Philosophical aspects of the steady-state universe

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Modern standard big bang cosmology was preceded by a 15-year controversy with the rival steady-state theory of the universe. At a time when cosmologically relevant observations were scarce and cosmology was widely regarded as an immature science, or not a science at all, much of the debate took place by means of arguments that were essentially philosophical. Remarkably, professional philosophers, including some of the key figures of Anglo-American philosophy of science, took an active part in the debate; no less remarkably, the involved astronomers and physicists sometimes listened to them. This article reviews the controversy over the steady-state theory as seen from the perspective of contemporary philosophy of science and offers an appraisal of how and to what extent philosophers and scientists entered a dialogue.

1. Introduction

Although the steady-state theory of the universe has long been recognized to be wrong, insofar as it is definitively ruled out by observations,1 from a historical point of view it was more than just a failed alternative to the big bang standard model that has reigned supreme for more than half a century. For nearly 2 decades the theory stood in the center of a heated debate between two irreconcilable conceptions of the universe that eventually led to the currently accepted view of an evolutionary universe with a beginning in time (Kragh 1996). Of importance in

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1. The discovery of the cosmic microwave background was the main reason for the rejection of the classical steady-state theory. The theory also disagreed with radio-astronomical data, with measurements of the cosmic abundance of helium, and with the distribution of quasars. To this falsifying evidence came in the 1970s measurements of the amount of deuterium in the universe.
In the present context, the steady-state theory attracted wide attention not only among physicists and astronomers but also among philosophers and theologians. Indeed, a considerable part of the protracted controversy was of a philosophical nature, sometimes explicitly and at other times implicitly. It was one of those rare cases in modern science in which professional scientists interacted directly and at occasions even fruitfully with philosophers.

The interaction was asymmetric insofar as philosophers typically took more interest in the views of the scientists than the latter took in the arguments of the philosophers. Not all of the involved scientists listened to the philosophers, but some did and even took their contributions seriously. Whether they realized it or not, they acted as philosophers of science. The degree to which the cosmological controversy attracted wide attention outside the circles of physicists and astronomers, and also outside the popular arena, may be illustrated by the scholarly but nonscientific journals covering the controversy and the associated steady-state alternative. In the period from about 1948 to the early 1970s, English-language journals in this category included *Mind, Philosophy*, the *British Journal for the Philosophy of Science*, the *Review of Metaphysics*, *Philosophy of Science*, the *Journal of Philosophy*, the *Monist, Theological Studies*, and the *Proceedings of the Aristotelian Society*. Among the philosophers either inspiring or contributing to the debate were notables such as Karl Popper, Adolf Grünbaum, Milton Karl Munitz, Michael Scriven, E. H. Hutten, Rom Harre, Stephen Toulmin, and Norwood Russell Hanson. To these should be added contributors bridging the science-philosophy barrier, of whom Gerald J. Whitrow, Mario Bunge, Herbert Dingle, and Richard Schlegel were the most important. Remarkably, the cosmology-philosophy discussion during the period involved almost exclusively Britons and Americans.

Although the steady-state theory has attracted only moderate attention in recent history and philosophy of science, there are several studies that discuss in detail the philosophical aspects of the controversy between this theory and the evolution theories based on general relativity.2 This essay is limited to a study of the complex role that philosophers and philosophical arguments (whether due to philosophers or not) played during the early phase of the cosmological controversy during the 1950s. Apart from a brief section on the scientific status of

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2. Two major books published in 1965 are particularly interesting because they were completed at a time when the controversy was not yet finally settled: Merleau-Ponty (1965) and North (1965). The books were reviewed in the *British Journal for the Philosophy of Science* by two leading theoretical physicists involved in cosmological research: George F. R. Ellis (1967), who reviewed North, and Dennis Sciama (1968), who reviewed Merleau-Ponty. For more recent historical-philosophical analyses of the steady-state theory, see Balashov (1994), Gale and Urani (1999), and de Swart (2020).
cosmology at the time, it focuses on two key issues in the debate: the hypothesis of continual creation of matter and the actual infinite quantities turning up in the steady-state universe and elsewhere in cosmology.

