The Neandertals may have pursued a wide range of foods, which required more work to consume, Churchill says. Lieberman has proposed that Neandertals relied more heavily on hunting for their food than on foraging because they may have used the environment in a different way—perhaps at different seasons or when it was colder than when the moderns were there. Or Neandertals may have been less efficient at using their tools to butcher or prepare their food: Work by Trinkaus and others has shown that their front teeth have more wear than do moderns' teeth, as if they needed to use them as vices to hold things.

This picture of inefficient Neandertals, says Trinkaus, fits with evidence from their hip joints. In studies published in 1993, Trinkaus examined a knob at the top of the femur, or thigh bone, which fits into the hip socket. At birth this knob, known as the femoral neck, is vertical like the shaft of the femur. But studies of modern humans have demonstrated that the more active the child, the more the femoral neck bends inward and downward as the youngster grows. And Trinkaus has found that the femoral necks of the Neandertals are more sharply bent than those of the early moderns, which indicates that the Neandertals were more active as children. Perhaps, he says, the Neandertals moved as a group in pursuit of their food, while the moderns could split up, leaving their young with baby-sitters while they hunted and bringing back food to them at the end of the day.

If Trinkaus is right, it would mean that a different way of life was emerging among the early moderns in the Skhul and Qafzeh caves. Better food procurement and a more elaborate social system that protected children to a greater degree could have produced changes in population health and survival that gave these people the means to evolutionary success. "It must be something else beyond the tools," Trinkaus says.

But while many of Trinkaus's colleagues do embrace his findings about arms and efficiency, some worry that going from hip structure to social structure is venturing too far. Bar-Yosef, for instance, grumbles that "I have my reservations about simplistic interpretations of the functional morphology. I see no evidence for different social structures."

Still, this summer Bar-Yosef and his colleague Mary Stiner of the University of Arizona plan to test Trinkaus's ideas about differences in behavior near Mount Carmel by looking for differences in the type of small animals that the two groups hunted or the cut marks that show how they butchered them: "We will try to test the hypothesis that they were using their arms differently. Minor differences can make a major difference in determining what population is more successful than another."

–Ann Gibbons

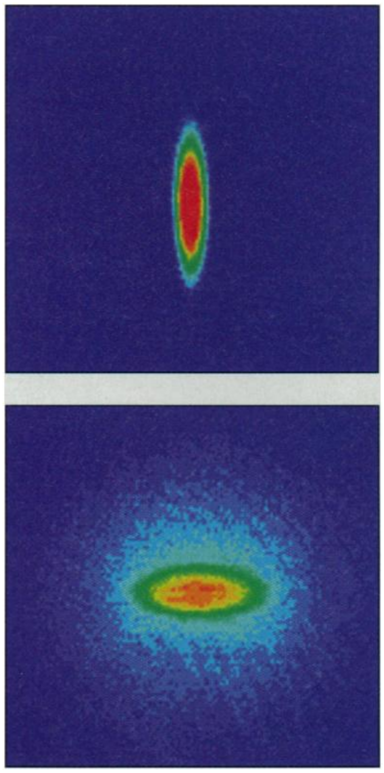
PHYSICS

Bose-Einstein Condensates Display Their First Tricks

A year ago this month, physicists finally realized what for decades had seemed at best a dream, if not a fantasy. On 5 June last year, a team at the University of Colorado and the National Institute of Standards and Technology (NIST) in Boulder created a new state of matter: a Bose-Einstein condensate, in which a cloud of atoms is cooled so close to absolute zero that their quantum-mechanical waves merge (*Science*, 14 July 1995, pp. 152, 182, and 198). In effect, the atoms act like a single macroscopic particle—one that still obeys the microscopic laws of quantum physics. But with barely 1000 atoms in a condensate that lasted just a few seconds, the Colorado team could do no more than say they'd done it.

Since that first triumphal announcement the field has erupted. It's gone from "a little bit of condensate squirting out of a tap and everyone cheering," says Oxford University physicist Keith Burnett, "to seeing these macroscopic condensates, millions of atoms, and the first quantitative experiments; the ability to directly photograph them, manipulate them, squeeze them, squash them, and even make them ring."

