and patterning, opens up a wide range of new applications for hot-electron-driven chemistry. The LEE source might also prove a critical tool for obtaining a deeper nanoscale understanding of radiation chemistry and biology, and material degradation by high-energy radiation in general. ❒

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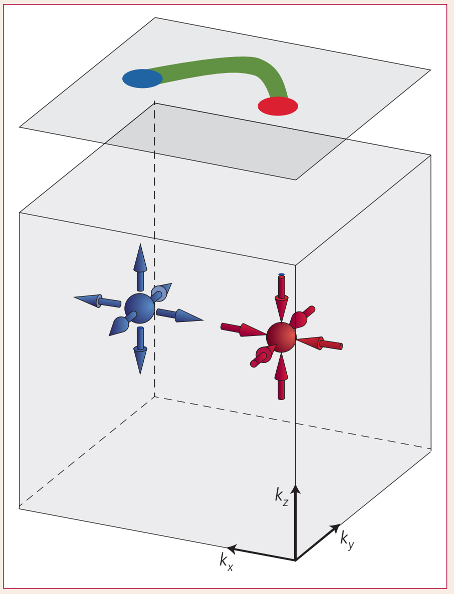
WEYL FERMIONS

Massless yet real

The quantum description of spin-1/2 particles is given by the solutions of the Dirac equation. In 1929, one year after Paul Dirac published it, Hermann Weyl reported that, for massless particles, the equation could be split into a system of two equations whose solutions are distinguished by chirality. These massless spin-1/2 particles, so-called Weyl fermions, have never been found in nature. Neutrinos had long been considered to be Weyl fermions, until their tiny mass — which is at least one million times lighter than that of electrons — was detected at the Super-Kamiokande neutrino observatory in Japan in the late 1990s, and then in subsequent experiments elsewhere.

Theoretical studies have predicted that Weyl fermions, in the form of low-energy excitations or quasiparticles, could be hosted in crystals — called Weyl semimetals — whose conduction properties are determined, as in topological insulators, by the topological properties of the bulk electron wavefunctions. Whereas topological insulators are insulators in the bulk, in Weyl semimetals the conduction and valence bands touch each other at some particular energies (Weyl points, represented as red and blue spheres in the figure), allowing the propagation of electron waves that behave as Weyl quasiparticles in the bulk. And, whereas the surface of a topological insulator displays a metallic behaviour, that of a Weyl semimetal shows a more complex behaviour in momentum space, with spin-polarized surface states (Fermi arcs, shown in green) connecting two bulk Weyl nodes of opposite chirality (blue and red dots). Now, following previous theoretical predictions[1,2], a group led by M. Zahid Hasan reports in *Science* the experimental demonstration that monopnictide TaAs is a Weyl semimetal[3].



REF. 3; AAAS

Zahid Hasan and co-authors probed the electronic structure of TaAs with vacuum ultraviolet and soft X-ray angle-resolved photoemission spectroscopy (ARPES). Ultraviolet measurements are sensitive to the surface of the material and revealed the existence of Fermi arcs, whereas soft X-ray ARPES is sensitive to the bulk and showed the existence of the Weyl nodes. The authors demonstrate that the positions of these features in momentum space, and the particular form of the band structure close to the Weyl points, are in good agreement with their theoretical predictions. And the fact that the terminations of the Fermi arcs coincide with the projections of the Weyl nodes provides further evidence for the topological nature of the observations.

Weyl semimetals are expected to have unusual transport and optical properties that result from the chiral properties and the exotic trajectories that the charges and excitations must follow. For instance, according to the predictions by the same group[2], an electron in a Fermi arc of TaAs would move back and forth between the top and bottom surfaces under the application of a vertical magnetic field, following a constant-energy contour. Starting at a Fermi arc at the top surface, the electron would move along it by changing its momentum until reaching the end of the arc, which is a Weyl point. The electron would then travel in real space towards the bottom surface. Once there, its momentum would change following another Fermi arc until it reached another Weyl point that would allow it to travel through the material back to the top surface.

The topological character of Weyl semimetals implies that their exotic properties must be robust against external perturbations, thus making them ideal candidates for practical applications in electronics, optoelectronics and, perhaps, quantum computing. And because of their massless character, Weyl fermions could lead to faster and lower-power consumer-electronic devices.

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