# Bose Einstein Condensation

**An introduction to Bose Einstein Condensation**

It's official: a physicist's laboratory is the coldest place in the universe. Physicists and physical chemists are finding that having the coldest place in the universe is becoming increasingly useful. Small collections of atoms or ions cooled to ultra-low temperatures provide the ideal laboratory for a wide variety of applications, including the study of fundamental physics, the development of sensors and ultra-precise time clocks and possibly the development of a future generation of supercomputers.

Bose-Einstein condensation describes the collapse of the atoms into a single quantum state. This phenomenon was predicted in the 1920's, and derived originally from Satyendra Bose's work on the statistical mechanics of photons, and subsequently formalized by Albert Einstein. Governed by the Bose-Einstein statistics, a Bose gas describes the statistical distribution of certain types of identical particles known as bosons. "Bosonic particles", are allowed to share quantum states with each other.

Einstein speculated that cooling bosonic atoms to a very low temperature, to beyond a "critical temperature" for the atom, would cause them to condense into the lowest available quantum state, resulting in a new wavelike form. In this state, a cloud of atoms will form a macroscopic quantum state in which all the atoms share the same space and have phase coherence in their wavefunctions.

Thus, as the value for momentum becomes more certain, the position of the atoms becomes more uncertain or (in quantum mechanical terms), the wavepacket that describes an individual atom becomes "delocalized".

As the atoms cool down, their kinetic energy and hence their momentum reduce. Heisenberg's uncertainty principle (as shown on the right) confirms this.

x = the uncertainty in the measured value of positionp = the uncertainty in the measured value of a component of momentumh = reduced Planck constant

Laser cooling can reduce the temperatures of atoms to a few billionths of a degree above the coldest temperature it is possible to achieve: absolute zero Kelvin (-273.15°C). This environment created in the laboratory is even colder than the most remote regions of deep space, which are pervaded by cold microwave radiation - the afterglow of the big bang. So, advanced techniques are evolving to create, trap and manipulate such novel states - another challenge is to see them.

$$\Delta x \Delta p \geq \frac{\hbar}{2}$$

Heisenberg's uncertainty principle