2. Steady-State Theory in a Nutshell

The steady-state alternative to cosmological evolution models based on general relativity was introduced in two articles of 1948, one written by Fred Hoyle (1948) and the other by Hermann Bondi and Thomas Gold. The two were quite different insofar as Hoyle’s was a field theory with a mathematical formulation close to relativistic cosmology but including a “creation tensor.” In contrast, Bondi and Gold rejected general relativity as the proper foundation of a theory of the universe as a whole. The Bondi-Gold version was remarkably nonmathematical, relying almost exclusively on deductions from a general assumption of a philosophical nature, what they called the perfect cosmological principle (PCP): “The universe is postulated to be homogeneous and stationary in its large-scale appearance as well as in its physical laws” (Bondi and Gold 1948, 254).

According to the two Cambridge physicists, the PCP was of such a fundamental nature that without it cosmology would no longer be a science. As they argued at length, unrestricted repeatability of laboratory experiments was at the very heart of science and could be rationally justified only in an unchanging universe. Their complete confidence in the PCP as a sine qua non for science was based on philosophical arguments alone. Bondi and Gold (1948, 255) even stated that “we shall be willing if necessary to reject theoretical extrapolations from experimental results if they conflict with the perfect cosmological principle even if the theories concerned are generally accepted.” At the same time, they were careful not to introduce the PCP as being true by necessity, to base the new steady-state theory on an a priori foundation. Quite the contrary, they insisted that the PCP was a testable assumption that, if falsified, would not only prove the steady-state theory wrong but also make scientific cosmology impossible.

In the preface to his influential textbook *Cosmology*, Bondi (1952) emphasized that although he did not regard “cosmology as a minor branch of general relativity,” neither did he regard it as “a branch of philosophy and logic.” Hoyle too accepted the PCP, but with the important difference that he considered it a consequence of his field equations and not an independent postulate. Whatever the status of the PCP, it was controversial and widely considered objectionable. To some critics of the steady-state theory, the PCP was one more indication of the theory’s “rationalist” nature as opposed to the “empiricist” nature of relativistic cosmology (de Swart 2020).
According to Herbert Dingle (1956), an astrophysicist who had turned to history and philosophy of science, the PCP was no better than the philosophical dogma underlying Aristotle’s cosmos. Dingle had earlier launched a similar attack on the forms of rationalistic “cosmythology” that he found in the cosmological theories of Arthur Eddington, Paul Dirac, and Edward A. Milne, and he now turned his wrath against the steady-state theorists. His vitriolic attack on Bondi, Hoyle, and Gold caused wide public attention but was ignored by the accused parties. Bondi simply did not take Dingle seriously. Among the few supporters of Dingle’s views was the Argentine physicist-philosopher Mario Bunge, who in a paper of 1962 argued that continual creation of matter was miraculous. To Dingle and Bunge, the steady-state theory was plainly unscientific (Bunge 1962).

As a professor of history and philosophy of science at University College London, and formerly a professor of natural philosophy at Imperial College, Dingle was considered an expert in the still-immature field of scholarship (Aitken 2005). In 1948 he founded the Philosophy of Science Group, the precursor of the British Society for the Philosophy of Science, and he was also a prime mover in the formation of the British Society for the History of Science (Butler 1949). In addition to his position in British history and philosophy of science, in the early 1950s Dingle served as president of the Royal Astronomical Society and as head of the historical commission of the Astronomical Union. He was a person whose views, often controversial, were taken seriously, although more by philosophers than by scientists. During the 1950s, Dingle got involved in a controversy over the correct understanding of special relativity theory and the so-called twin paradox in particular. His claim that Einstein was wrong further estranged him from the community of theoretical physicists (Chang 1993).

