Magnetic-tunneling-induced Weyl node annihilation in TaP

Subject Code: A04

With the support by the National Natural Science Foundation of China, a collaborative study by the research groups led by Prof. Jia Shuang (**贾爽**) from Peking University, Prof. Lu Haizhou (**卢海舟**) from the South University of Science and Technology of China (SUSTech), and Prof. Wang Junfeng (**王俊峰**) from Huazhong University of Science and Technology demonstrated the annihilation of Weyl nodes in topological Weyl semimetal TaP, which was published in *Nature Physics* (2017, doi: 10.1038/nphys4183). The first author is PhD student Cheng-Long Zhang from Peking University.

One of the frontiers in physics is to explore quasiparticles described by the Dirac equation in topological materials. Paul M. Dirac proposed the Dirac equation in 1928, which can describe different quasiparticles, such as Dirac, Majorana, and Weyl fermions. A recent breakthrough is the discovery of topological Weyl semimetals, in which quasi-particles manifest themselves as the Weyl fermion, a long-sought crucial elemental particle in quantum field theory. These topologically protected Weyl quasiparticles are stable except annihilated by a collision of two chirality-opposite nodes in momentum space, which shall hardly occur when the band structure remains intact.

In this work, Prof. Jia's team prepared high-quality topological Weyl semimetal TaP and performed the experiment at Wuhan National High Magnetic Field Center, with assistance from Prof. Wang Junfeng's team. At 34.4 Tesla and at temperatures of 1.5 to 20 Kelvin, the Hall resistance shows an unexpected sign reversal (Figure (a)), which could be a signature of Weyl nodes annihilation induced by the magnetic field. Weyl fermions have no mass and have to appear in pairs, carrying opposite chirality in each pair. A very strong magnetic field can tunnel the two chirality-opposite lowest Laudau bands in TaP when the reciprocal of magnetic length and momentum separation of Weyl nodes is comparable. This leads to a sizable gap, or in other words, Weyl fermions acquire mass and lose chirality. In this sense, they are annihilated (Figure (b)). Prof. Lu's team performed theoretical simulations, which support the physical picture of the Weyl node annihilation.

The discovery will deepen our understanding on various low-energy topological quasi-particles in condensed matter physics.

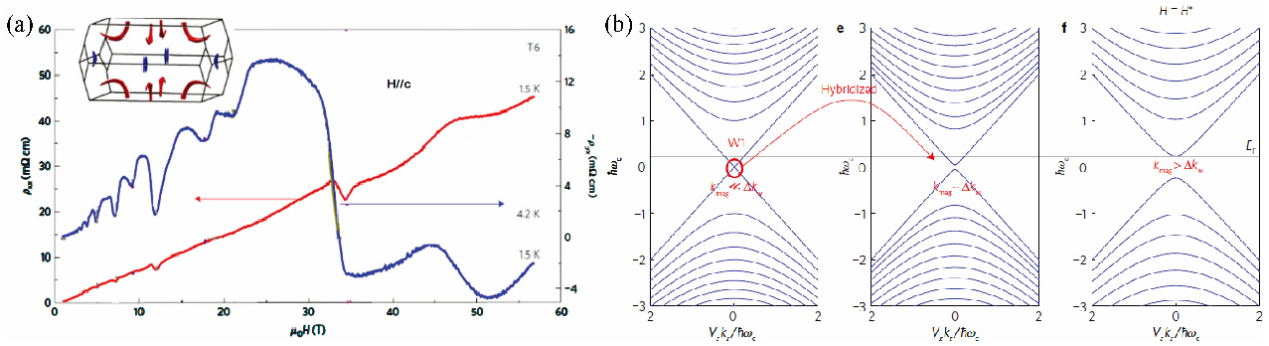

Figure (a) The Hall and magneto-resistance signals for TaP in magnetic field. A sign reversal of Hall signal occurs at 34.4 T (Inset: Weyl fermi pockets of TaP in 1st BZ); (b) Laudau bands under different strengths of magnetic fields. A sizable gap opens in strong magnetic fields.