Cosmology and Controversy

THE HISTORICAL DEVELOPMENT OF TWO THEORIES OF THE UNIVERSE

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observed by additional items of information based on the *absence* of detectable phenomena." This was an approach that McVittie found totally unacceptable. Instead, the proper approach would be to emphasize positive, inductive knowledge, to "discover how much can be found out about the universe through measurements that yield non-null results rather than by the consideration of logical possibilities which might conceivably be the case." McVittie discussed the same themes at a conference in Padova in the fall of 1964, celebrating the quatercentenary of Galileo's birth.[159] Several of McVittie's arguments were similar to those put forward by Dingle in the debates of 1937 and 1953. He even associated the rationalist school of cosmology with Aristotle's system and the empirical approach with Galileo's physics. And as Whitrow had objected to Dingle's historical analogy in 1937—pointing out that Aristotle was in fact more empirically oriented than Galileo—so he now, twenty-seven years later, made the same point in reply to McVittie's analogy.

Needless to say, the difference in attitude between McVittie and the steady-state theoreticians was philosophical in nature, and hence could not be resolved by scientific means.

5.3 Religion, Politics, and the Universe

The cosmological controversy was not only fueled by philosophical arguments; it was also tied up with views of a religious, ethical, and political nature, that is, with the prevailing ideological climate of the period. That there was such influence is beyond doubt, but it is not obvious in what way, if any, it affected the controversy. I shall argue that in the end it was, by and large, much ado about nothing. Although interesting in its own right, and certainly illuminating as a case in the history of ideas, the discussions about cosmology's religious and political implications had virtually no impact on the path followed by scientific cosmology.

Theology and Cosmological Models

For most of its history, cosmology has been part of mankind's religious rather than scientific world view. With the progress of astronomy and the advent of cosmological models based on the laws of physics, the association between cosmology and religion loosened, but it never disappeared. It probably never will. In previous chapters we have seen how religious views played an essential part in Millikan's cosmology, and how the relationship between cosmology and religion was constantly discussed by both theologians and astronomers, including de Sitter, Jeans, Eddington, Milne, Barnes, and Lemaître. The expanding universe and Lemaître's big-bang theory were sometimes interpreted as support of the Christian view of creation, although most astronomers refrained from drawing such conclusions. But, as Bertrand Russell, a sharp critic of any such interpretation, observed, "Theologians have grown grateful

for small mercies, and they do not much care what sort of God the man of science gives them so long as he gives them one at all." On the whole, the attempts to turn modern physical science into support of religion were less than convincing and often contradictory. Russell teasingly remarked: "Eddington deduces religion from the fact that atoms do not obey the laws of mathematics, Jeans deduces it from the fact that they do."[160]

The temptation to use cosmology as a scientific argument for Christianity, in one of its many versions, was evident in England at the time when the steady-state theory emerged. Milne explicitly interpreted his cosmological theory in religious terms, and about the same time a similar view was defended by another British mathematical physicist, Edmund Whittaker. In books from the 1940s, Whittaker suggested giving a modernized Thomist proof of God's existence based on the new cosmology. He argued that the knowledge of a temporal beginning of the universe proved the existence of God as the ultimate cause of the world. Moreover, modern science, according to Whittaker, led to a single and transcendent God in accordance with the Christian view. "Recent researches have led to the conclusion that the universe cannot have existed for an infinite time in the past, at any rate under the operation of the laws of nature as we know them: there must have been a beginning of the present cosmic order, a creation as we may call it, and we are even in a position to calculate approximately when it happened."[161] Whittaker believed that not only did science support deism, it also implied a rejection of pantheism; for if God was identified with creative evolution then it would be necessary for God to be born, and such a notion he considered meaningless. As to the problem of the creation of the world, his view was the conventional one, namely, that "the Creation itself being a unique event is of course outside science altogether."[162]

Milne agreed with Whittaker on this point, but believed that he could give reasons why the world was created as a transcendental singularity. In his *Modern Cosmology and the Christian Idea of God*, he wrote: "We can make no propositions about the state of affairs *at* $t = 0$; in the divine act of creation, God is unobserved and unwitnessed, even in principle. . . . We can form no idea of an actual event occurring at $t = 0$; we can make propositions in principle only *after* the event $t = 0$. As for why the event happened, we can only say that had no such event happened, we should not be here to discuss it."[163] Apart from the creation event, Milne believed that everything else about the universe is rational. "To say that the universe is rational is to say that its Creator is rational," he declared.[164] However, Milne's rational ideas of a rational God creating a rational universe were wanting in clarity. As pointed out by a theologian, if the universe is rational in the sense that it is logically necessary, it is difficult to see how any theistic implications can follow.[165]

There can be little doubt that the discussions among Hoyle, Gold, and Bondi, which led to a tentative formulation of the steady-state theory in 1947, were colored negatively by the views expounded by Whittaker, Milne, and other religious scientists. The three steady-state pioneers were atheists and

