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CREATION AND THE "NEW" COSMOLOGY*

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1

IN the recent, much-publicised cosmology of 'continuous creation'[1] a number of issues of specifically philosophical interest are raised, whose resolution proves essential for an understanding and evaluation of the theory as a whole. These issues revolve about the precise *meaning* to be given to the concept of creation as it functions in the theory and the *methodological grounds* offered by way of justification for its use. Accordingly, whatever might be the fate of the theory as it undergoes the ordinary checks of mathematical analysis and observational verification, I shall argue that much of the philosophic (sometimes euphemistically called 'aesthetic') commentary provided by its authors exhibits a number of difficulties and obscurities that stand in the way of its total acceptability as formulated at present.

2

The essential novelty of the theory consists in the suggestion that matter is being created in all epochs and throughout space at a statistically uniform rate which is sufficient to compensate for the continuing expansion of the universe, and thus to maintain the universe in a steady-state (in a generalised hydrodynamic sense) and at an over-all constant density. The expansion is inferred from the observed red-shift in the spectra of galaxies, which is interpreted as due to their recessional motion. Matter, it is proposed, is being created in an elemental form at random throughout space in a way which is independent of the matter already existent in various stages of agglomeration. The calculated rate of creation is roughly the mass-equivalent of one hydrogen atom per litre of volume every billion years. It is accordingly a process which, because of its virtually

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[1] Also known technically as the 'steady-state theory of the expanding universe'; the original papers are: H. Bondi and T. Gold, *Mon. Not. Roy. Astr. Soc.*, 1948, **108**, 252; F. Hoyle, *Mon. Not. Roy. Astr. Soc.*, 1948, **108**, 372; F. Hoyle, *Mon. Not. Roy. Astr. Soc.*, 1949, **109**, 365; cf. W. H. McCrea, *Endeavour*, 1950, **9**, 3; H. Bondi, *Cosmology*, Cambridge, 1952, Ch. 12.

infinitesimal proportions, is incapable on practical grounds of direct confirmation. Through a gradual process of condensation and accretion, conglomerate macroscopic bodies are eventually built up to the enormous proportions of galaxies and clusters of galaxies. At any given time, within a sufficiently large volume of space, the number of galaxies remains constant since new ones are continually being formed to replace those disappearing over the 'horizon' of the observable universe. The theory allows for the idea of a universe whose existence in time is infinite both in the past and the future, and whose existence in space is likewise infinite in extent though the range of observability is set by the limiting velocity of light.

3

It is claimed for the concept of creation as it figures in this theory that it is wholly removed from the intellectually suspect domains of metaphysics and theology and now finally established within the domain of scientific accuracy and comprehension. On earlier theories

> it was believed that the creation process occurred at a definite ascertainable epoch in the past. Properly interpreted this point of view sidesteps the whole question; for unless we say *how* the creation occurred, nothing has been achieved. Indeed the word 'creation' in this context was simply a device for terminating the discussion as soon as an awkward question had been posed.[1]

With the steady-state theory

> the problem of the origin of the universe, that is, the problem of creation, is brought within the scope of physical inquiry, and is examined in detail instead of, as in other theories, being handed over to metaphysics.[2]

With respect to these claims, however, it is important to keep two points clearly distinguished. One has to do with the consequences or effects of matter when 'given' as existing, the other has to do with the possible antecedents or causes which bring it into existence. In discussing creation, the authors of the steady-state theory believe it sufficient to explore the former without any attention to the latter. It is here that there is to be found one crucial philosophical difficulty in their account. Thus one set of questions has to do with the specific

[1] Hoyle, *New York Times Magazine*, 1st June, 1952, p. 12
[2] Bondi, *Cosmology*, p. 140

properties which matter is said to possess when it appears or, allegedly, is created : properties such as spatial distribution, rate of appearance, initial velocity, ' temperature ', atomic structure and the like. This is what is referred to as the 'physics ' of creation. It is the filling out of these details, the drawing of their consequences, i.e. the linking of them with the facts of astrophysics, atomic theory, and observational astronomy, which underlies the claim that creation is therewith brought within the scope of scientific understanding. And there can be no doubt that progress in this direction makes for the kind of deepening and broadening of insight which is characteristic of science. *Yet the possible success of this line of inquiry would leave completely unaffected the crucial claim that what has been investigated is matter which has been created.* Those theories like Lemaître's or Milne's which posit a point singularity in the finite past, identified as Creation, are actually in this respect not at all inferior to the steady-state theory. For they, too, undertake to give us what may be regarded as the ' physics ' of creation, i.e. specifications as to initial motions, material composition and the like. The complaint that they locate the creation at a singular point in the past, thus making it inaccessible, is justified if it emphasises that the creation *process* is left shrouded in mystery. Hoyle, therefore, is quite correct when he remarks that