Despite the marked difference in style and spirit of the two versions of steady-state cosmology appearing in 1948, they led to the same physical and astronomical consequences. Given that the time scale of the steady-state universe was infinite in both directions, the problem of cosmic creation was avoided. The same was the case with the so-called age paradox, of stars and galaxies being older than the universe. The concept of a finite-age universe was declared illegitimate. Contrary to older ideas of a stationary universe, the founders of the steady-state theory accepted the expansion of the universe as an empirical fact and derived from their theory that space must be flat and expand exponentially. Since the density of matter remained constant, it followed that matter must be continually created throughout space, a most controversial claim. Not only was it possible to calculate the constant matter density; the rate of matter creation could also be deduced from theory. For the first quantity the result was $5 \times 10^{-28} \text{g/cm}^3$ and for the second it was $10^{-43} \text{g/cm}^3/\text{s}$, or about three hydrogen atoms per cubic meter per million years.
Moreover, whereas galaxy formation was restricted to a certain cosmic era according to evolution cosmologies of the big bang type, according to steady-state theory galaxies were formed at all times, and their average age was given by the inverse of the measurable Hubble constant. This result was obtained by the Irish-born physicist William Hunter McCrea (1950). McCrea was one of the earliest and most important converts to the steady-state theory, which appealed to his desire of basing cosmology on fundamental principles of a philosophical nature. While a student at Cambridge University he attended lectures on philosophy by John McTaggart and Bertrand Russell, and he continued to maintain an interest in the physics-philosophy relationship. Even more than Bondi, and much more than Hoyle, McCrea’s approach to cosmology was inspired by philosophical reflections.

The sketch of steady-state theory given above refers to the classical theory based on the PCP and primarily defended by Bondi, Gold, Hoyle, and McCrea through the 1950s. Another early convert to steady-state cosmology was the young Dennis Sciama, who was fascinated by the theory’s philosophical and methodological qualities. Sciama defended the steady-state theory for more than a decade. During the 1960s Hoyle and his collaborator Jayant Narlikar modified the original steady-state theory in a variety of ways, finally abandoning the PCP while maintaining matter creation and a temporally infinite universe. This later phase is outside the scope of the present essay (see Kragh 1996).

3. The Scientific Status of Physical Cosmology

In the early 1950s cosmology was scarcely recognized as a respectable scientific discipline by the majority of physicists and astronomers. Physical cosmology (as distinct from mathematical and philosophical cosmology) had a low reputation, and the choice between cosmological models was often described as a personal judgment based on aesthetic rather than rational and empirical criteria (Kragh 1996, 219–23). In a course given about 1953, the pioneer radio astronomer and later Nobel Prize laureate Martin Ryle said, “Cosmologists have always lived in a happy state of being able to postulate theories which have no chance of being disproved—all that was necessary was that they should work in the observable Universe” (Sullivan 1990, 321). Ryle would soon come out as an active opponent of steady-state cosmology, which contributed significantly to its downfall.

Philosophers generally agreed with the pessimistic view expressed by Ryle and many other physicists and astronomers. “Several features of cosmology are of striking philosophical interest,” wrote Thomas Goudge (1954, 444), a philosophy professor at the University of Toronto, in a review essay on Bondi’s Cosmology.
But Goudge doubted that current cosmology, whether in the standard evolutionary version or in the new steady-state version, was truly scientific. Cosmology, he concluded, “is thus a domain where mathematics and the imagination combine in a fascinating attempt to ‘triangulate the universe’” (447). It is worth noting that Bondi’s book received a review in a premier journal of philosophy, which would not normally review scientific textbooks. The reason was undoubtedly that the subject of the book, cosmology, was still considered of interest to philosophers and part of their domain.

The unsettled state of cosmology is illustrated by a prize essay on the age of the universe announced by the newly established *British Journal for the Philosophy of Science* in 1953. The journal was founded in 1950, with the Australian-British historian of science Alastair Crombie as its first editor. The 26 essays submitted by scientists and philosophers were judged by a four-member committee including Karl Popper, who tended to consider the question of a finite or infinite cosmic past to be scientifically meaningless. This was also the conclusion of one of the prize winners, the 26-year-old British philosopher Michael Scriven, who at the time was preparing for his PhD at Oxford University, with Gilbert Ryle (the uncle of Martin Ryle) as his supervisor. The other prize winner, the chemist John T. Davies at King’s College London (where Bondi taught also), was less pessimistic in his discussion of how to choose between rival models of the universe. Interestingly, he referred in this context to Popper’s *Logik der Forschung*, which had not yet been translated into English: “As Popper has emphasised, the criterion of a scientific theory is that it must be possible for an observational check to be devised . . . by which it might be disproved” (Davies 1954, 199).