either hostile or indifferent to organized religion; the same was the case with Sciama, the most important of the younger theoreticians. Although the motives behind the steady-state model were not religious (or, rather, not antireligious), it must surely have added to their satisfaction that it was possible to design a universe in which there allegedly was no room for a Creator.[166] At any rate, Hoyle made a point of associating the steady-state theory with atheism, and, conversely, the big-bang theory with religion in general, and theism in particular. He did so on many occasions, first and most provocatively in his *Nature of the Universe* of 1950. These utterances—one can hardly call them arguments—appeared in his popular works and never turned up in his scientific articles and addresses, where he followed the unwritten rule of avoiding explicit references to religious and political matters. As we have seen, Hoyle reacted strongly to the notion of a temporal beginning of the universe, a concept he found intolerable from both a scientific and a philosophical view. It was a notion "quite characteristic of the outlook of primitive peoples" who postulate the existence of gods to explain the physical world. When Hoyle was in his early teens he concluded that religious ideas were just fairy tales with no foundation in reality, and he never changed this simplistic atheistic view. Bondi and Gold largely shared his views,[167] but they left the overt association with religion to their colleague, who had no hesitations in spelling it out. He asserted that "It is not a point in support of this [steady-state] theory that it contains conclusions for which we might happen to have an emotional preference," and yet it is all too evident that Hoyle did have such emotional preferences.[168] Clearly, Hoyle was not only antireligious but also, and especially, anticlerical. His dislike of organized religion popped up in the most unexpected places, such as in a popular book on the universe in which he explained that the conflict in Northern Ireland could be settled simply by arresting "every priest and clergyman in Ireland and to commit every man jack of them to long jail sentences on the charge of causing civil war."[169] Somehow Hoyle believed that the steady-state theory was preferable not only from a scientific point of view, but also from a political and an ethical point of view. He intimated that this cosmological model might help in realizing higher human values, such as "exposing the futility of nationalistic strife. It is in just such a way that the New Cosmology may come to affect the whole organization of society."[170] How this should come about he did not explain.

Hoyle's rather offhand remarks about religion can hardly be considered a serious attempt to discuss the theological implications of cosmology, and they were probably not intended as such. But they had the effect of polarizing the public debate and causing concern in a large part of the religious community that some astronomers were now trying to undermine Christian faith. Theologians maintained that the steady-state theory held no authority in science, and that faith in God had anyway nothing to do with what cosmological view happened to be accepted at the time being. Yet the concern was widespread. At the Modern Churchmen's Conference in Cambridge in 1950, several mem-

bers were disturbed by Hoyle's recently published book and its effect on people's attitude to Christianity.[171]

In the case of Wallace Sargent, a fifteen-year-old English schoolboy, Hoyle's lectures did indeed have the feared effect. Sargent, who later made a distinguished career in astronomy, recalled that listening to Hoyle's broadcast series and reading his book made him "violently antireligious," and brought him into trouble with the school authorities. When Sargent did graduate work in astrophysics in the late 1950s, he clearly favored the steady-state model. Among his reasons was that he considered the theory to be associated with an atheistic world view.[172]

Now there is no one-to-one relationship between cosmological and religious views, if there is any at all, and sympathy for the steady-state theory did not necessarily imply atheism, any more than sympathy for the big-bang theory implied theism. Recall that Dean W. R. Inge defended a kind of steady-state universe as being "more in accordance with what we may imagine to be the will of God" than the big-bang universe.[173] The attitude of Lovell provides another example of the lack of one-to-one correlation between steady-state theory and atheism.

Bernard Lovell was, like Whittaker, a devoted Christian, but he did not regard the steady-state theory a threat against theism; creation of matter, whether continuous or sudden, was for him a sign of divine activity. Lovell's view concerning the relationship between science and religion was influenced by the organic-metaphysical system of the mathematician and philosopher Alfred North Whitehead's. According to this system, God is immanent rather than transcendent: "He is not the beginning in the sense of being in the past of all members. He is the presupposed actuality of conceptual operation, in unison of becoming with every other creative act." Whitehead's and Lovell's God was a constantly intervening and interacting universal being, who "is not *before* all creation but *with* all creation."[174] From such a perspective there is no fundamental separation of science and religion. As far as cosmology is concerned, it is a religious view which can easily accommodate, indeed, is in harmony with, an eternal universe with continual creation of matter.

It may furthermore be argued that the negation of the heat death in the steady-state theory, and the possibility of endless life that this model implies, are appealing features to the religious mind. Such considerations may have had an effect in some astronomers' sympathy for steady-state cosmology. But then, of course, one doesn't have to be religious to appreciate the prospect of eternal life. Sciama, who was an atheist, once referred to his devotion to steady-state theory in about 1960 as follows: "Partly, I think, because it's the only model in which it seems evident that life will continue somewhere. . . . even if the galaxy ages and dies out, there will always be new, young galaxies where life will presumably develop. And therefore the torch keeps being carried forward. I think that was probably the most important item for me."[175] Contrary to the other steady-state theoreticians, McCrea was a practising Christian (Anglican). He had strong religious convictions and believed that

ultimately cosmology requires the concept of God. In 1974 he emphasized that, as far as he was concerned, the universe is purposeful and "purpose is inseparable from person, and the Person of the Creator is revealed in the person of Christ."[176] Whether this view also influenced McCrea's scientific work is not clear, but Gold suspected that McCrea had religious motivations for supporting the steady-state theory. He recalled that the Cambridge trio felt embarrassed at the thought that McCrea used the theory as part of what they believed was religious propaganda.[177]

The debate about continual creation of matter in cosmology replayed to some extent themes discussed in the nineteenth century's controversy over the spontaneous generation of life. In both cases, it was the *spontaneous* creation, of either matter or life, that caused so much heat. Darwin thought that "it is mere rubbish, thinking at present of the origin of life; one might as well think of the origin of matter."[178] Yet spontaneous generation was historically associated with Darwinism and other evolutionary theories, and in some quarters spontaneous generation was seen as a threat against the Christian Church. In the 1870s religiously motivated attacks on spontaneous generation were common as part of the attempts to counter the harmful influence of Darwinism. A professor of medicine at Paris, Paul Chauffard, linked spontaneous generation with atheism, materialism, and modernism. He warned that the new biology would lead to "general doctrines whose subversive application will lead to the ruin of a civilization imbued with spiritualism."[179] But just as twentieth-century continual creation of matter could be reconciled with religion, so could nineteenth-century spontaneous generation of life. At least one French scientist argued that God's creative faculty did not stop with the first origin of life; if life were perpetually and spontaneously generated, this would only demonstrate the continual presence of divine activity. The biological debate in the 1870s was again a replay of themes discussed earlier in geology. For example, according to the 1789 steady-state vision of George Toulmin, the eternity of the world and the slow, continual changes in its structure "enforce the excellence of moral rectitude; and the existence of a Supreme Being—infinite in wisdom, goodness, and intelligence."[180]

