ORIGIN AND AGE OF THE UNIVERSE APPRAISED BY SCIENCE

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THE question of the duration of the universe is as pertinent and engrossing today as it ever was. Tremendous discoveries bearing on this problem have been made in recent years by the sciences of astronomy, astrophysics, and cosmology. To speak intelligibly of creation and the universe, the theologian can ill dispense with a background knowledge of these findings.

When did the immense history of the universe begin? If we look forward toward the future, we do not perceive any compelling reason for asserting that the world, or at least its material component, must come to an end. If we let our thoughts roam back toward an ever receding past, can we not conceive a universe that never began? Or is a beginning imperative? Revelation, which instructs us about the end of the world, also attests the fact that it had a first instant. Can its witness be confirmed by science?

By studying the present structure, movements, and laws of the cosmos, science is able to push back into the past until it arrives at a form of the universe which is the origin of the form it exhibits today, and to calculate the duration of its history. Science is at home in this order of relations among successive stages. Is it also in a position to decide whether, prior to the remotest stage it can reach by its proper methods, further duration is impossible?

APPROACH TO THE PROBLEM

The dogma of faith, that the universe has a temporal duration, can in no way embarrass science. Revelation teaches that the world began, but does not tell us when it began. Science is unrestricted in its liberty to search for the initial point of departure from which the present state of the world evolved.

Half a century ago, scientists were not much concerned about the origin or age of the universe. They blandly disregarded the question, as a beginning would imply creation; and they tended to shy away from the very thought of creation. This attitude has changed. Astronomy and astrophysics have uncovered an amazing array of facts impossible to ignore, and they indicate that an eternal evolution of matter is impossible; hence a beginning of the cosmos must necessarily be considered. The results of scientific investigation converge toward a zero hour of time and space, distant from the present by some billions of years. One author goes so far as to assert, "Astronomers of today no longer dare to speak of the eternity of the world."[1] This may be an exaggeration; yet it reflects the dominant view.

Pondering on the implications of the second law of thermodynamics was a powerful factor in the shift of attitude. Progressive degradation of energy, which finds expression in this law, has been known for a century, but scientists have been reluctant to acknowledge what it involved. The second law of thermodynamics is best understood in connection with the first law, that of the conservation of mass-energy. This principle states that the total energy in the universe is constant and indestructible; it can vary in form or quality, but the quantity remains always the same. However, although the amount of energy never alters, the energy itself is not forever available. For, according to the second law, which "is a fact, and by far the most important fact, of all science,"[2] the energy of the world is subject to continuous degradation or diminution of utility. Every transformation of energy is accompanied by a release of heat, with the result that the quantity of calorific energy in the world is constantly increasing; as the latter, for the most part, is useless for producing work, useful energy is progressively decreasing.[3] Since physical phenomena regularly entail the production of some heat, the energy dissipated in heat must gradually augment until all energy is transformed into heat. Thus the quantity of unusable energy, or the entropy of the universe, is constantly growing; a time must come when all the energy in the world, vast as it is, will have passed over to this form. On that day no more work will be possible and a reign of final stagnation will be inaugurated. Accordingly the universe is steadily running down toward the equalization of all the energy of its various regions and parts; it will be a dead world in

[1] O. Spülbeck, *Vom Werden des Weltalls* (Berlin, 1950) p. 20.

[2] Emile Meyerson, *Identity and Reality* (London and New York, 1930) p. 278; cf. p. 272.

[3] For example, a steam engine can transform only 15 to 20 per cent of calorific energy into useful work; the rest is lost.

which all bodies must have the same temperature. No exchange of energy is possible in such a state of thermal death.

The inference from all this is obvious. If the universe is to have an end, it had to have a beginning. If the clock is running down, it must have been wound up at a definite time. For if the world were without beginning, its progressive loss of energy, involving the aging and decline of the cosmos, would have brought about, on any assignable day in the past, the arrest of every mechanical process. But we observe vigorous movement and life in the universe; therefore its degradation must be marked by limited time. If the universe had existed from eternity, by now or at any possible hour in the past, all its energy would have been transformed into calorific energy; temperature throughout the universe would be uniform and all activity would be at an end. The very fact that temperatures vary by millions of degrees in different parts of the universe points to its youthfulness and indicates a beginning a finite period of time ago.

