Rationalism versus Empiricism in Cosmology

The temptation to substitute logic for observation is peculiarly hard to resist in astronomy.

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The four books which I propose to discuss in this article were all written by British scientists and are intended to inform the general public. Books of this kind are increasingly widely read today, and they largely determine the view of astronomy, and of science generally, which is held by the man in the street. Indeed, the opinions of professional astronomers are not uninfluenced by them. I have therefore thought it worth while to analyze, in more detail than is customary in reviews, the contents of these four works. I shall frequently employ quotations, the sources of which will be specified as clearly as possible. This I do because I hope the reader will look up the originals and decide for himself if the use I make of these quotations is or is not justified.

I begin with a rapid survey of the contents of the four books. Chapters 1, 3, and 4 of Hermann Bondi's **The Universe at Large** (Doubleday, New York, 1960; 154 pp.; $0.95) contain an account of the author's view of the nature of scientific theory, of the expansion of the universe, and of theories of cosmology with tests thereof. Chapters 2 and 5 through 12 deal with selected topics in astronomy, including Olbers' paradox on why the sky is dark at night; the internal constitution of stars; interstellar gas clouds; the earth's radiation belts, its motion and magnetic properties; Newtonian gravitation, celestial mechanics, and the theory of the tides.

Rival Theories of Cosmology [by H. Bondi, W. B. Bonnor, R. A. Lyttleton, and G. J. Whitrow (Oxford University Press, New York, 1961; 60 pp.; $2.25)] contains the substance of talks made on the BBC by Bonnor, Bondi, and Lyttleton, together with a discussion session among these speakers under the chairmanship of Whitrow. The topics covered are the cosmology based on Einstein's general relativity (Bonnor), the steady-state theory (Bondi), and a variant of that theory in which it is assumed that the electric charges on protons and electrons do not exactly balance each other (Lyttleton).

Fred Hoyle's **The Nature of the Universe** (Harper, New York, 1960; 141 pp.; $3) is a revised edition of the book with the same title which he published in 1950. The first two chapters contain a certain amount of descriptive material on the solar system, the sun, and the stars. Then come three chapters on the origins and ultimate fates of stars and on the origin of the solar system. These chapters are followed by an account of the expanding universe from the standpoint of the steady-state theory. The last chapter is devoted to such topics as man's place in the universe and the nature of religion.

Finally, Reginald O. Kapp's **Towards a Unified Cosmology** (Basic Books, New York, 1960; 303 pp.; $6.50) is a book of a somewhat different character, for it contains a complete exposition of the author's doctrine. This is based on certain a priori principles among which is found the notion that matter is created, and is also disappearing, without cause. The book is mainly devoted to a justification of these principles, to the description of the author's ideas on the origin and evolution of galaxies, and to a new theory of gravitation. How stars are formed and why stars and galaxies rotate are questions to which answers are also provided.

The authors belong to different schools of scientific thought. Bondi, Hoyle, and Lyttleton are advocates of the steady-state theory of the universe, Bonnor is a supporter of Einstein's general relativity, and Whitrow may here be thought of as a neutral referee. Kapp has his own personal views, though he tries to draw liberally from both the steady-state theory and general relativity.

Views of Astronomy and Cosmology

Let us now return to a more detailed consideration of *The Universe at Large* and *Rival Theories of Cosmology*. The chapters of the first work fall into two different groups. In chapters 2 and 5 through 12 as much stress is laid on the results of observation as on those of theory, and conclusions are presented with due qualifications. The statements it contains would, in the main, be agreed to by most astronomers. The presentation in these chapters has another virtue, namely, that a great deal of thought has evidently been given to finding excellent simple analogies for the recondite subjects under discussion. The effortless prose should not deceive the reader; beneath it lies much hard work in discovering the best illustration.

