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# The Age of the Universe

Donald Cancienne

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# The Age of the Universe

Man, from the dawning years of intellectual wonder until the present day, has inquired about the origin and duration of the universe. Out of the speculations of the Pre-Socratic philosophers the question of the *eternity of the world* was born: did the universe have a beginning as Anaxagoras taught or, according to the view of Empedocles, was it always in existence "alternating between states of motion and rest"? The Golden Age of Greek philosophy continued the debate, with Aristotle opting for an eternal world. In the Middle Ages the question took on theological overtones and St. Thomas Aquinas was actually censured by an Ecclesiastical Court for holding a "dangerous position." In the modern period of philosophy one finds Immanuel Kant, in his *Critique of Pure Reason*, listing the question of the eternity of the world as one of the "antinomies of pure reason": human reason is unable to decide between the thesis of the Rationalist, that the world had a beginning in time and is limited in space, and the antithesis of the Empiricist, that the world had no beginning and is infinite in time and space.

However, in recent years, the eternity of the world has apparently shifted from a more or less philosophical question to a predominantly experimental one. This shift is evidenced in the formulation: "What is the age of the universe?" Our contemporary problematic can be traced, on the one hand, to certain remarkable advances in the field of cosmogony and, on the other hand, to far reaching *world-models* which provide a framework in which to interpret the new findings.

As a consequence, some scientists feel that a definitive answer to whether or not the universe is eternal may soon be had. Reading such findings as the recession of galaxies into the context of a specific world-model, they see "the age of the universe" as an attempt to date the absolute beginning of all physical systems.

However, not all cosmologists are of the same opinion. Others express reservations as to the very meaning of the question "the age of the universe." For example, Otto Struve remarks:

> We cannot help asking ourselves: What lies beyond the ten billion light-year boundary of the observable universe? What is the meaning of the words: the age of the universe; and what happened earlier than ten billion years ago?[1]

And Milton Munitz adds:

> Does it make sense, and if so, what is it to say that the universe has a finite age or had a beginning or is finite or infinite in its spatial extent?[2]

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1. Otto Struve, *The Universe* (Cambridge: The M. I.T. Press, 1962), p.155.
2. Milton Munitz, *Space, Time and Creation* (Illinois: The Free Press, 1957), p.37.

In this present article we wish to treat three points. First, by way of background, to survey some of the remarkable discoveries and techniques which have converted the question of the eternity of the world into an experimental problematic. Secondly, the nature and function of world-models will be explained and the chief world-models described. Finally, an attempt will be made to classify the opinions of current cosmologists in regard to the meaning of the age of the universe.

## I. HOW THE PHILOSOPHICAL QUESTION OF THE ETERNITY OF THE WORLD WAS TRANSFORMED INTO THE QUESTION OF THE AGE OF THE UNIVERSE

### A. THE DISCOVERY OF NEBULÆ AND THE FIRST THEORIES ADVANCED ABOUT THEIR NATURE

Astronomy was by no means an undeveloped discipline in Ancient and Medieval times. Observations of a most precise sort were recorded and analyzed with the aid of a highly refined mathematics: the many theories formulated to account for the movement of the planets is but one example. However, in regard to the large scale structure and origin of the universe, observation played a lesser part than philosophical reasoning and even mythology.

The Renaissance astronomer, thanks to his new instruments, perceived that the heavens were far more vast and complex than previously imagined. Theories about the structure and origin of the universe multiplied as observational data grew.

Edwin P. Hubble, a name which figures prominantly in the history we are about to narrate, pictures the universe in the following way:

> The earth we inhabit is a member of the solar system — a minor satellite of the sun. The sun is a star among the many millions which form the stellar system. The stellar system is a swarm of stars isolated in space. It drifts through the universe as a swarm of bees drifts through the summer air. From our position somewhere within the system, we look out through the swarm of stars, past the borders, into the universe beyond.
>
> The universe is empty, for the most part, but here and there, separated by immense intervals, we find other stellar systems, comparable to our own. They are so remote that, except in the nearest systems, we do not see the individual stars of which they are composed. These huge stellar systems appear as dim patches of light. Long ago they were named 'nebulæ' or 'clouds' — mysterious bodies whose nature was a favorite subject for speculation.[1]

It is these last named nebulæ which must first occupy our attention. For in truth, the solution to the riddle of their nature marks one of the most fascinating and far reaching advances of modern science.

1. Edwin Hubble, *The Realm of the Nebulæ* (New York: Dover Publications, Inc., 1958), p.20.

The presence in the sky of "mysterious clouds or patches of light" had been a source of puzzlement since antiquity. The most easily visible of these, the Milky Way, occasioned many, and often fantastic, theories. Galileo, however, must be credited with the first real success in describing their struture. In spite of the low power of his telescope, he was able to resolve a few of these patches which, to the unaided eye appear as a single huge light source, into individual stars. Although we now know that some nebulæ are in fact not composed of stars, Galileo's discovery opened wide a new path for future exploration.

An Englishman, Thomas Wright, elaborated upon Galileo's data to formulate one of the first modern structural theories of the heavens. In 1750 he advanced the idea that the Milky Way was shaped like a flat disk and that our sun was but one star in a single system of stars. The fact that stars appeared more numerous in one region was due to man's vantage point in the system: stars appear in greater numbers as we look into the plane of the disk and more scarce as we gaze away from the plane.[1]

The possibility that the Milky Way formed an isolated stellar system of which the earth was but an infinitesimally small member raised the question as to the other nebulæ: might these not also be stellar systems?

Merely five years after Wright published his thesis, Immanuel Kant suggested an infinitely extended space interspersed with "island universes." In a passage remarkable at once for its precise reasoning as well as its close resemblance to the actual state of affairs, Kant discusses and rejects the views of Derham and Maupertius. The former said that the patches were openings in the firmament through which the fiery Empyrean is seen. Maupertius thought, on the other hand, that nebulæ are enormous single bodies, flattened by rapid rotation. The great German philosopher replies:

> It is much more natural and reasonable to assume that a nebula is not a unique and solitary sun, but a system of numerous suns, which appear crowded, because of their distance, into a space so limited that their light, which would be imperceptible were each of them isolated, suffices, owing to their enormous numbers, to give a pale and uniform luster.
>
> Their analogy with our own system of stars; their form, which is precisely what it should be according to our theory; the faintness of their light, which denotes an infinite distance; all are in admirable accord and lead us to consider these elliptical spots as systems of the same order as our own — in a word, to be Milky Ways similar to the one whose constitution we have explained.[2]

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1. James A. COLEMAN, *Modern Theories of the Universe* (New York: New American Library, 1963), p.16.

2. E. KANT, *Allgemeine Naturgeschichte und Theorie des Himmels*, published in 1755. Translation by E. HUBBLE, *op. cit.*, p.24.

William Herschel (1738-1822), the pioneer of modern statistical astronomy, mapped out the heavens in a systematic way and discovered many additional nebulæ. He writes:

> ...the stupendous sidereal system we inhabit, consisting of many millions of stars, is, in all probability, a detached nebula. Among the great number which I have now already seen, amounting to more than 900, there are many which in all probability are equally extensive with that which we inhabit.[1]

Although this citation suggests that Herschel ascribed to Kant's notion of "island universes," he vacillated as to whether or not the majority of nebulæ were within or beyond the limits of our galaxy. Complete observational confirmation would not come for another century. Two factors in particular accounted for this delay; the lack of sufficiently refined instruments and ignorance of the precise distance of a single heavenly body outside the solar system.