> it is against the spirit of scientific enquiry to regard observable effects as arising from ' causes unknown to science' and this is, in principle, what creation in the past implies.[1]

But exactly the same criticism applies to the continuous creation theory. By spreading creation out in time and space, there is no reduction in the mystery, since multiplication of the occasions of creation as contrasted with the single unique event leaves it open to exactly the same objections as the latter.[2]

Hoyle, in particular, would argue on what he takes to be pragmatic grounds that all we need concern ourselves with is the ability of the theory to make successful predictions, its ability to work well.

> We do not ask [he tells us] ' Where does gravitation come from ?', or if we do, science supplies no answer. Or again, we do not ask, ' Why do electric and magnetic forces occur in nature ?' Instead we ask the question ' How does gravitation operate ?' ' How do electric and magnetic forces operate ?' Science does not seek to justify the

[1] Hoyle, *Mon. Not. Roy. Astr. Soc.*, 1948, **108**, 372
[2] cf. H. Dingle, *Scientific Adventure*, London, 1952, p. 166

> existence of gravitation and electromagnetism. What science does say is, 'If gravitation exists, then it works like this . . .' or 'If electricity exists then it works like this . . .' Exactly the same situation applies to the creation of matter. We cannot say why matter is created or where it comes from, but we can say 'If matter is created continuously then it is created in such and such a way.'[1]

It is true, of course, that scientific explanations do not undertake to give justifications in the above-intended sense, and in this sense it would be unwarranted to ask for the 'purpose' of creation. It is also true that in speaking of 'gravitation', 'electricity' and 'magnetism' all that is effectively involved for physics is bound up with the equations expressing these ideas, the rules according to which these are to be interpreted and their capacity to link known facts or predict fresh ones in a satisfactory way. If we would extend, however, these same ideas to the present theory, it would at best direct our estimation of its worth to an examination of what the equations contain, the various properties assigned to matter and the way we are enabled on the basis of these formulae to systematise our subject matter. It would, however, *not* justify the conclusion that matter has been 'created in such and such a way'.

4

In saying that matter is created, the authors of this theory are explicitly clear about the fact that it is an *ex nihilo* process. Bondi writes :

> It should be clearly understood that the creation here discussed is the formation of matter not out of radiation but out of nothing.[2]

Hoyle says :

> From time to time people ask where the created material comes from. Well, it does not come from anywhere. Matter simply appears—it is created. At one time the various atoms composing the material do not exist and at a later time they do.[3]

Finally, McCrea, in expounding the theory asserts :

> there can be no causal treatment in a physical sense of true creation. This is almost a matter of definition. If the creation of matter is caused, as is conceivable, by existing physical conditions, then the true creation

[1] Hoyle, *New York Times Magazine,* loc. cit.
[2] Bondi, *Cosmology,* p. 144
[3] Hoyle, *The Nature of the Universe,* Oxford, 1950, p. 125

> is of those conditions, and we should not try to give a physical theory of that creation. But we are here regarding the creation of matter as itself spontaneous, i.e. as something 'given' and not to be treated causally.[1]

Now to claim that matter 'simply appears', that it is a 'formation out of nothing', that its appearance is 'not to be treated causally', is simply to deny the *possibility* of achieving any kind of scientific explanation of its appearance. This is, however, clearly a species of dogmatism, the irrevocable claim to an *ignorabimus* which is incompatible with the spirit and method of scientific inquiry. It is one thing to say that we don't yet understand how a process takes place, even though we might adduce reasonable grounds for affirming the existence of the process. It is an altogether different matter to say that we shall never understand its mechanism. The latter violates a primary rule of science, as Peirce expressed it, 'not to block inquiry'.