The atheist Hoyle feared that big-bang cosmology might lead to religious propaganda of the sort he knew from Whittaker; indeed, he claimed that the big-bang picture included a first miracle which could only make sense in a religious context. Although he rarely referred to Gamow, it was his version of the big bang-theory he often had in mind. Gamow's theory was, after all, the main rival of the steady-state theory, and it was only Gamow who matched Hoyle in presenting cosmology in best-selling popular works with a wide audience. But Gamow was not the best target for Hoyle's arrows. He was not a religious man, and like most other cosmologists he was careful not to have his science drawn into the fuzzy realm of theology. In fact, the model he favored about 1950 was not a big-bang theory of the ordinary type, but an oscillating model in which each big bang was preceded by a big squeeze of an earlier universe. Such an oscillatory model is as far from theistic interpreta-

tions as is the steady-state theory. Still, the very title of his popular book of 1952, *The Creation of the Universe*, could not help invoking religious ideas in many people. Apart from a casual reference to St. Augustine, Gamow did not mention religious questions in the book, but in the second printing he nonetheless felt it necessary to include in the preface this note: "In view of the objections raised by some reviewers concerning the use of the word 'creation,' it should be explained that the author understands this term, not in the sense of 'making something out of nothing,' but rather as 'making something shapely out of shapelessness,' as, for example, in the phrase 'the latest creation of Parisian fashion.' "[181] This, together with a few other joyful remarks, was about all what Gamow had to say about the religious implications.

A Papal Intervention

Papers in the *Physical Review*, the world's leading journal for physics research, rarely contain references to God or the church. It may have disturbed some readers of the eighty-sixth volume of 1952 to find a paper by Gamow introduced by a lengthy quotation of an address by Pope Pius XII in which the pope in no uncertain terms endorsed the big-bang theory.[182] The quotation in a paper which otherwise had nothing to do with religion was presumably meant as just an eye opener, an unconventional joke of the sort Gamow excelled in. The background was an unusual intervention of the Catholic Church in the cosmological controversy which took place in 1951, and which fueled the discussion over the relationship between cosmology and religion. Had it not been for this rather clumsy intervention there might have been little more to say on the subject.

Pope Pius XII was a learned and enligthened man. He had an interest in astronomy and the other sciences, the latest results of which he wanted to utilize as rational support for the doctrines of the church. He was fascinated by the theory of the expanding universe and influenced by the writings of Jeans, Milne, and Whittaker, in particular. In 1950 the pope issued an encyclical letter on evolutionary biology in which he admitted the theory as a legitimate subject of scientific study and one which did not necessarily conflict with the teachings of the church. The following year, on 22 November 1951, he delivered an address to the Pontifical Academy of Sciences in the presence of several cardinals and the Italian minister for education. In his address, the pope dealt in considerable detail with the support to the notion of a Creator which he thought had recently come from cosmology. The basic argument of the pope was not only that is there no disagreement between the astronomers and the church, but that the results of modern science actually give ample evidence for the existence of a transcendental Creator. He endorsed the big-bang picture unreservedly from the start of his address: "Everything seems to indicate that the material content of the universe had a mighty beginning in time, being endowed at birth with vast reserves of energy, in virtue of which, at first rapidly, and then ever more slowly, it evolved into its present state."[183] After

having cited various methods of determing the size and age of the universe, he pointed out that these figures "involve no new idea even for the simplest of the faithful. They introduce nothing different from the opening words of Genesis, '*In the beginning* God created heaven and earth . . .' —that is to say, at the beginnings of things in time." The essence of the pope's message is contained in the following excerpt:

> What was the nature and condition of the first matter of the universe? The answers given differ considerably from one another according to the theories on which they are based. Yet, there is a certain amount of agreement. It is agreed that the density, pressure and temperature of primitive matter must each have touched prodigious values.* . . .
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> Clearly and critically, as when it [the enlightened mind] examines facts and passes judgment on them, it perceives the work of creative omnipotence and recognizes that its power, set in motion by the mighty *Fiat* of the Creating Spirit billions of years ago, called into existence with a gesture of generous love and spread over the universe matter bursting with energy. Indeed, it would seem that present-day science, with one sweep back across the centuries, has succeeded in bearing witness to the august instant of the primordial *Fiat Lux*, when, along with matter, there burst forth from nothing a sea of light and radiation, and the elements split and churned and formed into millions of galaxies. . . .
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> What, then, is the importance of modern science in the argument for the existence of God based on change in the universe? By means of exact and detailed research into the large-scale and small-scale worlds it has considerably broadened and deepened the empirical foundation on which the argument rests, and from which it concludes to the existence of an *Ens a se*, immutable by His very nature. . . . Thus, with that concreteness which is characteristic of physical proofs, it has confirmed the contingency of the universe and also the well-founded deduction as to the epoch when the world came forth from the hands of the Creator. Hence, creation took place. We say: therefore, there is a Creator. Therefore, God exists![184]

The pope's presentation of the position of contemporary cosmology was biased in that he gave a harmonious picture of the field which had no justification except that it served his purpose. After all, the big-bang theory was far from unanimously accepted in 1951. "It is worthy to note," said the pope, "that modern scholars in these fields [astronomy and physics] regard the idea of creation as quite compatible with scientific conceptions, and that they are even led naturally to such a conclusion by their researches." This might sound like a reference to the creation cosmology of Bondi, Gold, and Hoyle, the only theory in which creation of matter was claimed to be "compatible with scientific conceptions." In fact, it was a reference to the big-bang theories of Lemaître and Gamow, and the Pope only indirectly alluded to the fact that there were rival cosmologies such as the steady-state theory. He did so in discussing the law of entropy, the consequence of which—the ultimate heat death—he accepted as agreeing with Christian belief. The "unduly gratuitous" hypothesis of "continued supplementary creation" was briefly dismissed. It is

remarkable that physicists in the 1920s—Millikan and MacMillan—introduced a steady-state universe in order to save the world from the heat death and thereby to argue a Christian world view, whereas thirty years later the pope sanctioned a diametrically opposite view. And recall that Dean Inge found the stationary, recurrent universe to be in better accord with Christian belief than the big-bang universe.