The completion in 1845 of Lord Rosse's 72-inch reflecting telescope did much to offset the instrumental shortcomings of the day. By means of it, Rosse discovered a startling feature of certain nebulæ:

> For the first time the famous spiral structure, lavishly employed by nature in the organic world, was revealed in the heavens. Nothing like it had ever been seen by any previous observer, but Lord Rosse ultimately catalogued fourteen nebulæ of this particular shape.[2]

A further advance in experimental methods aided in the classification of the nebulae. In 1864 Sir William Huggins began analyzing, by means of a spectrograph, the light emanations from various nebulæ. The spectrum of a light sources shows the particular colors or wave lengths which are radiated, together with their relative abundance, thus giving information concerning the nature and physical conditions of the light source. An incandescent solid, for example, radiates all colors in characteristic patterns. Thus, Huggins was able to show that some nebulæ are in reality masses of luminous gas, destroying the supposition that all nebulæ were members of a single homogeneous group.[3]

Although both the 72-inch telescope and the use of the spectrograph were tremendous steps forward, they were still insufficient. Most nebulæ are so faint that long exposure upon a photographic plate is needed for their detection. The era of photographic astronomy and the solution of the "distance problem" bring us to the twentieth century and phase two of our history. But before considering this phase, a more precise notion of what is meant by a nebula is essential.

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1. W. Herschel, cited by G. Whitrow, *The Structure and Evolution of the Universe* (New York: Harper and Row, 1959), p.20.

2. Whitrow, *op. cit.*, p.32.

3. Hubble, *op. cit.*, p.26.

Unfortunately, "nebula" is not used univocally and, even worse, is often interchanged with the term "galaxy." Nebula is the older and more generic term, and was used to denote any luminous, cloud-like patch. However, nebula is no longer applied to that large group of objects known as star or globular clusters; with moderate power telescopes, such figurations are easily seen to be subordinate members of our own stellar system. Hence, star-clusters have been withdrawn from the list of nebulæ and form a separate and distinct class of objects. That leaves but two quite different kinds of astronomical bodies for which the term "nebula" is still used. On the one hand are the clouds of dust and gas, numbering about fifty in all, which are scattered among the stars of our galaxy. On the other hand are the remaining objects, numbering most probably in the billions, which are now recognized as independent stellar systems scattered through space beyond the limits of the Galaxy.

Because of the greater predominance of the second type, "nebula" used unqualified is taken to mean these last mentioned stellar systems, Kant's "island universes." For a like reason, the term "galaxy" is often substituted for the same entity, even though, as Hubble points out, "the authoritative definition of 'galaxy' is the Milky Way."[1]

### B. CONFIRMATION OF THE FACT THAT MOST NEBULÆ ARE EXTRAGALACTIC

The history of astronomy has been called a history of receding horizons. If this is true, its epochs are marked off by the success had in measuring the distance of the various heavenly bodies. In the first epoch of astronomy the distance of the moon was determined by the Greeks. In the seventeenth century, the distance of the sun and the planets were calculated with a fair degree of accuracy. But the problems involved in pushing the horizons back still further, to the stars and beyond the Galaxy, were enormous. The fact that one star appears brighter than another can stem from either of two factors: it is very near, or else it is a gigantic body but vastly remote.

> Only when the gap was bridged, only when the distances of a small, sample collection of stars had been actually measured, was the nature determined of the inhabitants of the realm beyond the solar system.[2]

The first reliable measurement of a star's distance was made in 1838 by the German astronomer Bessel. The key to his success lay in the application of two things already known: stellar motion and

1. HUBBLE, *op. cit.*, p.17. N.B. When "galaxy" is in fact meant to signify only the Milky Way, it is usually capitalized.

2. *Ibid.*, p.22.

measurement by what is known as the parallax of a star.[1] He noted that a faint object, 61 Cygni, had an extremely fast movement, an interval of only 300 years being required to carry it across the sky a distance equal to the diameter of the moon. He concluded that such rapid angular motion relative to the general background of more distant stars must be due to its relative proximity. His estimate of its distance, 60 billion miles, differs from the currently accepted value by only a few percent.

However, the use of parallactic motion as a basic method of measurement is, practically speaking, applicable only to the nearer stars. The parallactic orbit of a star at the distance of the furthest globular clusters is about equivalent, as Jeans expressed it, to the size of a pinhead at the other side of the Atlantic. Some more workable yardstick was required for fathoming the distances at which nebulæ were believed to lie.

The desired yardstick was found in connection with the observation of Stars known as Cepheids (after the type example, Delta Cephei). Cepheids are pulsating stars which brighten rapidly and fade slowly, repeating the cycle continuously and faithfully. Between 1908 and 1912 Miss Leavitt of the Harvard College Observatory studied the periods of Cepheids in the distant Magellanic Cloud, a star cluster which is a neighbor or satellite of our galactic system. She found that a definite *period luminosity* relation existed between the brighter and the fainter Cepheids in the Cloud. Now, wherever a Cepheid may be found, the period will indicate the absolute luminosity, and the apparent faintness then measures the distance. It was by this method that the first reliable distances of nebulæ were determined.

In 1924 Hubble made the final and decisive step which pushed man's horizons beyond his own galaxy once and for all. Using the 100-inch telescope at Mount Wilson, he succeeded in identifying Cepheids in the nearer spiral nebulæ. With these as his yardstick, he concluded that the nebulæ of which they were members were five times farther away than the Magellanic Clouds, i. e., in the order of a million light years. At last, the fact that most nebulæ are truly extragalactic had been confirmed observationally.

However, even while Hubble mapped out the new found realm of the nebulæ, an unexpected, if not unbelieveable, phenomenon was forcing itself into contention; its explanation and interpretation will carry our history into its final phase, that of the expanding universe.

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1. The parallax of a star is the angle subtended at the star by the mean radius of the orbit of the earth ($9.29 \times 10$ miles). Parallaxes are measured by direct triangulation from opposite points on the earth's orbit around the sun. The astronomical unit known as a parsec arosed from this method of measuring, a parsec or parallax of one second of arc having the value of 3.258 light years. Cf. A. Spitz-F. GAYNOR, *Dictionary of Astronomy and Astronautics*. (Paterson: Littlefield, Adams, 1960), p.290.

### C. THE HYPOTHESIS OF THE "EXPANDING UNIVERSE"

Like many landmarks in the physical sciences, the "expanding universe" resulted from a new interpretation given to already existent data. The key in this case was the use of light spectra and the so-called Doppler effect.

The properties of sound and light are similar in many respects. It was long known that the wave length of a sound source approaching an observer is of a higher pitch than that of a receding source. From the increase or decrease in wave-frequency the speed of the moving sound source can be calculated. An Austrian mathematician, Christian Doppler, reasoned that the same principle was applicable to moving light sources. Since each type of luminous body gives off a characteristic spectrum, a shift in pattern toward violet (which is of high frequency) would indicate the movement of the source toward the observer, while a shift toward red would mean the source was moving away.

The first nebula whose spectra were analyzed for a red-shift or Doppler effect was that in Andromeda. It was found to have a negative velocity, indicating motion toward the observer. However, as more and more nebulæ were analyzed, the list was soon dominated by positive velocities. By 1930 an amazing series of photographs had been amassed which showed a progressive reddening of spectra; translated into velocities, it apparently meant that some nebulæ were receding from our line of vision at nearly 25,000 miles per second.

Of course, the conclusion that distant galaxies are receding from our own follows only if the red-shifts are in reality Doppler effects. The fact that the spectra of extragalactic nebulæ shift bodily toward the red is denied by no one. But such shifts may be due to either of two causes: the recession of objects from the observer (Doppler effects) or to some "hitherto unrecognized principle in physics."[1] There is the possibility, for example, that the staggering expanses of space which nebular light must traverse could be a cause of the red-shifts; this is the hypothesis of the so-called "fatigued light ray." Althought Whitrow as recently as 1954 still expressed doubts regarding the interpretation of the shifts as Doppler effects, few would seem to share his reservations. The opinion Eddington expressed over thirty years ago better reflects the current consensus. While admitting that factors like the loss of energy of light quanta could account for the red-shifts, he remarks:

...yet, the theories of light little justify any such assumption (...) I think, then, we have no excuse for doubting the genuineness of the observed

1. HUBBLE, *op. cit.*, p.122.

velocities; except in so far as they share the general uncertainty that surrounds all our attempts to probe in the secrets of nature.[1]

That no one any longer seriously questions the general notion of an expanding universe is seen in the fact that all the current world-models, to which we are about to turn our attention, consider the recession of the galaxies as one of the key factors to be accounted for.

