

Giants on Whose Shoulders Others Have Stood

Genesis of the Big Bang

▶ Ralph A. Alpher and Robert Herman
Oxford U. Press, New York, 2001.
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Reviewed by Martin O. Harwit

In the mid-1980s, I became interested in the earliest predictions of the cosmic microwave background radiation (CMBR). I looked up everything I could find in the scientific literature and went on to tape interviews for the American Institute of Physics not only with Ralph A. Alpher and Robert Herman, the authors of *Genesis of the Big Bang*, but also with Robert H. Dicke, P. James E. Peebles, and David T. Wilkinson, at Princeton, where some of the earliest measurements of the background radiation had been made. Interviews with Arno Penzias and Robert W. Wilson, the two discoverers of the radiation, had by then already been conducted by others. Together, these interviews revealed the importance and prescience of the work of Alpher and Herman.

In the 1940s, George Gamow initiated a research program based on the proposition that the universe must once have been very hot and could have created heavy elements in a rapid adiabatic expansion; Alpher became involved in this line of study in his doctoral thesis work with Gamow. But Gamow did not carry the work far enough to predict the existence of the CMBR. Although, later, he was often credited with the discovery, the young Alpher and Herman did that on their own. They have lived through the entire era of modern cosmology and played a leading role in setting up its foundations.

Readers of PHYSICS TODAY may want to skip the book's first chapter, a lengthy introduction to elementary physics and astronomy for the lay-

man, and start with the second chapter, which provides a brief history of early cosmological thinking. The real excitement starts in chapter 3, where the authors describe the development of the Big Bang model, including much of their own and Gamow's work. They go on to discuss the controversies with rival models, which were in contention with the Big Bang for several decades, and then they recapitulate the observational discovery of the CMBR. In later chapters, they provide insights on inflationary models, the anthropic principle, and the future evolution of the universe. Teachers of a college course in astrophysics or cosmology will find the brief quantitative appendix particularly useful. Here, the basic equations of relativistic cosmology are laid out at a level that physics majors will be able to grasp.

The book is full of insights based on the authors' overview of developments in the past half century. Everywhere, we find personal reminiscences. Some are clearly painful for the authors, whose groundbreaking advances were long neglected.

Having published the results of their calculations that "the temperature in the universe at the present time is found to be about 5°K " (*Nature* **162**, 774 [1948]), Alpher and Herman went on to work out the detailed evolution of the early universe. In a 1953 collaboration with James W. Follin Jr, they gave a quantitative depiction of the synthesis of light elements in the early universe and predicted that there should be a cosmic neutrino background bath at a temperature $(11/4)^{1/3}$ lower than that of the CMBR (*Physical Review* **92**, 1347 [1953], equation 35). The neutrino bath remains to be discovered. So does the even more elusive graviton bath the three authors predicted in the same paper.

In his book *The First Three Minutes* (Basic Books, New York, 1977) Steven Weinberg refers to the work of Alpher, Herman, and Follin as "the first thoroughly modern analysis of the early history of the universe." However, when the CMBR was finally discovered in 1965, the scientific world had forgotten that Alpher and Herman had worked out the strikingly accurate portrait of the early universe and

that the vestiges they had predicted should be observable today. Many honors were passed out, but the authors of this book were not among the recipients. Never judge scientists by the honors they did not receive!

Introduction to the Replica Theory of Disordered Statistical Systems

▶ Viktor Dotsenko
Cambridge U. Press, New York, 2001. \$74.95 (220 pp.).
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Understanding statistical systems with quenched (or frozen-in) disorder has proved surprisingly challenging. The "replica method," proposed by Mark Kac, remains one of the few successful theoretical tools for analyzing these systems. The method involves "creating" multiple copies of the system, averaging over the disorder, and then taking the number of copies to zero. But this turns out to be the least bizarre part.

The proving ground for the replica method was the spin glass, a disordered magnetic system in which the local couplings vary randomly in sign (and possibly magnitude). In a landmark paper, Sam Edwards and Philip Anderson boiled the problem down to its physical essentials. But even David Sherrington and Scott Kirkpatrick's further simplification to an infinite-range model proved surprisingly difficult to treat. What is now believed to be its correct solution—the replica symmetry breaking (RSB) approach of Giorgio Parisi—took several years to appear and another several years to be interpreted.

The idea of breaking the replica symmetry (that is, assuming that, somehow, different copies of the system should not be regarded as identical) was originally suggested by the work of Jairo de Almeida and David Thouless. But Parisi identified the correct pattern of RSB for the infinite-range model. His solution's eventual interpretation, as a new type of broken symmetry with an exotic arrangement of numerous low-temperature phases, generated widespread excitement.

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