The progress was on display last month at a symposium on Bose condensates held in Ann Arbor, Michigan, by the American Physical Society Division of Atomic, Molecular, and Optical Physics. There, a team at the Massachusetts Institute of Technology (MIT) led by physicist Wolfgang Ketterle reported developing a new atom trap that can create condensates of 5 million sodium atoms, shaped like elfin cigars a third of a millimeter long, that survive for half a minute. With the new trap, along with a technique the MIT workers have developed for imaging condensates without destroying them, the MIT and Colorado groups are well on their way to studying this new state of matter. They may even be on the way to putting it to work in atomic lasers, which would do for atoms what lasers do for light and take the world of atomic manipulation and measurement to levels of precision and accuracy never before seen. "Before, the atom laser was just a pipe dream," says physicist William Phillips of NIST in Gaithersburg, Maryland, "but the existence of these Bose condensates makes it a reality."



MEWES *ET AL.*

Condensate unleashed. Successive images show shadow of a millimeter-long cloud of atoms containing Bose-Einstein condensate as it expands from its initial cigar shape *(top)*.

So far, however, only the MIT and Boulder teams are making this kind of headway. After the NIST–University of Colorado announcement last year, researchers speculated that any physicist might quickly concoct a Bose condensate with $50,000 in equipment and a little expertise. That seemed reasonable when reports of successful condensates followed from two other groups that had long been pursuing them, one led by Randy Hulet at Rice University and the other by Ketterle at MIT. But since then no one else has been able to create a cloud of atoms cold and dense enough to form a Bose condensate, and even Hulet says that it is only now that his group has compelling evidence for a condensate. "In the exuberance of the moment," says University of Colorado physicist Eric Cornell, "it was easy for us to forget that we'd been working at the project for 6 years before achieving it and there were lots of problems we had to solve along the way."

Indeed, most of the scientific progress came only this spring, after the MIT researchers redesigned the magnetic trap used to cool and hold the condensate. The first condensates were made by cooling atoms with lasers and confining them in a cone-shaped magnetic field that traps the coldest atoms at the center and allows hotter atoms to "evaporate" away. Because the cone-shaped field falls to zero at the very center, however, even cold atoms can leak out of the trap, so the Colorado group had to rotate the cone, continually moving the hole at its center to prevent atoms from slipping out, while the MIT group plugged the hole with a laser beam.

Now Ketterle and his collaborators have adapted a trap designed by MIT physicist David Pritchard, which relies on a cloverleaf arrangement of magnetic coils to create a magnetic field that doesn't fall to zero and doesn't need to be rotated or plugged. As a result the new trap is simpler than the cone-shaped ones, and it also confines the atoms more tightly, opening the way to long-lived, million-atom condensates. "For us this trap is the end of development," says Ketterle. "It's simply a superior way of doing it. I spent 6 years of my life building atom traps, and this might be the last atom trap I will build." Both the Rice and the NIST–University of Colorado teams are now using similar trap configurations.

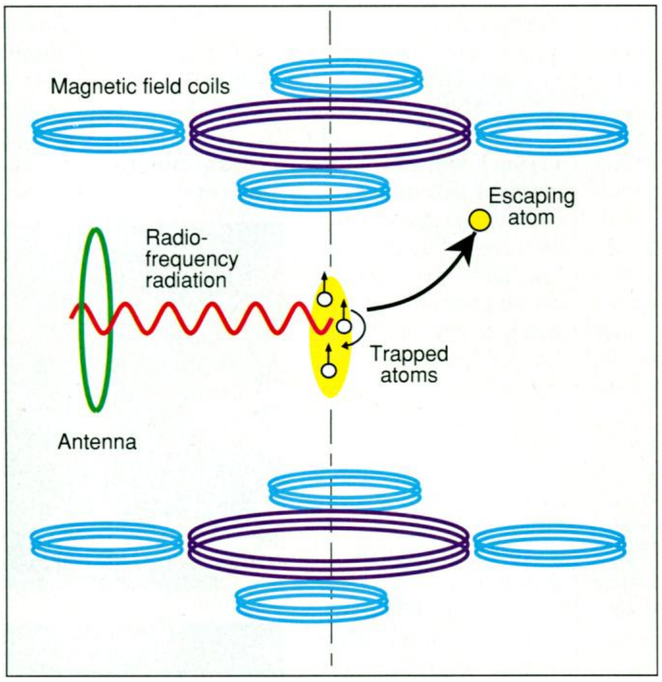
The size and stability of the resulting condensates have allowed the teams to start probing their properties. Ketterle and Deborah Jin of the NIST–Colorado group reported at the meeting that they've found that the growth rate and ultimate size of Bose condensates nicely matches theoretical predictions. Both teams also reported being able to test the condensates' fluid behavior, as if they were materials scientists studying a new liquid. As Ketterle puts it, they managed to "ring the condensate like a bell" by suddenly changing the electromagnetic potential of the trap.

