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We've seen particles that are massless only when moving one direction

Inside a hunk of a material called a semimetal, scientists have uncovered signatures of bizarre particles that sometimes move like they have no mass, but at other times move just like a very massive particle

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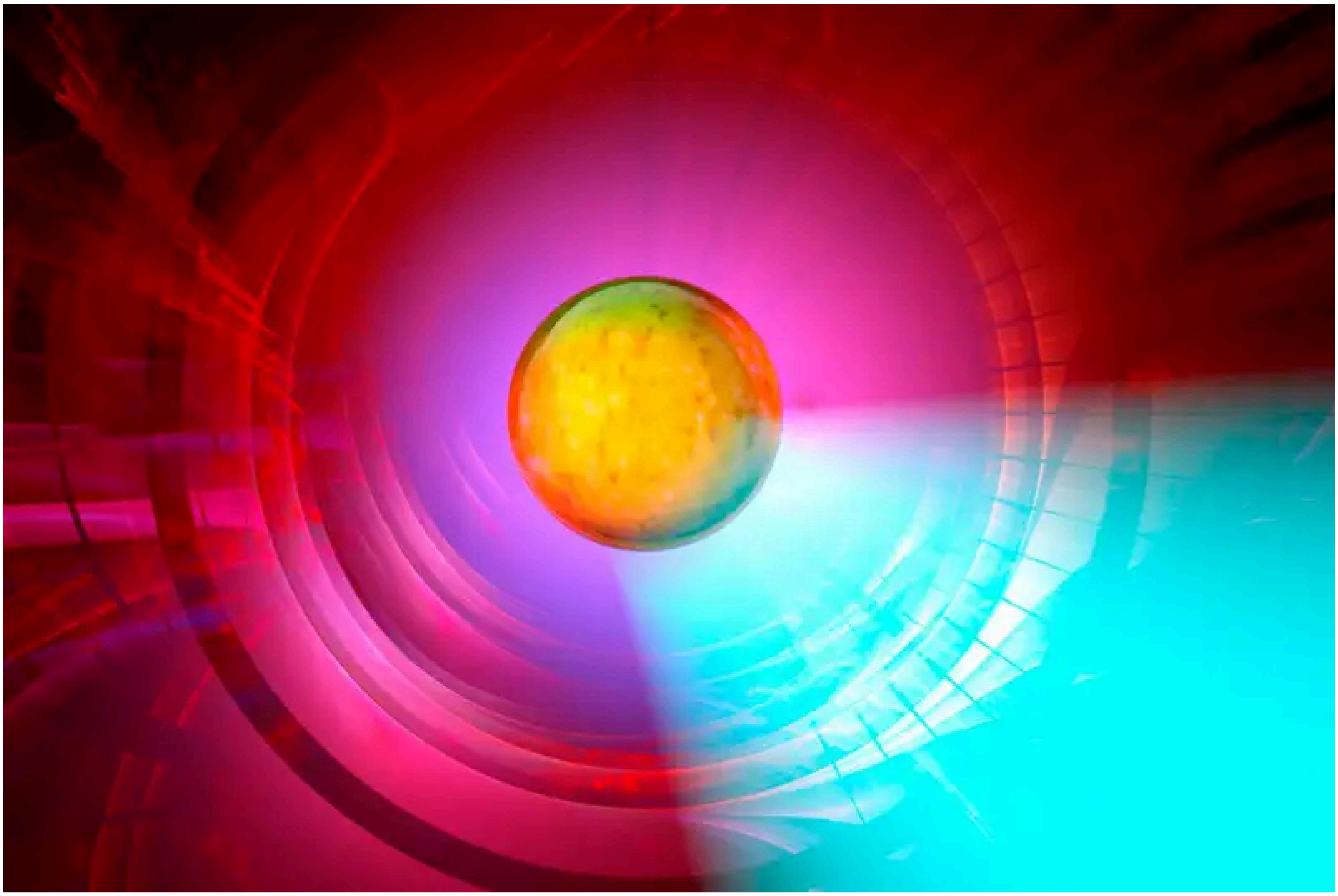

Mass-shifting particles have finally been spotted
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Strange particles that have mass when moving one direction but no mass when moving in another were first theorised more than a decade ago. Now, these mass-shifting particles have been glimpsed in a semimetal exposed to extreme conditions.

“This [particle] is very bizarre. You can imagine walking on the streets of New York and if you go straight, you are super light, you are massless. But turn 90 degrees east or west, and you become super massive,” says Yinming Shao https://science.psu.edu/physics/people/yjs5413 at the Pennsylvania State University. He and his colleagues came across these so-called semi-Dirac fermions while studying how metals behave when exposed to high magnetic fields.

They focused on a compound of zirconium, silicone and sulphur – it is a shiny semimetal that conducts electricity like any other metal, but with properties that become unusual in extreme conditions. The researchers cooled a chunk of it down to only a few degrees above absolute zero, and then exposed it to a magnetic field more than ten million times stronger than Earth’s

/article/2268520-earths-magnetic-field-flipping-linked-to-extinctions-42000-years-ago/#:~:text=The%2520most%2520recent%2520reversal%2520of,large%2520mammals%2520and%2520the%2520Neanderthals..

This field forced the electrons inside the semimetal to behave bizarrely. Instead of moving forwards in a kind of river of electric current, they began to trace out circular trajectories, like eddies in that river. And because they were so cold, they were also susceptible to quantum effects, meaning each acted like a wave that self-reinforced as it flowed around the eddy. These behaviours caused the semi-Dirac fermions to emerge.

To uncover them, the team shined infrared light onto the semimetal and analysed the way it reflected back. This revealed how the particles inside the material responded to being hit by light /article/mg26234940-300-how-materials-that-rewind-light-can-test-physics-most-extreme-ideas/. The researchers varied the magnetic field strengths and frequencies of light to identify the "fingerprint" of a semi-Dirac fermion. Shao says this phenomenon had been theorised 16 years ago for materials like graphene /article/2410612-first-working-graphene-semiconductor-could-lead-to-faster-computers/, but his team had to develop a mathematical model for this compound metal to confirm they were matching the fingerprint to the right exotic particle.

When the magnetic field pointed in the same direction as the moving particles, it was as if they had no mass at all. But when the magnetic field was at a right angle to the particles' trajectories, they had mass.

Gilles Montambaux https://gilles.montambaux.com/ at Paris-Sud University in France, who worked on some of the earliest mathematical studies of semi-Dirac fermions, says the new material required a much more complex model than graphene, so the team's "theoretical analysis is remarkable".

Warren Pickett https://physics.ucdavis.edu/directory/faculty/warren-pickett at the University of California, Davis, who was part of the team that first identified semi-Dirac fermions as a new type of theoretical particle, says sorting through all the data to find the particle must have been challenging because the semimetal also contains many other particles that interact with light.

"It is exciting that experimentalists were able to realise those quasiparticles in a real quantum material," says Bruno Uchoa https://www.ou.edu/cqrt/people/bruno-uchoa at the University of Oklahoma. He says semi-Dirac fermions are an exotic hybrid of regular electrons that exist in any metal and more unusual cosmic particles like massless neutrinos. As such, they stand a chance of revealing many new physical behaviours, he says. For instance, they may be able to form a viscous fluid inside the semimetal, which would be rather different than conventional electronic currents.

But Shao says there are many open questions regarding what semi-Dirac fermions can do that need to be answered before they can be put to practical use. "For this material, there's still many mysteries to further explore," he says.

Reference: *Physical Review X*, forthcoming https://journals.aps.org/prx/accepted/c307eKeaE0c1ad0de8353db53a799be662b8dde40