Bose-Einstein Condensate Turns 10

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Albert Einstein predicted it in 1924 but it wasn't until 1995 that scientists in a Boulder, Colo., laboratory were able to chill atoms to almost absolute zero and create a strange new form of matter called Bose-Einstein condensate.
Now approaching its 10th anniversary, the discovery launched a new field of atomic physics that has spawned about 4,000 scientific papers and a treasure-trove of scientific discoveries. The original apparatus that made the Boulder discovery is now at the Smithsonian Institution.

Carl E. Wieman, a distinguished professor of physics at the University of Colorado at Boulder, and Eric A. Cornell, a research physicist and fellow with the National Institute of Standards and Technology, led the team that produced the first condensate at 10:54 a.m. on June 5, 1995. For what happened that day in a laboratory at JILA, a joint institute of CU-Boulder and NIST, they were awarded the 2001 Nobel Prize in physics.

Working with Wieman and Cornell on the initial Bose-Einstein condensation were postdoctoral researcher Michael Anderson and CU-Boulder graduate students Jason Ensher and Michael Matthews.

The condensate allows scientists to study the strange world of quantum physics as if they are looking through a giant magnifying glass and has opened new perspectives for understanding the elusive phenomena of superconductivity, superfluidity and magnetism.

Predicted by Einstein, who built on the work of Satyendra Nath Bose, the condensate occurs when the wavelengths of individual atoms begin to overlap and start behaving in identical fashion to form a "superatom." The "superatom" occurs when laboratory apparatus is used to chill a group of atoms to just a few hundred billionths of a degree above absolute zero, or minus 459 degrees Fahrenheit.

Today, scientists around the world are manipulating condensates made from a variety of gases to probe their scientific properties. Charles Clark, a NIST theorist who studies the condensates, estimates that at least one new paper on the subject appears each day.

It also has led to many other discoveries, including the creation of the first-ever fermionic condensate, which was cited by the American Institute of Physics as one of the top three physics research developments of 2003.

Deborah Jin, a physicist at NIST and JILA and an adjoint associate professor of physics at CU-Boulder, led a group creating a condensate of supercold, paired fermion atoms behaving in perfect unison. While the Bose-Einstein experiments used one class of quantum particles known as bosons, Jin's group used the other class of quantum particles found in nature.

This was important to physicists because all the basic building blocks of matter are fermions. The ability to meld fermions into a uniform quantum state may lead to better understanding of superconductivity, in which electricity flows through certain metals with no resistance.

"Certainly the area that is getting the most attention these days is the work on coupled fermionic systems to see condensates in paired fermions," Wieman said. "In ordinary bosonic condensates, probably the most interesting work involves putting them in lattices of light and so one has a large number of separated little pieces of a condensate, and one can control how well they couple together. That is showing a variety of interesting behaviors," Wieman said.

A NIST group led by William D. Phillips, a 1997 Nobel Prize winner in physics, has used Bose-Einstein condensates to pursue a possible approach to creating a quantum computer -- using laser-cooled atoms to act as quantum bits when trapped in optical lattices, egg-carton-shaped traps created by intersecting laser beams.

The condensate also has been used to form an atomic laser and could result in a better atomic clock and highly sensitive detectors of gravity and magnetic fields.

Wieman started searching for Bose-Einstein condensation about 15 years ago with a combination laser and magnetic cooling apparatus that he designed himself. He pioneered the use of $200 diode lasers -- the same type used in compact disc players -- showing they could replace the $150,000 lasers others were using. Cornell joined the effort about a year later.

Since Wieman and Cornell created the first Bose-Einstein condensate consisting of about 2,000 rubidium atoms in 1995, scientists "quickly advanced to condensates of about a million atoms, and since then have inched up very slowly to somewhere around 10 million," Wieman said. They also can form condensates out of numerous different elements, including sodium, potassium, lithium, cesium, hydrogen and helium.

Nearly all of the experiments still use the original 1995 technique of optical and magnetic trapping.

Wieman and Cornell have continued to explore the properties of Bose-Einstein condensates. In 1999 they led a group that created the first vortices ever seen in the condensates and also did extensive studies of two-component condensates.

In 2001, Wieman and Cornell were part of a CU-Boulder and JILA team that was able to make a Bose-Einstein condensate shrink -- an event which was followed by a tiny explosion. The team said the phenomenon was similar in some ways to a microscopic supernova explosion and dubbed it a "Bosenova."

Currently, "I am looking at processes by which the atoms in the condensate are converted into molecules," Wieman said. "They are very peculiar sorts of molecules, and the processes by which they can be formed is very different from conventional chemistry.

"So we are studying the properties of these molecules, the molecular condensates created, and the process of molecular formation. We are also nearly finished building an experiment that will look at the interactions between condensates of different isotopes of rubidium."

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More information on Bose-Einstein condensation can be found at jilawww.colorado.edu/bec/ or visit the Physics 2000 Web site for a description featuring interactive images at www.Colorado.EDU/physics/2000/bec/index.html.

Source: University of Colorado at Boulder