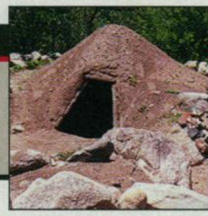
PAGE 1649
Chimp exodus is planned



1650
Native Americans vs. gamma ray telescope

QUANTUM CONDENSATES

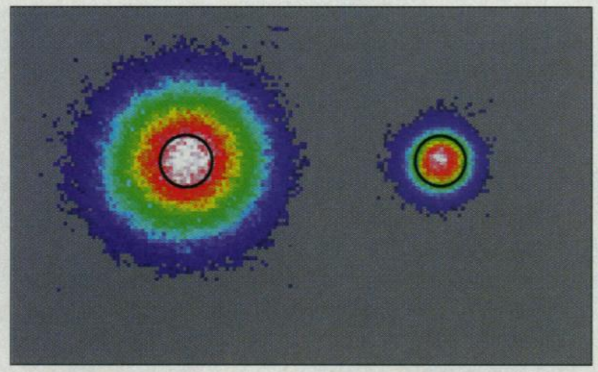
After Bosons, Physicists Tame the Rest of the Particle Kingdom

In 1995, physicists captured the world's imagination by creating a Bose-Einstein condensate (BEC)—a new kind of matter in which the atoms are chilled to such a low temperature that they become locked into a single quantum state, forming a kind of superatom (*Science*, 14 July 1995, pp. 152, 182, and 198). That achievement, by physicists at JILA, a government/university lab in Boulder, Colorado, was only half the story of quantum condensates, however. All the particles of nature fall into one of two categories, bosons and fermions, and BECs could only be made with bosons. Now another team at JILA has gone further by coaxing a vapor of reluctant fermions into a low-temperature quantum state of its own.

On page 1703, physicist Deborah Jin and grad student Brian DeMarco report how they enlisted some subtle lab tricks to trap and cool atoms of potassium-40 until the fundamental quantum properties of the fermions took over and the cold vapor became totally dominated by their wavelike nature. "The experiment is ingenious, and the challenge of cooling a gas of fermions is considerable," says Dan Kleppner of the Massachusetts Institute of Technology, whom many consider the godfather of quantum condensation studies. And the creation of the cold fermion gas, which displays energy levels like those of electrons around an atom, "is a very significant development," he says. With luck, it will be the first step toward an even stranger state of matter—a collection of fermions so cold that they seek each other out as partners, forming pairs that resemble the pairs of particles that are key to superconductors and superfluids.

Bosons and fermions are distinguished by their "spin"—a purely quantum mechanical property that has magnitude and direction, making them act like tiny bar magnets. Bosons, which include photons and the W and Z particles of high-energy physics, all have zero or integer spin, while fermions, such as electrons, quarks, neutrons, and protons, have half-integer spin. Composite particles, such as atoms, also fall into one of the camps, depending on how the spins of their constituent particles add up.

This seemingly minuscule distinction has profound consequences. The most significant effect is seen when two identical particles, both in the same quantum state, come together. Identical bosons are neighborly types, happy to share the same location. But fermions are irascible—two identical fermions cannot stand to be in the same place at the same time. This phenomenon is known as the exclusion principle, and it dramatically affects how particles behave. Because electrons are fermions, they can't all occupy the lowest energy level available to them in an atom. Instead they must stack up, like painters on a ladder. The different arrays of electrons on the energy ladders of different atoms give rise to the variety of chemical elements we see in nature.



Released. Two clouds of potassium atoms, hundreds of micrometers across, just after release from a low-temperature quantum state. The right-hand cloud started out colder.

Bosons, on the other hand, are happy to coexist in the same quantum state. All they need is a very low temperature so that thermal agitation does not bounce them out again. The cooling technique originally used at JILA relied on collisions that send more energy off with one particle than another. The more energetic particles are selectively spirited away, leaving a colder gas behind—a high-tech version of letting a cup of coffee cool by evaporation. "Evaporative cooling has been the workhorse in Bose condensation," says Randy Hulet of Rice University in Houston. But the technique won't work for fermions because they are excluded from being in the same place at the same time, so they can never collide in this way.

To get around this problem, Jin placed a gas of potassium atoms—fermions because the spins of their protons, neutrons, and electrons add up to a half-integer sum—in a magnetic field. Such a field splits the energy levels available to the atoms into many more levels, each a different quantum state. She then used lasers and radio waves to excite her potassium vapor so that half of the atoms were in one of these states and half were in another. Although atoms in one state cannot collide with each other, they can collide with the atoms in the other state because they are no longer identical and no longer forbidden from colliding by the exclusion principle. In effect, one gas cools the other and vice versa. "It's just a beautiful scheme," says Kleppner.

When Jin and DeMarco had succeeded in cooling the gas down to about 300 nanokelvin (0.3 millionth of a degree above absolute zero), they saw the critical signs of the atoms locking into their places on the lowest rungs of the Fermi energy ladder. One sign was that the energy of the potassium vapor was very slightly higher than expected for a classical gas at the same temperature, because the exclusion principle forces fermionic atoms to occupy higher states on the energy ladder—they cannot all drop down into the lowest level. The researchers measured the energy by taking snapshots and gauging how far the atoms moved over time, then compared the results with theoretical predictions to confirm the existence of the quantum fermion vapor. The fermion gas with its lack of atom collisions could have useful spin-offs, says Hulet, in the form of atomic clocks with much higher precision than those in use today. Atomic clocks rely on light emission that inevitably gets slightly scrambled by atom collisions.

