Cosmology and Controversy: The Historical Development of Two Theories of the Universe. Helge Kragh. Princeton, N.J., Princeton University Press, 1996, pp.xiii+500, US$35 (cloth)

From antiquity, people have speculated about the temporal extent of the past: is the universe infinite in the past, or does it possess a finite age? However, until quite recently, almost all of this speculation proceeded *a priori*—witness the discussion of this question in Kant's first antinomy—and almost everyone recognised that there was no empirical data available which might be appealed to in order to decide the matter. Moreover, until quite recently, there were many people prepared to assert that we would never have—and perhaps even could never have—empirical grounds for a decision between the two hypotheses in question.

In 1953, the *British Journal for the Philosophy of Science* announced an essay prize on this topic—and on the related topic of whether any empirical content could be assigned to the concept of the age of the universe. Michael Scriven won the prize and—perhaps unsurprisingly at a time when the shadows of logical positivism still loomed large and dark in philosophy—defended the view that no verifiable claim could be made either that the universe has a finite age or that it does not: in his view, adjudication was "not within the power of science to determine, nor will it ever be". And most of the other published essays which had been submitted for the competition expressed similar views.

Today, however, less than fifty years on, the dominant view amongst scientists—and, indeed, amongst informed people generally—is that Scriven and his fellow essayists were wrong: not only is it possible to scientifically verify the claim that the age of the universe is finite, such verification has actually already occurred. According to the more or less received view of these matters, prior to 1917, cosmology did not even exist as a science; and prior to the mid–1960s, there was such a paucity of decent evidence, that it was impossible to decide definitely in favour of one hypothesis and against the other. According to this view, however, in the light of evidence which accumulated from the early decades of this century—and which piled up at a rapidly increasing rate from the early 1960s—it has now become clear that our universe is finite in the past, and that it originated in a very rapid explosion from an *extremely* small and *extremely* dense state.

Helge Kragh's book is a fascinating description of some of the historical development of modern scientific conceptions of the history of the universe, and of the path by which we have arrived at the widespread conviction that there is good empirical reason for thinking that the universe is finite in the past. However, Kragh makes no attempt to provide a complete history of the development of modern cosmology. Rather, the focus is on the period between 1940 and 1965, during the time when there was a reasonable–sized body of scientists who defended steady–state theories of the universe (which are committed to the claim that the universe is infinite in the past), and also a comparably–sized body of scientists who defended the view that the history of the universe involved a Big Bang in which the heavier elements were synthesised from lighter elements (and amongst whom there were some who were committed to the claim that the universe is finite in the past).

Kragh's main interest is in describing the rise and fall of steady state cosmologies, and the reasons for the eventual triumph of hot Big Bang cosmologies over these competitors.

The book begins with a brief account of Einstein's application of his general relativistic ideas to cosmology, the discovery by Einstein and de Sitter of static solutions to the general relativistic field equations, the later discovery by Friedmann and Lemaitre of non–stationary solutions to these equations, and the contemporaneous empirical work by Hubble and others observing galactic redshifts which came to be interpreted in the early 1930s as evidence that the universe is expanding.

Chapter 2 ("Lemaitre's Fireworks Universe") begins with a more detailed discussion of the discovery of non–stationary relativistic models by Friedmann (and then Lemaitre) in the early 1920s, the reasons why this work was ignored until the end of that decade, and Lemaitre's development of a kind of Big Bang model for the universe—"the primeval atom hypothesis"—in the early 1930s. (Note that non–stationary models need not be Big Bang models in which time is finite in the past. Some non–stationary models are cyclical; others—such as the one which Lemaitre developed in the 1920s—involve evolution from a quasi–static state which occupies an infinite amount of past time.) This chapter then goes on to discuss alternative cosmological theories which were developed in the 1930s, focussing in particular on models which were not derived as solutions to the field equations of general relativity—e.g. the theories of Milne, Dirac and Jordan. Some of the ideas and methods which were used in these theories had an important influence on the subsequent development of steady state theories, even though the theories themselves are based on the idea that the universe evolves from an initial singular state. Finally, the chapter concludes with an introductory discussion of a long–standing difficulty for Big Bang theories—namely, evidence that some things in the universe are actually much older than the age of the universe which is predicted by the Big Bang theories.