Considerations of this kind cannot be shoved aside. When the present century began, however, scientists still preferred to evade the issue. Pretexts could readily be found to justify their attitude. The second law of thermodynamics or of increasing entropy specifies only the direction of the approaching equalization, not its rate. Since this speed depended on unknown processes, no calculations of time intervals were possible. Again, the validity of the law for unlimited time and space was regarded as questionable; we cannot with full certainty extend the principle of the degradation of energy to the universe in its entirety. We know only a fragment of it, and so are unable to reconstruct with a sure hand either the whole of space with all the bodies that occupy it or the evolution of the whole in time.

Several ways of making calculations were devised during the second quarter of the century and led to an upheaval in scientific outlook. A finite age had to be acknowledged for radioactive elements. More impressive was the evidence presented by the recession of nebulae outside our own galaxy, the Milky Way. Such nebulae appear to be rushing away from one another at unimaginable speeds; if these mutual recessions have been going on continuously in the past, all the matter observable in the universe must, at some time that is only finitely remote, have been condensed into a relatively small compass. Computations of the rate of decay in radioactive isotopes and of the speed of the flying galaxies were repeatedly made. With due allowance for uncertainties in theory and observation, the time limits required for such phenomena were found to be, not indeed equal, but of a similar order of magnitude, and adjustments were quite possible. The conviction of a finite age for the universe soon became common. A time was provisionally set at some three to five billion years ago when the universe was tightly compressed in a state of extreme density and temperature. Then occurred a tremendous explosion that accounted for the formation of elements and catapulted fragments of matter in every direction to form the universe until it took the aspect we observe today.[4]

If scientists are able to lead us back to such a beginning, can they tell us more about its nature? Have we discovered the real beginning of matter, its emergence from nothing by creation, or only a primordial substructure? In other words, is the beginning absolute or only relative?

According to one view, the initial stage need not represent an absolute beginning; it is merely the first phase of the evolution of our contemporary world. The age of the universe is thus taken to mean the time scale during which the world developed from a primitive state lacking all distinction in celestial bodies to the complicated cosmos of the present. A more radical view tolerated nothing less than an absolute beginning, the effect of a creative act. The ultimate choice between the two alternatives, perpetual existence of matter or creation, may not be wholly within the province of positive science regarded as theory verified by observation; yet science has its voice on this subject, and we ought to listen to it.

At any rate, by mid-century general agreement had been achieved on several items. The Hubble-Humason law, formulated in 1928, which stated the velocity of the recession of extragalactic nebulae in proportion to their distances, induced abandonment of a previous "long" time scale of thousands of billions of years to a "short" time scale of a few billion years for the history of the universe. Other lines

[4] Cf. G. Stein, S.J., "L'Universo, donde?", *Civiltà cattolica* 100 (1949) 263; E. J. Öpik, "The Time Scale of Our Universe," *Annual Report of the Smithsonian Institution* (1955) p. 204.

of argumentation, based on time scales for the earth, radioactive elements, the evolution of stars, the stability of double stars and star clusters, led to conclusions of a similar order. Two paramount questions emerged: When did the universe begin? What was the original state of matter? Outstanding experts in astronomy, astrophysics, and atomic physics have collaborated in an endeavor to answer these fascinating queries.

Since the structure of the universe is a strong index of its history, a brief description of the world as known today will be presented. This will be followed by a review of the methods employed to fix the age of atoms and elements, then of the earth, the stars, and the galaxies. After that, some theories about the origin of the universe will be weighed. At the end we shall turn to our main enquiry: What contribution does contemporary science make toward the solution of the ancient problem about the eternity of the world?

SUMMARY DESCRIPTION OF THE UNIVERSE

Measurement of cosmic time is closely tied up with an inventory and localization of the objects distributed throughout space. Any knowledge we may gain of the age of the universe depends greatly on its structure, its dimensions, and its present form. The long history of the universe has left its mark on the material we are now able to examine; we may gather information about that history by studying the composition of stars and galaxies. With the aid of modern apparatus, the movements of galaxies in relation to one another can be much more accurately gauged than was possible a few years ago; study of these phenomena yields an important clue for assessing their ages.