Popper’s celebrated work was well known among philosophers and also by some scientists even before it appeared as *Logic of Scientific Discovery* in 1959. Five years earlier Bondi and Gerald Whitrow engaged in a public discussion concerning the scientific status of physical cosmology (Whitrow and Bondi 1954). Whitrow, who was trained in mathematics and theoretical astronomy, was a specialist in relativity theory and the author of one of the first ever monographs on cosmology, *The Structure and Evolution of the Universe*, published in 1949. In the discussion with Bondi, Popper’s falsifiability criterion entered significantly, implicitly as well as explicitly. While Whitrow argued that philosophical arguments would always remain an essential part of the study of the universe, Bondi optimistically stated

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3. The prize essay was to address the question, “What is the logical and scientific status of the temporal origin and age of the Universe?” The committee added, but only in a parenthesis, “for example, as used in recent cosmological work” (see p. 92 of vol. 4, no. 13). The subject of the essay competition was not further motivated, and there was no reference to either steady-state or big bang cosmology, which authors might or might not include under the label “recent cosmological work.”
that cosmology was quickly on its way to replacing philosophy with observation and physical theory. Contrary to Whitrow, who could see no agreement about methodological standards across the rival theories of cosmology, Bondi suggested that the falsifiability criterion—“the cardinal test of any science”—enjoyed general acceptance.

Bondi was fascinated by Popper’s philosophy of science, which he first encountered in the late 1940s. In subsequent expositions of the steady-state universe and science generally, he emerged as an enthusiastic advocate of Popperianism and of the falsifiability criterion in particular. Thus, in a lecture of 1958, Bondi (1958, 60) summarized Popper’s methodology by stating that “only a vulnerable theory that suggests ways by which it can be disproved is fertile and of scientific use.” On this and other occasions he stressed that as far as risky predictions were concerned, the steady-state theory of the universe was clearly superior to the class of relativistic evolution theories. Although Popper was well informed about the cosmological controversy, he preferred to follow it from the sidelines rather than intervene in it, as other philosophers did. Popper and Bondi met frequently, as did Popper and Whitrow, but apparently Popper was somewhat doubtful about the possibility of a truly scientific cosmology. Late in life he expressed disbelief in the big bang theory and also dissatisfaction with the PCP at the basis of the classical steady-state theory. Nevertheless, he liked the matter creation inherent in this theory and thought that Bondi and Gold should originally have given primacy to matter creation rather than the PCP (Kragh 2013).

Among the philosophers discussing the criteria for establishing cosmology as a science was the 34-year-old Oxford philosopher Rom Harré, who today may be best known for his works on critical realism and social theory. By means of logical and philosophical arguments he came to the conclusion that cosmogony (or “cosmogeny” as he spelled it) was not and never would be a science. “Astrogeny is the only science of beginnings that we can have,” Harré (1962, 112) asserted. In contrast, physical cosmology, in the limited sense of the study of physical processes in the universe, could qualify as a science under certain conditions. For this kind of study Harré coined the term “cosmophysics,” which he contrasted to the study of cosmological models. Although he did not express support for the steady-state theory, he clearly considered it to be more scientific than the cosmogonic theories aimed at tracing the evolution of the universe back to some primordial state.

Stephen Toulmin was yet another young British philosopher who entered the discussion of the scientific status of cosmology. During the early 1950s, when he wrote his much-used introductory textbook *The Philosophy of Science*, Toulmin was mainly occupied with philosophy of science. In an extensive essay of 1957, published at the height of the cosmological controversy, he concluded that no
statement about the universe at large could possibly be legitimate from a scientific point of view. Toulmin (1957) examined in particular the old question of the so-called heat death—that the universe runs down as a consequence of unavoidable growth in entropy—but denied that thermodynamics or other laws of nature applied to the universe as a whole. He likewise dismissed the hypothesis of an abrupt origin of the universe as nothing but a creation myth. Although Toulmin was aware that there was no heat death in the steady-state universe and also no origin in time, he refrained from expressing support for the cosmological theory of Hoyle and his allies. As late as 1965 Toulmin confirmed that cosmological theory was essentially philosophical rather than scientific (Toulmin and Goodfield 1965).

