BOOKS: COSMOLOGY

The Big Bang's Radical Brother

David W. Hogg and Matias Zaldarriaga

Throughout the last few decades, Fred Hoyle, Geoffrey Burbidge, and Jayant Narlikar have done the cosmology community a great service by developing and defending a serious alternative to Big Bang models of cosmic origins. *A Different Approach to Cosmology* is a summary of their work, most of which has appeared in the refereed literature, accompanied by useful commentary.

A Different Approach to Cosmology
From a Static Universe Through the Big Bang Towards Reality
by Fred Hoyle, Geoffrey Burbidge, and Jayant V. Narlikar
Cambridge University Press, New York, 2000. 369 pp. $59.95, £35. ISBN 0-521-66223-0.

In the first half of the 20th century, cosmology was transformed from speculation to science with the discovery that the universe is expanding and with the development of a range of quantitative cosmological models. Big Bang models postulate a beginning to the expansion, with all matter created at the initial instant; steady state models allow for eternal expansion by postulating continuous, spatially distributed creation of matter throughout time. Big Bang models come in two flavors: hot, in which the universe started at an unimaginably high temperature and has been cooling ever since, and cold, in which the universe started at essentially zero temperature and was later heated up by the formation of stars and quasars.

The simplest steady state models are ruled out, because if the universe truly is in a steady state, the statistical properties of its contents must not change with time. There is now very good evidence that galaxies and quasars are evolving. For this reason, the authors concentrate on "quasi–steady state" models, in which the density of the universe varies with time, but in an oscillatory way. These oscillations keep the universe's statistical properties almost constant when averaged over many tens of billions of years but allow for evolution on the timescales on which it has been observed.

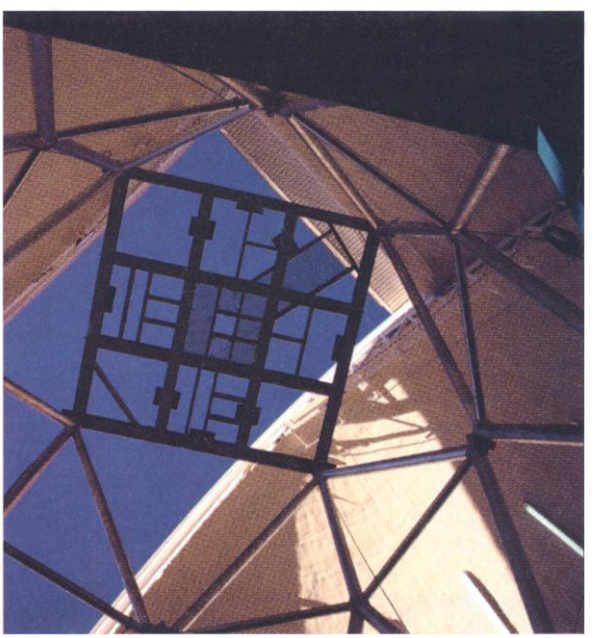
The view currently popular among professional cosmologists is that all quasi–steady state and cold Big Bang models are ruled out by the data and that only hot Big Bang models are viable. The authors contend that the popular view is wrong. They argue that some steady state models are consistent with the observations and, further, that steady state models are far more plausible.

Unfortunately, the fundamental cosmological observations against which hot Big Bang and quasi–steady state models can be compared are limited. Not for a lack of data, but because it is rarely easy to make quantitative predictions in either model. The observed cosmic microwave background (an almost isotropic 2.7 K radiation field) is, in hot Big Bang models, the relict heat from the Big Bang itself; in quasi–steady state models, it is the energy released in the creation of helium from hydrogen. In hot Big Bang models, the light elements such as helium, deuterium, and lithium were created minutes after the Big Bang, when the universe was still hot enough to sustain nuclear fusion. The ratio of baryonic (ordinary) matter to microwave background photons can be used to accurately calculate the relative abundances of these light elements. The observed ratios are, at least roughly, in agreement. In the quasi–steady state scenario, it is harder to compute these relative abundances. The authors argue that the different elements are produced in different places, either in "matter creation events" or in the nucleosynthetic processes that power stars.