Chapter 3 ("Gamow's Big Bang") describes the development from the mid–1930s of Gamow's Big Bang theory, which has its origins in the attempt to provide a theory of stellar energy and the origins and distribution of the chemical elements which are found in the universe. By 1948, this theory—which owed much to the work of Alpher, Bethe, Delter and others—was well-developed. Indeed, as is well known, by this time Alpher and Herman had already made an accutate prediction of the temperature of the cosmic microwave background radiation on the basis of the theory. However, the theory also faced difficulties: in particular, no–one knew how to solve the "mass-gap" problem which stymied attempts to account for the development of elements heavier than helium in the initial cosmic explosion. For reasons which Kragh explores, interest in the theory waned, and the theory "went into hibernation" from the mid–1950s until the mid–1960s.

Chapter 4 ("The Steady–State Alternative") describes the development of steady–state cosmologies by the Cambridge trio of Hoyle, Bondi and Gold. The chapter begins with a discussion of precursors to this theory in the 1920s (and earlier) in the work of McMillan, Millikan, Nernst and Wiechert. (Interestingly, much of this work was prompted by the idea that a steady–state universe which avoided "the heat death of the universe" was far more consonant with Christian belief than any universes "wound up" by God at a finite time in the past and then allowed to "run down".) Discussion then turns to the work of Hoyle, and of Bondi and Gold, the initial development and publication of their theories, and the beginnings of scientific and public debate about the merit of these theories. (Hoyle's attack on Christian belief in his 1949 BBC talks, which promoted the steady–state theories to a large public audience, is noted and examined.) One important difference between the work of Hoyle and the work of Bondi and Gold concerns the status accorded to the 'perfect cosmological principle' (i.e. the claim that the universe is homogeneous and unchanging on sufficiently large scales). For Bondi and Gold, this principle is fundamental: it is defended on more or less *a priori* grounds, and to give it up is to give up steady–state cosmology. For Hoyle, however, there is no firm commitment to any principle of this kind; rather, the crucial objective is to avoid the initial singularities posited in many relativistic cosmologies.

Chapter 5 ("Creation and Controversy") begins with an examination of developments of, and modifications to, steady–state theories during the 1950s, focussing, in particular, on the development of field–theoretic interpretations of the theory by McCrea and Hoyle, and on attempts to find a plausible mechanism for the continual matter creation which is postulated by the theory. The rest of this chapter discusses developments and investigations of a more philosophical nature. First, there is an examination of 1950s discussion of the scientific credentials of cosmology (Bunge, Harre), the scientific credentials of steady–state cosmology (Dingle, Munitz, Whitrow, McCrea, Toulmin) and the scientific credentials of Big Bang cosmology (Popper, Bondi, Gold). Here, it is interesting to note that Bondi and Gold defend quite sophisticated views about the nature of science and scientific method (views which they claim are Popperian, but which seem to me to go beyond Popper in various ways). Second, there is an examination of religious and political responses to the cosmological controversy stirred up by the steady–state theory, including a look at Pope Pius XII's unreserved endorsement of Big Bang cosmology in 1951, and a survey of the state of cosmology in the USSR during the 1950s (where there was a widespread view that cosmology of any kind is non–Marxist).

Chapter 6 ("The Universe Observed") discusses the empirical evidence which had accumulated by 1960, and its bearing on steady–state theories of the universe. Kragh argues that this data—which includes a revised estimate of the Hubble constant leading to a greater estimated age for the universe, estimates of the deceleration parameter which measures the rate of slowing down of the expansion of the universe (based on optical measurements of redshift magnitudes), and data about the distribution of radio sources in the cosmos (produced by Ryle and others)—was not decisive evidence against the steady–state theories. This chapter also contains an account of the development by Hoyle, Fowler, et. al. of a theory of the synthesis of elements in stars and supernovae which accurately predicted the abundances of elements in the universe. While this theory of element formation shows that Gamow's initial motivations for developing his Big Bang theory were misconceived, it does not in any way support steady–state theories: many other reasons have since emerged for accepting Big Bang theories.

Chapter 7 ("From Controversy to Marginalisation") begins with an examination of the impact on steady–state theories of further evidence which was discovered during the

