When the other half gets really cold

In 1995, physicists showed that chilling wispy gases to nearly absolute zero can yield remarkable effects. If the gas atoms are of the type known as bosons, a cloud of them can snap into a single quantum mechanical state, forming a Bose-Einstein condensate (SN: 7/15/95, p. 36). Only about half the atoms in the universe, however, are bosons.

Now, physicists in Colorado at the same institute that made the first Bose-Einstein condensate report cooling a dilute cloud of the other type of atoms, known as fermions, to extraordinarily low temperatures. In that frigid condition, the atoms behave in a way that only quantum mechanics can explain.

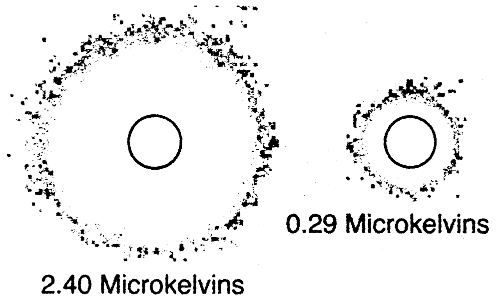
"That's exciting because there are all kinds of neat stuff we can do with ultracold fermions," comments Randall Hulet of Rice University in Houston.

Whereas bosons coalesce into a condensate of atoms that are all at the same energy level, fermions form a so-called Fermi sea, in which each atom occupies a different rung on the energy ladder. That sea is so dilute that room air is about 10 million times as dense.

Fermions obey a rule of quantum mechanics known as the Pauli exclusion principle. It forbids identical fermions to occupy the same energy level. As Daniel Kleppner of the Massachusetts Institute of Technology puts it, "Bosons love to come together; fermions can't stand each other."

That exclusivity helps prevent electrons, protons, and neutrons, which are all fermions, from coalescing. The enforced separateness of fermions accounts for the stability of all materials. It also explains the order of the periodic table of elements, the pressure that stops neutron stars from collapsing, and countless other phenomena, says Brian DeMarco of JILA, a joint institute of the National Institute of Standards and Technology (NIST) and the University of Colorado, both in Boulder.

DeMarco and Jin/NIST, U. Colo.



These two patterns reflect the energy distributions in two clouds of potassium-40 atoms. Colors represent gas density, decreasing from the center outward. Radius represents energy. Classical physics predicts that more of the atoms on right would fall within the black ring, but these atoms, of the type called fermions, assumed higher energies.

In the past, researchers have observed Fermi seas in other forms of matter, such as free electrons in a metal and a solution of superfluid helium-3 dissolved in helium-4 liquid.

The new results provide "the first evidence of the quantum mechanics of fermions in a real, honest-to-goodness gas," says DeMarco. He and Deborah S. Jin, also of JILA, describe the findings in the Sept. 10 SCIENCE.

Kleppner says the new work is "a beautiful experiment and very clever."

Although Hulet finds the progress in fermion cooling encouraging because "it shows that some of the techniques will work," he says that the experiment uncovers no new physics. Researchers will have to drive the temperature down much lower to observe novel phenomena, he says. At around 30 nanokelvins, for instance, pairs of fermions in the gas behave as single bosons. Study of such Cooper pairs could shed light on superconductivity, he suggests.

In their experiments at JILA, DeMarco and Jin magnetically trapped batches of about 100 million atoms of potassium-40. Their method of reducing the temperature resembles the cooling of a cup of coffee.

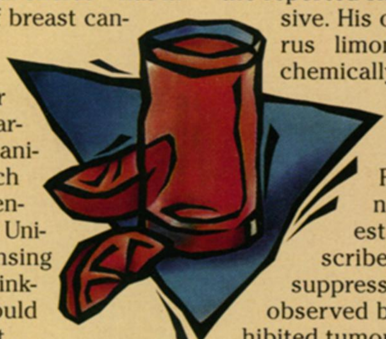
They forced the most energetic atoms to evaporate. That left the rest to redistribute energy via collisions and thus lower their average energy and temperature. As temperatures dipped below 300 nanokelvins, measurements of gas energy showed that "there was more than you would expect classically because the atoms couldn't [all] go to the lowest energy levels," DeMarco says.

Working with identical fermions is tricky because their solitary nature nixes certain types of collisions. The team had to mix potassium-40 atoms differing in a trait called spin to get enough collisions to chill the gas. Meanwhile, Hulet blends fermions with bosons in his experiments. —*P. Weiss*

Oranges juice up cancer protection

Several classes of bitter citrus compounds have looked promising as anticancer agents in laboratory tests. A new study indicates that long-term consumption of orange juice, a source of such chemicals, cuts cancer risk in rats.

In test-tube studies, one class of the bitter compounds—flavonoids—has inhibited the growth of breast cancer cells (SN: 5/4/96, p. 287). Related studies showed that bitter citrus limonoids similarly ward off cancer in animals. Mulling over such data, Maurice R. Bennink of Michigan State University in East Lansing wondered whether drinking orange juice would have a beneficial effect.



His team injected 60 young rats with a chemical that causes colon cancer and then raised half of the animals on a normal diet. The others received orange juice instead of drinking water—and less sugar in their food to compensate for sugars in the juice.

At an American Institute for Cancer Research meeting last week in Washington, D.C., Bennink reported that after 7 months, 22 of the animals receiving a normal diet had developed colon cancers. Only 17 of the rats on the orange-juice diet showed tumors. That's 77 percent of the control group's incidence.

Concludes Bennink, whose work was supported by orange-juice producer Tropicana Products of Bradenton, Fla., "These data show orange juice helps protect against cancer." He says that the study might also apply to breast, prostate, and lung cancers.

Bandaru S. Reddy of the American Health Foundation in Valhalla, N.Y., was not surprised by Bennink's finding of an orange juice benefit. However, he calls the reported risk reduction unimpressive. His own data show that citrus limonoids protect against chemically induced colon cancer in lab animals.

Luke K.T. Lam of LKT Laboratories in St. Paul, Minn., finds Bennink's data "quite interesting," although he describes as "borderline" the suppression of cancer incidence observed by Bennink. Lam has inhibited tumors in the lung, skin, and forestomach of mice with limonoids.

The scientists don't know what compounds in orange juice underlie its effect. The juice is rich in one limonoid—a sugar-containing version of limonin, which suppressed tumors in Lam's experiments. It's possible, Lam speculates, that rats convert the juice's limonoid into limonin.

Indeed, argues Gary D. Manners of the Agricultural Research Service in Albany, Calif., "there is no doubt that these [anticancer] citrus compounds are bioavailable in animals to the site of a cancer." The question remains whether they are similarly available in people. To find out, his team will soon begin measuring the human body's uptake of limonoids from orange juice. —*J. Raloff*