Recent progress in astronomical instruments and techniques enables us to acquire a good idea of the universe. The 200-inch telescope on Palomar Mountain in California probes out to more than two billion light-years, and new radio telescopes now under construction promise to add a third billion. Since 1949 the Palomar Observatory, in conjunction with the National Geographic Society, has been making a "Sky Survey" with the 48-inch Schmidt telescope.[5] Published results

[5] The Big Schmidt is in reality a gigantic wide-angle camera. According to Ira Sprague Bowen, director of Mount Wilson and Palomar Observatories, it could photograph a candle flame 10,000 miles away; cf. *National Geographic* 110 (1956) 780.

of observations make possible a description of the cosmos that goes far beyond what was known even a decade ago.

Our sun, a ball of extremely hot gases and metals, a million times the size of the earth, is an average star in a vast stellar system that has the shape of a flattened disk or lens. This is the Milky Way Galaxy. In the entire sky only about 6000 stars are near enough or bright enough to be seen by the human eye. They form part of our galaxy, in which telescopes have discovered more than a hundred billion stars or suns.

The stars that make up this island in the universe are immense, luminous spheres. In mass they vary from those that weigh one-twentieth as much as the sun to those that surpass ten suns. Their luminosity presents greater differences; some are 100,000 times brighter than the sun, others have only a slight fraction, down to a millionth part, of the sun's brilliance. This radiance is sustained by thermonuclear reactions by which hydrogen is transformed into helium, deep in the interiors of the stars, where temperatures mount up to many millions of degrees.

The Milky Way is so large that light, speeding 186,000 miles a second, needs a hundred thousand years to cross it. The thickness of the disk at the middle is some 10,000 light-years.[6] The sun, with its retinue of earth and other planets, is located at some 26,000 light-years from the center.

The entire galaxy revolves about its core, with a speed that swings the sun around it in 200 million years; some 250 million years are required for a complete rotation of the whole galaxy. In addition to their participation in the general movement of rotation, the stars have their own movements, some displacing others. Frequently they are associated in pairs or binaries; often they are grouped in clusters, containing hundreds of thousands of stars, some close together, others diffused in feeble concentration.

Just as stars tend to gather into clusters and whole galaxies, so, too, galaxies form clusters. Our Milky Way is a member, perhaps an outrider, of a cluster of seventeen galaxies, grouped within a radius of

[6] With distances so vast, the light-year conveniently replaces the mile or kilometer as unit of measurement. In our familiar terms, the solar system is more than 7,300,000,000 miles in diameter, and the Milky Way is 600,000,000,000,000,000 miles in diameter.

about a million light-years. Outside this cluster, eight million light-years have to be traversed before the next galaxy is encountered.

Enormous as it is, the Milky Way is a quite ordinary example of galaxies so numerous as to be uncountable. Apart from Andromeda, which appears as a small, oval blot of light, galaxies are visible only to telescope and camera. Statistics based on observations made with the 100-inch telescope at Mount Wilson lead to a total of 100 million galaxies, of which the most remote are 500 million light-years away. But the sky survey conducted by the National Geographic Society and the Palomar Observatory has expanded known space at least twenty-five times.[7] When the astronomer of the survey, George O. Abell, began his work in the summer of 1949, scarcely three dozen clusters of galaxies had been seen; now these largest blocks of matter, veritable archipelagoes of galaxies, are known to exist by the tens of thousands, at distances two or even three times more remote than had previously been estimated. On some of the 1758 photomaps of the sky survey, as many galaxies can be counted as there are stars in our own galaxy. Many of the plates made with the Schmidt telescope reveal 50,000 or more galaxies in an area the size of the Big Dipper. When the 200-inch Hale telescope is turned to the skies, the faint blurs of light registered on the plates blossom out into clusters of galaxies, some containing hundreds of island universes.[8] The most distant cluster thus far observed is much more than a billion light-years away. Beyond the possibilities of telescopic observation, calculations based on the movements of known galaxies suggest that the number of galaxies in the entire universe is thousands of times greater than will ever come within range of astronomical instruments.[9]

Whether clusters of galaxies are scattered at random or are rather uniformly distributed throughout space, is not yet clear. Such evidence as is being accumulated intimates that the more remote nebulae, apart from their tendency to gather into clusters, are more or less evenly distributed.[10]

[7] G. O. Abell, "Exploring the Farthest Reaches of Space," *National Geographic* 110 (1956) 782.

[8] *Ibid.*, p. 784.