An important prediction of hot Big Bang models is that the cosmic background radiation will have a near-perfect blackbody spectrum, as is indeed observed. The upper limits on departures from blackbody are so stringent that it is difficult for other models to satisfy this requirement. The authors make their quasi–steady state satisfy it, but only by tuning a newly postulated parameter: the optical depth of the universe in a very special kind of thermalizing dust. This dust has to be given quite different properties from the dust mixed among the gas and stars in our own and nearby galaxies. Because the blackbody spectrum requires the introduction of new parameters, it cannot be counted as an explanatory success of their model, until that thermalizing dust is observed in some other way.

On the other hand, there certainly are observations against which hot Big Bang models do not fare well. For example, they require that a majority of the universe's matter be in some nonbaryonic form; the quasi–steady state models do not.

Today, efforts in cosmology are focused on understanding not only the universe's mean properties but also its fluctuations. In the context of Big Bang models, all fluctuations grow from tiny primordial differences in density. This common origin produces nontrivial relations between fluctuations of the cosmic background radiation temperature and the present-day distribution of matter. There are no quantitative statements about these observables in this book; partly because quasi–steady state models have not been so well studied, but also because they do not have an initial period in which fluctuations are small and easy to characterize. This absence counts against these models,



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BROWSINGS

Tools of Vision. Photographs of Telescopes and Particle Accelerators. *Neelon Crawford.* An exhibition at the National Academy of Sciences, Washington, DC, 26 September 2000 to 15 January 2001. See www.deep-pool.com/tov.html.

Crawford presents carefully composed images of equipment used to probe the distant reaches of the universe and the fine structure of matter. This picture looks up through the mirror support structure of the 8-meter Gemini South telescope on Cerro Pachon, Chile.

The authors are at the Institute for Advanced Study, 1 Einstein Drive, Princeton, NJ 08540, USA. E-mail: hogg@ias.edu and matiasz@ias.edu

because the relations predicted by hot Big Bang models have been verified observationally, at least roughly, and extremely precise tests are on the horizon.

In the 1960s and 1970s, there was insufficient evidence to definitively distinguish between Big Bang and steady state models. The authors are clearly bitter that many cosmologists favored Big Bang models during this period of inconclusive data. Their stories about this interval are central to the book and make fascinating reading. Unfortunately, almost none of their historical anecdotes are supported with references or sources, even though they often paint unflattering portraits of the people involved. Historians of science will read this book as source material, not as a contribution to their field.

Presently, the observations do, we believe, strongly support hot Big Bang models over the quasi–steady state alternatives. In an observational science like cosmology, theories are not subject to laboratory experiments but are evaluated by their explanatory relations. "Predictions" of a theory are usually relations between otherwise independent observables. Because of their introduction of a set of free parameters and new physical effects, the quasi–steady state models have fewer empirically verified explanatory relations than the hot Big Bang. In this respect we believe that the latter is a much better explanation of the data. If forthcoming determinations of the fluctuations in the cosmic background radiation are consistent with the extremely precise predictions of hot Big Bang models, the evidence will be almost insurmountable. The latest observational results point in this direction.

On a minor note, *A Different Approach to Cosmology* is not well edited. The book contains some repetition, and it is not clearly aimed at either specialists or a lay audience. However, by elucidating one of the hot Big Bang's competitors, the authors provide a good educational exercise for any graduate student interested in fundamental cosmology.

BROWSINGS

A World of Babies. Imagined Childcare Guides for Seven Societies. *Judy DeLoache and Alma Gottlieb.* Cambridge University Press, Cambridge, 2000. 296 pp. $49.95, £32.50. ISBN 0-521-66264-8. Paper, $16.95, £10.95. ISBN 0-521-66475-6.

DeLoache and Gottlieb take a lively approach to surveying the variety of ways in which humans bring up babies. They have assumed the guise of members of different societies to write short childcare manuals (after the style of Benjamin Spock) for Puritan New England and six present-day cultures from the Ivory Coast to Micronesia. Their fictional authors' accounts are based on findings from anthropologists, historians, and psychologists on what these cultures believe about babies and how they raise them.