In chapters 1, 3, and 4, which may profitably be read in conjunction with his contributions (chapter 2 and the debate in chapter 4) to *Rival Theories of Cosmology*, Bondi is concerned with making a case for the steady-state theory, which he and T. Gold originated. The starting point is Karl Popper's dictum that a scientific theory can never be proved to be true but, instead, that certain theories can be proved to be false by an appeal to observation. This is probably unimpeachable doctrine, but Bondi goes on to write as if the excellence of a theory were measurable by the rapidity and ease with which it can be so disproved. Thus on page 45 of *Rival Theories* we have: "I certainly regard vulnerability to observation as the chief purpose of any theory." Or on page 35 of *The Universe at Large* we may read that one of the chief tasks of a theory is "to suggest methods of shooting down the theory." At this rate we should be justified in inventing a theory of gravitation which would prove that the orbit of every planet was necessarily a circle. The theory would be most vulnerable to observation and could, indeed, be immediately shot down.

The steady-state theory is built up from the assumption that the universe is uniform in space and time. This means that an observer located any-

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where in space and making his observations at any moment in the history of the universe sees the same world-picture as we do now from the earth. It is also accepted that the universe is expanding; this will lead to a steady diminution of the average density of matter and therefore to a change in the world-picture as time proceeds. To prevent this from happening, matter must be created out of nothing at just the right rate to restore the balance and keep the density constant. Once created, however, matter cannot be correspondingly annihilated though it may presumably be converted into energy.

In defending this theory, Bondi is not entirely consistent. For example, on page 23 of *The Universe at Large* he is discussing the possibility that the red shift phenomenon might have some other interpretation than a velocity of recession. Defenders of this view have "argued that all our interpretation was based on our local knowledge of physics, and that unknown effects might well occur in the depth of the universe that somehow falsify the picture that we receive. Nowadays, we have little patience with this type of argument." Now on page 17 of *Rival Theories* it is said that the creation of matter is "a major infringement of present formulations of physics," formulations that derive from our local knowledge. The creation of matter is admittedly not observable in terrestrial-scale experiments. It is therefore precisely one of those unknown effects, brought in to deal with the depth of the universe, with which we have little patience when they are invoked to explain the red shift.

The steady-state theory also asserts that galaxies are continually forming out of the newly created matter and that this process has been going on for an infinitely long time. There must therefore be somewhere in the universe infinitely old galaxies. Throughout their lifetimes matter has been created within them and in their neighborhoods. Their gravitational fields will have prevented the escape of this matter, and therefore the old galaxies will by now be enormously more massive than our own or than the galaxies which we do observe. These old massive galaxies are not observed and so have to be disposed of. This is done (page 46 of *The Universe at Large*) through the expansion effect. In fact "expansion to regions hard to see is the process of death" of a galaxy. Obviously this is a way out of the difficulty, provided that the observer is always located in a recently formed galaxy. An observer in an old massive galaxy would see it quite clearly around him. He would also conclude that his position in the universe was a peculiar one because the galaxies around him would, for the most part, be far less massive than his own. Therefore his world-picture would not be identical with the one which we, for example, obtain from the earth. This conclusion apparently contradicts the fundamental postulate of the theory, which states that all world-pictures are equivalent to one another, unless some device is introduced for killing off all possible observers on ancient galaxies.

In these four books there are a number of statements about Einstein's general relativity which are either incorrect or are true only with essential, and unstated, qualifications. Take, for example, the remark by Bondi on page 36 of *The Universe at Large* that the assumption of the large-scale uniformity of the universe "has to be added" to general relativity in order to produce a cosmology. In fact the assumption is added merely to make the mathematics simpler; there is nothing in general relativity which forces us to make it. Indeed, studies are at present in progess that aim at dispensing with the assumption. They are referred to briefly by Bonnor on page 9 of *Rival Theories of Cosmology*.