## II. WORLD MODELS

### A. WHAT A WORLD-MODEL IS AND WHY THEY ARE CONSTRUCTED

Our direct knowledge of the universe is confined to a limited region of space and time. In order to obtain some idea of the universe as a whole we must extrapolate and construct a world-model which will reproduce satisfactorily the principal features of the observable region.[2]

This citation is a fitting introduction to the subject of world-models for it underscores their three main characteristics.

First, there is *extrapolation*. Extrapolation, a fundamental methodological procedure in the physical sciences, consists in the analogous extension of what is already known to something inaccessible to direct knowledge and measurement. The inaccessibility in some cases is one of sheer numbers. Physical laws in general are of this type. Boyle's Law, for example, enunciates a relationship of constancy between the pressure and volume of a confined gas. But, since it is impossible, humanly speaking, to measure the reaction of every known gas under every conceivable pressure and temperature, what is true in a sufficient number of controlled experiments is extrapolated to cover every similar case.

In regard to world-models, the inaccessibility of direct knowledge is more than just statistical. More powerful telescopes will undoubtedly extend the frontiers of the observable universe. But nearly all astronomers agree that, no matter what future advances are made, man will never be able to know directly more than just a limited portion of the universe; for one thing, the velocity of recession has already carried innumerable galaxies beyond the range of instrumental detection. They speak, therefore, of a "sample of the universe." This means that an observable region is assumed to be typical, in its general features, of the universe as a whole. This fundamental extrapolation is at the base of every world-model.

The second characteristic of world-models is that they are *constructions*. This means that reason in addition to observation plays a

1. Arthur Eddington, *The Expanding Universe* (Cambridge: University Press, 1933), p. 17.

2. Whitrow, *The Structure and Evolution . . .*, p.48.

leading role. Just as an architect must conceive and design a structure before beginning to build, so too must the physical scientist have recourse to freely imagined structures in order to explore the unknowns of nature. Albert Einstein uses the example of a man trying to explain how a pocket watch works: if he is unable to remove the watch-back and has never before seen the mechanism of a watch, he is forced to imagine some structure which could account for the movement of the hands, the tick-tock, and the other observable effects. *Model* is the term used in the sciences to describe these structures which reason, taking the part of an architect, freely constructs.

*World-models must reproduce satisfactorily the principal features of the observable region.* Although reason is free in its basic choice of a structure, a model must be altered or altogether abandoned if it fails to "work," i.e., account for already known phenomena. Thus, a world-model provides a description or image of the universe as a whole which agrees as closely as possible with a representative sample of it. No model will ever perfectly describe the actual universe. But, as more and more known laws are deduced from the imagined structure, the picture it offers becomes more and more reliable.

It should not be thought that cosmology is the only discipline in which models are used, nor that they are something of recent origin. Models or constructs have long been a part of our mathematical heritage; e.g., the Euclidean demonstration that the sum of the three angles of a triangle equals two right angles involves the construction of a model.

However, unlike all other types of models which are concerned with only *a part* of the universe, a world-model attempts to represent satisfactorily the large-scale features of the whole universe as well as provide an adequate background for all the general laws and phenomena of nature. Because of the difficulties involved, it is not surprising that there has been no general agreement upon any single model. Part of the difficulty stems from the desire to integrate structure with theory.

A world-model, in effect, must fulfill two functions if it is to offer a complete image of the universe. First of all, it reproduces the temporal-spatial structure of the universe along mathematical lines. A variety of contrasting hypothetical structures can be obtained depending on whether one works with Euclidean, Riemannian or some other type of space. However, since the ultimate aim of a world-model is not merely to project possible mathematical structures but to determine whether and how such structures are physically possible, some cosmic theory is called for. In an evolutionary model, for instance, a chemical or nuclear interpretation for the recession of galaxies may be offered. In a steady-state model, on the other hand, some explanation is needed to account for the unchanging structure predicated by the model.

Thus, in a complete world-model, a wedding between structure and theory is essential.

### B. A DESCRIPTION OF THE CHIEF WORLD-MODELS

#### 1. *Purely structural models*

Quite understandably, the earliest world-models incorporated only the structural features of the universe. Since most models utilize Einstein's Relativity Equations or are even direct extensions of them, it will not be out of place to consider "Einstein's Universe" even though it is merely a structural model.

Since General Theory of Relativity is essentially a new explanation of gravity and its effects upon large masses, it is not surprising that its equations should be applied to the structure of the universe as a whole. This Einstein did in 1917. He made two important assumptions to facilitate the construction of his model. One was that the universe is isotropic, i. e., no portion of the universe is appreciably different from any other despite apparent local irregularities. The other assumption was that the universe is homogeneous; this means that matter is distributed in a uniform and continuous manner with the relative motion of the various parts being negligible. Obviously, both these assumptions clash with the Newtonian concept of a finite material universe spread throughout infinite Euclidean space.

How, then, could Einstein say that space was not infinitely extended without reverting to the untenable notion of a boundary ? His solution was to construct his model according to spherical geometry, a logical enough step since General Relativity already predicted the curvature of space. If the curvature is made positive, then the space of the universe will bend around and complete itself like a ring. The model therefore resembles the surface of a sphere which is unbounded in the sense that one can move over it without ever coming to an edge, yet at the same time its area is finite.

However, in working out his equations according to such a model, Einstein came up against a curious impasse: he was unable to find any solution which described a static universe, which, since the huge recessional velocities of nebulæ had not yet been discovered, was the only sort of universe to be expected. He therefore modified his law of gravitation slightly by introducing an additional term into the equation, the famous $\lambda$ term or cosmical constant. Its effect upon bodies would be analogous to a mutual repulsion. Although in local gravitational problems the term can be neglected, Einstein assumed that it was significant when considering the universe as a whole.

At great distances, then, repulsion outweighs the gravitational attraction by which the universe would be drawn together into a single mass point. Thus, the two forces counterbalance and equilibrium is established; a facile means of keeping the universe static and finite was found. Commenting on this, Eddington remarks:

I think Einstein showed his greatness in the simple and drastic way he disposed of difficulties at infinity. He abolished infinity (...) by making space at great distances bend round until it closed up.[1]

In summation, we might say that Einstein's model treats the universe, mathematically speaking, as a three-dimensional surface embedded in a four-dimensional space-time continuum. The three spatial co-ordinates are treated according to spherical geometry while the fourth dimension, time, is regarded as straight; this means that time flows at the same rate at all points of the static universe. Thus, Einstein maintains the existence of an absolute or cosmic time for the universe as a whole, relativity being reserved for local phenomena.

His model represents a basically mathematical attempt to describe the structure of the universe, observational evidence not being offered in support of its main features. Likewise, no accompanying theories as to the origin, expansion or duration of the universe are built into the model.

2. *Structural-theoretical models*

We turn now to those more recent and exciting models which combine structure with cosmic theory. Popularization has canonized the names of the three leading representatives and we will abide by these names. Of the first two theories, one uses an infinite space and postulates a universe which is finite in duration (the "Big Bang" or explosion-expansion models), the other a universe of finite space but of infinite or eternal duration (the "Oscillating" or cyclical models). The third theory, the "Steady-State," proposes that the universe is infinite in both space and duration. Although groupings often complicate rather than simplify, the three theories can be reduced to two main types: *evolutionary* (the Big Bang and Oscillating models) and *steady-state*.[2] Thus, the models can be schematized as follows:

Evolutionary models:

*i — infinite space, finite duration*
Lemaître-Eddington
Milne (Gamow)

1. *Op. cit.*, p.21. Eddington makes a further remark in regard to space which should be noted. He stresses the distinction that should be always made between real, physical space as opposed to mathematical space: "Geometers can invent spaces which have either or neither of these properties [repulsion and attraction]; but actual space, surveyed by physical measurement, is not of so unlimited a nature."