More important than the pope's partisan view of the cosmological scene was the very essence of his message, the claimed concordance between science and religion. The rationalistic message, that big-bang cosmology's notion of the beginning of the universe justified or supported the religious concept of a created world, was hard to swallow for many theologians, both within and without the Catholic Church. According to many theologians, both then and now, the cosmological creation is something very different from creation in the religious sense. Science does not, and cannot, support religion in any direct way. If this was the case, religion itself would seem to have to follow the changes which necessarily take place in science, to be subservient to science instead of being a supreme truth of revelation. As a theologian concluded in 1956, "The whole question whether the world had a beginning or not is, in the last resort, profoundly unimportant for theology."[185] All the same, there is no doubt that the pope's intervention left among many people the impression that the biblical Genesis had literally been proved by big-bang cosmology; and, conversely, that a good Christian, or at least a good Catholic, could not possibly accept the steady-state theory.

Lemaître, whose theory of the primeval universe formed the backbone of the pope's argument, was not at all happy with the address. Himself a Catholic priest and high-ranking member of the Pontifical Academy, Lemaître believed that astronomy and theology were two separate contexts which should not be mixed. He also felt that the big-bang theory was still a hypothesis, and that the pope had presented it in a much too authoritative way. He was therefore quite upset and found it necessary to intervene, together with Daniel O'Connell, the director of the Vatican Observatory and science adviser to the pope.[186] Apparently they succeeded in persuading the pope that the close association between science and theology that he had argued was helpful neither to science nor to the church. Less than a year after the speech at the Vatican Academy, the pope delivered an address to six hundred and fifty astronomers gathered in Rome for the Eighth General Assembly of the International Astronomical Union. It may have been tempting for the pope to proceed along the same track he had followed in 1951, not least because the Rome conference witnessed Baade's announcement of a time scale much smaller than had previously been accepted; in the view of many astronomers, this discovery made the big-bang theory appear even more likely, and the steady-state alternative even less likely. But this was not what happened. The Rome discourse, delivered in Castel Gandolfo, differed markedly from the previous address, being much more moderate and avoiding specific references to the metaphysical and religious implications of the big-bang theory.[187] Never again did Pope Pius XII try to make cosmology support Christian dogma. Incidentally, the Rome

meeting illustrated the politically and ideologically sensitive aspects of cosmology. The meeting was originally planned to take place in 1951 in Leningrad (St. Petersburg), but was canceled because of the Korean War. It caused much resentment among the Soviet delegates that the meeting was transferred to a North Atlantic Treaty Organization country and that it included a papal discourse. Recalling the pope's propaganda the previous year, the four Soviet delegates stayed away from the discourse and the subsequent audience.

The pope's 1951 address was exactly the kind of religious interpretation and use of cosmology that Hoyle detested. It must have confirmed him in his suspicion of an unholy alliance between big-bang cosmology and organized religion. Although the Catholic Church did not proceed along the path taken in November 1951, of course the discussion of the relationship between religion and the two rival cosmologies did not end. I shall not deal systematically with this relationship during the 1950s; it suffices to recall the positions of Lovell and Bonnor in this respect. The atheist Bonnor rejected big-bang theory for largely the same reasons as Hoyle did; among these, that it lent support to divine creation. "The underlying motive is, of course, to bring in God as creator," Bonnor stated. "It seems like the opportunity Christian theology has been waiting for ever since science began to depose religion from the minds of rational men in the seventeenth century."[188] This motive, which Bonnor rejected emphatically, was clearly exhibited in the pope's address of 1951. But, as mentioned, Bonnor nonetheless rejected steady-state cosmology. Lovell, the theist, avoided choosing between the two models. He found both equally unsatisfactory because they did not provide an explanation of creation of matter, a common lacuna which he—as earlier the pope—reserved for divine intervention. Lovell's argument for religion differed slightly from the pope's, though: whereas the pope saw big-bang cosmology as positively leading to a transcendental Creator, Lovell chose to see divine signs in those border areas of cosmology which seemed to defy science.

Naturally, the question of the relationship between religion and cosmology, or science in general, continued to be a concern of the Catholic Church. In a message of 1 June 1988 Pope John Paul II stressed that "Christianity possesses the source of its justification within itself and does not expect science to constitute its primary apologetic." Although arguing for some kind of consonance, he warned specifically against "making uncritical and overhasty use for apologetic purposes of such recent theories as that of the 'Big Bang' in cosmology."[189] The pope's remark undoubtedly referred to the dominant big-bang theory in the late 1980s, but it could as well have referred to his predecessor in Rome, Pius XII.

Cosmology in the Soviet Union

The role of religion in the cosmological controversy in the 1950s was intimately connected with the political and ideological situation in the period. In order to understand the controversy in a wider sense it is necessary also to look at these factors, the zeitgeist, as prevalent in the Western world in the

postwar years. Generally speaking, the decade after the emergence of the steady-state theory in 1948 was characterized by the cold war and its associated values, including a reaction against materialism and, of course, communism. If a view, scientific or not, could somehow be associated with marxist values, it would be more easily discredited than a view which reflected opposite values. This sort of mechanism can also be witnessed in the cosmological controversy as it took place outside the scientific journals and meetings. In this covert struggle, cosmological models were sometimes intimated to be associated with either positive or negative values, the latter typically being materialism, marxism, atheism, and totalitarianism. The negative values were derived from Soviet communism—where they were considered positive, of course.