Illustrations of statements needing qualification will be found on page 37 of *The Universe at Large* and on page 119 of *The Nature of the Universe*. It is said that certain models of the universe deduced from general relativity involve an initial "nuclear explosion" or a "big bang" which initiates the start of the expansion. What general relativity itself demonstrates is that, if we push the assumption of uniformity too far back into the past, this idealization will have the following consequence. It will appear that the motion of expansion of the universe has begun from a state in which all the matter in the universe was concentrated at a single mathematical point. But general relativity predicts no nuclear explosion, big bang, or instantaneous creation, for that matter, as the cause of the start of the expansion at that moment. Such notions have been woven round the predictions of general relativity by imaginative writers. The correct interpretation of the initial instant, as a product of an oversimplified mathematical treatment of a complex problem, is well brought out by Bonnor in chapter 1 of *Rival Theories*. In this book we find him, a doughty warrior outnumbered two to one, stoutly maintaining the general relativity point of view that scientific cosmology should be based on the laws of physics as we know them from experiment and observation rather than on hypotheses and principles laid down a priori.

The chapter headed "Tests in cosmology" in *The Universe at Large* throws a clear light on the attitude of the advocates of the steady-state theory toward astronomical observation. An argument against the theory would be the detection of some change in the properties of galaxies which depended systematically on distance. This would really be a time variation, for the further away a galaxy is, the further back in time the light by which we now see it departed from the galaxy. In pointing this out, Bondi fails to mention that an effect of this kind has been suggested with regard to the nature of clusters of galaxies (*1*). Another test mentioned is the character of the increase in the number of galaxies with distance. Again there is a failure to mention the fact that the observations we do possess—those that refer to galaxies that are radio sources—fail so far to conform to the predictions of the steady-state theory (*2*). Two other tests suggested are possible only if we accept a certain theory of the formation of galaxies and a theory of the formation of the elements, respectively. These are not observational tests but rather examinations of the concordance between the steady-state theory and certain other theories. Finally there lies under the statement (page 55) "there are many other tests which are too technical to be considered here" perhaps the most significant test of all. This refers to the way in which the red shift varies with increasing distance. The often repeated remark in these books that the red shift of a galaxy is proportional to its distance is only a rough first approximation. The observational work carried out up to 1956, and extended during the past 5 years, reveals that the relationship is a more complicated one. This in turn can be shown to imply that the acceleration of the expansion is negative at the present time. The steady-state theory, however, predicts that the opposite is the case, namely, that the acceleration must always be positive. This difficulty is referred to indirectly by Lyttleton (pages 22 and 23 of *Rival Theories*), who dismisses it by arguing in effect that to rely on observation alone is to adopt the wrong attitude in science.

Lyttleton's main contribution to *Rival Theories* is an account of a theory which he and Bondi had just published in the technical literature (*3*). It is postulated that the positive charge on a proton is slightly in excess of the corresponding negative charge on an electron. If this is so, then a hydrogen atom will have a slight positive charge. If, again, the universe is thought of as a highly rarefied cloud of hydrogen gas, matters can be adjusted so that the electrical repulsion between the charged hydrogen atoms counteracts gravitational attraction and produces a general expansion of the universe. But to achieve this result it is also necessary to modify the well-established Maxwell equations of the electromagnetic field. The modification proposed implies that the outward flow of charged hydrogen atoms will produce no magnetic field (page 27, *Rival Theories of Cosmology*). Be this as it may, the theory has satisfied Bondi's criterion for a good theory: the experimentalists "shot it down" almost immediately. Hillas and Crankshaw (*4*) showed that the required excess positive charge for the proton as compared with the electron was not present and, further, that the experiment could have detected the excess even if it had been 1/100 as large as Bondi and Lyttleton needed for their theory.

We may conclude this discussion of our first two volumes by remarking on Whitrow's skill as an impartial chairman. If, following some cataclysm, *Rival Theories* were the only book published in the 20th century to survive the disaster, the archeologists of the future would have the greatest difficulty in deducing from this volume what his views on cosmology really were. Happily for us, he has recorded them elsewhere (*5*).

