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Dirac Semimetals in Two Dimensions

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Graphene is well-known for its unusual band structure, which features a pair of two dimensional Dirac points – band degeneracies with linear dispersion – at the Fermi level, and has served as the canonical platform for exploring the novel physics that arises near such points. However, spin-orbit interaction breaks the degeneracy at the Dirac points, so that graphene is formally a quantum spin Hall insulator. In this talk I will discuss the theory of two dimensional materials with Dirac points that *persist* in the presence of spin-orbit interaction. These Dirac points are preserved by nonsymmorphic symmetries, which describe lattice invariance under a combined point group operation and fractional translation. This is the only means of protecting Dirac points against spin-orbit coupling in two dimensions, and such Dirac points are unique in marking the transition between topological and trivial insulating states. I will describe the general properties of these Dirac points and the nature of their protection by nonsymmorphic symmetry operations, and contrast them with Dirac points protected by symmorphic symmetries in both the three dimensional case and the spin-orbit-free two dimensional case. I will then delineate the possible configurations of two dimensional Dirac materials, classifying them by protective symmetries. The role of 2D Dirac materials as transition phases will be described in detail, and the topological and trivial phases that result from various modes of symmetry breaking will be explored. Finally, I will discuss the potential for realization of both Dirac materials and their derivative phases, paying special attention to relevant chemical considerations.