Suppose that indeed it were established in some way that matter does appear in the manner and with the various properties as claimed. We should then be able to speak of this as a 'law of nature' in one sense of that phrase, namely, as a regularity found to hold in fact. But it is precisely as a regularity that one would look for its explanation. And this criticism holds regardless of the particular philosophy of science one adopts. It will commonly be granted that the primary task of science is the discovery of laws. On one account, such laws are basically generalisations. Even where science advances to the level involving the establishment of an intricate deductive system or logical hierarchy of such laws, those which are in a given system the premisses of the system are still essentially statements of regularity.[2] Another view takes the primary technique of scientific explanation to consist in

[1] McCrea, *Endeavour*, loc. cit., 7

[2] e.g. a recent statement of this view: 'To explain a law . . . is to incorporate it in an established deductive system in which it is deducible from higher level laws. To explain these higher-level laws is to incorporate them and the deductive system in which they serve as premisses, in an established deductive system which is more comprehensive and in which these laws appear as conclusions. To explain the still-higher-level laws serving as premisses in this more comprehensive deductive system will require their deduction from laws at a still higher level in a still more comprehensive system. At each stage of explanation a 'Why?' question can significantly be asked of the explanatory hypotheses; there is no ultimate end to the hierarchy of scientific explanation, and thus no completely final explanation.' R. B. Braithwaite, *Scientific Explanation*, Cambridge, 1953, p. 347.

the application of laws or theories regarded as modes of representation of phenomena and involving characteristic techniques of calculation or rules of inference, while not themselves being facts or generalisations of facts.[1] On either view science always leaves the way open for more adequate explanations, and does not regard any given explanation as final. If we proceed by looking for more and more inclusive generalisations, then no given regularity (generalisation) is ultimate, i.e. in principle unexplainable; the demand always exists for finding a more inclusive generalisation under which a given one may be subsumed, i.e. deduced and so explained. And if we consider the primary technique of explanation to reside in the use of laws or theories interpreted as essentially techniques of inference, then, confronted with a hitherto unexplained regularity, it will be the objective of inquiry to find a theory whose way of looking at phenomena and whose mode of operation will enable the regularity to be understood. (Here, the question as to what 'explains' the theory is a meaningless one, since theories are not like generalisations and are not explained by subsumption under 'wider' theories. At best the rules which characterise one theory are incorporated, i.e. added to other rules which yield a more refined theory.) Given, then, the statement of the regularity with which matter appears, there is no reason, no methodological warrant, for insisting that this is itself an ultimate fact, capable of explaining other facts but incapable of being explained itself.

A confirmation by way of illustration of the above general criticisms is to be found in the recent work of McCrea and McVittie.[2] Both seek, on the basis of the main ideas of the steady-state theory, to find some way in which the creation process can be made genuinely intelligible—and thus not a creation process at all. The basic suggestion put forward by McCrea and worked out in a slightly different manner by McVittie is that on the basis of relativity as distinguished from Newtonian theory, one can look for a connection between stress and the 'creation' of matter. With a negative stress as made possible in relativity theory, the creation of matter becomes the mass-equivalent of work done by this negative stress in the expansion of the universe. With the possibility as allowed under relativity views of the conversion of stress into mass and *vice-versa*, the creation of matter is no longer an

[1] cf. S. Toulmin, *The Philosophy of Science*, London, 1953, pp. 42, 84 ff.; W. H. Watson, *On Understanding Physics*, Cambridge, 1938, pp. 52 ff.

[2] McCrea, *Proc. Roy. Soc.* (A), 1951, **206**, 562; G. C. McVittie, *Proc. Roy. Soc.* (A), 1952, **211**, 295

ex nihilo process. From a methodological point of view (whatever might be the technical value of these suggestions) one sees here at work the scientific mind typically engaged in finding connections rather than showing its willingness to accept some fact as inexplicable.