Hoyle and the Universe

The first edition of *The Nature of the Universe* appeared in 1950 and consisted of the texts of a series of lectures delivered over the BBC shortly before. It is perhaps one of the most widely read popular books on astronomy and cosmology; it is very well written, and Hoyle states regarding the second edition, "I have tried not to change the general style and plan of the book." The method of exposition is to state conclusions with an air of absolute certainty. The conclusion may be one that is well founded in observational and theoretical work or it may be a highly questionable idea that has occurred to the author or to one of his colleagues. It is also a very interesting exercise to compare the present edition with the original one. Let me give some illustrations of the author's method. ["I" refers to the first edition (Mentor Books, New York, 1950); "II" similarly refers to the present edition.]

In II (chapter 1), Hoyle describes the earth, the planets, and the satellites of the solar system. At one point he refers to the theory that the so-called craters on the Moon are the results of meteor impacts. In this theory, the maria, which are the large dark areas on the Moon almost devoid of large craters, are thought to be the consequences of impacts by very large meteors indeed. Considerable areas of the Moon were liquefied and, on congealing again, formed relatively flat plains. No reference to this interpretation is made by Hoyle; he quotes instead an idea "pointed out [to me] by my colleague, Gold" (I, page 19; II, page 13). This is that the maria represent regions covered by an extremely deep layer of dust which has buried all the peaks and craters. We see therefore the top of a sea of dust. Unfortunately this explanation ceases to be plausible as soon as we look at a large-scale photograph of the surface of one of the maria. It then leaps to the eye that we are contemplating a plain of rock covered with small sharp irregularities, tiny craters, cracks, and so on.

Or take the discussion of the formation of the earth. In I (page 86) the answer to the origin of the "complicated rare material out of which the earth and the planets are made" could be given "in two sentences." The explanation was that the earth and the planets were formed out of a small remnant of the gases that resulted from the supernova explosion of a star. This star had been the sun's companion in a binary system; it was ejected from the neighborhood of the sun during the explosion and is now unrecognized. But now turn to II (chapter 5) which "has been entirely rewritten." This is certainly true, for there is no longer any mention of the sun ever having had a companion which suffered a supernova explosion. Instead the sun in its early history developed a gaseous ring, angular momentum was transferred to the ring by the action of magnetic forces, and some of the gas condensed into the planets. In support of this view we have (II, page 98): "astronomical observation provides ample evidence that rapidly rotating stars do in fact grow disks of gas in this fashion." My own impression of the professional literature is that the "ample evidence" is principally based on the interpretation of the spectrum of one star, Pleione (*6*), and that Hoyle himself is uncertain whether a disk or a shell of gas is in question (*7*). That the spectral peculiarities of one star, or even of a small number of stars, may be interpreted by postulating a disk of gas hardly constitutes the ample evidence provided by astronomical observation which would be required as a starting point in a theory of the origin of the solar system. Equally strange is the statement (II, page 101): "the overwhelming proportion of the water [in the whole planetary material] is now to be found in the great planets, not in the small inner planets." I was under the impression that the only planet for which we had indubitable observational evidence for the presence of water in substantial quantity was the earth, a small inner planet. Hoyle here appears to be drawing on an early theoretical model of the planet Jupiter proposed by Wildt in which a large shell of ice is postulated in its interior. A recent survey article on the subject of planetary interiors (*8*) makes no mention of water or ice in the interiors of Jupiter and Saturn, which are regarded as largely composed of hydrogen and helium with unspecified heavy elements in their small central cores.

In summary, one can say that, without warning his readers, Hoyle selected one of the many theories of the origin of the solar system in 1950 and another one in 1960. On each occasion the selected theory is presented as if it were the only possibility (*9*), were strongly supported by the evidence, and were generally agreed to by astronomers.

When Hoyle is writing on the internal constitution of the sun and stars, to which he has himself made great contributions, he has an excellent and well-balanced tale to tell (II, chapter 2). Energy generation, chemical composition, the difference between an ordinary "main sequence" star and a red giant, and other relevant matters are all clearly and succinctly described. However, in the next two chapters on the origin, the future, and the final state of a star, we have a return to the technique of presenting personal opinions as if they were the generally agreed-on results of astronomical research. In 1950 (I, page 59) a main element in star development was the process of accretion by which stars swept up the interstellar material. This process has inexplicably disappeared from the picture in 1960. Stars now condense out of the interstellar gas in groups and not singly, an idea presented in the words (II, page 71) "the more dramatic answer is the correct one. Stars are born in groups." In fact, this is a useful hypothesis on which astronomers are now working; certain stars may well be born in groups, but it would be a bold astronomer who would assert that he knows that *all* stars are produced in this way.

