includes maps released in a 1989 report that shows more radioactivity deposited northeast of Gomel than had been reported in 1986.

At first the 1989 report seemed like newly discovered information. But we now know that half a dozen pages describing the radioactive fallout in Byelorussia and the USSR were written for the official report in 1986 and then taken out at the last moment by an order from "higher up." But the radioactivity was included in the totals that the Russians presented in 1986. Zhores states that "it now seems likely that for the population of 40 million for which in the Il'in and Pavlowki report in 1987 an accumulated dose of 186 200 sievert was estimated in the next 70 years will be close to 1 000 000 sievert. And this is a conservative estimate." This is almost certainly wrong. These numbers will be confirmed or denied by the forthcoming report of an International Atomic Energy Agency study group. Zhores's bias here is a pity, because it would have been interesting to hear a Russian scientist's speculations on the political reasons for the suppression of information in 1986.

Zhores has an excellent set of illustrations: I was pleased to be able to provide two of them. Alas, the publisher eliminated a discussion of the reason that the solitary tree in one figure was left standing when all others had been removed because of their radioactivity. This area, the Pripyat marshes, lies along the line of the German advance in 1941. In 1942 and 1943 the forest was full of partisans. When one was caught, the Nazis found the horizontal branches of that tree to be convenient for the purpose of hanging. This information was not freely given because it was thought that foreigners might not understand. But as a schoolboy, I had followed every detail of the military action with interest and anguish. When I saw the tree, my heart went out to the brave Ukrainians of those years. The Chernobyl accident was a minuscule problem in comparison. Let us hope neither experience will ever be repeated.

The Early Universe

Edward W. Kolb and Michael S. Turner
Addison–Wesley, Redwood City, Calif., 1990. 547 pp. $50.50 hc ISBN 0-201-11603-0

The Big Bang is alive and well. Despite press reports and the occasional article or editorial in *Nature*, physicists can relax and appreciate the richness of this theory with little risk of running into any imminent paradigm shift. *The Early Universe*, intended for an audience of physicists and astronomers, presents a concise and comprehensive exploration of the interface of particle physics and cosmology. The authors, Edward Kolb and Michael Turner, are adept and distinguished theoretical astrophysicists who have made important contributions to our understanding of the early universe. Their intention is to describe the present status of a rapidly developing frontier field of research in a coherent monograph that will provide a thorough introduction for either the beginning graduate student or the curious physicist.

It is a remarkable achievement to have been able to trace our history back to a mere 10^{-43} seconds after the beginning of the universe. Skeptics may question the experimental evidence that underpins this evolutionary tale, and philosophers—or even particle physicists—may quibble at certain leaps of faith. Yet the effort is heroic, and the results are occasionally so appealing that one longs for a more definitive proof. The only reasonably secure artifact from the earliest epochs of the universe is the relative abundance of the light elements. Armed with a substantial amount of helium—about one quarter of the baryonic mass in the universe—and a seasoning of deuterium and lithium, one can concoct a reasonably robust record of cosmic history back to the first second or so after the Big Bang.

Some of the most important issues however are decided long before. The entropy of the universe and the density fluctuations that seeded large-scale structure were laid down somewhere between 10^{-43} and 10^{-10} seconds after the Big Bang. This represents the realm of unknown or at least highly speculative physics.

At 10^{-10} seconds, when the temperature of the universe was 100 GeV and the electromagnetic and weak nuclear interactions were distinctive forces, the physics is reasonably well understood. Particle accelerator experiments have thoroughly probed this energy range, where the standard model of elementary particles is described by the theory of quantum electrodynamics and crowned with success by the discovery at LEP of the W and Z bosons. The early universe has become a laboratory for testing particle physics theories. The number of neutrino species inferred from light-element abundances, where an excessive number would speed up the expansion and overproduce helium, confirms the number measured by means of the width of the Z-boson decay channels. If a neutrino species were massive and unstable, its out-of-equilibrium decay products—if it decayed via weak-interaction channels—would produce unacceptable distortions in the cosmic microwave background, measured to be blackbody-like to better than one percent near its peak intensity. Of course, one can adjust the decay time scale to be sufficiently short (less than a month) to hide any decay photons: Even then, only a narrow window remains; otherwise some of the fragile products of primordial nucleosynthesis, such as deuterium, would be destroyed. The ingenuity of particle theorists is such however that one can adjust the branching ratio into photons so that interesting astrophysical signatures are generated, thereby opening up new areas for the experimentalists to constrain.

It is at much higher energies—where the number of adjustable parameters in one's favorite particle theory is finite but embarassingly large—that we have an overwhelming array of theoretical options from which to choose. Inflation promises to explain such questions as why the universe is as large as it is and as spatially flat as it appears, and it prescribes the form of the primordial density fluctuations, yet the nature of the phase transition that triggered the inflationary expansion phase is elusive. Adjust the details of the grand unification symmetry-breaking scheme, and one can produce widely differing descriptions of the universe when the inflation has subsided. This means that we do not yet have a fully predictive theory on hand. Not that this has inhibited theorists, of course, who launch into highly detailed scenarios of cosmic evolution that are based on inevitably subjective choices of initial conditions.

Invariably, it is the observed universe—its dark-matter content, its large-scale galaxy distribution, the peculiar motions of galaxies, the cosmic microwave background isotropy and distortion-free spectrum, the abundances of the light elements—that limit the initial parameter space. Nevertheless, the fact that we even have the possibility of retrodicting the universe today back to grand unification energy scales of 10^{15} GeV or beyond, no matter how non-uniquely, is a dramatic development in cosmology that has emerged over the past decade. *The Early Universe* is a long-anticipated guide to the new cosmology that lies at the interface of particle physics and astrophysics. It succeeds in capturing the flavor of this emerging field of research.

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The Almighty Chance

Ya. B. Zel'dovich, A. A. Ruzmaikin and D. D. Sokoloff
World Scientific, Teaneck, N. J., 1990. 316 pp. $28.00 pb ISBN 9971-50-917-2

This volume by the well-known and influential Soviet physicist Yakov Zel'dovich was completed after his death by his younger colleagues Alexander Ruzmaikin and Dimitri Sokoloff. It presents a novel and personal view of many interesting problems that lie at the interface of statistical mechanics, nonlinear physics and continuum mechanics. The topics are loosely tied together by an emphasis on fluctuations and random processes. Included are discussions of Brownian motion, fractal concepts, percolation, random hydrodynamic motions, intermittency in various fields of physics, magnetohydrodynamics and some aspects of cosmology.

Though the book is described as a "text" in the preface, the level of presentation fluctuates widely, extending from the rudiments of probability theory to a fairly technical discussion of the moments of a scalar field in a random medium. An informal tone and a mixture of insight, mathematical deduction and simple scaling arguments reveal the special character of Zel'dovich's thinking. The book contains thoughtful discussions of basic problems that others might have considered to be in need of renewed attention (for example, Brownian motion). In these respects, the character of the book is reminiscent of the Feynman lectures (but at a more advanced level).

The majority of the book is devoted to problems that are less familiar to most physicists. For example, fluctuating fields are common in many nonlinear systems, including fluids and plasmas. After giving an elementary example of the manner in which rare fluctuations can dominate the behavior of the higher moments, the authors explore the behavior of a model nonlinear field equation involving both nonlinearity and relaxation governed by a potential. They consider various cases, including constant and fluctuating potentials and nonlinearity that may or may not depend on the potential. Their aim is