Destruction of Weyl nodes and a New State in TaAs above 80 Teslas

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The spin up and spin down electrons in Dirac materials, such as graphene, share a Dirac-cone in momentum space. Weyl semimetals split this degeneracy into two Weyl-nodes with opposite handedness of spin-chirality, this provides the possibility of observing new phenomena. Weyl electrons, for example, are predicted to give rise to a chiral anomaly, whereby parallel electric and magnetic fields can pump an imbalance between the Weyl nodes leading to a topologically protected current.

To date all Weyl metals not only possess Weyl electrons but also trivial electrons, complicating the search for the associated phenomena. Our solution was to use extreme magnetic fields (95 tesla) to drive the Weyl metal TaAs deep into its quantum limit where only the purely chiral zeroth Landau levels are populated, and there we observed the chiral anomaly.

This illustrates how high magnetic fields can be used to overcome material constraints and access a state composed purely of Weyl fermions, and points the way to inducing new correlated states of matter composed of these exotic quasiparticles.

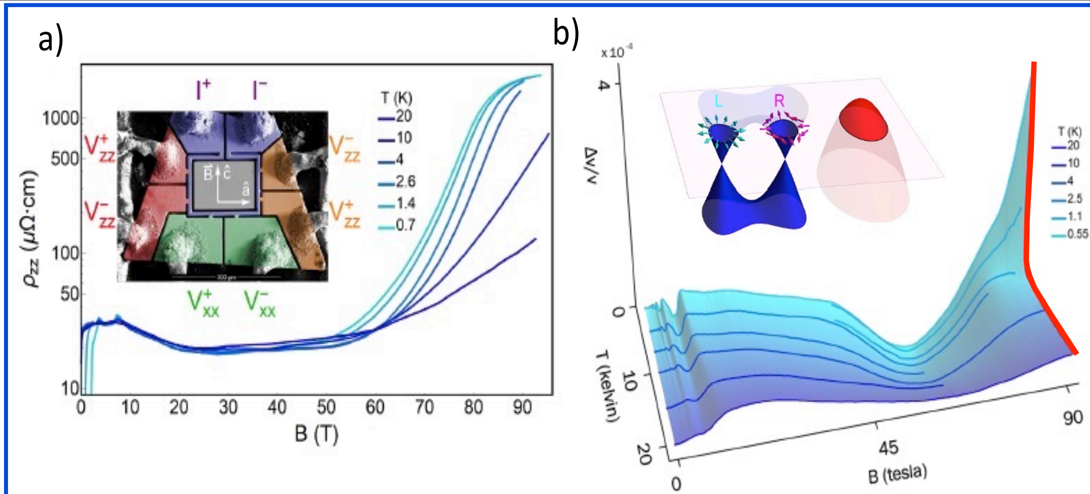

Figure (a) Resistivity of the Weyl semimetal, TaAs, for both current and magnetic field along the c-axis from T=20K to 0.7K. Quantum oscillations from the Weyl pockets are visible up to 7.5T, followed by a decrease and then saturation of the resistivity in temperature and field up to 50T. Above 50T, there is a two order-of-magnitude increase resistivity at low temperature, signifying the opening of an energy gap. The inset shows single-crystal TaAs microstructured using focused-ion-beam (FIB) lithography for both ρ_{zz} and ρ_{xx} measurements. **(b)** Change of the longitudinal sound speed measured at 315 MHz for both the sound propagation and magnetic field along the c-axis. Above 2.5K, the sound velocity flattens out above 80T and the attenuation is only weakly field dependent. Below 2.5K, however, both the sound velocity and the ultrasonic attenuation increase rapidly with field. The red line at 90T highlights the abruptness of the high-field transition as a function of temperature. The inset illustrates the hole dispersion (red), and electron-like Weyl fermions (blue), separated into distinct right and left-handed chiralities.

Facilities: 100 tesla and 65 tesla short pulsed magnet systems.

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