4. Continual Creation of Matter

The element of spontaneous and continual matter creation in steady-state cosmology was a major reason why the theory of Bondi, Hoyle, and their allies was considered controversial. The issue was widely discussed by physicists and astronomers, and no less widely by philosophers and theologians. After all, the principle of matter-energy conservation was a cornerstone in science, satisfied by all fundamental theories including quantum mechanics and general relativity. While Bondi and Gold had introduced matter creation as a consequence of the PCP, in Hoyle’s version it was the result of a “creation tensor” that replaced the cosmological term $\Lambda g_{\mu\nu}$ in Einstein’s field equations ($\Lambda$ is the cosmological constant and $g_{\mu\nu}$ the metrical tensor). However, the creation tensor was just a formal quantity offering no physical explanation of how matter was created in empty space.

With a fresh PhD from Yale University, in a letter to Scientific American of 1953, the German-born philosopher Adolf Grünbaum denied one of Dingle’s accusations against the steady-state theory, namely, that it relied on (in Dingle’s words) a “continuous series of miracles” (Grünbaum 1953, 8; for Grünbaum’s early interest in and mastery of cosmology, see also Grünbaum [1952]). As he pointed out, matter creation also appeared in big bang cosmology, only on a much larger scale and confined to the very beginning of the universe. Moreover, why should matter conservation be a more natural state than matter nonconservation? Bondi was aware of Grünbaum’s intervention, and in a private letter of December 11, 1953, he acknowledged his arguments (Kragh 1996, 226). At about the same time that he wrote his important monographs Patterns of Discovery and The Concept of the Positron, another prominent American philosopher, Norwood Russell Hanson, dealt with the philosophical aspects of modern cosmology in a way somewhat similar to Grünbaum’s. According to Hanson (1963, 471), “Hoyle, Bondi, and Gold are certainly correct in arguing that this
‘continuous creation’ assumption is on exactly the same logical footing as the seldom-stated, but much more orthodox, presupposition that all matter was ‘originally created’ in the initial ‘Big Bang.’” Hanson suggested that the controversy between the two rival worldviews was essentially of a semantic rather than scientific nature.4

While Grünbaum, Harré, and Hanson were willing to consider the steady-state version of continual matter creation as a possibility, the American philosopher Milton Karl Munitz, at New York University, was not. Munitz was principally occupied with metaphysics and moral philosophy, which he aimed to present in a naturalistic framework. The mysteriousness of creation remained a central theme in his many publications, which included an early in-depth analysis of matter creation in modern cosmologies.5 Munitz felt provoked by the steady-state cosmologists’ claim to have removed the concept of creation from metaphysics and theology to the more trustworthy domain of exact science. While Bondi (1952, 140) confidently stated that the problem of creation had now been “brought within the scope of physical inquiry, and is examined in detail instead of, as in other theories, being handed over to metaphysics,” Munitz emphatically disagreed. What worried him in particular was that the steady-state creation of matter was an ex nihilo process and therefore unexplainable in principle. Munitz (1954, 36) found this to be “clearly a species of dogmatism, the irrevocable claim to an ignorabimus which is incompatible with the spirit and method of scientific inquiry.” He complained that by its very nature the concept of continual creation as employed in the steady-state theory was meaningless because it, being an ex nihilo process, could not possibly be explained in terms of some causal mechanism.

Among the philosophers writing on cosmology in the 1950s, Munitz and Grünbaum were the only ones who continued to cultivate the field throughout their academic careers. Munitz’s last book on the subject, The Question of Reality, was published in 1990. In an important monograph of 1957 Munitz expanded his critical examination of modern cosmological theories with special reference to the concept of creation. Far from being scientific, this concept, as it appeared in

4. Hanson (1963, 467) seriously misunderstood the steady-state theory, witnessed by his claim that this theory shared with the big bang theory the view that “our universe, in its very early youth, was considerably different in constitution and appearance from what it is now.” The claim appeared thrice in the paper and thus was more than just a slip of the pen.

5. Munitz’s first work relating to modern cosmology was a critical analysis of Kant’s view on space, time, and the universe (Munitz 1951). “Are the Kantian strictures against cosmology in any way effective against contemporary scientific efforts?,” he asked on the opening page of the article, answering the question with a no. In the article, Munitz did not refer to either the steady-state theory or relativistic models with a finite past. The only cosmologist he mentioned by name was Milne.
the steady-state theory, expressed a Platonic idealism disguised in scientific rhetoric, he charged. “To say that matter is found in the universe leaves open the possibility of explaining its appearance, whereas to say that it is created not only denies such a possibility but also employs a term without any significant content” (Munitz 1957, 162).