[9] Cf. M. Grison, *Problèmes d'origines: L'Univers, les vivants, l'homme* (Paris, 1954) p. 43.

[10] H. P. Robertson, "The Universe," *Scientific American* 195 (1956) 80. The entire issue of *Scientific American* for September, 1956, is devoted to astronomy in its relations

So far, no intergalactic matter has been detected. If such matter exists, it must be pure hydrogen gas, without dust or other kinds of gas; otherwise it would have been discovered. Within a few years, new radio telescopes, tuned to the one-note "song of hydrogen," may be able to determine whether such matter is present in intergalactic space. In our own galaxy, however, vast clouds of dust, known as "dark nebulae," dim the light of the stars, between which, also, diffuse clouds of almost transparent gas float. Similar clouds of dust and gases swirl in the spaces between the stars of other galaxies.

CONVERGENCE OF MEMORABLE DATES

Knowledge of space leads to knowledge of time on the cosmic scale, for it fixes some limits to the duration of the world. If certain galaxies are 500 million or several billion light-years away, the light we receive from them departed that long ago; hence they existed at that time.

We see the stars and galaxies as they were at the moment they emitted the light we receive today. On the whole, they do not exhibit great differences. Therefore some hundreds of millions of years do not mark a significant time in their existence, for such a period does not produce a considerable aging. Furthermore, we have no reason to suppose that the galaxies are still in their first revolutions; a complete rotation may be but a slight fraction of their duration. Their origin may go back to billions of years. However, we possess a number of means that converge marvelously toward more precise figures.

Age of Atoms and Elements

The universe is composed of a diverse, though orderly, system of elements, ranging from hydrogen to uranium. What are they made of? How account for their origin? What is their age? Study of these questions is proceeding today according to many methods. Investigation of the relative abundance of the various elements making up the universe has been one of the more fruitful lines of research, for such distribution is an indication of cosmic history. By analyzing the crust of the earth along with its oceans and atmosphere, the contents of mete-

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to cosmology. Authors of the articles are among the foremost scientists of America and Europe, specializing in mathematics, physics, mathematical physics, philosophy of science, and particularly astronomy. Subsequent references will designate it simply as *SA*, followed by page numbers.

orites, the light from stars as broken up by the spectroscope, and the cosmic ray particles that bombard our planet, computations of the proportions of the elements in the universe can be made. These procedures combine to show that the average abundance of elements throughout the universe is constant.[11]

Of all the elements that form the earth, the other planets, the sun, the stars, and the galaxies, hydrogen is by far the most abundant. Hydrogen accounts for some 93 per cent of the total number of atoms in the universe. Helium comes next, with about 7 per cent. The abundance of elements decreases with increasing atomic weight. An exception occurs in the elements of the iron group, which are ten thousand times more abundant than their neighbors in the sequence. Apart from this irregularity, the decline is general, so that the heaviest elements comprise only about a hundred millionth of the number of atoms in all matter. Thus all the elements heavier than helium taken together come to slightly more than one per cent of the world's mass;[12] hydrogen and helium make up about 99 per cent of the total material. Carbon, oxygen, nitrogen, and the metals form most of the rest. But hydrogen so predominates that we can assert with rough approximation that the universe is composed of it.

Among current theories advanced to account for the origin of the various chemical elements, the most prominent is the one proposed by George Gamow and his collaborators. He believes that at the beginning matter was composed merely of protons, neutrons, and electrons. This view starts with the postulate, based on the expansion of the cosmos, that the universe owes its origin to a superdense, primordial core that exploded some five billion years ago. After about five minutes the dispersing matter cooled sufficiently to permit a build-up of protons and neutrons into larger units, that is, from deutrons, composed of a neutron and a proton, up to the heaviest elements. Thus during the first thirty minutes of history, thermonuclear reactions would have accounted for the assortment of elements at present observed. Over the following millions of years the violently fleeing matter slowly began forming stars, planets, and galaxies.[13]

[11] W. A. Fowler, "Formation of the Elements," *Scientific Monthly* 84 (1957) 84. However, some giant stars have an overabundance of certain heavy elements relative to the rest of the universe; *ibid.*, p. 97.

[12] *Ibid.*, p. 86; see also Fowler, "The Origin of the Elements," *SA*, p. 82.

[13] G. Gamow, "The Evolutionary Universe," *SA*, p. 152; Fowler, *SA*, pp. 85, 87.

