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Topological Insulators and Nematic Phases from Spontaneous Symmetry Breaking in 2D Fermi Systems with Quadratic Band Crossings

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In the light of recent progress in the search for topologically nontrival states of matter, discovering and/or understanding new mechanisms which could stabilize these exotic states has become increasingly important. We have investigated two-dimensional semi-metallic fermionic systems with a quadratic band-crossing point in the single-particle energy spectrum. At the noninteracting level, this quadratic band-crossing point is found to be topologically stable for a Berry flux 2π if the point symmetry group has either fourfold or sixfold rotational symmetry. However, this putative topologically stable free-fermion quadratic band-crossing point is marginally unstable in the presence of arbitrarily weak short-range repulsive interactions. For spinless fermions in the weak-coupling limit, an insulating quantum anomalous Hall phase is stabilized with a nontrivial Chern number. For relatively stronger coupling, a semi-metallic nematic phase with spontaneous rotational symmetry breaking occurs. For spin-1/2 fermions, two additional phases, the Z_2 quantum-spin-Hall phase and the nematic-spin-nematic phase, are found.