1960s. Some versions of the steady–state theory were overthrown by data about x–ray background radiation which was obtained in 1962 and 1963; other versions which assumed the existence of large amounts of anti–matter in the universe were overthrown by results obtained by the satellite Explorer XI in 1961 and 1962. (The asymmetry which arises from this absent anti–matter remains a challenge to Big Bang theorists: this evidence rules out any theories which require equal amounts of matter and anti–matter.) Most of the extant versions of steady–state theories were challenged by improved data about the distribution of radio sources in the cosmos; and even more seriously challenged by the discovery of quasars (once it was well–established that these objects are only found at immense distances from the earth, hence contradicting the central contention of steady–state theories that the universe is uniform at the level of galaxies and above). The chapter moves on to discuss two kinds of evidence which appeared around 1965, and which provide direct support for Big Bang models. The first—and less important—was the discovery (by Hoyle and others) that much of the helium in the universe could not have arisen from stellar processes, and that Big Bang models give an accurate prediction of the amount of helium in the universe on the assumption that much helium originated very early in the history of the universe. The second—and much more well–known—evidence was produced by the rather accidental "discovery"—or, perhaps more accurately, "identification"—of the cosmic microwave background radiation, together with the finding that its temperature is accurately predicted by Alpher and Herman in their work on Gamow's Big Bang model. (The earliest "discovery" of the cosmic microwave background radiation was by McKellar, an Australian astrophysicist, who noted an excitation state of rotating cyanogen molecules at what is now recognised to be the temperature of the cosmic microwave background radiation.) By 1966, when this identification had been confirmed for a range of wavelengths, almost nobody but Hoyle and Narlikar continued to maintain the viability of steady–state models, and the vast majority of physicists came around to the view that some version of the Big Bang theory is correct. Hoyle continued to produce new versions of his theory—and many of these involved the introduction of ideas which proved fruitful elsewhere—but there seems to be little enthusiasm for these theories. This chapter concludes with some discussion of continuing objections to Big Bang theories (including objections based on new versions of the time–scale problem which was mentioned above in my account of chapter 2).

The book ends with some discussion about whether this history can properly be described as a "controversy", and some evaluation of the fruit of research into steady–state theories. There are a number of ironies in the history of the two theories under discussion. On the one hand, during the period between 1950 and 1965, there was little important work done within the framework of the Big Bang project and, moreover, it became apparent that Gamow's initial motivation for the development of Big Bang theories was mistaken. (This point only emerges towards the end of the book, and might have been given more prominence in the chapter on Gamow's work.) On the other hand, during the same period, there was lots of interesting and important work done within the framework of the steady–state project and, moreover, many fundamental cosmological assumptions were challenged and re–examined in the light of the work of Hoyle, Bondi and Gold. Nonetheless, it is the Big Bang theory which has triumphed; and there seems little likelihood that any of the steady–state theories from the past will be revived.

Why should philosophers be interested in this book? Because it is provides a nice case study from quite recent history which can be used to illuminate foundational issues in philosophy of science. In order to evaluate theories about how science actually works, one needs data about the workings of science; there is enough detail in this study of the rise and fall of steady–state theories to make readers feel confident that the workings of science in this particular case are actually being revealed to them. Apart from this rather general consideration, there are also particular issues in philosophy of science which are put into clear focus by the case of steady–state cosmology. For example, the approach of Bondi and Gold (in particular) raises interesting questions about the legitimate role of rationalistic methods in science: should we suppose—as many have done—that there is something unscientific about the use of (say) the perfect cosmological principle in the construction of cosmological theories? Bondi and Gold make interesting claims—which deserve further attention—about methodological considerations such as these. (Kragh also provides some discussion of these kinds of philosophical issues; in my view, this discussion is mostly fairly superficial, but it generally points in the direction of issues of genuine philosophical importance.)

Given the scope of Kragh's book, it should not be surprising to learn that it has some flaws. For example, in her review in Isis (88, 4, 1997, pp.724–5), Virginia Trimble notes that there are some mistakes in Kragh's physics. However—to judge from the sample which Trimble provides—these mistakes are all quite minor, given the purposes of the project in which Kragh is engaged. (In common with many of the physicists whom Kragh interviewed, Trimble is very dismissive of steady–state theories, and suggests that there could be no justification for the devotion of such a large book to them. However, as Kragh points out, the book is not primarily aimed at physicists, but rather at historians of science and historians of ideas. Moreover, one might be forgiven for wondering whether there is some tendency to rewrite history amongst those now pronouncing that they had always been certain that steady–state theories are a dreadful mistake. Certainly, it was not obvious in the 1950s that the empirical data would not turn out to vindicate the steady–state theorists.) Despite Trimble's cavils, I remain impressed by the breadth of Kragh's scholarship.

Kragh's book is reasonably accessible to people without a strong background in mathematics and physics. It does contain quite a few mathematical formulae and diagrams, but there is very little in the way of mathematical argumentation or demonstration—i.e. the formulae and diagrams are exhibited rather than used. The book is quite well–written and well–presented, and contains an extensive bibliography for readers who are interested in pursuing primary sources. (One error which should be corrected in the next edition occurs on p.233, where Brian Ellis is referred to as a 'British' philosopher! However, it is worth noting that, in the mid–1950s, Ellis argued that the question whether the past is infinite is an empirical question which could be settled by ordinary empirical means.)

I have no hesitation in recommending Kragh's book to a wide range of readers.

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