The main difficulty with the theory is that it does not well explain the formation of heavier elements. If neutron capture were the only means by which elements could be constructed, beginning with hydrogen, the process would seemingly get no farther than helium.[14] However, it does account for the formation of hydrogen and helium, which make up about 99 per cent of all the matter in the universe; the building of the other elements can be assigned to rarer processes within stars, as is explained in the second of the two main theories.[15] Gamow insists that some of the heavier elements were built by the capture of neutrons. Yet he acknowledges that it is improbable that the heavier elements could have been produced during the first half hour in their present abundance, and so is prepared to admit that most of them may have been formed later within the hot interiors of stars.[16] In any case, the uniform relative abundance of chemical elements strongly indicates that the whole universe issued from the same crucible.

The maximum age of some of the elements, that is, radioactive elements having a known rate of decay, can be determined. This rate is not subject to external influences of temperature or pressure. As the relentless process of decay can occur only for a finite interval of time, the radioactive elements must clearly have a finite age.[17] The calculations, based mostly on terrestrial observations, are regarded as valid for the universe, for the earth is a sample of the Milky Way Galaxy and hence of the cosmos. Accordingly science leads back to an epoch in which these elements were not as yet formed.

Can this moment be dated? Different radioactive elements yield somewhat different dates. If we admit that all the elements were formed more or less simultaneously, the study of uranium 235 provides a convenient measure of time. Like all radioactive substances, it disintegrates by generating final, stable products that remain enclosed in the mother substance. Since the time required for the production of a given quantity of such products can be reckoned, the interval elapsing from the beginning of the decay, that is, from the first mo-

[14] Fowler, "Origin of the Elements," *SA*, pp. 87 f.

[15] This theory is described in detail by Fowler, "Formation of the Elements," *Scientific Monthly* 84 (1957) 91–99.

[16] Gamow, *art. cit.*, p. 154.

[17] Öpik, "The Time Scale of Our Universe," *Annual Report of the Smithsonian Institution* (1955) p. 210.

ment of the element's existence, can be computed. Such computations, made repeatedly by different scientists, come to an age varying from 4.5 to 5.4 billion years. Calculations based on the quantity of atmospheric argon issuing from potassium 40 give 3.3 billion years, and those based on the quantity of radiogenic xenon 129 in the earth's atmosphere arising from iodine 129 indicate 3.6 billion years.[18] Study of thorium 232 may point to a greater age than that of any of the elements mentioned.[19] Even a considerable error in these figures will not affect the order of magnitude of the results. The very existence of such radioactive substances is a solid proof of the temporal origin of elements. Furthermore, conditions leading to the formation of the heavy radioactive isotopes cause the building and disintegration of the lighter elements; this is a consequence required by the theory of nuclear structure. Therefore the age of the radioactive isotopes is a good measure of the age of all the elements.[20]

In any case, there was a time, five or more billion years ago, when atomic structure was non-existent. Prior to that moment, matter existed under a preatomic form. It is represented as a gaseous or liquid substance composed of protons, electrons, and neutrons, or simply of neutrons, or even more simply as an enormous preatom. The events that would transform it into hydrogen, helium, carbon, iron, and the other elements had not yet begun.

Age of the Earth

Through the employment of methods based on radioactivity, the age of the earth has been determined with a high degree of exactness. Many geological formations contain quantities of uranium or thorium which, after successive transformations, are ultimately reduced to lead and helium. The rates of these disintegrations are unaffected by conditions of pressure and temperature; and since they are well known, the age of a rock can be assessed as soon as all its elements have been analyzed. The relation between the final products already formed and the original untransformed radioactive substance makes such calcu-

[18] *Ibid.*, p. 211; V. Mersch, S.J., "L'Origine de l'univers selon la science, "*Nouvelle revue théologique* 75 (1953) 242; T. de Dominicis, "La fisica nucleare e la creazione," *Doctor communis* 7 (1954) 225.

[19] Fowler, "Formation of the Elements," *Scientific Monthly* 84 (1957) 99.

