BOOK REVIEWS

The Clash of Cosmologies

Cosmology and Controversy. The Historical Development of Two Theories of the Universe. HELGE KRAGH. Princeton University Press, Princeton, NJ, 1996. xiv, 501 pp., illus. $35 or £27.50. ISBN 0-691-02623-8.

Did the universe have a beginning, or has it always existed? Is it finite or infinite in extent? Do its basic properties change with time, or do they remain the same? These questions about the cosmos are as old as civilization itself—for instance, 2500 years ago Heraclitus argued that everything continually changes while Parmenides countered that change was in principle impossible, since something cannot emerge from nothing. Although philosophers still argue such points, now at the fore are astronomers and physicists who over the past 50 years have tranformed cosmology from a mathematical exercise into an extraordinarily productive physical science. It is remarkable that no historian has heretofore described this transformation. Helge Kragh does so in fine style with this insightful, thoroughly researched treatment of the intellectual development of modern cosmology.

Cosmology and Controversy traces the development of cosmology from the first application of general relativity (in 1917, less than two years after the theory itself appeared) to the complete triumph of the big-bang picture in the late 1960s. The opening chapters lay out the scene before World War II, but the focus is on the years 1945 to 1965, during which two rival cosmologies fought for the minds and data of the scientific community. The first, with its roots in the 1920s, rested on general relativity and the expansion of the universe inferred from Edwin Hubble's studies of galaxies. After the war the Russian-American physicist George Gamow (who was motivated by the problem of the origin and relative abundances of the elements) and his collaborators Ralph Alpher and Robert Herman developed what became the essence of today's big-bang theory. By the application of nuclear physics to the relativistic solutions of a hot, dense universe, complex calculations of interactions between radiation and matter yielded results indicating a buildup of elements during the first 10 minutes. Despite various successes, this big-bang picture was largely ignored for over a decade, resurrected only when the 3 K microwave background radiation was discovered in 1965 by Arno Penzias and Robert Wilson and immediately explained by Robert Dicke and James Peebles as the remnant radiation from an early phase of a big bang.

The second theory was the steady-state alternative, created in 1948 at Cambridge University by Fred Hoyle, Hermann Bondi, and Thomas Gold. A reaction to the idea of evolving universes, the theory eliminated a single creation event beyond scientific analysis and obviated the difficulty that the Hubble time (then measured as 2 billion years) was much smaller than the age of Earth and the stars. Moreover, it was tightly constrained to make definite predictions. Kragh masterfully traces how both theories originated, evolved, faced the data, interacted with the public, and often (especially in England) fought each other tooth and nail. In the end steady-state perished under the weight of new evidence obtained from large radio source surveys (1961–64), the existence of quasars only at great distances (1963–66), the calculated abundance of helium produced in the first three minutes (1964–67), and, "the final blow to an already dying theory," the bath of 3 K radiation in which we live. Against this onslaught Hoyle continually modified the steady-state theory (and does so to this day), but he became increasingly isolated even from his former comrades in arms, who felt that such tinkering was eating at the core of the theory's beauty, namely its intrinsic simplicity and lack of room to maneuver.

Fascinating portions of the book deal with metascientific and extrascientific aspects of 20th-century cosmology—scientific methodology, epistemology and other aspects of philosophy, religion, and even politics. Kragh shows how philosophical predilections were paramount from the beginning, when Einstein introduced the mathematically ugly cosmological constant into his gravitational field equations because he felt the universe must be static. He was not alone—even Hubble was reluctant to accept the observed redshifts as representing an actual expansion of space, and Arthur Eddington in 1931 stated "the notion of a beginning of the present order of Nature is repugnant to me." Yet just at this time a Belgian astrophysicist and priest, Georges Lemaître, produced the first example of a big-bang–type universe, a physical cosmology that evolved from an early condensed state that he called the "primeval atom." Though many critics linked Lemaître's picture to his Christian belief in a Genesis-like creation, Kragh argues that there is no historical evidence for such a view. In fact Lemaître was embarrassed when in 1951 Pope Pius XII issued a statement that the big-bang picture clearly indicated that there was a creation event and therefore that a Creator must exist ("the mighty *Fiat* of the Creating Spirit billions of years ago [created] with a gesture of generous love matter bursting with energy."). As head of the Pontifical Academy of Sciences, Lemaître worked to quash any further inappropriate mixing of science and religion. On the other hand, the three founders of the steady-state model were all atheists, and Hoyle in particular was anti-Christian, for example in parts of his small 1950 book *The Nature of the Universe*, a remarkable best-seller in its time and still a good read.