5

It may be said, however, in rejoinder, that to refer to the possibility of subsumption under ' wider laws ' or ' incorporation within a wider theoretical framework ' is precisely to miss the whole point in speaking of creation at all, since whatever may be the case in other situations, here one intends by the very employment of this concept to underline the point that we are confronted with an ultimate fact, itself capable of serving as a fundamental premiss or rule of inference but, by the very fact of its being ultimate, incapable of inclusion within any wider or more basic framework. That this is an error has just been argued on the ground that there is no warrant for taking scientifically any premiss or rule as *absolutely* basic or unique. Further, as I shall now argue, the very use of the term ' creation ' in such an allegedly ultimate premiss or rule is vacuous. This has the result that it leaves the premiss or rule itself crucially indeterminate. As we have seen, there is an essential difference between the following two statements : (1) matter in an elemental form and with the various other properties as specified by the theory *is found* in the universe, and (2) matter in an elemental form and with the various other properties as specified by the theory *is created* in the universe. The authors of the theory insist on taking the second expression as the correct one, but whatever strength there is in the content of their proposals or methodologic soundness in their procedure lies in actually using the first expression. To say that matter is found in the universe leaves open the possibility of explaining its appearance, whereas to say it is created not only denies such a possibility but also *employs a term without any significant content.*

> I have often been asked [Hoyle tells us] ' Where does the newly created matter come from ?' This is also a meaningless question. [Like the question about the origin of the universe as a whole, according to him.] It is only because in everyday life people have got used to the idea that matter must be conserved. When a conjuror pulls a rabbit out of his hat we know that the rabbit did not suddenly come into existence at the moment we see it and therefore it makes sense to ask ' Where did

> the rabbit come from ?' But if the rabbit were indeed created by the conjuror, it might make no sense at all to ask this question.[1]

To which we must reply that, on the contrary, whether presented with rabbits or particles of matter it *does* make sense to ask ' Where did they come from ? ' To be told that where these are created it makes no sense to ask this question is *to beg the question*, to assume the meaningfulness and legitimacy of referring to the process as one of *creation*. Now as a matter of historical and etymological fact ' creation ', of course, *does* have a meaningfulness and legitimacy of employment in *certain contexts*. But it has notoriously undergone a series of transmutations and corruptions of meaning of which indeed the latest instance of degeneracy is to be found in the commentary accompanying the scientific theory we are examining. What is particularly noteworthy of this employment is the fact that the *last vestige* of meaning borrowed from its primary context of usage has been removed. This primary meaning of the term is to be found in the domain of human craftsmanship where it refers to the process of making some article of use such as a watch or a chair. What ' creation ' refers to here is at once a familiar and accessible fact of experience. Individual human beings, by virtue of some relatively distinctive use of skill and imagination are able to manipulate and transform already existent materials to yield a product whose structure and function can be appreciated by themselves or other members of the human community. When so located in this primary context of usage, the term ' creation ' allows of a literal analysis into such components as an agent or creator, materials used, methods of transformation or ' making ', and the finished product with its identifiable design or use. This literal meaning of the term has undergone, however, a variety of analogical extrapolations or truncations, which, while occasionally allowing innocent metaphors, have, instead of bringing fresh insight into another area, helped to breed confusion and support pseudo-explanatory devices. Thus what is in its primary usage a concept referring to a familiar fact of human experience, becomes under the pressure of uncontrolled analogical thought either a myth made to support ambitious metaphysical schemes, or, as it is transformed still further by theology, a cardinal mystery. The extension of the concept of creation beyond the domain of human craftsmanship to serve as a basis for cosmological speculation is the source of perhaps the most influential and persistent traditions of

[1] Hoyle, *New York Times Magazine*, loc. cit.