2. Although it is in accord with the Steady-State Model in regard to the infinite duration of the universe, an Oscillating Model is basically evolutionary and its proponents speak of it as such. For, in spite of the fact that the universe is said to contract periodically and turn in upon itself, in its over-all life cycles it can only be viewed as evolutionary.

*ii — finite space, infinite duration*
Sandage (Toland, Dauvillier)

Steady-State Models:
*i — infinite space, infinite duration*
Hoyle, Bondi - Gold

### 2.1 THE BIG BANG UNIVERSE

#### 2.11 — *Lemaître-Eddington*

The discovery of red-shifts in the extragalactic nebulæ played a big role in the search for new models, since Einstein's model predicted no noticeable over-all motion of the heavens, let alone vast velocities of recession. The first model constructed to include the observed velocities was presented in 1927 by a Belgian, Abbé Georges Lemaître. Because of the success Sir Arthur Eddington achieved in both publicizing and further developing the model, it is commonly referred to as the Lemaître-Eddington model.

One of the first premises of the model is its "cosmological principle." This is an assumption that observers on a planet in another galaxy, which we on earth see to be receding at, say, 37,000 miles per second, would, if they were equipped with similar instruments, see our own galaxy receding at the same velocity. Thus, neither observer would have the right to conclude that his galaxy was necessarily in a central position. But if all galaxies are receding away from one another, does it not follow that a galaxy such as Hydra, which is now almost beyond our view, must have been very much closer to us in the remote past? Lemaître concluded, then, that all the material of the universe was once contained in a much more compact space than it now occupies.

Going on this assumption, he attempted to reconstruct the conditions under which the universe from a compact state could have expanded to its present proportions, giving rise to the first evolutionary model of the universe and the famous hypothesis of the *atome primitif*. In Lemaître's own words:

> L'hypothèse de l'atome primitif consiste à chercher l'origine du monde dans la désintégration super-radioactive d'un atome unique dont la masse atomique était égale à la masse totale de l'univers.[1]

This "super-radioactive disintegration" of a single massive atom explains why his and similar explanations are referred to as the "Big Bang Theory." For such a high-density mass could only have remained intact a very short time before exploding because of internal instability. It was further supposed that the exploding and breaking-up pro-

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1. Georges LEMAÎTRE, *L'Univers*. (Louvain: E. Nauwelaerts, 1950), p.65.

cesses continued until the pieces were the size of the smallest atoms, electrons, protons and gamma rays being spewed out all during the process. It was at this time that the more complex atoms were formed.

Eventually, the initial momentum exhausted itself. The universe thereupon settled down into a nearly static condition, analogous to Einstein's model, wherein the forces of gravitational attraction and cosmical repulsion were in balance. During this phase the great clusters of galaxies began to form. Finally, the conditions of near equilibrium being upset, the forces of cosmical repulsion won out and the universe was launched on the career of expansion we are witnessing today.

Lemaître's theory, then, is evolutionary not only in the sense that the elements, stars and galaxies originated in progressive stages from nuclear interactions but also inasmuch as the universe itself passed through a succession of states or models: from expanding to static and back again to expanding. This succession of states has an important bearing on Lemaître's view in regard to the duration of the universe.

In Lemaître's model, the back-dating of recession only brings one to the period at which expansion from the static state began. How long was the universe in this state of equilibrium and what values are to be assigned to the phase which led up to it? The model cannot determine this with any precision. Lemaître himself believed the static phase was in the order of two billion years and the whole evolutionary process of finite duration.[1] Lovell thinks, speaking in the context of the model, that the current expansion marks but a comparatively recent phase, the two prior phases being about five times longer than the present one.

One important difference which Eddington introduced into Lemaître's model has to do with the number of states through which the universe might have passed. Eddington rejects the concept of a single super-dense atom and makes the first state consist of an even distribution of protons and electrons "extremely diffuse and filling all (spherical) space."[2] Unlike Lemaître's primeval atom which exploded after only a brief period of existence, Eddington says that the first state remained in equilibrium "for a very long time." Only when some inherent element of instability gained the upper hand did evolution get under way and it has continued irreversibly to the present day.

Thus, for Eddington, the universe evolved from a static state whereas Lemaître makes such a state but a second phase following a period of indefinite extension. Therefore, the application of Hubble's constant in the framework of Eddington's model seems to bring us back to a kind of first state. Whether or not Eddington interprets this first state as an absolute beginning will be decided later.

1. *Ibid.*, p.44.

2. Eddington, *The Expanding Universe...*, p.56.

2.12 — *Milne*

In 1936 an English mathematician, E. A. Milne, began work on a model which is as difficult to understand as it is interesting and original. Its most novel feature was the introduction of two different kinds of time, which really amounts to the construction of two distinct models. One time is called $T$-time (gravitational or clock time — that time of which the swinging pendulum and the rotating Earth are found in practice to be good approximations); the other is $t$-time or atomic time. This latter is the time associated with phenomena of the atomic world and is related to the frequencies of spectral lines from vibrating atoms, radioactive decay of nuclei, etc.

Milne believed there were good reasons for saying that both kinds of time *have not* been uniform in the past. Constructing his model (or models) on this assumption, he arrives at a curious conclusion: according to clock time an infinite number is obtained for the age of the universe, while according to $t$-time (atomic) the universe began at a point in which $t = O$.[1]

2.13 — *Gamow*

The Russian-born physicist George Gamow, whose many and reasonably clear works enjoy a large audience, has likewise formulated a rather original model, which, however, is a bit difficult to classifiy. Gamow's model uses an infinite space but, unlike Lemaître-Eddington or Milne, he seems to hold for a universe of infinite duration as well. Thus, his model has features common to all three groups of theories. Perhaps, after describing it, the problem of its classification will be easier.

According to Gamow, the universe contracted or "collapsed" from an epoch in which the density of matter was zero for an infinite length of time; the cosmic mass, as a result of this collapse, was "squeezed into a pulp" in a "nuclear cooking process" analogous to the conditions existing in the center of an exploding atomic bomb. As this mass emerged from the "Big Squeeze," it cooled rapidly and elementary particles began "to stick to one another and form aggregates of different complexities."[2] The universe at this stage was gaseous and stayed this way for perhaps 30,000,000 years. Then, when the radiant energy of the gas began to wane, matter of present atomic densities took over, the forces of Newtonian gravity came into play

1. E. A. Milne, *Modern Cosmology and the Christian Idea of God*. (Oxford: Clarendon Press, 1952), p.64ff.

2. George Gamow, *The Creation of the Universe* (New York: New American Library, 1952), p.134. The use of such appealing images as the "Big Squeeze" and "nuclear cooking" account for much of the popular success of Gamow's writings. His efforts to speak in non-technical language, however, often make it difficult to know exactly where he stands on controversial issues or how strictly he wishes us to take some of his statements.

and stars and galaxies formed. Finally, Gamow sees the expansion of the galaxies as a winning out of inertial velocities over gravitational pull:

> ...we have a case similar to that of a rocket moving away from the earth with a velocity far higher than escape velocity. The distances between the neighboring galaxies are bound to increase beyond any limit, and there is no chance that the present expansion will ever stop or turn into a collapse.[1]

Thus, Gamow considers the last epoch of the universe as an analogue of the first: for an infinite time the average density will approach zero.

Because of its detailed, step-by-step analysis, Gamow's world-model is regarded by many as the most satisfying of all the evolutionary models. He has succeeded in accounting for the formation of nearly all the elements. In addition, he has plotted an element-formation curve for their distribution which is in good agreement with the observed abundance distribution curve as found in nature.

