New Forms of Matter: Weyl Fermions, Fermi Arcs and Topological Nodal-line Metals

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Discovery of topological insulator materials led to the search for related topological states of matter beyond insulators. In general, topological materials can host Dirac, Majorana or Weyl fermions as emergent quasiparticles on their boundaries, vortices or the bulk. Theory suggests that a Weyl semimetal is a gapless system (unlike gapped or insulating systems, for review see, Hasan & Kane, Rev. of Mod. Phys. 82, 3045 (2010)) whose low energy bulk excitations are massless Weyl fermions (see, theory reviews by Volovik (2009) and Turner & Vishwanath (2013)). The chiralities associated with the Weyl nodes can be understood as topological charges leading to split monopoles and anti-monopoles of Berry curvature in momentum space. Due to this topology a Weyl semimetal exhibits Fermi arc quasiparticles on its surface and chiral anomaly in its bulk electromagnetic transport response. These arcs (“fractional” Fermi surfaces) are discontinuous or disjoint segments of a two dimensional Fermi contour, which are terminated onto the projections of the bulk Weyl nodes on the surface. Such Fermi arc quasiparticles can live only on the boundary of a 3D crystal in conjunction with the Weyl nodes and collectively represent the realization of a new state of topological matter in recent experiments. In this talk I present our theoretical prediction of Weyl semimetal states in TaAs materials (Huang, Xu et.al., Nature Commun. 6:7373 (2015), submitted Nov. 2014) and topological nodal-line states in PbTaSe2/TlTaSe2 class of materials (Bian, Xu et.al., Nature Commun. 2015) and their experimental discoveries (Xu, Belopolski et.al., Science 2015, Science Adv. 2015, Nature Physics 2015) in these materials. Collectively, our bulk-boundary measurements via ARPES and spin-ARPES provide strong experimental evidence for the existence of topological semimetals.