Did Adam and Eve Have Navels? Discourses on Reflexology, Numerology, Urine Therapy, and Other Dubious Subjects. *Martin Gardner.* Norton, New York, 2000. 345 pp. $26.95, C$37.99, £18.95. ISBN 0-393-04963-9.

Most of the essays in this collection, drawn from the author's column in *Skeptical Inquirer,* debunk what Gardner describes as "far out cases of pseudoscience." Other chapters examine such topics as Freud's theory of dreams, the Sokal hoax, and the religious beliefs of Darwin, Stephen Jay Gould, and Isaac Newton.

Lucifer's Legacy. The Meaning of Asymmetry. *Frank Close.* Oxford University Press, Oxford, 2000. 267 pp. $27.50, £16.99. ISBN 0-19-850380-6.

Why do mirrors seem to reverse left and right but not up and down? This question is one of the many topics Close considers in a popular account of the origins and implications of asymmetry that ranges from the Tuileries Gardens in Paris, through molecular biology and a whirlwind tour of particle physics, to the puzzles of superstring theory.

Mendel's Demon. Gene Justice and the Complexity of Life. *Mark Ridley.* Weidenfeld and Nicolson, London, 2000. 351 pp. £20. ISBN 0-297-64634-6.

Sex, gender, and complexity are some of the features of life that Ridley seeks to explain in this intriguing book. He discusses how life adapted to deal with mutational mistakes in the copying of DNA, and he argues that the complicated process of meiosis evolved to check selfish genes. In a final chapter, Ridley speculates on how emerging new genetic and reproductive technologies might allow the evolution of organisms with more flexible morphologies or more complex intellect and social organization.

The Two-Mile Time Machine. Ice Cores, Abrupt Climate Change, and Our Future. *Richard B. Alley.* Princeton University Press, Princeton, NJ, 2000. 237 pp. $24.95, £15.95. ISBN 0-691-00493-5.

Building on the findings from ice cores the author and other researchers have recovered from Greenland glaciers, Alley offers a broad overview of the fluctuating climates of the past 110,000 years. He discusses the abnormal stability of the past 10,000 years, examines the crucial roles of ocean currents, and concludes that human activities may increase the chances of large, abrupt changes.

Something New Under the Sun. An Environmental History of the Twentieth-Century World. *John R. McNeill.* Norton, New York, 2000. 447 pp. $29.95, C$42. ISBN 0-393-04917-5. Allen Lane, London, £20. ISBN 0-713- 99462-2.

According to McNeill, what is new is both the extent human impact on Earth's lands, waters, air, and biota and the rates of change in our surroundings. In a deft blend of anecdotes and quantitative data, historian McNeill dispassionately sketches the environmental changes of the past century. He notes that extraordinary circumstances (including inexpensive energy from fossil fuels, rapid population growth, and expanding economies) have set up an inherently uncertain future that is likely to require substantial changes in many societies.

Wild Minds. What Animals Really Think. *Marc D. Hauser.* Holt, New York, 2000. 425 pp. $25, ISBN 0-8050-5669-6. Allen Lane, London, £18.99. ISBN 0-713-99471-1.

Whether or not animals have thoughts, their minds allow them to count, communicate, and socialize. Combining insights from experiments and field observations (often from his own research) and perspectives from evolutionary theory and cognitive sciences, Hauser presents an informative and enjoyable account centered on what it is that animals need to think about.

The Mysteries Within. A Surgeon Reflects on Medical Myths. *Sherwin B. Nuland.* Simon and Schuster, New York, 2000. 286 pp. $24. ISBN 0-684-85486-4.

Nuland explores the ways in which five organs have been understood by physicians and the laity from early times through the present day. His accounts of the stomach, liver, spleen, heart, and uterus incorporate medicine, folklore, and the author's own clinical experiences.

Science's Books *et al.* section wishes to thank our reviewers, the members of *Science*'s Board of Reviewing Editors, and the many other individuals who have provided suggestions and counsel over the course of the year. We are particularly grateful for the efforts of our Book Review Advisory Board: David Bloom (Harvard University), Michael S. Gazzaniga (Dartmouth College), Richard Shweder (University of Chicago), Robert Solow (Massachusetts Institute of Technology), David Voss (*Science*), Edward Wasserman (DuPont), and Lewis Wolpert (University College, London).