However, I do not believe that he has succeeded as well in integrating the structural aspects of his model with his theory on the genesis of the elements. It seems that the "infinite" past and future times of his model remain mathematical infinites: his equations simply announce which *would* result *if* times with a negative sign in relation to $t=0$ were inserted into the model. For example, that a process opposite to a universal expansion, viz., universal contraction, would follow. In the steady-state model, as will be seen, an infinite past and future are predicted to be features of the actual universe and flow from the principles of the model.

Returning now to the problem of how to classify Gamow's model, it seems he has simply gone a step further than Eddington, and made the epoch which antedates the present expansion one of infinite duration. However, Gamow does not believe another contracting phase of the universe will follow the current expansion: the universe's history comprises one infinite contraction followed by one infinite expansion. Thus, it seems better to consider the Gamow model as evolutionary in the sense of the explosion-type models, with an opening being left at *both* ends for a temporal infinity.

### 2.2 — THE OSCILLATING UNIVERSE

A second main group of theories, projecting an oscillating or cyclical universe, is more recent and steadily increasing in popularity. This popularity is due, perhaps, to the waning influence of the Steady-State Universe. For, if a model is desired which permits a universe of infinite duration, the only alternative to a steady-state model seems to be an oscillating one.

1. *Ibid.*, p.42.

One of the leading names associated with the Oscillating Universe is that of Allan R. Sandage. However, certain of his confreres at the Mount Palomar Observatory and the California Institute of Technology, most notably R. C. Tolman, share his views. In its broad lines, the notion of a universe which oscillates in never-ending cycles is not new. The idea of an "eternal return" antedates Aristotle. However, in the ancient hypothesis, each recurring cycle was an exact duplicate or mirror of the preceding—a view rejected by Aristotle as well as the present day proponents of the Oscillating Universe.

According to Sandage, the universe undergoes periodic explosions analogous to those postulated by the first group of evolutionary models. Thus, at a given moment, all the matter of the universe is massed at a single point: consequent upon its violent explosion, stars and galaxies expand outward. However, the entire process is said to slow down after a period of about 41 billion years. The galaxies and stars thereupon contract and come together, in another 41 billion years, to a similar point-mass. Following a new explosion, the universe again departs on another over-all cycle of 82 billion years: "le processus se répète indéfiniment, et il aurait toujours existé ainsi."[1]

A further reason why this model, so apparently satisfying, has received serious attention only in the last few years is a marked shift in thinking regarding the application of entropy or the second law of thermodynamics. Men like Sir James Jeans believed that, due to entropy, the expansion of the universe was irreversible and, because of the constant loss of avaiblable energy, all cosmic processes would come inevitably to a standstill or "heat-death."

At present, however, more and more physicists, if not questioning the actual validity of the second law of thermodynamics, question seriously its wholesale extension to the most remote regions of the universe. Consequently, new hypotheses are appearing which offer feasible explanations of how reversibility in the cosmic processes is possible. One of the more interesting is that proposed by A. Dauvillier.

Dauvillier makes extensive use of the kinetic theory of gases as originally formulated by Kelvin and expended by Poincaré. Kelvin advanced the rather imaginative supposition that galaxies behave something like gases, the stars being analogous to molecules. However, there are important differences. In a galaxy, there is no molecular chaos as is found in a normally contained gas and stars have a very high degree of free movement in relation to the galaxy as a whole. Moreover, a contained gas cools itself through constant contact with its retaining surface. A free gaseous mass, on the contrary, has no such exchange with an exterior; it conserves its kinetic temperature and

1. Renaud DE LA TAILLE, "L'univers: mais qu'est-ce que c'est?", *Science et Vie*, No. 585, tome CIX (juin 1966), p.96.

internal energy. Thus it remains indefinitely in the same state if equilibrium is once realized.[1]

Dauvillier is indebted to Poincaré for his explanation of how galaxies pass through different stages and shapes in the course of their evolution. But, once again, the analogy between gases and galaxies cannot be made too strict. For, in the kinetic theory, molecular collisions are perfectly elastic and the molecules themselves indestructible. This allows for no evolution of the system.

Stars, however, are subject to gravitational attractions which often result in collisions. Of the various possible types of stellar collisions, Dauvillier assigns a capital importance to what he calls *collisions centrales*. These, which can perhaps be described as "head-on," are cataclysmic events and, according to his hypothesis, produce a "gas" of elementary particles at extremely high temperatures which assures the thermo-nuclear synthesis of new elements. Thus, through such collisions, Dauvillier feels he has found an answer to how the universe can escape a "death-heat" and perpetuate itself eternally.

### 2.3 — THE STEADY-STATE UNIVERSE

The Steady-State Model is by far the most original and controversial of all the world-models. It owes its inception to two English physicists, H. Bondi and T. Gold, who first published it in 1948. Although a few others have espoused its main features, the name of Fred Hoyle must be singled out as its chief exponent and spokesman.

In all the evolutionary models, Big Bang or Oscillating, the General Relativity equations form the basic mathematical framework. The originators of the Steady-State Model, however, make much less extensive use of Einstein's equations. Still, they agree that any world-model must account for the phenomenon of recession. However, as Boyle insists, a super explosion is not the only explanation for the observed velocities.

> The upholders of the theory of a singularity origin for the universe put too much stock in expansion. Because space is becoming more and more empty, it seems that it was once more densely occupied than it is today, that it was once jammed packed with matter not so very long ago (...) yet there are alternate conclusions to expansion.[2]

Thus, Hoyle accuses the "evolutionists" of building their model upon a purely arbitrary starting condition, namely, that of the expansion of the universe. In a steady-state theory, on the contrary, such arbitrary conditions "have been disposed of." For the steady-state theory is

1. A. DAUVILLIER, *Les Hypothèses Cosmogoniques* (Paris: Masson, 1963), p.121.
2. Fred HOYLE, *Frontiers of Astronomy* (London: Heinemann, 1955), p.314.

claimed to be deductive in that its conclusions, including an explanation of recession, are derived from a single "straightforward principle of great power."

This first principle of the new theory is a radical extension of the cosmological principle. With Bondi and Gold, the cosmological principle of the evolutionary theory which states that the universe would appear to be the same to any observer, wherever situated in space, becomes the "*perfect* cosmological principle" according to which the universe is the same throughout *all time* as well as space. In other words, it is assumed that the universe presents the same large-scale picture not only from every possible vantage point in space but from any time as well, past, present or future. Thus, the universe in its general features would be unchanging and the same today as it always was and always will be. Not that nothing ages or varies in the universe; new planets, stars and galaxies are being born continually just as old ones burn out or pass beyond the limits of observation. However, there is no evolution of the universe, but only of individual stars and galaxies.

The reason Bondi feels such a perfect cosmological principle should be adopted is fundamentally a methodological one:

> All Cosmology is based on the assumption that our terrestrial knowledge of the physical world is applicable to the universe at large. But when we assume the universe was different than its present aspects at some other place or time, the attempt to apply physical laws becomes strange because of effects of which we are wholly ignorant. To avoid this, we assume that the universe presents the same aspect to every observer, wherever he is and at all times.[1]

But whatever may be the merits of such a principle from the viewpoint of simplicity of explanation, the effort to show how a steady-state universe is possible forced Bondi and Gold into the most controversial aspect of the theory, *continuous creation*. It is at this point that the steady-state model passes from a structural projection to a theory for the physical possibility of such a universe.

If the universe has always exhibited the same over all features, where does new material come from to replace that which fades out of the picture? *Creation* is proposed as the answer. However, the creation envisioned is not that of all matter in a single past event. Rather, the steady-state universe regards creation, in the words of Hoyle, "as an everyday affair." A "creation process" is now going on, just as it always has and always will, at a rate sufficient to insure the continual formation of new stars and galaxies. This demands, as calculated from the model's equations, that but a single new hydrogen atom

1. H. Bondi, *Cosmology* (Cambridge: University Press, 1961), p.141.

be created from a "creation field" per liter of volume of space every $5 \times 10^{11}$ years.[1]

Hoyle is in agreement with Bondi and Gold as to the steady-state structure of the universe and the hypothesis of continual creation. But instead of using the "perfect cosmological principle" as his departure point, Hoyle uses a set of local laws from which the steady-state configuration follows as a consequence.

