Physics Nobel awarded for new state of matter

By **DEBBIE BEREBICHEZ**

Last week, the Royal Swedish Society of Sciences announced the names of the three co-recipients of this year's Nobel prize in physics. Wolfang Ketterle, 43, Eric A. Cornell, 39, and Carl Wieman, 50, are recognized for achieving the creation of a Bose-Einstein condensate. Ordinary matter, of which objects around us are composed, is an intricate web of different kinds of atoms. Each kind of atom has a different energy and internal structure. A BEC, on the other hand, is an entirely new form of matter where all atoms have the same energy and appear to move as one. A "super-atom," as some people call it, a BEC exhibits properties unlike most things humanshhj have ordinary contact with.

An analogy between light and matter helps explain this special state. White light coming from a light bulb contains photons of all different colors—that is, with a wide variety of energies. Similarly, matter around us is composed of different kinds of atoms, with a lot of different energies and structures. A special collection of light particles oscillating together with the same energy is known as a laser beam. Analogously, a BEC is a unique kind of matter in which all atoms have the same energy and act as one.

In 1915, Neils Bohr came up with the idea that electrons in the atom could only have certain energies, and that these energies specified the orbits in which they would be moving around the nucleus. Only a number of specific orbits were possible. Although not entirely correct, this early model of the atom was the basis for the idea that electrons can "jump" between these special orbits. Because the energy can only change in jumps or "quanta," these different energy states are called "quantum states."

In a BEC, all atoms have their lowest possible energy, and thus they are in the lowest quantum state. All the objects we commonly see around have some of their properties because their particular atoms are arranged in different places. In a BEC, on the other hand, all atoms are occupying every point of space in the container at the same time. A different matter in its own kind, a BEC is neither a typical liquid, solid nor gas. It is not a state of matter that exists commonly in nature, but one that needs to be produced in a laboratory, and it occurs only at the incredibly low temperatures of a few billionths (0.000000001) of a degree above absolute zero.

To see how this is possible, it is important to understand that physicists think of the world as composed of very small particles that fall into two categories, "bosons," named after Indian physicist Satyendra Nath Bose, and "fermions," named after physicist Enrico Fermi. Bosons have an integral number of spin, and fermions have a half-integral number spin.

Spin can be thought of as the rotation of an electron about its own axis. Examples of bosons are phonons, mesons and gravitons; examples of fermions are electrons, neutrinos, muons and baryons.

Atoms too, have a total spin. Thus, atoms behave as fermions or bosons depending on whether their total spin is a half-integer or an integer one. A BEC is a collection of atoms of the boson type, that is cooled down to a very low temperature and in which atoms in the same energy state congregate.

When we say an object feels "hot," we are just giving a name to the physical phenomenon that the atoms inside it are moving fast and in arbitrary directions; when we say it feels "cold," the atoms inside the object are moving slowly. At the temperatures we usually experience in our everyday lives, there is enough energy to put the various atoms into a lot of different states of energy. However, at very low temperatures, bosons and fermions behave in very different ways. At very low temperatures, bosons will group together forming a collective state, whereas fermions with the same spin,will each be in a different state. In other words, bosons are gregarious, and fermions tend to be loners. Following the rules for bosons, when a BEC gas is cooled down, all atoms form a collective unit.

Bose-Einstein condensation is a phenomena that had been predicted since 1924, when Bose made theoretical predictions regarding photons. At the time, people considered these predictions to be so strange that Bose could not get them published. Ultimately, he sent his results to Albert Einstein, who realized that the same rules might also apply to certain kinds of atoms. Einstein further expanded Bose's theory and later worked with Bose to formulate what are called "Bose-Einstein statistics." This area of physics predicts that if a gas of bosons were cooled to a very low temperature, right before reaching absolute zero, a remarkable transition would take place and all the atoms would suddenly gather in the lowest possible state of energy. This process is comparable with the one of a gas condensing to form drops of liquid, thus the term Bose-Einstein condensation.

It was not until 1995 that researchers at the University of Colorado at Boulder and a group at M.I.T. were able to create the condensate. The physicists trapped the atoms using magnetic fields, then sent laser light to slow and cool the atoms down. They then proceeded to let the warmer atoms break out of the container, thus cooling the sample further.

They were then left with atoms very close to absolute zero. The creation of a BEC has furthered the opportunities to understand fundamental laws of nature. It is possible that in the future, BECs will help scientists build extremely sensitive measurement instruments. Potential uses for the BEC include semiconductor fabrication, better atomic clocks and many new applications in lithography and nanotechnology.