"The easiest way to think of it is as a standing sound wave," says Cornell. "The condensate is a little blob, and you can get a sound wave, which sets up a standing wave, and you can then measure the frequency of different modes" by running the experiment over and over, each time opening the trap after a different interval and observing the shape of the expanding atom cloud. From such "ringing" experiments, both groups ultimately hope to learn whether the condensates, as predicted, behave the same way as superfluid liquid helium. As Ketterle explains, superfluids offer virtually no resistance to motion—they have no viscosity—so a superfluid condensate should ring indefinitely.

Ketterle and his colleagues have also learned how to image the condensates while they are still in the trap without destroying them—no mean feat, because the photons needed to make an image also heat the condensate. Their technique has provided the answer to one of the original mysteries of Bose condensates: What would they look like? How would light interact with a macroscopic quantum mechanical state? The week after they created their first condensate last year, says Ketterle, they hit a new batch of the stuff with a laser, and before the condensate vanished "we saw blackness. Just a completely black disk."

But the MIT researchers were using light at a frequency their sodium atoms simply absorbed. In effect, they were looking at the condensate's shadow. Now they've taken to tuning the laser far from this "resonant frequency" and found that they can use photons refracted by atoms in the condensate to make an image. Explains Cornell, "Think of the cloud as a perfectly clear glass marble. It doesn't absorb light; it just redirects it, like a lens." Adds Ketterle, "By just collecting the deflected photons, we saw a very clear image of a condensate inside a trap. We call it the first direct observation of condensate itself."

Because photons that are scattered deposit very little heat in the condensate, unlike absorbed photons, the imaging technique leaves the condensate intact, allowing Ketterle and colleagues to make multiple images—a motion picture. As the condensate forms, says Ketterle, they first see a "fuzzy-looking, almost mysterious" cloud, which is the sodium gas cooling around the incipient condensate. As it cools further, a bright spot of atoms, the burgeoning condensate, appears in the center of the cloud. Cool further still and only the condensate is left. MIT physicist Dan Kleppner describes the images and the technology that produces them as "literally spectacular," while Cornell pays what may be the ultimate scientific compliment: "Really neat," he says, adding that he and his colleagues hope to use the same technique themselves.



Atoms in clover. Cloverleaf coils trap cold atoms that have the same spin; radio waves flip the spin of hotter atoms, allowing them to escape and cooling the atom cloud.

Burnett adds that the success of dispersive imaging opens the way to using lasers to distort or control the motion of the atoms. "The fact that the condensate is not destroyed," he says, "means you can use lasers to push them around without killing them."

The right kind of push, he and other physicists hope, will turn a Bose condensate into an atomic laser, a coherent, focused beam in which all the atoms—like photons in a laser beam—have identical quantum-mechanical wave functions. Ketterle points out that his team has already created a primitive atomic laser just by turning off their magnetic trap and letting the condensate fall. "It's a pulse of coherent matter," he says. "In a certain sense it is valid to call it a pulsed-atom atomic laser."

A useful atomic laser, though, would propel the pulse of coherent matter with a laser or by gently launching it with a magnetic field—what Ketterle calls a "magnetic sling." For starters, such lasers could be used to lay down atoms on a substrate with extraordinary precision, a technology that could conceivably replace photolithography, the current technique for laying out microcircuitry. They would also hold promise for building atomic interferometers, measuring devices that—because the wavelengths of atoms are much smaller than those of light—could be used for making measurements far more precise than can be made with laser interferometry.

"As a general statement," says Ketterle, "if you now want to do something demanding with light, you just use coherent light, a laser. If later on you want to do something demanding with atomic beams, you will use a coherent beam of atoms, an atom laser." Although, he adds, the atomic laser by definition can never have the same utility as a light laser. "A coherent atomic beam can only survive in an ultrahigh vacuum," he says. "So we'll never be able to build a better CD player or supermarket scanner. But it will still represent the ultimate control over atomic beams."

–**Gary Taubes**