Since the late 1920s there had begun in the Soviet Union an attempt to make the country's astronomy more congruent with the official ideological line of the communist party. Astronomers should serve the party by providing anticlerical propaganda and exposing the idealistic cosmological views of the West, in particular those which implied a creation of the world.[190] According to the party's ideology, as it was formulated in the late 1930s, cosmological models with a finite time scale had to be rejected because of their theistic implications. In 1947, Andrei Zhdanov, the notorious chief ideologue, expressed it in this way: "The reactionary scientists Lemaître, Milne and others made use of the 'red shift' in order to strengthen religious views on the structure of the universe . . . Falsifiers of science want to revive the fairy tale of the origin of the world from nothing . . . Another failure of the 'theory' in question consists in the fact that it brings us to the idealistic attitude of assuming the world to be finite."[191] As in physics and other areas of science, in astronomy Stalinism led to a sycophantic tradition of hailing Lenin and Stalin, if not as great scientists then as great philosophers of science. A Soviet astronomer, P. P. Parenago, ended a book on astronomy with a tribute to "the greatest genius of all mankind, comrade Stalin."[192]

Although relativistic cosmology was not necessarily seen as bourgeois idealism, the very application of physical theories to the universe as a whole was regarded as suspect. Soviet authorities claimed that it was unscientific and against the spirit of dialectical materialism to extrapolate local laws of physics, such as the theory of relativity, to the entire universe. In accordance with this view, cosmology as such was often seen as unmarxist. Incidentally, the criticism of relativistic cosmology's extrapolatory approach was, apart from its basis in Marxist-Leninist ideology, largely the same as the one later argued by the steady-state theoreticians. In 1948, party officials renewed their efforts to clean Soviet astronomy of bourgeois attitudes, the most dangerous of which was the relativistic theory of a closed expanding universe. This theory was, the astronomer V. E. Llov warned in 1953, a "cancerous tumor that corrodes modern astronomical theory and is the main ideological enemy of materialist science."[193] A conference of the U.S.S.R. Society of Astronomy and Geodesy taking place in Leningrad in December 1948 illustrates the heavy politicization of Soviet astronomers, but also their different opinions concerning ideological questions.[194] Some of them argued that the expanding universe was a capitalist myth and that the redshift had to be explained otherwise; other participants disagreed, and pointed out, as did Dmitri Iwanenko, that the theory of the expanding universe originated with Friedmann and thus, as a *Soviet* theory, should not be dismissed as bourgeois idealism.

Naturally, the pope's address of 1951 was taken as the final proof, if such was needed, that big-bang cosmologies were religious and not scientific views. The left-wing intellectual and procommunist French magazine *La Pensée* introduced in 1951 an article on Soviet cosmogony in this way: "For the first time, in fact, in the history of the Catholic Church, a sovereign Pontiff, abandoning all attempts for conciliation with Genesis, throws his support behind certain cosmogonic hypotheses, which, even they, too, postulate a creation of kinds ('expanding universe' of Lemaître, Milne, and others), are far removed from the creation story of the Scriptures. . . . This new position of the Pope . . . seems to announce a closer united front of diverse idealist philosophies, against materialism and true science."[195] Whereas cosmology was widely seen as a suspect and quasi-religious field, cosmogony in the narrower meaning—the formation of the earth, the moon, the stars, and the galaxies—was an accepted branch of astronomy which was pursued by several Soviet scientists. The theory of terrestrial and lunar cosmogony which *La Pensée* contrasted with Western cosmology was the one proposed in 1949 by Otto I. Schmidt, a leading Soviet mathematician, geographer, and arctic explorer. Neither Schmidt nor other Soviet cosmogonists dealt with the entire universe, so the comparison may seem somewhat flawed.

Soviet views on cosmology in the 1950s may be exemplified by the work of Victor Ambarzumian, probably the most important Soviet astrophysicist of the period. Belonging to the same generation as Gamow and Bronstein, Ambarzumian had a distinguished career in national and international astrophysics and was considered an authority on stellar evolution. Born in 1908, he graduated in mathematics and astronomy from Leningrad State University in 1928. Six years later he organized a department of astrophysics at the University, the first in the Soviet Union, and in 1946 he founded the Biurakan Observatory in his native Armenia. Ambarzumian was also an academician (i.e., a member of the U.S.S.R. Academy of Sciences) and a convinced marxist who was deeply influenced by the doctrines of dialectical materialism. According to Ambarzumian, cosmology proper was a myth, an unjustified extrapolation of observations and theories based on the empirically accessible part of the universe (the "metagalaxy") to the hypothetical construct of the entire world.[196] Ambarzumian was not opposed to relativistic cosmology (the only scientific form of cosmology he admitted), if cosmology was taken in a more restricted sense; but he found it premature to discuss world models of the kind suggested by Western cosmologists. In a lecture in 1963 he affirmed this position, which was also held by many astronomers in the West. "I personally

think that at the current stage it does not even make sense to compare these models with observations in a detailed fashion."[197]

The Soviet communist party was much less interested in cosmology than it was in genetics. There were no purges and no Lysenko in Soviet astronomy, but then there was no Vavilov either. Yet the official ideology had a serious effect on Soviet astronomy, which responded by simply avoiding ideologically sensitive areas, including cosmology in the Western sense of the word. There was no official ban on cosmology, but the few studies which were published all avoided model construction as the field was pursued in Great Britain, in particular. The official view continued to be that cosmology cannot be treated scientifically; that the universe is infinite in space and time; and that matter is conserved. From 1934 to 1958 there appeared no cosmological models from Soviet astronomers or physicists which corresponded to the kind of models that were discussed in the West.[198] On the other hand, there were no attempts to formulate an independent, dialectical-materialist cosmology either. That is, Soviet astronomers conformed to the dogma of the communist party by giving up the study of the universe as a whole.