Now Jin's group and others are looking toward a still more exciting future prospect: coaxing atoms into pairs. In a superconductor, electrons bounce off the material's crystal lattice in a way that causes them to attract each other slightly and form associations called Cooper pairs, which allow the electrons to surf through the solid with no resistance. Something similar happens in liquid helium-3,

CREDIT: D. JIN

where the atoms—also fermions—pair up to create what's known as a superfluid. Physicists hope that if a fermionic atomic vapor can be cooled to still lower temperatures, the atoms will pair up to form a kind of atomic superconductor. But it won't be easy, Jin says, given the challenge of cooling fermions. "The possibility of getting pairs would be quite fabulous," adds Kleppner, "but it is not something you can do immediately." —DAVID VOSS

LASER PHYSICS

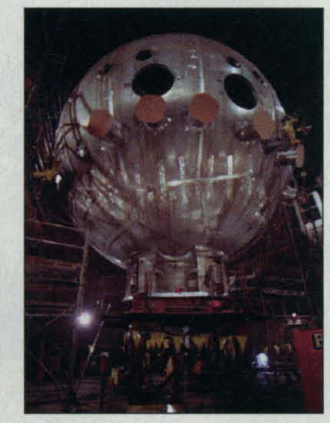
DOE Slams Livermore For Hiding NIF Problems

Halfway through its construction, the world's largest laser faces management turmoil and technical problems. Department of Energy (DOE) Secretary Bill Richardson last week ordered a major shake-up at the National Ignition Facility (NIF), a $1.2 billion device to simulate nuclear explosions and probe the practicality of fusion energy. Richardson said he was "gravely disappointed" to learn that officials at Lawrence Livermore National Laboratory in California, which manages the project, had failed to inform him of impending cost overruns and delays. The criticism, accompanied by a financial penalty assessed on the University of California, which runs the lab, comes on the heels of the sudden resignation of NIF's chief after it was revealed that he had improperly claimed to hold a doctoral degree.

The tardy warning of NIF's woes, described in an internal report submitted shortly before Richardson made his 3 September announcement, "deeply disturbed" him, he said. NIF officials had assured him as recently as June that the project was "on cost and on schedule," he noted: "Clearly, we have had a major management surprise in our quest for a quantum-leap program for laser physics."

DOE has spent nearly $800 million on the stadium-sized NIF complex, which was originally due to be finished in 2003. Its 192 laser beams are supposed to ignite a tiny capsule of deuterium-tritium fuel in experiments designed to replicate the reactions that occur in exploding nuclear weapons. While many arms control experts say NIF is needed to ensure the safety and reliability of the U.S. nuclear stockpile now that the government has stopped underground tests, critics have challenged its feasibility and DOE's cost estimates (*Science*, 18 July 1997, p. 304).

Eleven scientific and management reviews over the last half-decade have concluded that the project is on solid technical and financial footing. In late March, for instance, a consulting firm carrying out a congressionally mandated review found "no major areas of concern" and concluded that NIF was "well-planned, documented, and managed." But last week, lab officials held a special meeting to look into problems that had been rumored for months.



Less than beaming. DOE criticizes Livermore's oversight of NIF, whose target capsule is shown under construction.

"Denial of these kinds of problems is unacceptable," Richardson said, noting that he had asked Livermore officials to "take action against any personnel who kept these issues from the [DOE]." His six-point reform plan also stripped the lab of major construction responsibilities, ordering that "major assembly and integration" be "contracted out to the best in industry." In addition, Richardson will withhold "at least" $2 million of a $5.6 million management payment to the University of California, which manages Livermore.

Richardson plans to name an independent panel to get NIF "back on track." Although he said its problems are primarily managerial, "not technological—the underlying science of the NIF remains sound"—Livermore sources have identified at least one technical glitch. They say that dust particles in the building holding the lasers, which include hundreds of specialized lenses and windows, could undermine scientific measurements. "There has been a realization that they may have to make [the building] cleaner," says one academic familiar with the situation. "The intensity of the light is so strong that even specks of dust can burn up and damage the optics by etching or pitting them." The problem poses an unwelcome choice for NIF planners, he says: Spend more to make the building cleaner, or accept a device that may operate less efficiently and require expensive maintenance later.

How much it will cost to solve this and other problems remains unclear. Although some observers say the overrun could be $300 million, DOE sources suggest it will be less. Whatever the cost, Richardson said DOE will not ask Congress for additional funding but instead will divert money from existing DOE and Livermore budgets. Although that approach will be unpopular with researchers whose programs are affected, it should help mute criticism in Congress, which has so far supported DOE's $254 million NIF request for next year.

Still, lawmakers are unlikely to let these events go unnoticed. At a minimum, says one House aide, the overruns could prompt an audit by the General Accounting Office, Congress's investigative arm. Other staffers are pushing Livermore officials to explain what happened to NIF chief Michael Campbell, who stepped down on 25 August after an anonymous whistleblower informed Livermore brass that Campbell had never finished his Ph.D. dissertation despite claiming to hold a doctoral degree from Princeton University. Indeed, says one aide, Richardson's displeasure may be just the first of a series of new problems facing NIF. —DAVID MALAKOFF

THE OZONE LAYER

Burnt by the Sun Down Under

When it's winter in the north and summer in the south, many cold-weary tourists from Europe and North America flock to New Zealand for its wild backcountry and radiant sunshine. They may be getting more than they bargained for.

On page 1709, scientists at the National Institute of Water and Atmospheric Re-

CREDITS: LAWRENCE LIVERMORE NATIONAL LABORATORY