NATURE | NEWS

Big Bang gravitational effect observed in lab crystal

Phenomenon thought to occur only in exotic, high-energy physics environments seen in quantum material.

Philip Ball

20 July 2017

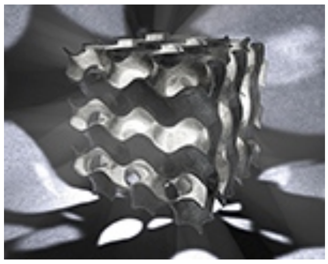
Robert Strasser, Kees Scherer; collage: Michael Büker

A laboratory crystal can be used to demonstrate how the curvature of space-time might affect Weyl fermions.

An exotic effect in particle physics that's theorized to occur in immense gravitational fields — near a black hole, or in conditions just after the Big Bang — has been seen in a lump of material in a laboratory, physicists report.

A team led by physicist Johannes Gooth at IBM Research near Zurich, Switzerland, say they have seen evidence for a long-predicted effect called the axial–gravitational anomaly[1]. It states that huge gravitational fields — which general relativity describes as the result of enormous masses curving space-time — should destroy the symmetry of particular kinds of particles that usually come in mirror-image pairs, creating more of one particle and less of another.

The kinds of conditions needed to prove this unusual breakdown of a fundamental 'conservation law' can't be created in a laboratory. But the researchers exploited a peculiar parallel between gravity and temperature to create a lab analogue of the anomaly in niobium phosphide crystals. "This anomaly is so hard to measure that even indirect evidence is a major breakthrough," says team member Adolfo Grushin of the University of California, Berkeley.



The strange topology that is reshaping physics

Inside the crystal, the effect is as if a drawerful of pairs of gloves were suddenly to acquire an excess of right-handed gloves because some of the left-handed ones had switched handedness. The result, published in *Nature*[2], bolsters an emerging view that quantum materials — crystals whose properties are dominated by quantum-mechanical effects – can act as experimental test-beds for physics effects that could only otherwise be seen under exotic circumstances.

Quasiparticles and quantum materials

The particles affected by the anomaly are known as Weyl fermions, which were proposed in the 1920s by mathematician Hermann Weyl. These particles differ from other kinds of fermions (such as the electron) because they seem to have no mass, and because they also have a kind of handedness, or chirality.

Weyl fermions have never been seen as individual physical entities — although it's thought they might be fleetingly involved in the decays of other kinds of particles. But they have been spotted as 'quasiparticles' inside some crystals. In these materials, quantum-mechanical effects cause a material's electrons to move together in such a way that their collective behaviour resembles that of Weyl fermions. The chiral Weyl fermions are generally produced in equal numbers, like mirror-image pairs.