It is important to realize that the official attitude to Western cosmological models did not discriminate very much among the various versions. Basically, they were all unscientific and bore the imprint of bourgeois idealism. It goes without saying that theories with a creation in the past, such as Lemaître's and Gamow's, were categorically rejected. At a meeting in Leningrad in December 1948, Soviet astronomers confirmed in a resolution the necessity to fight against the "reactionary-idealistic 'theory' of a finite widening of the universe . . . [and] to expose tirelessly this astronomical idealism, which helps clericalism."[199] The same year one of the most distinguished astronomers in the Soviet Union, Boris Vorontzoff-Velyaminov, attacked George Gamow's big-bang theory. This theory was not only unscientific, he claimed, it was also invented by a former Soviet citizen who had betrayed his country. So: "The Americanized apostate Gamow . . . advances new theories only for the sake of sensation [and] with amazing ease, sometimes even after a few months, discards them in order to propose a new, equally sensational theory."[200] From the undeniable fact that official Soviet astronomy rejected evolutionary cosmological theories it does not follow, however, that they endorsed steady-state theories. Still, this was what Gamow intimated when he quoted Vorontzoff-Velyaminov's attack in the preface of his *Creation of the Universe*. The forced logic seems to have been that since big-bang cosmology was so repulsive to Soviet communism, then the main rival of this cosmology, the steady-state theory, must be regarded with sympathy among communists. Gamow did not actually say so, but he claimed that Vorontzoff-Velyaminov adopted a steady-state cosmology of the same kind as that of Hoyle, Bondi, and Gold. Although he added that Vorontzoff-Velyaminov's reasons were "entirely different" from those of the British astronomers, and that the Russian advocated the view "in the field of stellar evolution" (and not cosmology), the mere

association between marxist orthodoxy and steady-state theory would suggest to many readers that the latter theory somehow was politically suspect.

In fact, Soviet astronomers and ideologues seem to have considered the steady-state theory no less reactionary and bourgeois than the big-bang theory. According to the American, Russian-born astronomer Otto Struve, Llov accused not only Gamow, Lemaître, and Weizsäcker of cultivating a reactionary bourgeois ideology, but also Hoyle, Bondi, and Gold.[201] The infinity of the steady-state universe in both space and time might have been an appealing feature, but if so it was all destroyed by the continual *creation* of matter, which was strictly intolerable to true Marxist-Leninists. Creation of matter out of nothing, whether taking part all at once or continuously, just smacked too much of religion and idealism. Together with the steady-state theory, the theories of Dirac and Jordan were therefore categorically rejected. Hoyle visited Moscow in 1958 to participate in the meeting of the International Astronomical Union. He recalled: "Judge my astonishment on my first visit to the Soviet Union when I was told in all seriousness by Russian scientists that my ideas would have been more acceptable in Russia if a different form of words had been used. The words 'origin' or 'matter-forming' would be O.K., but creation in Soviet Union was definitely out."[202]

The homogeneity principles were a stumbling block, too, and the perfect cosmological principle was seen as even more suspect than the narrow principle. In 1953 two Soviet astronomers, B. V. Kukarkin and A. G. Masevich, who had both attended the meeting of the International Astronomical Union in Rome the previous year, criticized Jordan's theory for being open to religious exploitation. They also explicitly denounced the steady-state theory as "the thoroughly idealistic and absurd theory of the creation of matter."[203] It must be concluded that the various intimations of some sort of association, however indirect, between Soviet communism and either of the two rival cosmologies are unfounded. The only association was negative, and it held equally for both kinds of cosmologies.

The weak position of cosmology in Soviet astronomy was noted at a meeting of the Commission for Cosmogony of the U.S.S.R. Astronomical Council in December 1956. Most of the speakers agreed with Ambarzumian, who admitted that "cosmological problems are somewhat neglected in the USSR" and called for more work in cosmology and extragalactic astronomy.[204] It was decided to stimulate such work, but it took some years before cosmology became visible in Soviet astronomical journals. For example, the first three volumes of *Soviet Astronomy*, first published in 1957, included no articles under the section "Cosmology and Cosmogony"; during the 1960s the number increased to an average of seven papers per volume. Moreover, when cosmology was dealt with it was in a different way than in the West. There seems to have been no interest in the controversy between big-bang and steady-state models, which was barely referred to at all. Almost all scientific papers avoided mentioning the steady-state theory, and when it was alluded

to it was under other names, such as "the concept of a nonevolving universe remaining in a stationary state developed in recent years by F. Hoyle, D. Bondi [*sic*] and others."[205]

The neglect of cosmology in the Soviet Union in the 1950s does not mean that the subject was completely absent from the country's science. For example, in 1959 twenty-two-year-old Igor Novikov took a course in cosmology under A. L. Zelmanov, a Moscow theoretician who since the late 1930s had written surveys of relativistic cosmology and studied possible generalizations of the Friedmann-Lemaître theory. Zelmanov's course was basically mathematical, rather than physical, but it included a thorough discussion of all relativistic world models, including Lemaître's big-bang model. The course taught Novikov mathematical cosmology but did not arouse an interest in the physical aspects of the subject.[206] It was only a couple of years later, when Novikov came under the influence of Zel'dovich, that he discovered that cosmology might be studied also from a physical and astronomical point of view.

