ term, when time-reversal symmetry is broken and the surfaces are gapped. Just as changing the coefficients and charges of 2D Chern-Simons theory allows one to obtain fractional quantum Hall states starting from integer states, BF theory could also describe (at a macroscopic level) fractional 3D topological insulators with fractional statistics of point-like and line-like objects. Preprint available at http://arxiv.org/abs/1011.3485.

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