metaphysical thought. Its classic source is to be found in Plato. It is from Plato that metaphysical idealism and supernaturalism derive their inspiration in constructing a cosmology. Plato himself makes a clear and explicit appeal to human craftsmanship as the ' root metaphor ' employed in constructing his own theory of the universe. Plato's use of the imagery of human art in the myth of the *Timaeus* is guided by the profound conviction that such intelligibility as the world possesses is, at bottom, a purposive one, an adumbration of the Ideal Good. The cosmogony he pictures is conveyed in terms of a story not intended to be taken literally in its details. The Demiurge as ' creator ', the ' pre-existent, recalcitrant materials ' (the realm of Necessity and Chance) transformed by ' rational persuasion ' and purposive craftsmanship modelled on the Ideal and issuing in a world which exhibits a ' mixture ' of reason and necessity —all of these are not to be found in the ' creation ' of the cosmos in any literal way as is the case with ordinary craftsmanship. Conscious and deliberate myth here serves a philosophic conviction (itself the projection of a blind faith) in the designful character of the universe, the negation of all that the materialists and Sophists of Plato's day had proclaimed. Theology simply carried forward what Plato had here begun. What had been a conscious myth now became a literally intended mystery. The Creator not only cannot be located in the familiar world, He is no longer merely a symbol. His existence, literally claimed, is a ' transcendent ' one and basically an article of faith. Similarly the process of creation becomes a divine mystery, the most real of facts but shielded from human understanding.[1] Even human creation becomes, through an inverting rationalisation, no longer the primary and guiding image. Instead it is now *man's imitation* of the infinite divine capacity and as such accorded a secondary, derivative status.[2] Throughout there is the pervading faith, continuous with Plato's, in the purposive character of the universe, and all that it contains. As we turn to the present day, the manner in which we find creation appealed to in the steady-state theory is one which, in effect, carries this progressive mystification to its last stage. For all of the sustaining motives or analogical threads of comparison with art are gone. Scientific cosmology, of course, now not only makes no claims about the designful character of the universe ; it also stops short of making any reference to the Creator or the process of His making. It is not even claimed that these are

[1] cf. Augustine, *Confessions,* Book 11, §§ 4, 5

[2] cf. Maritain, J., *Art and Scholasticism,* pp. 123 ff.

mysteries whose existence is to be believed in even though not understood. All that it would retain is the fact that matter in an elemental form is created continuously. But if the Maker, the process of making, and the purpose are gone, *what is there left to the concept of creation ?* Doesn't the very description of the appearance or presence of matter as one which is due to creation lose *all* its significance ? Isn't it a case of its having lost not merely its primary meaning, but even its various attenuated analogical modifications as in metaphysics and theology ? If the *sole content* of the concept of creation is now simply that matter appears or is present, then far from this being a case of creation, it is at best, as previously suggested, a fact which invites scientific explanation.

6

We turn, finally, to an argument of a methodological kind offered by Bondi in justification of the use of the concept of creation. Here it is important to note that the types of argument employed on the one side by Hoyle and on the other by Bondi reflect two radically different philosophies of science at work, reflected in the way each proceeds to build up the theory, though the end results are essentially similar. Hoyle, who works out his proposals within the framework of the field equations of the general theory of relativity, introduces a modification in the expression of those equations which allows him the opportunity of developing a cosmological model different in crucial respects from those hitherto encompassed within the gamut of ' relativistic cosmologies '. The primary justification in his eyes for entertaining both the modifications in the equations and the resultant cosmology is the fact that it can be submitted to the test of prediction. We have already seen that this pragmatic appeal, correct and important as it is, in no way warrants the interpretation that if the theory proves successful, what has been confirmed is the claim that matter has been *created*. Meanwhile Bondi develops the theory along lines strongly reminiscent in some respects of the ' *a priori* deductive ' approach of Milne.[1] He would develop the cosmology not with the aid of the relativistic field equations but on the basis of what is regarded as a crucial principle, the *Perfect Cosmological Principle*. It is this principle which, it is claimed, warrants the introduction of the concept of creation.

[1] cf. M. K. Munitz, ' Scientific Method in Cosmology ', *Phil. of Science*, 1952, **19**, 108

The Perfect Cosmological Principle may be formulated briefly as the statement that ' apart from local irregularities the universe presents the same aspect from any place at any time '.[1] Restriction to the case of spatial homogeneity, as is usually the case with the great variety of current cosmological models other than the steady-state one, gives what is called the ' narrow cosmological principle '. According to it, all positions in *space* are regarded as equivalent, from any of which a description of the universe can be made, since such descriptions will agree with one another.[2] Bondi would widen the principle to include a homegeneity or equivalence of times as well. The warrant for adopting the widened or ' perfect ' principle is two-fold, according to him. In the first place, unless the principle were adopted, there would be no justification for assuming the general validity of physical laws. Taking laws as generalisations, the argument maintains that all ordinary physical science rests upon the basic axiom of the ' unrestricted repeatability of all experiments '. The repetition of an experiment and the expectation that it will yield the same results as the law specifies, assumes that change of place and time in the performance of the experiment will have no effect upon the result.