Still another variation is that offered by William McCrea. He disapproves of picturing continuous creation as a true *creatio ex nihilo:*

> It was always rather silly, McCrea thinks, to assign to space, which is the absence of matter, the ability to create tangible things such as hydrogen atoms. He bases his own theory on the principle that "continual creation of new matter is a property of existing matter depending upon its physical state."[2]

For McCrea, it is from within the heart of galaxies that new matter comes forth in the form of atoms, gathering together to form new stars or adding to the mass of old ones. Eventually, the galaxy reaches a limit, breaks up and gives off a discharge of matter that forms the nucleus of another galaxy. New galaxies are thus formed at the proper rate to fill the vacant spaces left by expansion.

In this section we explained what world-models are and sketched the content of a few of the main ones. It was not our purpose, nor is it within our competence, to pronounce upon their individual validity or relative superiority. The judgment of experts, time, and, above all, observational confirmation, can alone decide which, if any, presents the truest picture of the actual universe.

## III. OPINIONS OF COSMOLOGISTS AS TO THE MEANING OF THE "AGE OF THE UNIVERSE"

From the familiarity with world-models gained in the preceding section we are now in a position to answer the question: "What, in ordinary language, do astronomers and cosmologists mean when they speak of the age of the universe?" In the framework of their structural-theoretical models, they posit either a finite or an infinite duration for the universe. But do they wish us to take these temporal values literally and in a "real" sense? Do they hold, in a word, that their models can help solve the age-old problem of whether or not the universe had a beginning?

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1. *Ibid.*, p.144. Bondi leaves no doubt as to the meaning he attaches to the word "creation." "It should be clearly understood that the creation here discussed is the formation of matter not out of radiation but *out of nothing.*"

2. *Ibid.*, p.151. *Time*, December 18, 1964, p.68.

It seems that current thinking on the meaning of the age of the universe can be divided roughly into three groups:

1) Authors taking an *overly simple approach*; in this category are included those who consider the question as an attempt to date the temporally first thing as well as, at the opposite extreme, those who take the question as devoid of all meaning because they feel the universe *cannot* have had a beginning.

2) Authors taking a *more cautious approach*; this category includes those who realize the great difficulty of the question and the inability of science to give a final answer at present. However, they do not feel that a definitive answer is impossible and look forward to an eventual solution.

3) Those who maintain that the question is *fundamentally unanswerable within the context of the sciences.*

## A. AN OVERLY SIMPLE APPROACH

### 1. WHITTAKER AND JEANS

On the basis of their writings, Sir Edmund Whittaker and Sir James Jeans must be accused of taking an overly simple approach to the question of the age of the universe. Both think, although for different reasons, that experimental findings can establish that the universe had a beginning.

Whittaker was led into unjustified assumptions by an extrinsic, although laudable, motive: the desire to supply natural theology with a subsidiary argument for the existence of God. As St. Thomas Aquinas mentions, it is easier to argue to the existence of a Creator when the world is assumed to have had a beginning in time.

Whittaker is not unaware of the "time-scale problem," i.e., which kind of time, if any, can be said to measure all the processes of the universe. Nonetheless, he takes the time-scale of recession as normative in determining the age of the universe. Assuming that an evolutionary model describes the actual universe and that recession has been more or less constant, he sees no difficulty in turning back the "cosmic clocks" to arrive at "the beginning":

If we suppose that the extragalactic nebulæ always receded in the direction and with the speeds we now observe, it is evident that this is because, at some moment in the past, they were grouped together in a comparatively restricted space; we can speak of this moment as the beginning of the universe.[1]

1. Edmund WHITTAKER, *The Beginning and the End of the World.* A conference pronounced at King's College, 1942. (My own translation from the French edition of Albin Michel: Paris, 1953) p.116.

While he does express reservations about whether the date obtained by this method will ever be fully verified, he apparently has no reservations about the legitimacy of the method itself. Nor does he hesitate to identify the point-origin obtained by the back-dating of recession with the act of divine creation:

When we trace back the development of the world system (...) we arrive at a moment where this development began. This is the terminal point of physical science, the most distant glance that our natural faculties can cast upon the material universe. There is no reason to suppose that matter (or energy, which is the same thing) existed before this moment in an inert condition (...) it is more simple to suppose a creation *ex nihilo*, an operation of the Divine Will to pull Nature from nothingness.[1]

It is obvious that Whittaker's conclusions overstep both his premises and available evidence. Even if it is supposed that the rate of recession has been constant, it is *not* evident that all galaxies were once grouped together; such a configuration occurs only in terms of a few evolutionary models. Again, while it may be "more simple" to identify a first epoch with a primeval creation *ex nihilo*, he offers no proof (nor can be) that nothing existed before this epoch.

It might be argued that Whittaker is talking only hypothetically and does not intend his arguments as more than probable indications that the world had a beginning. However, his acknowledged apologetic starting point militates against such a benign interpretation. In sum, it seems that his approach must be labeled as misdirected and invalid — a verdict in which J. V. Peach concurs:

Whittaker assumes that the question of the age of the universe has a straightforward meaning and is answerable in the context of the sciences, and over-interprets one particular cosmological theory.[2]

The writings of James Jeans manifest a similar negligence of the rational and experimental exigencies of the problem. Jeans's work reflects the thinking of a period slightly earlier than Whittaker's; a period, hence, in which the import of Hubble's constant was just beginning to be discussed. For this reason, we find no attempt by Jeans to date the universe by means of the time-scale of recession. Nevertheless, he was convinced that the universe had to have a finite past and that it is heading irreversibly for a future demise.

Jeans places great stock in the Second Law of Thermodynamics and a time-scale derived fron an approximation of the weight of nebulae. Entropy implies that the flow of energy in the universe is a one way

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1. *Ibid.* p.146.

2. J. V. Peach, s.j., "The Age of the Universe," *Heythrop Journal*, Vol. III (April, 1962), p.113.

or "downhill" process. If the universe is actively maintained by the continual transformation of quanta of energy, then, after each transformation, energy would become less and less available. "Therefore," concludes Jeans, "the active life of the universe must eventually cease." He continues:

The energy is still there, but it has lost all capacity for change. We are left with a dead, although possibly warm, universe — a "heat-death." This rules out any possibility of a cyclic universe; with the universe as with mortals, the only possible life is progress to the grave.[1]

Having disposed of an endless future for the universe, Jeans turns his attention to its past and the question of a beginning. Basing himself on the hypothesis that the luminosity of nebulæ is caused by the annihilation of their atoms, he concludes that it is possible to determine, in rough numbers, the length of time that matter was in a nebular state. Using this method, he approximates the age of several nebulæ. This, in turn, brings him to the following conclusion:

Apart from detailed figures, however, it is clear that we cannot go backward in time forever. Each step back in time involves an increase in the total weight of the universe, and, just as with individual stars, we cannot go so far back that this total weight becomes infinite.[2]

Therefore, as with Whittaker, the progressive back-tracking of a particular cosmic process is presumed to lead to a definite event, or series of events "at some time not infinitely remote."

Finally, Jeans attempts to prove that this "event" in the finite past was not preceded by a state in which other matter or universes existed. If, says Jeans, all the matter in the universe were to annihilate itself the rise in over-all temperature would only be slight. But if the radiation from a series of dead universes were streaming through space, the temperature rise on the earth's surface would be "enough to boil our oceans." Thus, he assumes that an infinite number of previous universes is impossible because mankind, with his earth, would have perished long ago from the radiation accumulated from their disintegration.

For all these reasons, Sir James Jeans maintains that the universe is of finite duration. We will not attempt, nor is it necessary, to refute each of them. In general, his whole procedure suffers from the same defects as Whittaker's: he over-extends hypotheses which have validity only in a limited context or in terms of certain models. In particular, he places far too much emphasis on the role of entropy in the cosmic processes.

