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Number 621 #2, January 17, 2003 by Phil Schewe, James Riordon, and Ben Stein

A Strongly Interacting Degenerate Fermi Gas

A strongly interacting degenerate fermi gas, an ultracold lithium-6 gas which expands in a strangely lopsided fashion, has been produced for the first time by Duke University researchers (John Thomas, 919-660-2508). Performed on a tabletop, these results can provide universal insights into all strongly interacting fermions, including the neutrons in neutron stars, the quarks in atomic nuclei, and the electrons in superconductors. In addition to producing never-before-seen behavior in fermions, this experiment may have provided the first evidence of a previously unseen fermion-pairing phenomenon called "resonance superfluidity." The specially prepared lithium-6 gas behaves in a markedly different fashion from ordinary gases, those whose atoms essentially do not interact with one another. When a cloud of ordinary gas expands in a vacuum, it usually spreads out with equal speed in all directions. This means that a spherical cloud becomes a larger sphere. Even a cigar-shaped cloud smooths out the differences in its dimensions and adopts a spherical shape.

But something very different occurs in the lithium-6 gas, whose atoms interact with the maximum amount allowed by the laws of quantum mechanics. Trapped in a laser beam and cooled to 800 nanokelvins by optical methods, the gas cloud started off with the shape of a vertical cigar. But when released from its laser trap, the cloud hardly expanded in the vertical direction, but it spread out rapidly in the horizontal direction. The cloud ended up as a wide, horizontal ellipsoid (a 3D ellipse; see figures). What had happened? The researchers had created a special version of a degenerate Fermi gas (see Updates 447, and 580). "Degenerate" means that the deBroglie wavelength of the fermion atoms is greater than the average distance between them, causing the atoms to "overlap" with each other just as bosons overlap with each other in a Bose-Einstein condensate. But in previous degenerate Fermi gases, the atoms did not interact strongly with one another.

In this experiment, the researchers used a magnetic field that caused the lithium atoms to interact quite strongly with one another, to an extent never before reached in a degenerate Fermi gas. As a result, each atom interacted with its kin over a region significantly larger than the average distance between atoms. Because of the strong interactions among the atoms, Thomas says, the gas completely changed its own shape while spreading out. To explain fully this "anisotropic expansion," the researchers suggest two possibilities, neither of which they can distinguish at the present time: Either they were observing a new kind of long-range collision between atoms, or they witnessed resonance superfluidity, a relatively high-temperature form of superfluidity that would be triggered by tuning the interactions between fermions. (*O'Hara et al.*, Science, 13 December 2002.)

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