> We see, therefore, that in all our physics we have presupposed a certain uniformity of space and time ; we have assumed that we live in a world that is homogeneous at least as far as the laws of nature are concerned. Hence the underlying axiom of our physics makes certain demands on the structure of the universe ; it requires a cosmological uniformity. [3]

Secondly, any attempt to apply the generalisations won on the basis of terrestrial experience to vaster regions of space and time and ultimately to the structure of the universe as a whole, requires some justification for extrapolating such generalisations. Here reliance is made on an argument originally due to Mach, and illustrated in connection with the dynamical fact of rotation, that there is a strong ' coupling ' between the outcome of terrestrial experiments and the distribution

[1] Bondi, *Cosmology*, p. 12

[2] More accurately : ' All large-scale averages of quantities derived from astronomical observations (i.e. determinations of the mean density of space, average size of galaxies, ratio of condensed to uncondensed matter, etc.) would tend statistically to a similar value independent of the positions of the observer, as the range of the observation is increased ; provided only that the observations from different places are carried out at equivalent times.' Bondi, *Mon. Not. Roy. Astr. Soc.*, 1948, **108**, 253

[3] Bondi, *Cosmology*, pp. 11-12

of distant matter, e.g. in the system of the fixed stars. It is maintained in a general way, similarly, that

> we can hence not contemplate a laboratory which is shielded to exclude all influence from the outside ; and for the same reason we cannot have any logical basis for choosing physical laws and constants and assigning to them an existence independent of the structure of the universe.[1]

Only some general assumption about the character of the universe at large will permit the use of laws and constants as holding without qualification throughout all regions of space and time. Here, moreover, instead of assuming that the laws and constants themselves undergo change, due to a general ' evolution ' of the universe, which would require—in order to make such a change or evolution itself meaningful and specifiable—the arbitrary stipulation that *some* laws or constants are indeed *invariable*, the proposal is made to avoid all such arbitrariness by rejecting all reference to an evolving or changing universe. This is accomplished by the Perfect Cosmological Principle which postulates that the universe is homogeneous and stationary in its large-scale appearance as well as in its physical laws.[2]

Use now is made of the cosmological principle in conjunction with the observed fact of local thermodynamic disequilibrium (the fact that more energy is found to exist in the form of matter than in that of radiation, as well as the fact that more energy is being radiated than is being absorbed by matter) to yield the conception of an expanding universe, a conception also supported by the observed recession of the nebulae. However, in order to satisfy the perfect cosmological principle, which requires a stationary (but not static) universe, together with expansion, there must be an abandonment of the principle of hydrodynamic continuity.

> By the perfect cosmological principle the average density of matter must not undergo a secular change. There is only one way in which a constant density can be compatible with a motion of expansion, and that is by the *continual creation of matter*. Only if the diminution of density due to the drift to infinity is counteracted by a constant replenishment of newly created matter can an expanding universe preserve an unchanging aspect.[3]

[1] *Mon. Not. Roy. Astr. Soc.*, 1948, **108**, 253
[2] ibid., p. 254
[3] *Cosmology*, p. 143

The above argument involves two essential features of philosophic significance, one having to do with the logical status of the Perfect Cosmological Principle, the second with the 'deduction' allegedly made from it to the fact of creation.

The account given of the Perfect Cosmological Principle is in many ways strongly reminiscent of traditional discussions of the doctrine of the Uniformity of Nature offered as a solution to the problem of induction. As such, it suffers from precisely the same general difficulties that are already well recognised to hold for that more familiar formula, among them the fact that as a generalisation it has whatever weaknesses are alleged to belong to other generalisations. It cannot be known with certainty[1] if its truth-value is in any way dependent upon an appeal to experience. If experience, on the other hand, does not enter into its establishment, then one must claim for it self-evidence, but this notoriously fails as a criterion of truth. Interpreted in its most favourable light, the Perfect Cosmological Principle, like the Principle of the Uniformity of Nature, functions not as a factual statement at all, capable of serving as a premiss in an argument, but as a definition that functions as a criterion or rule of what in the language of science is to be regarded as a law. To be a law, the rule now asserts, is to be a statement which by its very *meaning* asserts a structural connection among a selected number of factors. This connection *could not be otherwise* than it is at various places or times without surrendering its own distinctive and individual nature. The law, consequently, *could not* change or be different; at best we should employ *another* law and this in turn asserts a specific invariance or uniformity. So regarded, the Perfect Cosmological Principle is, to be sure, essential to science. However, it is not to be regarded as providing for other sciences a logical underpinning which is fathered upon cosmology. Cosmology shares such a principle equally with other sciences, since it is but a formal principle, a rule of the game, a defining characteristic of the techniques of representation which science employs regardless of its subject matter.