[20] Öpik, *art. cit.*, p. 210.

lations possible; now that the rate of decay of the radioactive substance has been firmly established, the time during which the disintegration has been going on can be computed from the amount of the end product which has accumulated. The figures are accurate within the limits of eight to ten per cent.[21]

Measurements made by this procedure fix the age of the oldest specimens of the earth's crust, found in Africa, at 2.9 billion years. As there is no reason to think that the oldest rocks have been examined in laboratories, we may confidently suppose that the age of the earth is greater than the oldest samples thus far analyzed. Scientists are well agreed that the figure, 3.5 billion years, represents the true age of the earth. A similar age, or one somewhat higher, is assigned to our solar system, as the formation of the earth and the planets must have occurred within relatively short time intervals.[22] This is confirmed by studies of meteorites reaching our earth from other planets or even from stars outside the solar system. Analyses of these specimens by radioactive methods indicate that the age of the solar system or its parent nebula is close to 4.5 billion years.[23]

Age of Stars

1. **Stellar combustion.** The stars were not all born at the same time. Some are young and some are old; indeed, at the present time some are in process of formation. In the diffuse clouds of interstellar gas and dust which are numerous in our galaxy, embryonic groupings of matter are observable. As they continue to contract they will gradually heat up until they eventually condense into stars blazing with light.

According to common astronomical interpretation, all the billions of stars in the universe were formed in this way from dilute, turbulent masses of gas consisting of hydrogen atoms. Under the force of gravitational attraction, vast areas of gas condense into stars. As a star contracts more and more, its interior becomes exceedingly hot and dense. When the temperature at the center reaches some five million degrees, the protons collide with sufficient energy to fuse and form deuterons. Then deuterons combine with protons to form helium 3, and

[21] *Ibid.*, p. 208.

[22] *Ibid.*, p. 209; see the references here given to scientists who have arrived at these estimates by employing methods of extrapolation.

[23] *Ibid.*, 213, 223; cf. Fowler, "The Origin of the Elements," *SA*, p. 91.

two helium 3 nuclei can fuse to produce helium 4, with ejection of two protons. The result of the chain is the conversion of four atoms of hydrogen into an atom of helium.[24]

The core of helium developing in the star's center slowly grows. But as the hydrogen fuel in the interior is consumed, the core starts to cool and then to contract, because the force of gravitation regains its ascendancy. This causes a new rise of temperature at the center, which heats up the outer envelope of hydrogen. The swollen surface then shines with cooler, redder light, and the star has become a "red giant."[25]

Red giants cannot regenerate and conserve their heat except by contracting, which greatly augments their internal heat, resulting in nuclear reactions. But such processes can continue only so long as sufficient reserves of hydrogen are available. Little by little these reserves are used up by the transformation of hydrogen into helium. When at last they are exhausted, contraction alone can cause heat which ultimately, however, must drop until the star ends up as a "white dwarf" of tremendous density and small mass. These white dwarfs are incapable of radiation and are doomed to total extinction.[26]

When the explanation of the luminosity of the stars was found to consist in the gradually accelerating conversion of their initial hydrogen into helium, the way was open for a good computation of their ages. Stars may be regarded as gigantic fires producing heat energy, although the reactions in stars differ greatly from those taking place in ordinary fires familiar to us on earth. In the nuclear combustion going on in the interiors of stars, where temperatures mount up to many millions of degrees, the combustible matter is hydrogen, and the residue—ashes or cinders, so to speak—is helium. Little by little the hydrogen is consumed and is replaced by helium. This process has been functioning since the origin of the stars. Examination of the proportions of their hydrogen and helium—"fuel" and "ashes"—can roughly fix their antiquity.

Studies of the relationship between the content of hydrogen and helium indicate that most of the known stars have not yet had time

[24] Fowler, *art. cit.*, p. 88; cf. De Dominicis, "La fisica nucleare e la creazione," *Doctor communis* 7 (1954) 223.

[25] Fowler, *loc. cit.*

[26] P. Humbert, "La fin du monde et la science," *Lumière et vie* 11 (1953) 21 f.

to consume a notable part of their combustible material, for they are still rich in hydrogen and poor in helium. In the estimate of the majority of astrophysicists, a period of some five billion years well represents the age of the stars.[27]

The method based on stellar combustion is strikingly confirmed by several other lines of investigation.