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1. James JEANS, *The Universe Around Us* (Cambridge: University Press, 1938), p.347.
2. *Ibid.*, p.353.

2. DAUVILLIER

Although at the opposite pole from Whittaker and Jeans, A. Dauvillier takes an equally simple view of questions about the eternity of the world. He contends that false problems of a metaphysical character continually creep into cosmology; as a prime instance, he mentions "les faux et insolubles problèmes métaphysiques d'âge de l'Univers, de commencement et de fin."[1]

But what reasons does he offer for his position that the universe must be eternal? One is based on the nature of statistical laws:

> ...l'Univers est formé de trop de galaxies et celles-ci sont constituées de trop d'étoiles, pour que son aspect statistique ait jamais pu changer (...) il est tel qu'il a toujours été. Il ne change que dans le détail, à l'échelle de la galaxie et de l'étoile.[2]

A second reason is even more simple: no other world-model is possible except a cyclical one. He reaches his conclusion by a sort of syllogism. His major is that no plausible theory of the universe can be metaphysical in character:

> De tout temps, les hommes ont cherché à construire des systèmes du Monde, à partir de leurs propres croyances et il en est résulté une riche, mais stérile, floraison d'hypothèses.[3]

Therefore, any theory of the universe must be relativistic (as opposed to metaphysical) and account for the evolution of the elements, the stars and galaxies (which, statistically, are unchanging). But, since reversibility is the condition of eternity, the only valid model possible is one based on cosmic cycles. This is confirmed by "experience":

> Tous les phénomènes que nous observons sont cycliques, depuis les cycles météorologique, biologiques et géochimiques, jusqu'aux cycles géologiques, et il doit en être ainsi de toutes choses.[4]

The fallaciousness of this manner of arguing is obvious. The use of statistical laws in modern physics is a well-established and most fruitful procedure. However, because, statistically speaking, the overall aspect of the universe may be unchanging, it does not follow that the *actual* universe is and always was the same.

His contention that the only model possible is a cyclical one is itself a metaphysical supposition; for the only argument which Dauvillier advances against theories positing a point-origin is that they are

1. DAUVILLIER, *op. cit.*, p.16.
2. *Ibid.*, p.119.
3. *Ibid.*, p.120.
4. *Ibid.*

"metaphysical." But the denial of metaphysics is itself a metaphysical position. Thus, Dauvillier's great desire to eliminate any metaphysical presuppositions forces him into one of his own. Likewise, the appeal to the observation of cycles in a number of natural processes is no more than an indication that cycles *might* be found on a larger scale; few would go so far as to say "therefore it *must* be such for *all* things."

In sum, Dauvillier's approach must be labeled as simple and misdirected as Whittaker's and Jeans's. His main error consists in ruling out even the possibility of a model with a point-origin. Two opposing types of models — those which predict a finite duration for the universe and those which predict an infinite duration — will always remain distinct possibilities. Therefore, it can never be stated with certainty that the predictions of one type alone are necessarily and uniquely true.

### B. A MORE CAUTIOUS APPROACH

Those can be considered to take a more cautious approach who see as impossible any *straightforward answer* to questions about the age of the universe. In opposition to men like Whittaker, the back-dating of any natural process as a direct means of determining the age of the universe is ruled out. However, they point out that a certain convention or way of speaking has gained general acceptance. Taking "universe" to mean the present large-scale structure of the universe, the time-scale of galactic recession can be *called* the age of the universe. This convention allows astronomers, speaking in terms of an evolutionary-explosion model, to assign a lowest bound or minimum age: "the universe must be at least $x$ years old." However, a clear-cut distinction is made between what "is called" the age of the universe (its lowest bound) and the "real thing" (the identification of its duration with a given time-scale).[1]

It can perhaps be said that the foregoing presents the thinking of most cosmologists about the age of the universe. However, there is still much disagreement about the more fundamental question of whether science can *ever* determine whether the universe had a beginning or is eternal. It is those who feel that a definitive answer to this question is possible whom we have grouped under this second classification.

A. C. Lovell, a pioneer in radio-astronomy, is confident that a decision between the leading world-models is close at hand:

As individuals we must face the possibility that within the next few years astronomers may be able to speak with unanimity about the ultimate cosmological problem. (...) I have no doubt that within a few years these

1. Peach, *op. cit.*, p.116.

instruments [radio telescopes] will enable us to resolve the conflict which I have described between the evolutionary and steady-state models.[1]

It seems that Lovell's predictions have already been partially realized. Discoveries in connection with quasars and various distant radio signals have been interpreted as casting serious doubts upon the Steady-State Theory. But if these findings should receive further confirmation, what, according to Lovell, would be the state of our knowledge?

He doubts whether or not there can ever be a scientific description of the creation of the primeval material of the universe; the discussion of creation "moves cosmology over into metaphysics." However, he continues,

... the *epoch* of this transfer may be now and at all future time, or it may have been 20 billion years ago. In respect of creation, the most that we can hope from our future scientific observations is a precise *determination of this epoch.*[2]

Therefore, Lovell implies that, should a model postulating a point-origin receive irrefutable confirmation, we would know without any doubt that the universe had a beginning (even though no physical process could be turned back to determine its precise age). On the contrary, if a model predicting an infinite duration should win out, we would know with like certainty that the universe has no beginning and is eternal. Thus, he sees in the isolation of a unique world-model by observational confirmation the solution to the question of the duration of the universe.

G. J. Whitrow seems to be of substantially the same opinion as Lovell. While personally convinced that the world is of finite duration and ascribing to a Lemaître type model, he admits that "no final and compelling proof of the finite range of past time has yet been discovered." However, he does not seem to rule out the possibility of such proof. He feels that the distribution of the clusters of galaxies and information supplied by the frequency of past collisions "may hold the ultimate key to the great problem of the age of the universe, since this problem is intimately connected with the question of its basic structure." He continues:

For, if the universe is expanding, then it can only have existed in its present state for a finite time, although the actual measurement of this time will depend on whether the recession of the galaxies is approximately uniform or was different in the past.

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1. A. C. LOVELL, *The Individual and the Universe* (New York: New American Library, 1961), p.122.

2. *Ibid.*

> If, however, the universe is in a steady-state, with new clusters of galaxies continually being formed as older ones move away form each other, then the total range of past time must be infinite.[1]

Thus, Whitrow also feels that a decisive confirmation of a single type of model will bring with it the solution to the question of the duration of the universe.

The thinking of many in the "steady-state camp" is similar. Hoyle says that "an entirely decisive confirmation of the Steady-State Theory would be obtained if clusters could be detected at an early stage of formation, before their constituent galaxies compacted."[2] Bondi lists a number of possible observational tests by which the theory might be confirmed, e.g., radio-astronomical counts, a more exact measurement of the red-shifts, a clear-cut determination of the mean density of the universe. Thus, like Hoyle, he feels that experimental findings will eventually tip the scales in favor of one or the other of the theories. If and when such a confirmation is had, they see the question of the duration of the universe settled once and for all:

> The old queries about the beginning and end of the Universe are dealt with in a surprising manner — by saying that they are meaningless, for the reason that the Universe did not have a beginning and it will not have an end. Every cluster of galaxies, every star, every atom had a beginning, but not the Universe itself.[3]

### C. THE QUESTION OF THE DURATION OF THE UNIVERSE IS ULTIMATELY INSOLVABLE

Within our third grouping of opinions mention can be made, first of all, of E. A. Milne. It might be thought that Milne would hold a position similar to that of Whittaker, since he constructs a model which posits a point-origin. However, such an interpretation overlooks a methodology which militates against it. Milne takes a position somewhere between men like Hobbes, who would deduce all the laws of physics with a mathematical rigor, and Karl Pearson, for whom all natural phenomena are but routine occurrences about which science can never ask the question "why."

