PHYSICS

All Paired Up but Unable to Flow, Atoms Strain Key Conceptual Link

Day leads to night, life leads to death, winter leads to spring; some things necessarily imply others. So it has seemed in physics: At very low temperatures, certain particles pair, and when they do, the pairs inevitably gang up to form a "superfluid" that flows without resistance. That explains how electrons glide through superconductors, how atoms of helium-3 form a liquid with no viscosity, and perhaps, how neutrons circulate through neutron stars. But an experiment reported on page 867 breaks the pairing-to-superfluidity connection. Atoms in an ultracold gas can pair but do not flow without resistance, even at temperatures approaching absolute zero, physicists report.

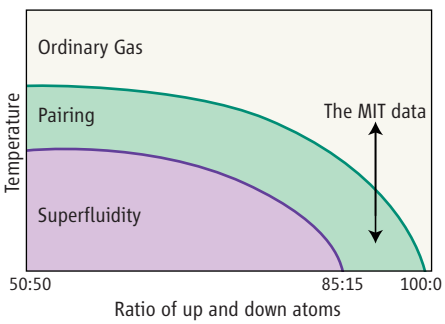
"If they have found a [zero temperature] state that has pairing but no superfluidity, that would be revolutionary," says Mohit Randeria, a theorist at Ohio State University in Columbus. But he cautions that it's too early to rewrite the physics texts.

How atoms and other quantum particles behave depends on how they spin. Particles can have only certain fixed amounts of spin, and those with an integer multiple of a basic amount called Planck's constant are known as bosons. They are sociable particles that at low temperature can crowd into a single jumbo quantum wave, which is the key to superfluidity. In contrast, particles with an extra half bit of spin are known as fermions and are loners. No two identical fermions can occupy the same quantum wave or state.

Fermions can get together, however, if they form loose overlapping pairs that act like bosons. In a superconductor, an electron spinning in one direction pairs with another spinning the opposite way, and atoms in ultracold gases can pair similarly. But what happens when the particles spinning one way outnumber those spinning the other way?

To find out, Christian Schunck, Wolfgang Ketterle, and colleagues at the Massachusetts Institute of Technology in Cambridge studied puffs of lithium-6 atoms. In previous work, they tested for superfluidity by rotating the clouds and looking for whirlpools called vortices, which are sure signs of a flowing quantum wave (*Science*, 23 December 2005, p. 1892). They fiddled with the ratio of up-spinning and down-spinning atoms and found that superfluidity persisted until the ratio reached about 85:15, with the pairs forcing the leftover up atoms to the cloud's edge. Larger mismatches quashed the superfluidity.

But in the new experiment, the team has found that even when the ratio is skewed enough to prevent superfluidity, the atoms still pair. The researchers used radio waves to pop the down-spinning atoms into an entirely different quantum state. As they lowered the temperature, they had to increase the energy of the waves by a particular amount. That's exactly what should happen if the atoms pair and extra energy is needed to break the pairs apart, Ketterle says.



Disconnect. When the up-spinning atoms greatly outnumber the down-spinning ones, the atoms still pair, but they do not form a superfluid.

The finding appears to clash with a theorem which states that fermions that do not form a superfluid cannot pair either. "What we really need now is a rethinking of pairing," says Rudolf Grimm, an experimenter at the University of Innsbruck in Austria. But theorist Kathryn Levin of the University of Chicago in Illinois says the theorem "just doesn't apply" because it relies on assumptions that aren't valid for the strongly interacting atoms.

Even so, the experiment marks a "triumph," Randeria says. He notes that at smaller mismatches, Ketterle and colleagues see the atoms pair above the temperature at which superfluidity is known to set in. Some physicists have argued that the electrons in high-temperature superconductors form such "preformed pairs," but this experiment provides far clearer evidence, Randeria says. In that much at least the coupling between pairing and superfluidity is unraveling. **–ADRIAN CHO**

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Transgenic Hay Mowed

A federal court extended a ban on planting of genetically engineered alfalfa last week. Alfalfa that has been altered to tolerate applications of the herbicide glyphosate will only be allowed back on the market after the U.S. Department of Agriculture (USDA) finishes a detailed environmental impact study. USDA says that could take 2 years.

The agency approved so-called Roundup Ready alfalfa in 2005, but 3 months ago, the U.S. District Court in San Francisco, California, ruled that the study should have come first (*Science*, 16 March, p. 1479). The judge in the case, Charles Breyer, imposed a temporary ban on planting in March and last week made the order permanent.

USDA will now examine the risk that increasing use of glyphosate will produce glyphosate-resistant weeds, as well as the economic impact on farmers of cross-pollination between conventional and genetically engineered alfalfa plants, especially those grown to produce seed. Several alfalfa seed producers in Idaho have reported finding traces of the Roundup Ready gene in stocks of conventional seed. In last week's decision, Breyer wrote that "such contamination is irreparable environmental harm." John Turner, an official with the USDA office that regulates transgenic crops, said that the judge "is asking questions that we haven't had to answer before," but he called the assignment "doable." USDA is considering hiring outside experts to help with the study.

–DAN CHARLES

A Commission Before Munitions

A House defense panel wants the Bush Administration to slow down its plans to build a new nuclear weapon. Last week, it voted to cut $45 million from the president's $88 million request for research on the Reliable Replacement Warhead (RRW) and use some of the money for more study.

The proposed blue-ribbon commission would "create a public discussion about future requirements for nuclear weapons," said Representative Ellen Tauscher (D–CA). Some opponents were hoping for more: "The subcommittee is taking a 'go slow' approach on the RRW rather than the 'no go' approach the program deserves," says a spokesperson for the Union of Concerned Scientists.

Now the focus shifts to a House spending panel, where chair Peter Visclosky (D–IN) has made known his doubts. The Senate's position is less clear. **–ELI KINTISCH**

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