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Discovery of Weyl fermion semimetal and topological Fermi arc quasiparticles in TaAs, NbAs, NbP, TaP and related materials

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Topological matter can host Dirac, Majorana and Weyl fermions as quasiparticle modes on their boundaries. First, I briefly mention the basic theoretical concepts defining insulators and superconductors where topological surface state modes are robust only in the presence of a gap (Hasan & Kane; Rev. of Mod. Phys. 82, 3045 (2010)). In these systems topological protection is lost once the gap is closed turning the system into a trivial metal. A Weyl semimetal is the rare exception in this scheme which is a topologically robust metal (semimetal) whose low energy emergent excitations are Weyl fermions. In a Weyl fermion semimetal, 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. This gives a measure of the topological strength of the system. Due to this topology a Weyl semimetal is expected to exhibit 2D Fermi arc quasiparticles on its surface (Wan et.al., 2011). These arcs ("fractional" Fermi surfaces) are discontinuous or disjoint segments of a two dimensional Fermi contour, which are terminated onto the projections of the Weyl fermion nodes on the surface we have observed experimentally in TaAs, NbAs, NbP class of materials (Xu, Belopolski et.al., Science 349, 613 (2015); Xu, Alidoust et.al., Nature Phys. (2015); Xu, Belopolski et.al., Science Adv. (2015), Belopolski, Xu et.al., arXiv (2015)) following our theoretical predictions (Huang, Xu, Belopolski et.al., Nature Commun. 6:7373 (2015), submitted in November 2014). Our theoretical predictions (Nature Commun. 2015) and experimental demonstrations (Science 2015, Nature Physics 2015, Science Advances 2015) reveal that these Fermi arc quasiparticles can only live on the boundary of a 3D crystal which collectively represents the realization of a new state of quantum matter beyond our earlier work on Fermi arcs in topological materials (Xu, Liu, Kushwaha et.al., Science 347, 294 (2015), adv.online (2014)). This work is in collaboration with Su-Yang Xu, Ilya Belopolski, Nasser Alidoust, Madhab Neupane, Chenglong Zhang, Raman Sankar, Shin-Ming Huang, Chi-Cheng Lee, Guoqing Chang, BaoKai Wang, Guang Bian, Hao Zheng, Daniel S. Sanchez, Fangcheng Chou, Hsin Lin, Shuang Jia, Titus Neupert. This work is supported by GBMF and U.S. DOE.

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