To say, moreover, that the Perfect Cosmological Principle is a formal principle means that it must surrender all power to serve as a

[1] If the demand is not for certainty, there is no need for the Principle since any ordinary generalisation involves inevitably the hazard that it will not continue to hold in instances beyond those already examined. Its truth-value, now construed as its probability, is in no way altered by the appeal to the essentially vague principle of the Uniformity of Nature.

premiss *in* an argument and the capacity to yield either by itself or in conjunction with other factual statements, results of a factual kind. Inasmuch as it is a rule governing the formulation and use of laws or theories, it cannot be regarded as *part* of a theory in cosmology. This, in effect, means that the criticisms made, for example, of other cosmological theories on its behalf (as supposedly the unique possession of the steady-state theory) are not warranted, and it also means that, in particular, the attempt to deduce from it, among other things, the existence of a continuous creation of matter is unjustified.

We must reject the claim that

> only in such a universe [the steady-state] . . . is there any basis for the assumption that the laws of physics are constant, and without such an assumption our knowledge, derived virtually at one instant of time must be quite inadequate for an interpretation of the universe and the dependence of its laws on its structure, and hence inadequate for any extrapolation into the future or the past.[1]

The steady-state theory is really in no better situation, methodologically speaking, than those theories which, for example, posit an ' evolution ' of the universe. For *any* theory, it is necessary to specify some relationship as invariant. If what are regarded as ' constants ' in one theory are regarded as ' variables ' in another, then in turn new constants must be set up to give the treatment some determinate form. Thus to be an item in an evolutionary process is to forfeit the status of being a law or constant. Only what expresses the structure of this process is entitled to this status. Now whether an evolutionary cosmology or a steady-state one is to be regarded as successful, cannot be settled by saying that for all theories but the steady-state one, the selection of laws is arbitrary. For in one sense *any* theory, by claiming certain relationships to hold and not others that are logically possible, is arbitrarily selective. Such selection must be justified now in the usual way by estimating the fruitfulness of its explanations and predictions.

Finally, no factual consequences such as are claimed to follow about the creation of matter can be drawn from the Perfect Cosmological Principle. To begin with, whether the universe is in a state of thermodynamic disequilibrium, or whether it is undergoing expansion, is something which we may claim to be the case or not, depending upon whether we take certain *arbitrarily selected* laws as holding in the

[1] Bondi, *Mon. Not. Roy. Astr. Soc.*, 1948, **108** 254

interpretation of given observational data. These laws, such as the Doppler principle, or the various laws of thermodynamics, or atomic physics, that formulate the relations between matter and radiation, energy, entropy and the like, are, at best, useful devices, but by no means unique, i.e. without logically possible alternatives. The Perfect Cosmological Principle is not joined with these laws as another premiss to yield the result that the universe as a whole is in a state of thermodynamic disequilibrium or expansion. One uses the laws themselves that state the properties of thermodynamic disequilibrium or expansion in the interpretation of the data, but there is no requirement that they *must* be used. Finally, even were such interpretations to prove fruitful, it does not follow that the interpretation of the universe as being in a steady-state requires the creation of matter as a necessary condition. It would be sufficient for the purposes of the steady-state theory to propose that the average density of matter be constant, without presuming to offer in *that* theory any explanation for the appearance of matter so invoked. To provide such an explanation might be left for another theory of 'finer grain' that might be forthcoming, without in any way weakening or causing the abandonment of the steady-state theory. One would thereby eschew dogmatism and the surrender of the search for intelligibility that is involved in the appeal to 'creation'.

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