Yakov Zel'dovich was a rising star in, and an energetic promotor of, cosmology in the Soviet Union. Born in Minsk in 1914, Zel'dovich studied chemistry at the Physical-Technical Institute in Leningrad. He was soon drawn into chemical physics and nuclear physics, and became a leading member of the Soviet nuclear bomb program. After his long-time occupation with nuclear physics, the chemist-turned-physicist drifted into space science and astrophysics, and from there to cosmology. Zel'dovich made it clear in 1962 that the steady-state theory was unacceptable. His reasons for rejecting it were that it was unnecessary, in conflict with the theory of relativity, and rested on the illegitimate concept of spontaneous creation of matter.[207] These were scientific reasons shared by many of his Western colleagues, and Zel'dovich did not include political or ideological arguments in his criticism. He was convinced that the general theory of relativity was complete and of universal applicability, that is, that all cosmology had to be based on Einstein's field equations. The question was to use existing theories correctly, not to introduce new ones: "In the past chemistry and astronomy have made great contributions to physics: the Mendeleev [periodic] table, the doctrine of molecules, the laws of electrolysis, formed the basis of the ideas about the structure of matter, and astronomy provided the law of universal gravitation and the first measurement of the speed of light. Now, however, in the second half of the twentieth century, it is the deep conviction of the author (not shared, by the way, by many of his colleagues) that it would be naive to expect from astronomy new data about nuclear reactions, the creation of elementary particles, and the laws of the general theory of relativity."[208]

From about that time Soviet cosmology experienced a shift, with more astronomers and physicists being involved in the field, and with a much reduced importance of ideological considerations. Remarkably, in 1962—at a time when the big-bang theory attracted little interest among Western scientists—Zel'dovich concluded that "it is deemed probable that in the earlier stages of the evolution of the universe there existed a homogeneous isotropic Friedmann nonstationary solution with the density of matter decreasing from an infinite value at the initial instant."[209] The kind of cosmology that Zel'dovich and his younger associate Igor Novikov favored was scarcely distinguishable from the one cultivated by Western mainstream big-bang relativists. Unorthodox theories, such as those of Hoyle or Dirac, were dismissed as quasi-scientific: "We do not agree with the 'theories' appearing from time to time with features that violate the fundamental laws of physics. Such theories are, for example, those in which there is constant creation of matter 'out of nothing' far from the singularity (the theory of the steady-state universe) or those which involve a decrease of the gravitational constant with time. . . . We adopt the viewpoint that the homogeneous and isotropic Universe can be examined within the realm of GTR [general theory of relativity]."[210]

Zel'dovich did not differ from his Western colleagues in his relativist orthodoxy, but he presented his view more candidly, as a conviction or belief which first and foremost was theoretically based. In a book-length review of cosmology completed in the beginning of 1965, which "lays no claim of impartiality," Zel'dovich made his stand clear: "We assume that there was a moment of infinite density, at $t = 0$, which is a singular solution. The existence of the infinite density can be regarded as essentially a question of belief. If so, *I do believe* and shall attempt to draw all possible conclusions from this belief, comparing these conclusions with the facts observed until some irresistible contradiction dissuades me. So far, I do not know of any such contradiction."[211] The same attitude characterized Zel'dovich's view of the steady-state theory, which he admitted was not decisively refuted by observation (this was shortly before the discovery of the cosmic microwave background). "The negative attitude toward the theory of creation is based on theoretical principles of a general character," among which energy conservation and general relativity counted heavily.[212]

When it came to the creation itself, Zel'dovich and Novikov were, like most of their colleagues, whether in the East or the West, vague and cautious. In a review article of 1967 they claimed that the fact that $R \to 0$ for $t \to 0$ "does not imply the creation of the universe 10^{10} years ago (i.e. at $t = 0$)." Their argument was that one can imagine a previously existing, contracting universe out of which our universe was born at $t = 0$, including conservation of baryons and entropy. "But the jump itself at $t = 0$ from one [contracting] solution to the other [expanding] is outside the limits of application of the Friedmann solution and the whole modern physics," they wrote.[213] Incidentally, this sounds very much like a repetition of the views previously stated by Milne, Whittaker, and Lemaître—the very scientists who a few years earlier were so scorned for importing religion into cosmology.

Not all Soviet cosmologists agreed with Zel'dovich's preference for homogeneous models and his acceptance of a cosmic singularity at the initial moment of time. M. F. Shirokov and I. Z. Fisher studied in 1962 a type of inhomogeneous world model which admitted discrete masses in the universe.[214] Their modified field equations had the same structure as Hoyle's

steady-state equations (4.2) but, as Shirokov and Fisher emphasized, the analogy was purely formal. Their theory remained on relativistic ground, but had the advantage that it avoided a space-time singularity at $t = 0$. Instead of this "unnatural property" the Shirokov-Fisher theory led for $t \to 0$ to a minimal universe, the density of which the two Russians estimated to be only about 10^{-4} g·cm^{-3}.

The dramatic change in Soviet cosmology is illustrated by the contents of the decennial jubilee volumes on astronomy of 1947, 1957, and 1967 (celebrating the thirty-, forty-, and fifty-year anniversaries of the 1917 revolution).[215] In the 1947 volume, published in 1948, forty-six publications on cosmology were included. Of these, twenty-five dealt with nonstandard explanations of the redshift, fourteen were popular or philosophical works, and only eight dealt with cosmology in the usual meaning of the term. The next volume, published in 1960, contained no papers on cosmology, although it included a bibliography. A drastic change in the field appeared with the 1967 volume. It now included a comprehensive review article on cosmology (by the veteran A. L. Zelmanov) as well as a list of references to a long series of works by Soviet astronomers and cosmologists, including Zel'dovich, Novikov, Fock, Lifshitz, Sakharov, Markov, Shklovsky, V. L. Ginzburg, and N. S. Kardashev. More important than the increase in numbers of Soviet articles on cosmology was the spirit of the post-1960 contributions: they were freed from ideological content and were in general favorable to the new big-bang theory.

