BOOKS

The Physics Leading up to Bose–Einstein Condensation

Bose–Einstein Condensation

Edited by Allan Griffin, David W. Snoke and Sandro Stringari
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Reviewed by Thomas Greytak

The recent realization of Bose–Einstein condensation in a dilute, ultra-cold atomic vapor by a group at the Joint Institute for Laboratory Astrophysics (see PHYSICS TODAY, August, page 17) has caused great excitement. BEC is a remarkable phenomenon: It is the only phase transition in nature that can take place in the absence of any interaction between particles. Nearly all statistical mechanics textbooks describe BEC in a homogeneous noninteracting gas; for many readers such a treatment will suffice.

Those seeking a deeper understanding will soon find that the physics of BEC can be quite subtle in realistic systems of interacting particles in spatially varying potentials. Fortunately *Bose–Einstein Condensation*, a timely collection of review articles originating from a June 1993 conference and edited by Allan Griffin, David W. Snoke and Sandro Stringari, addresses these subtleties in a thorough and systematic manner. As Snoke and Gordon Baym point out in the introduction, in its broadest sense "BEC is a common phenomenon occurring in physics on all scales, from condensed matter to nuclear, elementary particle, and astrophysics, with ideas flowing across boundaries between fields."

The question of what, in the strictest theoretical sense, constitutes BEC is discussed in articles by Kerson Huang, Phillippe Nozières and Anthony J. Leggett. Here one learns of the roles played by broken gauge symmetry, phase coherence, off-diagonal long-range order, condensates and superfluidity. Specific theoretical techniques for dealing with BEC are discussed in the articles by Franck Laloë and Sandro Stringari. There had been some concern in the community that even if the proper conditions for BEC were achieved, the nucleation time for the new state would be unacceptably long. Articles by Yuri M. Kagan and Henk T. C. Stoof present calculations of this nucleation time and find it to be pleasingly short. It has long been understood that the superfluid properties of liquid helium are intimately related to BEC. Paul E. Sokol reviews BEC in this strongly interacting system and discusses the fact that direct observation of the condensate fraction has not yet occurred.

When the 1993 meeting took place, experimental interest was focused on excitons in semiconductors and spin-polarized atomic hydrogen. The article by James P. Wolfe, Jia Ling Lin and David Snoke shows that their observation of a narrow, nonthermal component in the energy distribution of paraexcitons is consistent with BEC in the exciton gas. Experiments in other semiconductors are discussed by Andre Mysyrowicz and the theoretical aspects of excitonic BEC are covered by Leonid V. Keldysh. The search for BEC in spin-polarized hydrogen—its history, current status and future prospects—is covered in the articles by Isaac F. Silvera and this reviewer.

The one weakness of this collection is that the topic of BEC in gases of alkali metals is covered by just one review, an excellent one by Yuan Castin, Jean Dalibard and Claude Cohen-Tannoudji, focusing on light forces and laser cooling. This area has developed so quickly that one will have to look elsewhere for discussions of the recent technical advances—dark spot traps, the switch to evaporative cooling and hole-plugging schemes—that finally allowed BEC to be seen in a gas. The best way to learn about these latest advances is from the original articles cited in the most recent papers, such as the JILA paper announcing the discovery of BEC in rubidium vapor.

The book's final articles discuss BEC in terms of a broader range of phenomena. Mohit Randeria discusses the crossover from BCS superconductivity to BEC in Fermi systems, and Julius Ranninger shows how BEC of bipolarons may play a role in high-temperature superconductivity. Francesco Iachello discusses an approach to nuclear structure calculations based on a system of interacting bosons formed by pairing the fermions. Gerald E. Brown points out that in neutron stars the electrons could be replaced by kaons, which would then form a zero-momentum Bose–Einstein condensate, and he goes on to discuss the resulting equation of state.

Judging by the excitement associated with the first clear demonstration of BEC in a weakly interacting gas and by the number of groups trying to see the effect in other systems, BEC is going to be an active area for some time to come. *Bose–Einstein Condensation* will be a valuable reference for both those in the field and those who want to understand the physics behind this fascinating new state of matter.

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The First Nuclear Era: The Life and Times of a Technological Fixer

Alvin M. Weinberg
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Either Alvin Weinberg has a world-class memory or he started keeping a meticulous diary when he was a teenager. *The First Nuclear Era* is a detailed history of nuclear power in the United States—strictly as he perceived it. There is almost nothing about related events in other places, except as they were connected to his work, but the book is marvelously complete on the history that it does cover, and he was present for so much of it. Weinberg is particularly good at reminding us of the many roads not taken in the nuclear enterprise, any one of which might or might not have turned out splendidly. Life is full of such things, yet written history is not. This is a refreshing reminder of that deficiency.