Kragh contrasts the pragmatic, almost engineering-like approaches of American cosmologists, who applied their calculations of nuclear reactions to the early, hot universe, with the rationalist, deductivist approach of British cosmologists. For example, it was E. A. Milne of Oxford who first set down the "cosmological principle" (that the world appears the same to all observers) as a basis for any acceptable world model, but the steady-staters went one better with the "perfect cosmological principle," in which the universe appears the same to all observers *at all times*. Critics called such an approach ad hoc and "scientific romanticizing," but for its adherents the resulting model had an unmatched simplicity and aesthetic appeal. Many objected to steady-state's continuous, *ex nihilo* creation (at all times and all places) because it seemed patently unscientific and was a violation of the conservation of energy, but was the creation of the entire universe at $t = 0$ any less miraculous? Given the uniqueness of the universe, there were even those (such as Gerald Whitrow) who argued that cosmology could never be a proper, verifiable science. Bondi in particular reacted to this stance and stressed steady-state theory's intrinsic scientific superiority in its clear predictions and great susceptibility to being falsified, in clear contrast to the many free parameters in evolving-universe theories. For example, Martin Ryle announced in 1955 that his first large-scale survey of radio sources convincingly demonstrated that the early universe had a much higher density of radio sources and therefore that the universe was evolving and steady-state was dis-

Vignettes: Changing Times

Although it is true that, in the 300 years since Newton, most of theoretical science has been done using the rigorous, analytical approach, the reason for that is simply that that is the only kind of science that *could* be done .... The lack of computational power meant that researchers could only answer questions that had clean, elegant solutions.... It is only now that we have the ability to do complex calculations and simulations that we are discovering that a great many systems seem to have an inherent complexity that cannot be simplified.... After another 300 years, we will no doubt feel as comfortable using computer simulations to analyse nature as scientists today feel using Newton's laws of motion to describe the trajectory of a falling stone.

—*Glenn W. Rowe*, in *Theoretical Models in Biology: The Origin of Life, the Immune System, and the Brain* (Clarendon Press)

The body of mathematics to which the calculus gives rise embodies a certain swashbuckling style of thinking, at once bold and dramatic, given over to large intellectual gestures and indifferent, in large measure, to any very detailed description of the world. It is a style that has shaped the physical but not the biological sciences, and its success in Newtonian mechanics, general relativity, and quantum mechanics is among the miracles of mankind. But the era in thought that the calculus made possible is coming to an end. Everyone feels that this is so, and everyone is right.

—*David Berlinski*, in *A Tour of the Calculus* (Pantheon)

proved. In response not only did the steady-staters attack the quality of the observations (which in fact did turn out to be unreliable), but Bondi wrote a fascinating article, designed to raise the hackles of any empiricist, arguing that an observational "fact" was no more reliable than a bit of theoretical knowledge, both being derived from long chains of inference.

