**BOSE-EINSTEIN CONDENSATE (BEC)**

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In condensed matter physics, a Bose-Einstein condensate (BEC) is a state of matter (also called the fifth state of matter), which is typically formed when a gas of bosons at low densities is cooled to temperatures very close to absolute zero (-273.15 deegre centigrade, -459.67 deegre Fahrenheit). Under such conditions, a large fraction of bosons occupy the lowest quantum state, at which point microscopic quantum mechanical phenomena, particularly wave function interference, become apparent macroscopically. A BEC is formed by cooling a gas of extremely low density (about 1/100000 part of the density of the normal air) to ultra-low temperatures. The state was first predicted by Albert Einstein in 1925, following and crediting a pioneering paper by Satyandrenath Bose on the new field, now known as Quantum Statistics.

Satyandrenath Bose first sent a paper to Einstein on quantum statistics of light quanta (now called photons), in which he derived Planck’s quantum radiation law without any reference to classical physics. Einstein was impressed, translated the paper himself from English to German language and submitted it for Satyandrenath Bose to the Zeitschrift fur Physik, which published it in 1924. The Einstein manuscript, once believed to be lost, was found in a libraryat Leiden University in 2005. Einstein then extended Bose’s ideas to matter in two other papers. The result of this effort is the concept of a Bose gas, governed by Bose-Einstein statistics, which describes the statistical distribution of identical particles with integer spin, now called bosons. Bosons, particles that include the photon as well as atoms such as Helium-4, are allowed to share a quantum state. Einstein proposed that cooling bosonic atoms to a very low temperature would cause them to fall (or condense) into lowest accessible quantum state, resulting in a new form of matter. In 1938, fritz London proposed the BEC as a mechanism for superfluidity in Helium-4 and superconductivity. The quest to produce a Bose-Einstein condensate in the laboratory was stimulated by a paper published in 1976 by two Program Directors at the National Science Foundation (William Stwalley and Lewis Nosanow). This led to the immediate pursuit of the idea by four independent research groups ; these were led by Isaac Silvera (university of Amsterdam), Waiter Hardy (university of British Columbia), Thomas Greytak (Massachusetts Institute of Technology) and David Lee (Cornell University).

On 5th June 1995, the first gaseous condensate was produced by eric Cornell and Carl Wieman at the University of Colorado at Boulder NIST-JILA lab, in a gas of Rubidium atoms cooled to 170 nanokelvins. Shortly thereafter, wolfgang Ketterle at MIT produced a Bose-Einstein Condensate in a gas of Sodium atoms. For their achievements cornell, wieman and Ketterle received the 2001 nobel Prize in Physics. These early studies founded the field of ultracold atoms and hundreds of research groups around the world now routinely produce BECs of dilute atomic vapours in their labs. Since 1995, many other atomic species have been condensed and BECs have also been realized using molecules, quasi-particles and photons.

Compared to more commonly encountered states of matter, bose-Einstein condensates are extremely fragile. The slightest interaction with external environment can be enough to warm them past the condensation threshold, eliminating their interesting properties and forming a normal gas. Nevertheless, they have proven useful in exploring a wide range of questions in fundamental physics and the years since the initial discoveries by the JILA and MIT groups have seen an increase in experimental and theoretical activity. Examples include experiments that have demonstrated the interference between condensates due to wave-particle duality, the study of superfluidity and quantized vortices, the creation of bright matter wave solitons from Bose condensates confined to one dimension, and the slowing of light pulses to very low speeds using electromagnetically induced transparency. Vortices in Bose-Einstein condensates are also currently the subject of analogue gravity research, studying the possibility of modelling black holes and their related phenomena in such environment in the laboratory. Experimenters have also realized ‘optical lattices’, where the interference pattern from overlapping lasers provides a periodic potential. These have been used to explore the transition between a superfluid and a Mott insulator, and may be useful in studying Bose-Einstein condensation in fewer than three dimensions, for example the Tonks-Girardieu gas. Further, the sensitivity of the pinning transition of strongly interacting bosons confined in a shallow one-dimensional optical lattice originally observed by Haller, has been explored via a tweaking of the primary optical lattice by a secondary weaker one. Thus for a resulting weak bichromatic optical lattice, it has been found that the pinning transition is robust against the introduction of the weaker secondary optical lattice. Studies of vortices in non-uniform Bose-Einstein condensates as well as excitations of these systems by the application of moving repulsive or attractive obstacles, have also been undertaken. Within this context, the conditions for order and chaos in the dynamics of a trapped Bose-Einstein condensate have been explored by the application of moving blue and red-detuned laser beams via the time-dependent gross-Pitaevskii equation.

Bose-Einstein condensates composed of a wide range of produced isotopes. Cooling fermions to extremely temperatures has created degenerate gases, subject to the Pauli exclusion principle. To exhibit Bose-Einstein condensation, the fermions must pair up to form Bosonic compound particles (molescules or Cooper pairs). A current research interest is the creation of Bose-Einstein condensates in microgravity in order to use its properties for high precision of atom interferometry. The first demonstration of a BEC in weightlessness was achieved in 2008 at a drop tower in Bermen, Germany by a consortium of researchers led by Ernst M. Rasel from Leibniz University Hannover. The same team demonstrated in 2017 – the first creation of a Bose-Einstein condensate in space and it is also the subject of two ongoing experiments in International Space Station. Researchers in the new field of atomtronics use the properties of Bose-Einstein condensates when manipulating groups of identical cold atoms using lasers. BECs were proposed by Emmanuel David Tannenbaum for anti-stealth technology. In 2020, researchers reported the development of superconducting BEC and that there appears to be a smooth transition between BEC and Bardeen-Cooper-Shrieffer regimes. P.Sikivie and Q.Yang showed that cold dark matter axions form a Bose-Einstein condensate by thermalisation, because of gravitational self-interactions. Axions have not yet been confirmed to exist. However, the important search for them has been greatly enhanced with the completion of upgrades to the axion Dark matter experiment (ADMX) at the University of Washington in early 2018. Theoritically it is proved that groups of d-stars could form Bose-Einstein condensates due to prevailing low temperatures in the early universe and that BECs made of such hexaquarks with trapped electrons could behave like dark matter.

Bose-Einstein condensates had been obtained for a multitude of isotopes, mainly of alkaline metal, alkaline earth metal and lanthanide atoms. Research was finally successful in Hydrogen with the aid of the newly developed method of evaporative cooling. In contrast, the superfluid state of Helium-4 below 2.17 Kelvin is not a good example, because the interaction between the atoms is too strong. Only 8 percent of atoms are in the groundstate near absolute zero, rather than the 100 percent of a true condensate. The Bosonic behaviour of some of these alkaline gases appear odd at first sight, because their nuclei have half-integer total spin. It arises from a subtle interplay of electronic and nuclear spins at ultra low temperatures and corresponding excitation energies, the half-integer total spin of the electronic shell and half integer total spin of the nucleus are coupled by a very weak hyperfine interaction. The total spin of the atom, arising from this coupling is an integer of low value. The chemistry of systems at room temperature is determined by the electronic properties, which is essentially fermionic, since room temperature thermal excitations have typical energies much higher than the hyperfine values.