Weyl fermions exhibit paradoxical behavior

May 23 2017

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Theoretical physicists have found Weyl fermions to exhibit paradoxical behavior in contradiction to a 30-year-old fundamental theory of electromagnetism. The discovery has possible applications in spintronics. The study has been published in *Physical Review Letters*.

Physicists divide the world of elementary particles into two groups. On one side are force-carrying bosons, and on the other there are so-called fermions. The latter group comes in three different flavors. Dirac fermions are the most famous, comprising all matter. Physicists recently discovered Majorana fermions, which might form the basis of future quantum computers. Lastly, Weyl fermions exhibit weird behavior in, for example, electromagnets, which has sparked the interest of Prof. Carlo Beenakker's theoretical physics group.

Electromagnets

Conventional electromagnets work on the interplay between electrical currents and magnetic fields. Inside a dynamo, a rotating magnet generates electricity, and vice versa: Moving electrical charges in a wire wrapped around a metal bar will induce a magnetic field. Paradoxically, an electric current produced within the bar in the same direction would produce a magnetic field around it, in turn generating a current in the opposite direction, and the whole system would collapse.

Oddly enough, Beenakker and his group have found cases where this does actually happen. Following an idea from collaborator Prof. İnanç Adagideli (Sabanci University), Ph.D. student Thomas O'Brien built a computer simulation showing that materials harboring Weyl fermions actually exhibit this weird behavior. This has been observed before, but only at artificially short timescales, when the system didn't get time to correct for the anomaly. The Leiden/Sabanci collaboration showed that in special circumstances—at temperatures close to absolute zero when materials become superconducting—the strange scenario occurs indefinitely.

Until now, physicists considered this to be impossible due to underlying symmetries in the models used. That gives the discovery fundamental significance. "We study Weyl fermions mainly out of a fundamental interest," says O'Brien. "Still, this research gives more freedom in the use of magnetism and materials. Perhaps the additional flexibility in a Weyl semimetal will be of use in future electronics design."

More information: T. E. O'Brien, C. W. J. Beenakker, I. Adagideli, 'Superconductivity provides access to the chiral magnetic effect of an unpaired Weyl cone', *Physical Review Letters*, arxiv.org/abs/1612.06848

Provided by Leiden Institute of Physics