Munitz’s book was known to astronomers through a review in the journal *Observatory* written by the chemistry-trained cosmologist William Bonnor at Queen Elizabeth College, in London (Bonnor 1957). Like several other British physicists in the period, Bonnor had an interest in the philosophy of science, which he saw as an integrated element of scientific practice. He shared Popper’s critical attitude toward instrumentalism, arguing that it was unsatisfactory because it did not reflect the actual activities of physicists. As Bonnor (1958, 293) pointed out, cosmology was an area in which philosophical lines of reasoning were not only legitimate but also unavoidable: “In this subject the scientists themselves frequently conduct the philosophical arguments, sometimes almost without realising it.” In his review of Munitz’s *Space, Time, and Creation*, Bonnor (1957, 248) likewise wrote that because of the scarcity of relevant observational data, “each author resorts to philosophical principles to show the superiority of his own theory [and] cosmologists thus become fair game for Professor Munitz.”

Equally skeptical of big bang and steady-state theories, Bonnor was in favor of a cosmological model based on general relativity but without a beginning in time. His preferred model was cyclical, a closed universe that repeated itself indefinitely but with smooth transitions between the infinitely many cycles rather than an infinity of big bangs and big crunches. Bonnor found continual creation of matter to be highly objectionable because it violated the sacrosanct law of energy conservation and therefore also the theory of general relativity. His views about the nature of science and its proper methods differed in some respects from those held by Bondi. According to Bonnor, steady-state theory was phenomenological rather than explanatory, which made it much less fundamental than cosmological theories solidly based on general relativity.

In 1959 the BBC broadcast a symposium titled “Rival Theories of Cosmology” chaired by Whitrow and with Bondi, Bonnor, and the Cambridge astronomer Raymond Lyttleton as the discussants. Lyttleton was a former collaborator of Hoyle and generally in favor of the steady-state theory, which means that

6. The book was also reviewed in *Isis*, the leading history of science journal, by Gerald Holton (1959). According to Holton, who was an American physicist, educator, and leading historian of physics, the heated dispute over creation was of a philosophical nature and unlikely to change the course of scientific cosmology. Holton suggested that “Dr. Munitz overestimates perhaps the seriousness with which the Bondis, Golds, and Hoyles seem to join philosophical battles” (159).
supporters of the big bang universe were not represented in the symposium. In opposition to Bondi, Bonnor objected that abandoning the law of energy conservation was too high a price to pay for a theory of the universe that lived up to the Popperian standards of falsifiability, which the steady-state theory admittedly did. Bondi replied by confirming his absolute confidence in the falsifiability criterion, adding that Bonnor’s “views on what constitutes science must differ markedly from mine” (Bondi et al. 1960, 45). No professional philosopher participated in the BBC symposium, and yet much of the discussion taking place in it was concerned with philosophical rather than scientific issues.

Although antagonistic to the steady-state theory and its associated matter creation, Bonnor did not subscribe to Munitz’s argument that the hypothesis of matter creation was dogmatic, unnatural, and beyond rational explanation. In his review of Munitz’s book he rhetorically asked if matter (or energy) conservation could be explained and in this sense was more natural than nonconservation. His point was that while Munitz demanded an explanation for creation of matter, he took matter conservation to be unproblematic and in no need of explanation. Why this asymmetry? Why assume in advance that matter conservation is the natural state of the world and that only deviations from it need to be explained? Bonnor’s argument was essentially the same one that Grünbaum had suggested a few years earlier.

Attempts to free steady-state cosmology from the troublesome notion of creation out of nothing appeared even before Munitz’s critique. The first and most important of the attempts was by McCrea, who in the early 1950s rewrote Hoyle’s field equations by replacing the creation tensor with a term corresponding to a negative vacuum pressure (Kragh 1999). Instead of making use of the creation tensor itself as the primary postulate, McCrea’s negative pressure in space shifted the focus of the theory away from the mysterious creation of matter, which was no longer seen as an ex nihilo creation process but rather as a transformation. The new theory offered a kind of explanation of matter creation, but the explanation rested on the postulate of a hypothetical and uniform cosmic pressure with no direct physical effects. Although McCrea’s idea did not significantly change the discussion about continual creation of matter, about 3 decades later it reappeared in the form of a vacuum energy and pressure given by Einstein’s cosmological constant.