Although steady-state theory is not viable in today's cosmology, during its tenure cosmology matured into a rich discipline, and the big-bang picture became all the sharper while dueling its arch competitor. Moreover, many of the ideas that are held today first originated in the context of one or another form of steady-state theory: nucleosynthesis of heavy elements in the interiors of massive stars, powerful sources of radiation originating in gravitationally collapsed objects, and bubble universes, among others. These and many other episodes are thoroughly discussed in Kragh's volume. Today philosophical debating continues unabated, for example over whether or not it is more pleasing that the mean density of the universe should be exactly equal to the critical density for closure, as favored by most theorists. The steady-state story is instructive about the dangers of such reasoning, for the universe itself may have other ideas. As Dennis Sciama, a prominent steady-stater, wrote shortly after he had given up on the theory: "The steady-state theory has a sweep and beauty that for some unaccountable reason the architect of the universe appears to have overlooked. The universe in fact is a botched job, but I suppose we shall have to make the best of it."

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Browsings

Animal Cognition. An Introduction to Modern Comparative Psychology. Jacques Vauclair. Harvard University Press, Cambridge, MA, 1996. xvi, 206 pp., illus. $29.96 or £18.95. ISBN 0-674-03703-0.

An attempt to provide a broad perspective on how the question of how animals "think" is approached by "those scientists, psychologists *and* biologists, who look for answers mainly through experimentation."

The Big Bang and Other Explosions in Nuclear and Particle Astrophysics. David N. Schramm. World Scientific, River Edge, NJ, 1996. xx, 710 pp., illus. $94. ISBN 981-02-2-24-3.

Reprints of 80 papers on cosmological and other topics authored or coauthored by Schramm, 1973 to 1995.

Ethnobotany. Principles and Applications. C. M. Cotton. Wiley, New York, 1996. x, 424 pp., illus. $84.95 or £50, ISBN 0-471-96831-5; paper, $49.95 or £24.95, ISBN 0-471-95537-x.

A unified treatment for students and others of a field that engages both botanists and anthropologists, with emphasis on practical issues of plant use and management.

Ethnoveterinary Research and Development. Constance M. McCorkle, Evelyn Mathias, and Tjaart W. Schillhorn Van Veen, Eds. Intermediate Technology Publications, London, 1996 (U.S. distributor, Women, Ink, New York). vi, 338 pp., illus. Paper, $24.95 or £17.95. ISBN 1-85339-326-6. IT Studies in Indigenous Knowledge and Development.

Studies of beliefs and practices relating to the health and welfare of domestic animals among traditional peoples in Africa, India, the Americas, and elsewhere.

Evolutionary Archaeology. Theory and Application. Michael J. O'Brien, Ed. University of Utah Press, Salt Lake City, 1997. xvi, 329 pp., illus. $55, ISBN 0-87480-502-3; paper, $25, ISBN 0-87480-514-7. Foundations of Archaeological Inquiry.

A collection, with editorial discussion, of 14 "benchmark" essays (seven of them by R. C. Dunnell) on "how to apply scientific evolutionism to the study of variation in the archaeological record."

Fevered Lives. Tuberculosis in American Culture since 1870. Katherine Ott. Harvard University Press, Cambridge, MA, 1996. xii, 242 pp. + plates. $27.95 or £18.50. ISBN 0-674-29910-8.

Approaches to the management of tuberculosis from a time when "medical practice . . . was virtually a free-for-all" until its "disappear[ance] from public consciousness" in "a world characterized by systems of standardization and bureaucracy and the hopes offered by technology."

The Oxford Companion to Archaeology. Brian M. Fagan *et al.*, Eds. Oxford University Press, New York, 1997. xx, 844 pp., illus. $55 or £35. ISBN 0-19-507618-4.

Signed entries discussing geographic regions, sites and cultures studied, types of structure and artifact, techniques, theoretical concepts, and contributions of individual archaeologists, with a detailed index and a section of maps and charts.

Privatization in the Ancient Near East and Classical World. Michael Hudson and Baruch A. Levine, Eds. Peabody Museum of Archaeology and Ethnology, Cambridge, MA, 1996 (distributor, University of Pennsylvania Museum Publications, Philadelphia). viii, 308 pp. $25. ISBN 0-87365-955-4. Peabody Museum Bulletin 5. From a colloquium, New York, Nov. 1994.

Nine scholars discuss the origins of private property and consider the relations between public and private enterprise in a more agrarian world.