2. **Globular clusters.** The entire galaxy of the Milky Way rotates around its center. It does not turn like a solid wheel, for stars closer to the center revolve around it more rapidly than those farther out. Particular movements are superimposed on the movement of the whole galaxy. While all the stars rotate, some draw near to the center while others move away from it; some lag and others hurry along. Thus the configuration of the stars is constantly changing. Because of their movements, stars encounter one another, that is, they pass within a distance that causes them to exert a perceptible effect on one another by mutual attraction. Such encounters, relatively frequent on the cosmic scale, have occurred since the stars existed, and produce effects that accumulate with time and can be gauged, for the effects are more pronounced in proportion to the length of time their causes have been operative. In particular, the forces of attraction, repeatedly active among the encountering stars, tend to dissipate groups of stars called "globular clusters."

Examples of such clusters of stars are the Pleiades and the Hyades in the constellation Taurus. In recent years new clusters, among them the most distant masses of celestial matter associated with our galaxy, have been discovered.[28] They contain several hundred stars to hundreds of thousands of them. A real unity exists among members of a cluster; they form communities which have the same general movement and travel in convoys. They are held together by fluctuating forces of attraction, for individual members shift about at random like swarming midges. Two hostile powers war against a cluster without mercy and tend to break it up; these are encounters among them and

[27] V. Mersch, "L'Origine de l'univers selon la science," *Nouvelle revue théologique* 75 (1953) 238 f. In general, estimates vary from 4 billion to 6.5 billion years for the oldest stars.

[28] Abell, "Exploring the Farthest Reaches of Space," *National Geographic* 110 (1956) 788.

the attraction exerted by the center of the galaxy. Since the forces of cohesion among the members of a cluster are not dominant, the galactic attraction to which they are subject progressively disperses their unity. Also, encounters with other stars near which the group passes or which pass through the group produce a progressive dislocation; after an encounter the cluster will be less united than it was before. The final result of such actions over a long period of time is that stars escape from the group, so that eventually the cluster must disintegrate.

The very fact that globular clusters still exist is a proof of a relative youth of the stars. The rate at which they lose their component stars has been figured out: most clusters have an age of about one billion years.[29] Others have been in existence for some three billion years.[30] Estimates based on more recent observational data mount to 4.5 or 5 or 6.5 billion years as the probable age of the oldest globular clusters, as well as of the Milky Way Galaxy.[31]

3. **Double stars.** Many stars, up to a third of all that have been studied, associate to form partnerships of pairs or "binaries." Every time a member of a pair encounters another star, it is subjected to an attractional force. The gravitational forces exerted by other stars in the general neighborhood affect the two partners in different degrees. Numerous repetitions of such influences over long periods of time tend to separate the members of a binary, with a rate depending on the frequency of encounters and the original proximity of the partners.

The scale of distances between members of the double stars that have been studied indicates a relative youth of the stellar world. Binaries could not have been subjected to encounters with other stars for longer than about five billion years since the beginning of this process.[32]

Age of Galaxies

The basic fact requiring a relatively short time scale for the universe is the red-shift observed in spectra of the galaxies. By now this

[29] Öpik, "The Time Scale of Our Universe," *Annual Report of the Smithsonian Institution* (1955) p. 217.

[30] E. Whittaker, *Space and Spirit* (Hinsdale, Illinois, 1948) pp. 113 f.

[31] Öpik, *art. cit.*, p. 216; Fowler, "Formation of the Elements," *Scientific Monthly* 84 (1957) 99.

[32] Whittaker, *op. cit.*, p. 114; Öpik, *art. cit.*, p. 217.

red-shift is interpreted universally as denoting the mutual recession of galaxies from one another at enormous speeds. Various hypotheses put forward to substitute some other explanation have failed one after another. Red-shift measurements made with the 200-inch telescope on Palomar Mountain offer solid hope that a definite decision about the problem, whether the universe is constantly expanding, may soon be forthcoming.

The phenomenon of red-shift is extremely important for extending our knowledge about galaxies. During the decade of 1920, astronomers at the observatories at Mount Wilson and Flagstaff noted a curious detail in the spectra of galaxies. These spectra present the same general aspect as that of the sun. However, although the rays follow in the same series as in the spectrum of the sun, they are displaced in the range of colors, that is, of wave lengths. Instead of being in their normal position as compared with the spectrum of the sun, the H and K rays, revealing the presence of calcium, deviate toward the red end of the spectrum. This effect increases with the distance of the nebulae.

