Viewing, jiggling a novel state of matter

A dense cloud of sodium atoms chilled to a temperature barely above absolute zero acts like a lens. By slightly bending the path of laser light passing through it, such an aggregation enables researchers to obtain an image of the cloud.

This direct glimpse is one of the first insights into the behavior and characteristics of atoms in a remarkable state of matter known as a Bose-Einstein condensate. Created in the laboratory for the first time only last year, these unusual condensates consist of thousands or even millions of atoms in the same quantum state (SN: 7/15/95, p. 36).

"Several groups are now reliably making condensates, and they're starting to do science," says physicist Mark A. Edwards of Georgia Southern University in Statesboro. Researchers are checking theoretical predictions made years ago about what this state of matter would be like and are investigating various methods of manipulating such clumps of atoms.

A number of teams described their latest findings at an American Physical Society meeting held last week in Ann Arbor, Mich.

"Everybody was really quite excited to see how fast the field is moving," says Wolfgang Ketterle of the Massachusetts Institute of Technology. "All the experimental groups and theory groups reported major progress."

The physicists use laser and other techniques to cool atoms of an alkali metal, such as rubidium, sodium, or lithium, to temperatures below 2 microkelvins. When a gas of these atoms, all identical, gets sufficiently cold and dense, it reaches a state in which the quantum uncertainty in each atom's position is as large as the average distance between the atoms. Instead of becoming a liquid or solid, the entire clump behaves essentially as a single unit, a superparticle.

Bose-Einstein condensates display the same kind of quantum phenomena that characterize superconductors and superfluids. However, because these condensates are still gases, their behavior is, in principle, less complicated and easier to study than comparable effects in solids and liquids, where interactions between particles play a substantial role.

Eric A. Cornell and his colleagues at the University of Colorado and the National Institute of Standards and Technology (NIST), both in Boulder, were the first to achieve Bose-Einstein condensation. Using a refined technique to create condensates of rubidium atoms, the NIST-Colorado team has now verified a number of theoretical predictions, including how the condensate grows as the temperature decreases below the transition point. The researchers also demonstrated repulsive interactions between the atoms in the condensate.

"They found wonderful agreement with the theory," Edwards says.

Using a new, improved apparatus to trap 5 million sodium atoms, Ketterle and his coworkers presently hold the record for the largest number of atoms in a Bose-Einstein condensate (SN: 12/2/95, p. 373). Like the NIST-Colorado group, they checked various theoretical predictions, and they obtained similar results.

Ketterle and his colleagues were also able to generate the first direct images of Bose-Einstein condensation. They shone light of a wavelength that could penetrate the dense sodium cloud but was still slightly deflected by it.

"At first you see a diffuse cloud," Ketterle says. "Then you see a bright spot—an elongated droplet." The researchers could manipulate the droplet's shape by adjusting the magnetic field holding it in place.

Because this imaging technique does not disturb the condensate unduly, the researchers could, for the first time, view the same condensate twice. They may soon be able to take up to 100 images to track the condensate without destroying it, Ketterle remarks.

The MIT and NIST-Colorado collaborations also used magnetic pulses to disturb the condensate, making it ring like a bell. "We recorded the oscillations and measured their frequencies," says Ketterle. With better-defined pulses, Cornell and his coworkers discovered that only some types of excitations induce a response in the condensate.

"One of the exciting things about this is that it could be used for controlling a condensate," Edwards says. "You're able to make [the condensate] dance the way you want." —*I. Peterson*

It takes nerve to make muscles bond

When first formed, muscles are useless. Before the body can command a muscle into action, intimate couplings must form between muscle cells and nerve cells. Scientists are now close to understanding the biochemical discourse that allows the cells to create such bonds, according to three reports published last week.

Researchers have long known that the so-called neuromuscular junction, a specialized structure similar to the synapses that link nerve cells in the brain, develops at a spot on the muscle determined by the nerve. "The nerve cell comes in and says, Do it here," explains Zach W. Hall, director of the National Institute of Neurological Disorders and Stroke in Bethesda, Md.

A key element of the nerve cell's initial chat with a muscle cell appears to be a protein called agrin. Released by the nerve cell onto the muscle cell, agrin induces changes crucial to the construction of the muscle's side of a neuromuscular junction, including the clustering of proteins such as acetylcholine receptors, which recognizes the neurotransmitter released by the nerve cell.

Researchers have now confirmed agrin's importance by creating mice that can't make the protein. Such mice are dead at birth, never once breathing or moving, report Joshua R. Sanes of Washington University School of Medicine in St. Louis and his colleagues in the May 17 CELL.

As expected, agrin's absence leads to improper neuromuscular junction development, says Sanes' group. Yet other observed abnormalities, such as unusual growth of nerves, were not predicted and suggest that agrin's release also somehow affects nerve cells, says Sanes.

Investigators have also identified a protein on the surface of muscle cells that is needed for agrin to trigger junction formation. Two reports, also published in the May 17 CELL, point the finger at a molecule called MuSK.

Investigators at Regeneron Pharmaceuticals, a biotech firm in Tarrytown, N.Y., discovered MuSK last year and noticed that, in adult mice, it is normally found only at neuromuscular junctions. The researchers have now created mice lacking MuSK. The animals die at birth and appear to suffer from problems similar to those of the agrin-deficient mice, report Regeneron's George D. Yancopoulous and his colleagues.

Yancopoulous' group has further evidence that MuSK plays a key role in delivering the agrin signal to form a neuromuscular junction. For example, when they applied agrin to muscle cells from the MuSK-deficient mice, they did not observe normal clustering of acetylcholine receptors.

Agrin does not directly bind to MuSK. This suggests that MuSK may form a receptor complex with another, undetermined muscle surface protein that can latch onto agrin.

"That MuSK is involved is now clear, but the picture is still not complete," says Justin R. Fallon of the Worcester Foundation for Biomedical Research in Shrewsbury, Mass., who is studying whether a variant of dystroglycan, a known agrin-binding protein, may be MuSK's partner. —*J. Travis*