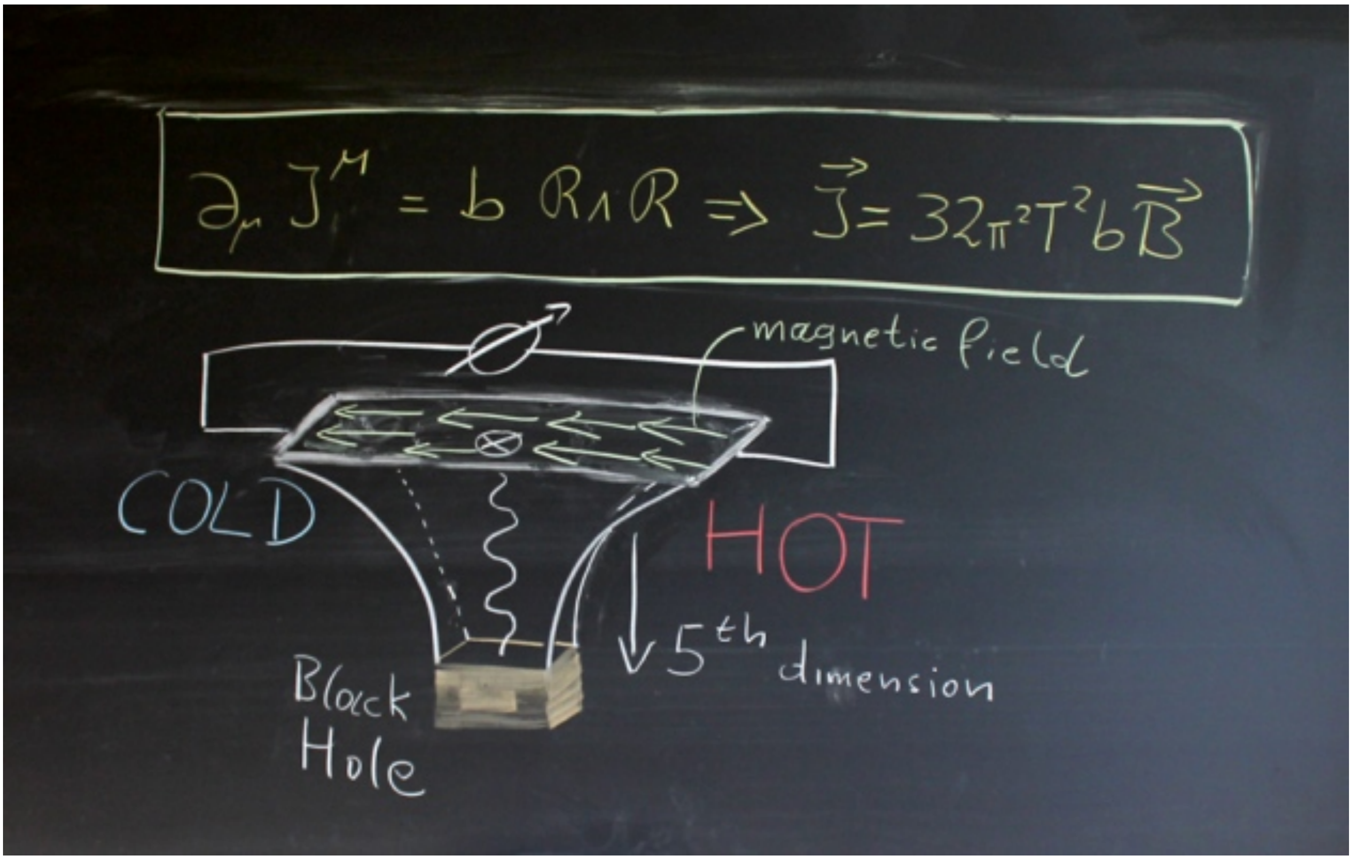
In 2015, researchers showed that strong magnetic and electric fields could break this symmetry inside a quantum material known as a Dirac semimetal[3] — vindicating a long-predicted effect in high-energy physics called the axial (or chiral) anomaly.

The quantum source of space-time

Now, Gooth's team has confirmed that gravity — or space-time curvature — can also destroy the symmetry. To do so, they relied on a connection between gravitational and temperature effects, which states that the effect of space-time curvature on Weyl fermions is mathematically equivalent to the effect of a gradient in temperature[4, 5]. In other words, the anomaly should also appear if one part of a material in which Weyl fermions appear is hotter than another.

The reason "is rooted in Einstein's famous equation $E = mc^2$", explains Gooth. "In relativistic quantum field theory, energy and mass flows become the same," he says. "Mass flow is driven by gravitational-field gradients, and energy flow by temperature gradients. The temperature gradient for the relativistic Weyl fermions thus mimics a gravitational-field gradient."

The researchers measured the conductivity of their crystalline niobium phosphide — which is known as a Weyl semimetal — in a microelectronic circuit. When they applied a thermal gradient and a magnetic field, they saw an induced electric current created by an imbalance in the two types of Weyl fermion: the number of left-handed quasiparticles moving in one direction through the sample was not the same as the number of right-handed ones moving in the opposite direction. Furthermore, "the behaviour of the current as we change the magnetic field is exactly what the theory of the axial–gravitational anomaly predicts", says Grushin.



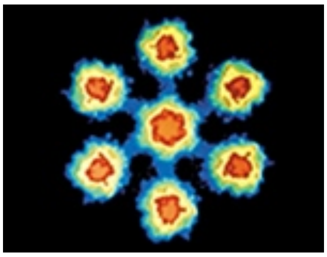
Karl Landsteiner

A chalkboard sketch shows how applying a temperature gradient to certain type of quantum material can mimic the conditions near a black hole.

Compelling evidence

Not everyone is persuaded that the researchers have observed what they claim. Boris Spivak, a physicist at the University of Washington in Seattle, insists that the axial–gravitational anomaly simply doesn't exist in Weyl semimetals. A temperature gradient, he says, can't induce electrons to convert between the two quasiparticles of different handedness. "There are many other mechanisms which can explain their data," Spivak says. He thinks the researchers are just measuring the impact of a magnetic field on the well-known thermoelectric effect, in which electrical currents are produced by temperature gradients.

But Gooth and his colleagues disagree. They say that the existence of the temperature-induced chiral anomaly is strongly supported by theory. And Subir Sachdev, a specialist on quantum effects in solid-state materials at Harvard University in Cambridge, Massachusetts, says the researchers have “compelling evidence for the physical consequences of the axial–gravitational anomaly”.