5. Actual Infinities and Related Problems

The steady-state universe was not only infinite in past and future time; it also contained an infinite number of hydrogen atoms and other particles. This follows from the PCP when combined with the deduction that space is flat, as given by
the space curvature parameter \( k = 0 \). By itself this was not extraordinary, for the feature of infinite space uniformly populated by particles was shared by some of the cosmological models of the relativistic big bang type. For example, the well-known Einstein–de Sitter model of 1932 assumed the ordinary cosmological principle as well as flat space. By the 1950s the chief exponent of physical big bang cosmology was the American nuclear physicist George Gamow, who insisted that cosmic space was negatively curved \( (k = -1) \) and therefore infinite. He did not consider this to be a problem. What was new and potentially troubling in the steady-state theory was that the infinite number of particles in the universe—anything from electrons to galaxies—continued to increase at a constant creation rate.

The problem of infinities, whether in a spatial or temporal sense, was old and had been discussed since the time of Aristotle. During the nineteenth century the consensus view was that so-called realized or actual infinities (as distinct from potential infinities) cannot exist. In the 1880s the German mathematician Georg Cantor developed an innovative theory of various kinds of infinite numbers, arguing that the actual infinite exists in the same meaning that finite numbers exist. However, it was generally assumed that Cantor’s theory was irrelevant to the real world studied by physicists and astronomers. According to the great mathematician David Hilbert (1925, 190), “The infinity is nowhere to be found in reality. It neither exists in nature nor provides a legitimate basis for rational thought—a remarkable harmony between being and thought. . . . The role that remains for the infinite is solely that of an idea” (my translation).

With the appearance of spatially flat and hyperbolic cosmological models in the 1930s, infinite space became a possibility, but the troublesome philosophical problems associated with cosmic spaces of this kind attracted little attention. To the limited extent that philosophers and theologians referred to the issue, they argued in favor of a closed space. “Infinite space is simply a scandal to human thought,” declared Ernest William Barnes (1931, 600), bishop of Birmingham and an accomplished mathematician. His argument was epistemic as well as theological, because only if God’s universe is finite can we hope to understand the full range of his activity. Two years later Barnes (1933) repeated his view in his book Scientific Theory and Religion, which included detailed chapters on relativistic cosmology.

Most cosmologists seem to have considered the infinite universe to be just an indefinitely large universe and thus nothing to worry about. According to some critics of the steady-state theory, however, the infinite number of particles appearing in this kind of universe led to consequences that were contradictory or at least highly bizarre. Moreover, the critics suggested that the temporally infinite past of the steady-state universe was similarly contradictory or bizarre. Elaborate
arguments of this kind, in part mathematical and in part philosophical, were pro-
posed by Whitrow and by the American physicist Richard Schlegel in the early
1960s. Schlegel had originally studied philosophy under Rudolf Carnap and
Herbert Feigl, and he only changed to physics after obtaining his MA degree
in philosophy. As a physicist at Michigan State University he continued to work
on the philosophical and conceptual aspects of science. For example, he partic-
ipated in the 1953 prize competition on the age of the universe (see sec. 3) with
an essay in which he concluded that the big bang theory was unscientific and
that the universe as a whole should be regarded as essentially atemporal (Schle-
gel 1954).

Schlegel (1965) argued that there cannot possibly be a number of real particles
that is larger than a denumerable infinity, that is, an infinite set that can be placed
in a one-to-one correspondence with the natural numbers. Since Schlegel believed
to have demonstrated that this was the case in the original steady-state theory of
Bondi, Gold, and Hoyle, he concluded that the theory was contradictory and
failed to represent the real universe. The question was discussed for a few years
but then vanished. None of the steady-state physicists found it worth respond-
ing to Schlegel’s mathematical-philosophical challenge.