Milne assumes that the universe is rational. Hence, its laws are more than just contingent propositions which might be otherwise. Observation serves as a guarantee that the laws deduced from a rationally constructed model are empirically correct.[4]

1. Whitrow, *op. cit.*, p.187-188.
2. Hoyle, *Frontiers...*, p.332.
3. *Ibid.*, p.301.
4. Milne, *Modern Cosmology...*, p.155.

Milne constructs a world-model positing creation at a point-singularity, since he believes any other alternative would involve rational impossibilities. But if this is so, should he not hold that the back-dating of some natural process would lead to the point at which all things began? Not at all. Although convinced, on rational grounds, that the universe must have been created with a beginning and that it has evolved steadily to its present proportions, he also realizes the limitations of his own method as well as the enormous difficulties of the question.

Physics must start from a rational base, but it is never certain that the base chosen is the unique possibility; the creation of the universe itself is a "supreme irrationality." By this Milne means that one may not ask why it was created this way rather than that, "or why it was created at a particular epoch. Thus, we may not say that creation occurred so many thousand years ago as if that dated it."[1]

Further obscuring the question of the age of the universe, and the very meaning of the question, is the intimate connection between space-time and an observer. Milne's model postulates two kinds of time because he felt this necessary to meet its unique requirements: a more or less "fixed" time, associated with atomic processes and one by which observers could measure epochs near at hand. The use of such temporal concepts, common to much of relativity physics, is sufficient to show that Milne never confused the mathematical, constructual time used in his models with a time-scale uniquely valid for the measurement of all events and processes.

> The universe as a whole has no age and no size, only an age and a size when a particular observer is singled out, at a particular stage of his experience (...) Each observer situated at the nucleus of a galaxy will regard himself as the "oldest inhabitant" of the universe; which is itself sufficient to show that the universe itself has no age.[2]

In fine, Milne does not ascribe a straightforward meaning to any figures — even his own — which might be assigned as the age of the universe. But beyond this, it seems he would readily admit that neither model, theory nor observational data will ever be able to settle the question of the duration of the universe. For his methodology, or, more accurately, his epistemology, lays down the axiom that we are never certain that the rational base chosen for a model is the only possible choice. Therefore, although a model becomes more reliable as its predictions receive increased confirmation, it can never fully represent the actual universe in all its features — especially as to an origin in time or lack of it.

1. *Ibid.*, p.33.

2. *Ibid.*, p.157.

In the second place, many of those whose approach to the philosophy of science is phenomenological would be in general agreement with the view that the duration of the universe is ultimately insolvable. One such representative is Milton Munitz. Munitz points out that, unlike physical phenomena which are open to more or less direct investigation, questions about the universe are in a special category. This is particularly true when one wishes to make propositions not about the "observable universe" or "a sample of the universe" but "the universe-as-a-whole."

'The universe-as-a-whole' does not constitute a name for some object of entity which exists antecedently to or independently of our inquiry and whose essence or structure we are trying to discover and articulate (...) The 'whole universe' is a term summing up the symbols and representations of a given theory or model of the universe which is proposed to guide predictions in regard to regions as yet to be observed.[1]

Beyond the general problems attaching to all questions about the universe are those involved in discussions of its age. Munitz asks whether the concepts "origin" and "age," when used in conjunction with "universe," might not "have a different status from the way in which these terms are understood when used in reference to objects or processes of a familiar empirical sort." As an instance of this "different status," he mentions the efforts made by some to ascertain the age of the universe.

Implicit in any such attempt is the singling out of some process to serve as a *natural clock*. However, although such "clocks" can give good accounts in regard to the origin and age of planets, stars and individual galaxies, "this does not compel one to accept an evolutionary approach which makes it necessary to assign an origin to the universe as a whole." "For," he continues,

... it is possible to admit evolutionary development in various astronomical subsystems and even in observable regions of the nebulæ — yet still uphold a concept of the universe as a whole to which *no* evolutionary development is assigned.[2]

Munitz, therefore, concurs upon a point already emphasized: since there is always the possibility of at least two types of models — those which posit an origin and those which do not — one can never be certain that the findings derived from one model alone are uniquely true. Moreover, even if a completely successful theory of cosmic evolution is devised, "it is still by a theoretically stipulated clock that we get back to $t = O$."[3]

1. MUNITZ, *Space, Time and Creation...*, p.36.
2. *Ibid.*, p.144.
3. *Ibid.*, p.151.

In conclusion, it seems fair to include Munitz among those who hold that the question of whether or not the world had a beginning is unanswerable by the physical sciences. I say this in spite of the fact that Munitz explicitly labels such a position as "skeptical." He phrases his own stand in the following terms:

We are never able to establish at any given time whether some account of the universe which happens to be preferred to other accounts proposed at the same time will remain adequate in the face of continuing inquiry.[1]

However, without insinuating that it is all just a matter of semantics, the two positions do seem substantially the same. For if, say in 1936, cosmologists were "sure" that the universe had a beginning and in 1956 they were equally "sure" that it did not have one, it must be admitted that complete certitude was lacking in both instances. Certitude, if it is to have any meaning at all, must imply that some proposition is assented to without fear of the opposite proving true. But if it is impossible to establish whether what science assents to today will continue to be accepted in the future, a fear of the opposite is present and complete certitude absent. Therefore, in the last analysis, Munitz would have to admit that the question of the duration of the universe is ultimately unanswerable, i.e., science can never offer more than probable arguments in behalf of the currently favored view of the question.

A number of other cosmologists are undoubtedly of the same opinion as Munitz. However, it is difficult to find any who states *explicitly* that the duration of the universe is insolvable. This is partly due to the general reticence of scientists to fixing limitations upon their investigations. But it also may arise from an awareness of the philosophical implications of the question. While some, such as Jeans and Whittaker, seem oblivious to the philosophical difficulties involved, others manifest a healthy respect for them and, for this reason, shy away from any clear-cut statements. The famous astronomer Otto Struve remarks:

These questions [the connection between physics and astronomy] bring us to the dim frontiers of knowledge where science merges with philosophy. We cannot help asking ourselves: What lies beyond the ten billion light-year boundary of the observable part of the universe? What is the meaning of the observable part of the universe? What is the meaning of the words: the age of the universe; and what happened earlier than ten billion years ago? (...) All these questions are important. Most of us have thought about them over and over, especially in our younger years; yet, most of us have found that we could not answer them. I believe that the aging process of a scientist's brain involves an involuntary tendency to shove such questions into his subsconscious mind and to deal more and more often with those

1. *Ibid.*, p. 179.

relatively simple questions that are capable of experimental or observational tests.[1]

Therefore, in his eyes, questions about the age and origin of the universe are not to be treated in the same way as those which are "capable of experimental or observational tests." Struve's own convictions are summed up, he informs us, in the words of Edwin Hubble: "Later, perhaps, in a happier generation, when the cost of a battleship can safely be diverted from insurance of survival to the consolations of philosophy, the march outward may be resumed."[2] That is, science will come to grips with those ultimate questions which cannot be answered by observational methods alone only when their frankly philosophical character is admitted and explored.

As a final adherent to the view that the duration of the universe cannot be known with certainty by scientific means, the name of J. V. Peach must be added. The following statement sums up his position, and our own, and is offered as a fitting conclusion to this article:

The problem of the 'age of the universe' has been looked upon by some in the past as a field in which a scientist could perhaps confirm or contradict a theologian's view as to the fact of Creation in time. This was an illusion. What a scientist can in fact do is far less grand, but nevertheless exciting. Estimates of ages of parts of the universe are now an essential part of the science of cosmology, and form a body of established facts that cosmological theory must take into account. It was an unfortunate confusion that led to a more exalted view of their importance.[3]

Donald CANCIENNE.

1. Otto STRUVE, *The Universe...*, p.155.

2. *Ibid.*, p.156.

3. PEACH, *op. cit.*, p.125.