Fire up the atom forge

The existence of the anomaly was not really in doubt, Sachdev adds, but “it is nice to see it appear in real materials”. He says it confirms that gravity interacts with quantum fields in the manner indicated by Einstein’s theories of relativity.

Grushin suspects that understanding how this anomaly manifests in these materials should lead to new physics. And IBM also hopes that the finding might be exploited in electronics, because it generates an electrical current inside the niobium phosphide crystal. Devices that expoit the anomaly might improve the efficiency of materials that can generate electrical energy from temperature gradients, Gooth says.

Nature doi:10.1038/nature.2017.22338

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2. Gooth, J. *et al*. *Nature* **547**, 324–327 (2017).
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Tim Meloche • 2017-07-20 07:19 PM

Yes I agree general relativity is a dead end when it comes to a theory that explains how the force of gravity is transferred. Perhaps it is time to shake it up and take a close look at the base fundamentals behind some current academic research. The challenge for fundamental analysis goes to the young up and coming academic researcher who is actively seeking solutions and innovation. If this is you then the principles of atomic gravity are your starting point! It may be your time to race past your peers with both prestige and setup a great career path. The principles of atomic gravity are tools used to advance academic research in the natural sciences. The principles describe the method to how the force of gravity is transferred in atomic structure. Understand the principles to understand the bigger picture. The next step is easy. A summary of the principles can be found in the google docs links below. It is better to understand the principles now before spending too many years chasing ghosts like the many vested current academic pre-retirees and retirees whose past research centered on the fundamentals of gravity through the theory of general relativity. New ideas are born and the old theories fade away demonstrating how the evolution of scientific knowledge has advanced through-out human endeavor. Take a step forward and get in the lead! https://docs.com/tim-g–meloche/7280/atomic-gravity?fromAR=1 https://docs.com/tim-g–meloche/4675/zero-g-flight-at-the-atomic-scale?c=ri2tXf.

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"The kinds of conditions needed to prove this unusual breakdown of a fundamental ‘conservation law’ can’t be created in a laboratory. But the researchers exploited a peculiar parallel between gravity and temperature to create a lab analogue of the anomaly in niobium phosphide crystals." A parallel between gravity and temperature?!? Theoretical physics is obviously absurd, even idiotic, and "the root of all the evil", the primary malignancy, is this: "Lee [Smolin] and I discussed these paradoxes at great length for many months, starting in January 2001. We would meet in cafés in South Kensington or Holland Park to mull over the problem. THE ROOT OF ALL THE EVIL WAS CLEARLY SPECIAL RELATIVITY. All these paradoxes resulted from well known effects such as length contraction, time dilation, or E=mc^2, all basic predictions of special relativity. And all denied the possibility of establishing a well-defined border, common to all observers, capable of containing new quantum gravitational effects." Joao Magueijo, Faster Than the Speed of Light, p. 250 http://www.amazon.com/Faster-Than-Speed-Light-Speculation/dp/0738205257 Philip Ball: "And by making the clock's tick relative - what happens simultaneously for one observer might seem sequential to another - Einstein's theory of special relativity not only destroyed any notion of absolute time but made time equivalent to a dimension in space: the future is already out there waiting for us; we just can't see it until we get there. This view is a logical and metaphysical dead end, says Smolin." http://www.guardian.co.uk/books/2013/jun/10/time-reborn-farewell-reality-review Pentcho Valev

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" The reason “is rooted in Einstein’s famous equation E = mc2”, explains Gooth. “In relativistic quantum field theory, energy and mass flows become the same,” he says. “Mass flow is driven by gravitational-field gradients, and energy flow by temperature gradients. The temperature gradient for the relativistic Weyl fermions thus mimics a gravitational-field gradient.” " Philip Ball, did you feel discomfort and guilt when you published this? I suspect you didn't, and the reason is simple - theoretical physics is dead anyway so no idiocy can be harmful anymore: New Scientist: "Saving time: Physics killed it. Do we need it back? [...] Einstein landed the fatal blow at the turn of the 20th century." http://www.newscientist.com/article/mg22029410.900 "[George] Ellis is up against one of the most successful theories in physics: special relativity. It revealed that there's no such thing as objective simultaneity. [...] Rescuing an objective "now" is a daunting task." https://www.newscientist.com/article/mg22730370-600-why-do-we-move-forwards-in-time/ "...says John Norton, a philosopher based at the University of Pittsburgh, Pennsylvania. Norton is hesitant to express it, but his instinct - and the consensus in physics - seems to be that space and time exist on their own. The trouble with this idea, though, is that it doesn't sit well with relativity, which describes space-time as a malleable fabric whose geometry can be changed by the gravity of stars, planets and matter." http://www.newscientist.com/article/mg20026831.500-what-makes-the-universe-tick.html Nobel Laureate David Gross observed, "Everyone in string theory is convinced...that spacetime is doomed. But we don't know what it's replaced by."