Hoyle is a supporter of the steady-state theory of cosmology, and his account of it (II, chapter 6) is similar to Bondi's. However, he adds two new ideas. One is that the newly created material "produces a pressure that leads to the steady expansion" (I, page 114; II, page 126). In contradiction to this, Hoyle proves in his technical papers (*10*) that the expansion of the steady-state universe is not contingent on the presence of a pressure and indeed takes place under the fundamental assumption that the pressure is always zero. The second idea is that the creation of new matter arises from a field which "you must think of as generated by the matter that exists already" (II, page 123). The notion is defended by analogy with a gravitational field, but there is no true resemblance. The gravitational field is a mathematical expression of the fact of astronomical observation that, wherever matter is observed, it appears to exert a gravitational force on other matter. There is no experimental or observational evidence of any kind which suggests that the mere presence of matter is responsible for the creation of new matter out of nothing.

The treatment of numerical values between the first and the second editions is also very interesting. Usually the text is not modified in any way, but the new value is simply inserted into the slot previously occupied by the old number. Here are some examples, the number found in the first edition being followed in brackets by the one occurring in the second. "The birth of the earth, which, as I shall show in a later chapter, occurred about 2500 [4500] million years ago" (I, page 18; II, page 11). "To give a numerical estimate, I would say that rather more than 1 [1000] million stars in the Milky Way possess planets" (I, page 30; II, page 25). "Calculation shows that the supply of hydrogen in the sun will last for about 50,000 [5,000] million years" (I, page 43; II, page 41). "A large matchbox full of it [the interstellar gas] would contain only about 10,000 [100] atoms" (I, page 54; II, page 67). "The speed [of the sun] is in the neighborhood of 1,000,000 [500,000] miles an hour" (I, page 55; II, page 67). Yet in both editions the sun takes 200 million years to complete one revolution round the center of the galaxy. This implies that the radius of the sun's orbit was halved between 1950 and 1960, news which will startle astronomers. "The estimate [of age] for the stars of the cluster M 67 comes out at about 15,000 million years" (II, page 82). But in 1950 we have "No estimate exceeds 4,000 million years" (I, page 74). Galaxies "certainly continue out to the fantastic distance of 1,000 [5,000] million light years" (I, page 100; II, page 110). Clearly a scientist may change his mind about such matters as knowledge develops. But the helpless reader has no means of knowing why and how these alterations have been made and whether the new values have any greater degree of certainty than the original ones. His bafflement can only be increased by the statement that "the time estimates of the astrophysicist . . . are reasonably definite and precise" (II, page 82). One might suppose that some at least of these numbers were misprints were it not for the fact that this book is laudably free of obvious ones. I have noticed three only: the nearest star is distant 4¼, and not 3, light years (I, page 52; II, page 65); "changing with" (II, page 120) replaces the original "monkeying with"; and there appears to be something essential omitted from a remark of Sherlock Holmes' (II, page 93).

Cosmology by Cogitation

It is the fate of those who have a professional interest in relativity and cosmology to receive through the mails, several times a year, closely typed manuscripts containing new theories of the universe. The covering letter is fairly stereotyped and runs as follows: The author of the manuscript has found a new principle which holds the key to all, or most of, the unsolved problems of physics and astronomy. He is himself not a specialist in science and therefore has neither the time nor the required background knowledge to make full use of his important idea. He has therefore approached a number of professional scientists who, in spite of his careful explanations, have shown no interest in the new principle. The author therefore has written up his theory, demonstrated as far as he can the important consequences to which it leads, and hopes that all professional scientists may thus be led to revise their work in the light of the new revelation.

