NATURE | NEWS

Super gas meets with no resistance

Atomic gas superfluid mimics its superconducting cousins for the first time, and could help scientists to model the early cosmos in the lab.

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28 November 2012

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Controlling superfluids in the lab may help us understand the universe's early history.

Superfluid gases that defy friction now have another 'superpower' to add to their arsenal. Quantum physicists have shown for the first time that atoms in these ultracold gases can also conduct without experiencing any resistance[1]. The experimental set-up might one day help to solve a long-standing mystery about superconductivity, and could even be used to model the early Universe in the lab.

Atoms within superfluids, which were first discovered[2] in the 1930s, do not experience resistance as they exploit quantum effects to band together. This means that they can perform bizarre feats, such as flowing up the walls of their containers. In theory, these atoms should also easily be able to conduct through a narrow channel, without feeling any resistance caused by the confined space — just as electrons in a superconductor move unhindered by electrical resistance. But until now, nobody had been able to demonstrate this in the lab.

“It always annoyed me that this defining feature — conductance without resistance — that had been used to discover superconductivity had never been shown in an atomic gas superfluid,” says Tilman Esslinger, a quantum physicist at the Swiss Federal Institute of Technology (ETH) in Zurich.

Chill then squeeze

Esslinger and his colleagues took up that challenge by manipulating a cloud of lithium atoms, chilled to just less than a microkelvin above absolute zero — 10 million times colder than deep space. Using lasers, they squeezed the gas into a dumbbell shape to create two reservoirs of atoms linked by a narrow bridge, with more atoms on the left than on the right. Finally, they blocked the bridge, using another 'gate' laser: when the beam was on, the bridge was closed; when it was off, the bridge was open, allowing atoms to pass from the more populated to the less crowded side.

At this stage, the cloud was not a superfluid, just a normal atomic gas. The team gradually lifted the gate and the atoms began to drift across the bridge at a speed of about 5 millimetres a second. The team then applied a magnetic field to the gas which forced it into an exotic quantum state, otherwise known as a superfluid. When the team repeated the same experiment with this superfluid — opening the laser gate and measuring the speed of the atoms as they did so — they noticed a considerable change.

“There was immediately a striking effect: no resistance at all, as though there was no channel,” says Esslinger. The drop in resistance occurred when the laser was tuned down from 1.2 microkelvin, with the gate fully closed, to 0.7 microkelvin, with the gate just under halfway open (the strength of the laser is determined by its temperature). At this point, the atoms rapidly sped up to around 30 millimetres a second.

Jan Zaanen, a condensed-matter physicist at the University of Leiden in the Netherlands, says that he is “awestruck” by the team’s prowess at accurately manipulating the superfluid.

Cosmos in a lab

The team’s experimental set-up could eventually be used to investigate the origin of other strange quantum effects. For instance, although most superconductors only work at temperatures near absolute zero, some solids are able to superconduct at unexpectedly high temperatures of about 70 kelvin. It is tough to pinpoint why this happens by looking directly at those materials because many other complex interactions within solids, such as the vibration of the atomic lattice, confuse matters.

But an atomic gas could be tuned to simulate high-temperature superconductivity in controlled conditions without such distractions, says Séamus Davis, a solid-state physicist at Cornell University in Ithaca, New York. “The dream is to learn more about superconductivity from these systems so we can work out how to make it survive at room temperature,” he says. “That would revolutionize technology.”

The work could also help to reveal the Universe’s early history, because the superfluid's quantum properties are similar to those of the hot fiery ball of gas — made up of elementary particles called quarks and gluons — that appeared soon after the Big Bang.

“Cosmologists don’t have exact equations to calculate what happens in such systems,” says Zaanen. “This could offer a way to model the cosmos, in the lab.”

Nature | doi:10.1038/nature.2012.11911

References

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