https://www.edge.org/response-detail/26563 Nima Arkani-Hamed (06:09): "Almost all of us believe that space-time doesn't really exist, space-time is doomed and has to be replaced by some more primitive building blocks." https://www.youtube.com/watch?v=U47kyV4TMnE What scientific idea is ready for retirement? Steve Giddings: "Spacetime. Physics has always been regarded as playing out on an underlying stage of space and time. Special relativity joined these into spacetime... [...] The apparent need to retire classical spacetime as a fundamental concept is profound..." https://edge.org/response-detail/25477 "Rethinking Einstein: The end of space-time [...] The stumbling block lies with their conflicting views of space and time. As seen by quantum theory, space and time are a static backdrop against which particles move. In Einstein's theories, by contrast, not only are space and time inextricably linked, but the resulting space-time is moulded by the bodies within it. [...] Something has to give in this tussle between general relativity and quantum mechanics, and the smart money says that it's relativity that will be the loser." http://www.newscientist.com/article/mg20727721.200-rethinking-einstein-the-end-of-spacetime.html "And by making the clock's tick relative - what happens simultaneously for one observer might seem sequential to another - Einstein's theory of special relativity not only destroyed any notion of absolute time but made time equivalent to a dimension in space: the future is already out there waiting for us; we just can't see it until we get there. This view is a logical and metaphysical dead end, says Smolin." http://www.guardian.co.uk/books/2013/jun/10/time-reborn-farewell-reality-review "Was Einstein wrong? At least in his understanding of time, Smolin argues, the great theorist of relativity was dead wrong. What is worse, by firmly enshrining his error in scientific orthodoxy, Einstein trapped his successors in insoluble dilemmas..." https://www.amazon.com/Time-Reborn-Crisis-Physics-Universe-ebook/dp/B00AEGQPFE Neil Turok: "It's the ultimate catastrophe: that theoretical physics has led to this crazy situation where the physicists are utterly confused and seem not to have any predictions at all." http://www2.macleans.ca/2013/09/05/perimeter-institute-and-the-crisis-in-modern-physics/ Frank Close: "In recent years, however, many physicists have developed theories of great mathematical elegance, but which are beyond the reach of empirical falsification, even in principle. The uncomfortable question that arises is whether they can still be regarded as science. Some scientists are proposing that the definition of what is "scientific" be loosened, while others fear that to do so could open the door for pseudo-scientists or charlatans to mislead the public and claim equal space for their views." http://www.prospectmagazine.co.uk/features/what-happens-when-we-cant-test-scientific-theories Sabine Hossenfelder: "Many of my colleagues believe this forest of theories will eventually be chopped down by data. But in the foundations of physics it has become extremely rare for any model to be ruled out. The accepted practice is instead to adjust the model so that it continues to agree with the lack of empirical support." http://www.nature.com.proxy.readcube.com/nphys/journal/v13/n4/full/nphys4079.html Sabine Hossenfelder (Bee): "The criticism you raise that there are lots of speculative models that have no known relevance for the description of nature has very little to do with string theory but is a general disease of the research area. Lots of theorists produce lots of models that have no chance of ever being tested or ruled out because that's how they earn a living. The smaller the probability of the model being ruled out in their lifetime, the better. It's basic economics. Survival of the 'fittest' resulting in the natural selection of invincible models that can forever be amended." http://www.math.columbia.edu/~woit/wordpress/?p=9375 Peter Woit: "As far as this stuff goes, we're now not only at John Horgan's "End of Science", but gone past it already and deep into something different." http://www.math.columbia.edu/~woit/wordpress/?p=7266 "But instead of celebrating, physicists are in mourning after a report showed a dramatic decline in the number of pupils studying physics at school. The number taking A-level physics has dropped by 38% over the past 15 years, a catastrophic meltdown that is set to continue over the next few years. The report warns that a shortage of physics teachers and a lack of interest from pupils could mean the end of physics in state schools. Thereafter, physics would be restricted to only those students who could afford to go to posh schools. Britain was the home of Isaac Newton, Michael Faraday and Paul Dirac, and Brits made world-class contributions to understanding gravity, quantum physics and electromagnetism - and yet the British physicist is now facing extinction. But so what? Physicists are not as cuddly as pandas, so who cares if we disappear?" http://www.guardian.co.uk/science/2005/nov/22/schools.g2 Pentcho Valev

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