These elements will be found in the opening paragraphs of the preface to Kapp's book, set forth in more elegant language than is customarily the case. There is also a defense of the point of view that a writer who seeks to unify all science cannot be expected to be equally familiar with the details of all branches of it. This is a valid defense with the following reservations: if the writer is an engineer, like Reginald Kapp, he cannot be excused from being ignorant of the fundamental ideas of classical mechanics, or, as Kapp calls them (page 47), "simple mechanics." Nor if he makes a conclusion drawn from a more recondite theory—general relativity in this case—basic to his exposition, can he be excused from showing ignorance of the aforesaid recondite theory.

In examining a work of this type a reviewer ought to allow the author the right to have his work discussed entirely within the framework he has laid down. The scientists to whom he has spoken will have pointed out the inconsistencies with experiment and observation and with the theories that have been developed to interpret the results. These inconsistencies are evidently regarded by the author as irrelevant; otherwise publication of the theory would not have been undertaken. Let us therefore ask whether Kapp has followed his own rules in carrying out his program.

The fundamental postulate is the Principle of Minimum Assumption. On page 34, Kapp says that a minimum assumption "can be recognized by the use in its formulation of the words 'any' or 'either.'" For instance the statement that a planetary system can have any number of planets is a minimum assumption; a statement to the effect that such a system cannot contain 13 planets is not. On page 38, the principle is also defined, in part, by the statement: "In physics a generalization that is logically possible is also physically possible." Finally, on page 43, the "criterion of minimum assumption" is equated with Occam's razor, the notion that hypotheses are not to be multiplied unnecessarily.

A second basic principle is that of the Symmetrical Impermanence of matter and energy (page 43). This states that any particle of matter or quantum of energy may have existed for any length of time and, conversely, may cease to exist at any time. Matter and energy can originate at random, without cause, and, conversely, can be extinguished in the same fashion.

Lastly there is the Cosmic Statute Book, a notion which is not fully explained, reference being made to an earlier work of the author's. It appears to be a compendium of prohibitions as to what can or cannot be done in physics and to be analogous to the Statute Book of a sovereign state. In the British one, for example, it is prohibited to drive a car on the right-hand side of the road. Logically one can drive on either side, and therefore the prohibition is an arbitrary one. On page 38 it is stated that "for the physicist there is no such thing as a Cosmic Statute Book."

Let us see what use the author makes of his principles. To analyze every application would mean writing a book longer than Kapp's, and therefore only a few key examples will be noticed. Consider the statement (page 81) that the "interstellar gas must be falling on to the stars." Suppose that this is so and that Symmetrical Impermanence is false. Then matter and energy have existed for all time, and the material of interstellar gas clouds would long ago have fallen into the stars. But interstellar gas clouds are observed; therefore new matter must have been created at intervals and, since stars are not of infinite mass, matter must also have been extinguished.

Now why does the interstellar gas "fall" on to the stars? Because the stars have gravitational fields and ponderable matter must be "falling everywhere down the potential gradients of the [gravitational] fields" (page 81). This notion that the direction of the velocity of a body in a gravitational field is always parallel to that of its acceleration is a recurrent theme. It first occurs on page 45, it is basic to the theory of interstellar clouds, it is used repeatedly in chapters 10 and 11 on the formation of galaxies, and it is repeated on pages 104 and 105. However, the Principle of Minimum Assumption would state that the velocity of a body in a gravitational field can have *any* direction relative to that of the potential gradient. This fact is an elementary consequence of simple mechanics, and it is amply illustrated in astronomical observation, for example, by the motion of the earth around the sun. Kapp has here drawn on the Cosmic Statute Book for an arbitrary prohibition, namely, that a body may not move except in the direction defined by that of the potential gradient. Without this rule, his theory of the existence of interstellar gas clouds and of the formation of galaxies goes by the board.

