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Classification of Topological Insulators and Superconductors: the "Ten-Fold Way"[1]

ANDREAS LUDWIG, Dept. of Physics, University of California, Santa Barbara

We review the exhaustive ten-fold classification scheme of topological insulators and superconductors. It is found that the conventional (i.e.: "Z_2", or 'spin-orbit') topological insulator, experimentally observed in 2D ('Quantum Spin Hall') and in 3D materials, is one of a total of five possible classes of topological insulators or superconductors which exist in every dimension of space. Different topological sectors within a given class can be labeled, depending on the case, by an integer winding number, or by a "binary" Z_2 quantity. The topological nature of the bulk manifests itself through the appearance of "topologically protected" surface states. These surface states completely evade the phenomenon of Anderson localization due to disorder. Examples of the additional topological phases in 3D include topological superconductors (i) with spin-singlet pairing, and (ii) with spin-orbit interactions, as well as ^{3}He B. – The classification of topological insulators (superconductors) in d dimensions is reduced to the problem of classifying Anderson localization at the (d-1)-dimensional sample boundary which, in turn, is solved. The resulting five symmetry classes of topological insulators (superconductors) found to exist in every dimension of space correspond to a certain subset of five of the ten generic symmetry classes of Hamiltonians introduced 16 years ago by Altland and Zirnbauer in the context of disordered systems (generalizing the three well-known "Wigner-Dyson" symmetry classes). For a significant part of the phases of topological insulators (superconductors) of the classification a characterization can be given in terms of the responses of the system. For these, the responses are described by a field theory possessing a [gauge, gravitational (thermal), or mixed] anomaly. This implies that these phases are well defined also in the presence of inter-fermion interactions.

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