As another example of the revolution in Soviet cosmology we may mention a paper by Andrei Sakharov, one of the fathers of the Soviet hydrogen bomb (together with Zel'dovich), and later a famous political dissident. In 1966 Sakharov suggested that the observed charge asymmetry—the nonexistence of cosmic antimatter—was a result of the violation of fundamental conservation laws in the primeval universe. He had in mind the violation of so-called *CP* invariance, which is the combined particle-antiparticle and left-right symmetry. The existence of *CP* nonconservation had been proved experimentally by American physicists in 1964, but only as a tiny effect in the decay of a particular kind of meson (the neutral kaon). According to Sakharov, *CP* nonconservation was important in the earliest phase of the big bang. Moreover, drawing on a proposal of his compatriot Moisei Markov, Sakharov speculated that "neutral spinless maximons (or photons) are produced at $t < 0$ from contracting matter having an excess of antiquarks, that they pass 'one through the other' at the instant $t = 0$ when the density is infinite, and decay with an excess of quarks when $t > 0$, realizing total *CPT* symmetry of the universe."[216] The hypothetical maximons had recently been suggested by Markov as primordial particles of the Planck mass $m = (\hbar c/\kappa)^{1/2} \approx 10^{-5}$ g. Markov's conclusion is worth quoting: "Since an energy of $\sim 10^{28}$ eV is necessary for the production of maximons, the possibility of producing such particles even in accelerators of the remote future is excluded. But one may assume that in its initial stage of development the matter in the Universe was composed predominantly of maximons. Assuming with the passage of time the initially present maximons are partially converted into forms of matter which we know, via the collapse mechanism of small masses, it is still possible to assume that part of the initially present maximons could have been preserved up to the present time."[217]

What I want to call to attention is not the specific content of either Sakharov's or Markov's works, but rather their spirit. For one thing, the authors unhesitatingly made use of the early big-bang universe and wrote freely about infinite densities and the time before the big bang; and, for another, they perceived the early universe as a testing ground for hypothetical particle physics. Such daring views—scarcely in the spirit of dogmatic dialectical materialism—would have been quite unheard of in the Soviet Union just a few years earlier. But by 1966 the tide had changed, and apparently irreversibly.

In the strange extrascientific debate of cosmology it was important, it seems, to present the preferred model as antimaterialistic, "materialism" being a naughty word in the period, associated as it was with communism. The opponents of the steady-state theory often labeled it materialistic, but Hoyle claimed that it was just the opposite. In a book of 1956, dealing amateurishly with almost everything from world politics to social problems, Hoyle described himself as a scientist "who fight[s] under the banner of Anti-Communism." The target of his cold war crusade was not only communism, but also, somewhat surprisingly, Catholicism. What these two ideologies had in common was, according to Hoyle, that they were both totalitarian belief systems: "Both Catholics and Communists argue by dogma. An argument is judged 'right' by these people because they judge it to be based on 'right' premises, not because it leads to results that accord with the facts. Indeed, if the facts should disagree with the dogma then so much the worse for the facts."[218] Hoyle did not refer to cosmology in this context, but it is revealing that he sometimes described the "official" cosmology with the same choice of words. He felt that the response of the astronomical community to the steady-state theory was dogmatic, and, bearing in mind the pope's address of 1951, he might have felt that big-bang mainstream cosmology and Catholicism shared at least their dogmatism; since communism certainly was dogmatic, too, he managed to tie together big-bang cosmology and communism. To be fair to Hoyle, this is my interpretation; Hoyle did not say so. It is worth noticing, if only to increase the confusion, that if the term "Catholics and Communists" in the quotation is replaced by "steady-state theory" we have almost exactly the criticism that Dingle leveled against the new cosmology of Bondi, Gold, and Hoyle!

The sometimes heated extrascientific debate about the two cosmological theories proceeded in an irregular and covert manner. It is difficult to judge its effects on the wider audience, but as far as the astronomical community is concerned it seems to have been ineffective. Scientists may have emotional preferences for a theory for all kinds of reasons, and it is possible that some of the astronomers and physicists who joined the cosmological controversy in

the 1950s did so motivated, consciously or not, by political or religious reasons. But if they did, it did not turn up in their scientific arguments and work. Even those scientists who admitted ideological and religious factors to be relevant, such as Hoyle, Sciama, and Bonnor, kept them strictly apart from their scientific work. All things considered, the extrascientific debate had almost no influence on the scientific developments in cosmology. Of much more importance were the observations and experiments to which we shall now turn.

CHAPTER 6

The Universe Observed

NEITHER PHILOSOPHICAL discussions nor religious and other metaphysical considerations made the steady-state theory appear a much less likely candidate for the structure of the universe by about 1960. The outcome of the controversy was decided by observations and experiments, pretty much in the same way that the fate of more ordinary physical theories is settled. But although observational testing was on the program ever since 1948, it took more than fifteen years before observations clearly indicated that evolutionary theories fitted better with the universe than the rival steady-state theory. And even then there was no undisputable proof of a big-bang universe, only increased evidence.

The difficulty in testing cosmological theories should not be surprising. Because of the subject matter of such theories, testing is necessarily based on indirect observational claims and long chains of inferences with ample room for discussion of each step. The cosmological tests in the 1950s and 1960s demonstrate how complicated and delicate testing is, and how intimately it is bound up with theory. But they also bear witness to the ingenuity of experimentalists and observational astronomers, and show that even theories so grand and fundamental as those in cosmology can be subjected to observational tests in essentially the same way as other theories in the more mundane parts of physics. Indeed, in special cases a cosmological theory can be tested by ordinary laboratory experiments, namely, if it relies crucially on a hypothesis which can be so tested. This was the case with the electrical universe model of Lyttleton, Bondi, and Hoyle. Dirac's cosmology with a varying gravitational constant was also refuted by experiments, although in this case they involved measurements from the Viking landers on Mars.

The kind of empirical work used in astronomy is usually referred to as observation, and not experiment. Ordinary experiments take place in the laboratory, where the scientist is able to maintain a certain amount of control of the objects or phenomena studied; they can be prepared and manipulated in the way required, and they can often also be produced. This active intervention of the experimentalist is not possible in astronomy, where, for obvious reasons, the objects are out of the astronomers' control. What the astronomer can do is basically to observe, register, and classify signals from celestial bodies. Yet there is no clear-cut distinction between observation and experiment, and in astronomy also ordinary experimental work is of the utmost importance in detecting and analyzing the signals from the heavens. The view, held by some