The same can be said of his treatment of radiation pressure on pages 93–95, the result being quoted also on page 120. It is asserted that the radiation pressure on an interstellar gas cloud always acts in the direction opposite to that of the gravitational potential gradient acting on the cloud. In fact, cloud and illuminating star move in directions different from that of the potential gradient that controls their motion, namely, that of the galaxy as a whole. The force of radiation pressure on the cloud due to the star's radiation is therefore, in general, different from that of the potential gradient. Here again a cardinal prerequisite of Kapp's theory is that the Cosmic Statute Book should contain a law by which the pressure of radiation and the gravitational potential gradient are forbidden to act at an angle to one another.

Let us look now at the notion of Symmetrical Impermanence itself. On page 52 it is stated that, when matter originates without cause, it is an elementary constituent of matter that so originates and this "may be a bit of differentiated space." On page 189 we have: "the origin of matter and the origin of space occur in association and the extinction of matter and the extinction of space also occur in association." Now consider the statements on page 109, the first of which is "the minimum assumption is that every region of space has at any given moment an equal probability of being the birthplace of a particle" and the inference that "the rate of origins is constant per unit volume." The minimum assumption implies only that the probability is a function of time alone. The selection of a constant value for this function is an arbitrary restriction of the kind found in the Cosmic Statute Book. Next, again on the same page, we have: "the minimum assumption is that every particle at that moment has an equal probability of becoming extinct" and the inference that "the rate of extinctions [is] constant per unit mass." The rates of origin and of extinction are therefore asymmetrical, one depending on unit volume, the other on unit mass. This asymmetry is defended on the ground that "in a perfect vacuum there can be no extinctions, for there is nothing to become extinct." But there is space in a vacuum, and it is not clear why the extinction of *empty* space is prohibited, since space *is* extinguishable when it happens to be occupied by matter. In any case, the processes of origin and of extinction could be logically brought into agreement so that both would depend on unit volume, and both would be variable with time. The notion would then still be in agreement with the Principle of Minimum Assumption and would be symmetrical to boot. Since Kapp does not proceed in this way, he must be relying on arbitrary prohibitions in the Cosmic Statute Book. The need for these prohibitions is found in his theory of gravitation in chapter 25, where the cause of a gravitational field is stated to be the extinction of matter. Since this theory appears to be based on a denial of Kapp's own rules, it need not be discussed further here.

It is when he comes to take over conclusions from general relativity that Kapp has most frequent recourse to the forbidden contents of his Cosmic Statute Book. This volume apparently contains statements in flat contradiction to the conclusions that can logically be deduced from general relativity; it also apparently contains arbitrary selection rules as to which of the correctly deduced results are to be permitted and which forbidden. I will illustrate Kapp's method by a few examples. On page 35 it is implied that the laws of physics are no longer necessarily of the kind that assume a Euclidean space. Einstein has introduced the minimum assumption that the geometry may be non-Euclidean. In fact, Einstein did more: his minimum assumption was that the geometry of space-time is non-Euclidean. The statement on page 271, namely, "the motion [of a particle] depends, according to the [general relativity] theory, only on the curvature of space" is consequently untrue. Cases are known in general relativity in which space is Euclidean but space-time is curved, and this state of affairs determines an accelerated motion for particles. On page 72, in chapter

25, and in appendix H it is stated to be a consequence of general relativity that, if the material content of the universe is increasing, its extent must be doing so. This is false because a basic postulate of general relativity is that mass cannot be created or destroyed, in Kapp's sense, though it is convertible into energy. Moreover it can be logically deduced from general relativity that the volume of space may be increasing or decreasing while the material content remains constant in amount. This occurs in the model universes of constant positive curvature. In other words, general relativity predicts no connection between the expansion of space and an increase or decrease in its material content. The interpretation of the red shift given on page 58 and the calculations on page 112 constitute an arbitrarily selected, special case from among the logically deducible predictions of general relativity. The statements on pages 73 and 74 imply that the intensity of a light source and the intensity of gravitation both fall off as the inverse square of the same "distance." That this is untrue is one of the most remarkable consequences logically deducible from general relativity. Lastly, it is to be noticed that, whenever a mathematical argument involving mechanics is carried out, the argument presupposes that classical mechanics is applicable, that is, that space must necessarily be Euclidean. Examples occur on pages 100, 101, 112, 113, 114, 183, 184, 220, and 221 and in chapter 21. Thus conclusions drawn from these arguments are not shown to be valid if Einstein's minimum assumption is adopted; they follow in fact from the Newtonian nonminimal assumption.