The question about infinity in steady-state cosmology reappeared in the early
1970s, at a time when the classical version of the theory had been abandoned and
the steady-state universe was defended only in the new versions proposed by Hoyle
and Narlikar. Philosophical arguments for or against infinite space and time tradi-
tionally took their departure in Kant’s first antinomy (thesis: the universe is finite
in space and time; antithesis: the universe is infinite with regard to both space and
time). This was also the approach of a British philosopher, N. W. Boyce, who in
1972 related his discussion to the steady-state theory and the thought experiment
known as “Hilbert’s hotel.” Originally conceived by Hilbert in a lecture of 1924,
the imagined hotel with an infinity of rooms was meant to illustrate how unreal
actual infinities are.7 Boyce (1972, 68) wrote, “‘Hilbert’s Hotel’ describes, meta-
phorically, the structure of the Universe as it is conceived by the ‘Steady State’
Cosmology. . . . Thus ‘Hilbert’s Hotel’ is no mere mathematical fiction, but, may
be the world we actually live in.”

In the cosmological controversy between the two rival world systems, theo-
logians and Christian writers entered no less prominently than did philosophers.
Indeed, it could be difficult to distinguish between the two groups, as theologians

7. Hilbert’s counterintuitive hotel became generally known only after 1952, when Gamow (1952)
in his widely read The Creation of the Universe called attention to the potential problem of an actual
infinity of objects in open cosmological models. None of the steady-state theorists mentioned Hilbert’s
hotel, although they were undoubtedly aware of it. For an account of the hotel and its relation to the
history of cosmology, see Kragh (2014).
often argued philosophically and philosophers often alluded to the religious contexts of the controversy (e.g., Grünbaum 1952; Toulmin 1957). It was widely assumed in the 1950s that the steady-state universe was contrary to theism or at least made God superfluous as a creator of the universe (McConnell 2006). Although none of the steady-state physicists made explicit references to religion in their scientific papers, such references appeared in popular books, articles, and public addresses.

Although a critic of the steady-state universe, Bonnor echoed Hoyle when he complained in the BBC symposium that “some scientists have identified the singularity at the start of the expansion with God” (Bondi et al. 1960, 6). While a few theologians were worried about what they perceived as atheistic elements in steady-state cosmology, this was not the general attitude. After all, since the Middle Ages it had been accepted that an eternal yet divinely created universe is perfectly possible. The leading radio astronomer Bernard Lovell (1959), a devoted Christian, pointed out that from a theological point of view there was no reason to worry about the theory of Hoyle and his allies. Whether matter was created abruptly or continuously, it was a sure sign of God’s activity. The same point was made by Eric Mascall, an Anglican theologian and philosopher with a background in mathematics and physics. As Mascall (1956, 155) concluded in a book on religion and science, “The whole question whether the world had a beginning or not is, in the last resort, profoundly unimportant for theology.” He even suggested that the steady-state theory’s continual creation was in better harmony with theism than the explosive creation assumed by the big bang theory.

6. Conclusion

Although the epic controversy between relativistic evolution theories and the rival steady-state theory of the universe was eventually terminated by new observations, throughout the 1950s and early 1960s philosophical arguments played an important role. On the one hand, a fairly large number of professional philosophers entered the game and offered their views in publications primarily aimed at the philosophical community. Both theories were widely considered problematic and even provoking from a philosophical point of view. On the other hand, several of the involved astronomers and physicists acted as philosophers of science and on occasion entered a dialogue with the philosophers. When they did so it was mostly to support their own favored model of the universe, although this kind of opportunistic motivation did not preclude that in some cases they were genuinely interested in and influenced by the views of philosophers. Bondi’s lifelong fascination with Popper’s falsifiability criterion is one example.
In brief, was physical cosmology a proper science? If not, could it ever become one? Since the debate concerned the very essence of science, it is not surprising that it was to a large extent philosophical in nature and appealed to many philosophers. The episode can be considered a case study in the interaction between scientists and philosophers and is therefore of equal interest to the history and the philosophy of science. From the perspective of modern physicists and astronomers, the whole debate may appear to be much ado about nothing. After all, it was the discovery of the cosmic microwave background and other observations that settled the question, not philosophical arguments. However, from a historical, nonpresentist perspective, this is less important, as the debate should be appraised independently of its outcome.

REFERENCES


