Abstract

Massless, relativistic fermions that are a solution of the Dirac equation where first introduced by H. Weyl as a model for the neutrino. Despite failing to describe any fundamental particle, it was discovered recently that Weyl fermions represent the low energy quasiparticles of certain semimetallic compounds (such as TaAs and NbAs). I will review the path to the discovery of Weyl semimetals that began with the study of graphene and nodal superconductors and has now evolved into a rich field of study encompassing solid-state compounds, photonic crystals, and ultra-cold atomic gases.

Distinct from high-energy physics, solid-state systems are never completely pure and the presence of disorder (representing dopants, dislocations, and impurities) must be taken into account. We will discuss the stability of three-dimensional Dirac and Weyl semimetals to the presence of disorder. Perturbative arguments suggest that the semimetal is stable to a weak amount of disorder and only becomes metallic after passing through a quantum critical point (QCP). First, we will discuss the evidence for the existence of the semimetal to metal QCP and show that it is distinct from the Anderson localization transition. Second, we will explore the non-perturbative effects of rare regions, from which we establish the existence of two distinct types of eigenstates in the weak disorder regime. The first are perturbatively renormalized Dirac states and the second are quasi-localized “rare” eigenstates. We find that these rare eigenstates contribute an exponentially small but non-zero density of states at zero energy, which converts the semimetal to a metal for an infinitesimal amount of disorder and the proposed QCP is avoided. Lastly, we show a quantum critical scaling regime still exists albeit only at finite energy or temperature.
Biographical Sketch

Jed H. Pixley is a postdoctoral fellow at the Condensed Matter Theory Center at the University of Maryland. He received his BS in physics and BA in pure mathematics at the University of California Santa Cruz in 2008. In 2014 he received his PhD in physics at Rice University. His research in condensed matter theory focuses on understanding quantum phases and their transitions in strongly correlated electronic systems, disordered topological semimetals, ultra cold atomic gases, and many-body localized systems.