It is perhaps illegitimate in discussing a theory of this type to point out where basic starting points in the discussion are contrary to observation. One only will therefore be mentioned. It occurs on pages 126, 127, and 131 where it is said that spiral nebulae rotate as though they were composed of a viscous fluid and that they are in uniform rotation. Measurements have shown that these statements are untrue; indeed the nonuniformity of the rotation, for different distances from the axis, is one of the problems to be solved in any theory of the rotation of these objects.

The foregoing examples of the nonapplication by Kapp of his own rules and of his free use of the entries in the (forbidden) Cosmic Statute Book are far from exhaustive. Indeed there is hardly a page in the book on which the reader can fail to find an instance. These internal self-contradictions may perhaps be one of the reasons for the lack of interest in his ideas that Kapp has detected among scientists.

We have seen that Kapp expressly states a principle which Bondi, Hoyle, and Lyttleton also seem unconsciously to follow. It is the dictum that what is logically possible is also physically possible. At first sight the principle appears to be quite harmless, for it seems merely to say that we must examine any idea that occurs to us. In practice, scientists are human; it is as unpleasant for them as for the next man to admit that an idea, once formulated and published, is, after all, either useless or unimportant in science. Assuredly one of the remarkable features of science is that logical possibility is by itself insufficient; one may even say that three or four hundred years ago the founders of modern science were struggling to establish this insufficiency. They had grasped the notion that the physical world had to be closely and continuously inspected if it was to be understood. The temptation to substitute logic for observation is peculiarly hard to resist in astronomy. This is because astronomical data are very difficult to come by, and the data rapidly diminish in number and accuracy as the objects we observe recede from the earth. We need only reflect on the scantiness of the information we possess about our nearest planetary neighbors, Venus and Mars, compared with the wealth of physical data which geophysicists and meteorologists can supply about the earth. Nevertheless, the fact that data may be scarce and inaccurate is no reason for failing to use them as our main guides in the formulation of theory. Perhaps I may be allowed to close this long review with one final comment. Once upon a time British science was sometimes criticized for being too empirical. During the past 30 years a number of a priori theories of cosmology, of which the steady-state theory is one, have completely reversed the trend, which is a curious and unexpected development.

References and Notes

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Social Sciences and General

The Future of Mankind. Karl Jaspers. Translated by E. B. Ashton. University of Chicago Press, Chicago, Ill., 1961. ix + 342 pp. $5.95.

The problem of this book is what Jaspers calls "the new fact"—the possibility of the thermonuclear termination of human history. What is his solution? That takes a little longer to say, but it may be said briefly that there is no "solution," if solution means some new and cleverer plan, strategy, law, or institution based upon our present thinking. It is the thinking itself which must be changed. And the change in question is not a mere shift of ideas, but a change that will involve our deepest sense of life.

The great merit of the book lies in the earnestness and humility with which Jaspers faces the new fact, unmasks spurious solutions, and searches for the attitude that would make hope reasonable. To recover reason in a situation maddening enough seemingly to defeat all reason is the principal aim of the book, but the reason which is found is hardly anything that can be encapsulated in a phrase. The reader who expects a new plan of action comparable to existing alternatives will be disappointed; but it is exactly that expectation which Jaspers regards as profoundly mistaken and which must be seen through if any hope is to be justified.

Nuclear Extinction

The first step must be to face the new fact squarely and in its depth. The new fact is not the death of an individual man or the disappearance of a nation; it is the possible extinction of humanity through its own action. But everybody "knows" this; and yet Jaspers feels we do not know it at all. "Today we see politicians whose countenance and deportment baffle us. Do they know where they stand, what they