The late Edwin P. Hubble and others interpreted the red-shift as the "Doppler effect," that is, the change in wave length perceptible when a source of radiation, such as a train whistle or a light, is in rapid motion. When such a source moves toward the observer, the wave length is shortened and the vibrations are rapid; if it moves away, the waves are lengthened and vibrations are slower. On this principle, if the light emitted by a star or a galaxy is shifted toward the red or long-wave end of the spectrum, we are led to infer that the body in question is moving away from us, at a velocity proportionate to the displacement of its radiations toward red.

This displacement of galactic spectra toward the red end, increasing with the distances of galaxies, indicates that the latter are drawing away from us with an accelerating rapidity; the more remote the galaxy, the greater its velocity of recession. The only plausible explanation of observed facts is that the entire system of galaxies is expanding, with a velocity that can be calculated.

On the basis of recent data contributed by Abell's sky survey, Dr. Milton L. Humason and Dr. Allan R. Sandage have been measuring the red-shifts of remote clusters of galaxies with a new spectograph of high efficiency placed in the focus cage of the 200-inch telescope on

Mount Palomar. The most distant galaxies thus measured for velocity as indicated by the red-shift are found to be receding at some 38,000 miles per second—which is a fifth of the speed of light. Early in 1956, Dr. William A. Baum, using special photoelectric equipment to detect the colors of light entering the Hale telescope, had estimated that one of the clusters is rushing away at the rate of 75,000 miles a second, which is two-fifths the speed of light. Some very faint clusters of galaxies, about a billion light-years distant, travel at a rate that is 6500 miles a second faster than in direct proportion to their remoteness, indicating that a billion years ago the universe was expanding more rapidly than it is at present.[33]

A confirmation of the conclusion that the universe is expanding at great velocities is furnished by developments in radio astronomy. Radio telescopes have an advantage over optical telescopes because of the fact that, owing to increasing red-shift, optical telescopes will not receive any appreciable light from celestial objects beyond a definite distance, whereas radio reception is less weakened by red-shift. Thus at a distance of three billion light-years, light coming from galaxies receding at half the speed of light would be shifted so far toward the red end of the spectrum that only part of it could be recorded on photographic plates; but the loss of radio energy suffered through shift of wave length is comparatively slight.[34]

During the past ten years many so-called "radio stars" have been discovered by radio telescopes. The source of their energy, which is not yet thoroughly understood, comes from colliding galaxies.[35] The great majority of the radio stars, which number some two thousand, seem to lie outside our galaxy, and to be distributed uniformly across the sky. Very few of them can be identified with visible objects, in spite of intensive scrutiny of photographic plates made with the largest telescope. The radio sources appear to increase in density proportionate to their distance, as is to be expected from the fact that only a few of them are within the range of the 200-inch telescope; the rest are beyond the reach of optical instruments.

[33] A. R. Sandage, "The Red-shift," *SA*, pp. 178-80; Abell, "Exploring the Farthest Reaches of Space," *National Geographic* 110 (1956) 787.

[34] M. Ryle, "Radio Galaxies," *SA*, p. 205.

[35] See R. Minkowski, "Colliding Galaxies," *SA*, pp. 125–34.

If most of the radio stars are collisions between galaxies, the inference is that such encounters occurred more frequently in remote space some billions of light-years distant. This suggests that the universe was considerably denser when the radio signals now being received from distant collisions began their journey toward us billions of years ago, for then such collisions between galaxies were more likely to happen.[36] In that case, the universe has been in process of expansion since, and also before, that far-off epoch.

Important conclusions about the age of the universe can be drawn from its expansion. If the galaxies are all receding from one another at velocities increasing with their distances, the process can be traced backwards. If the universe is expanding, it was less vast yesterday than it is today, for the galaxies were a little closer together. A thousand years or ten million years ago they were still closer. If we assume that the velocities of recession have remained constant in the past, it should be possible to go back in time and establish, for any date, the general aspect of the universe. Eventually a state must be reached when all the galaxies were crowded into an exceedingly compact mass; this would be the zero hour marking the start of cosmic expansion.

Up to a few years ago, such methods of calculation were entangled in a perplexing contradiction. Measurements of the velocities of galaxies in conjunction with their distances led to a time scale of less than two billion years for the universe, whereas the clock of radioactivity assigned an age of almost four billion years for the crust of the earth. How could a universe that is two billion years old contain rocks twice that age? However, the perplexity has been cleared up by Walter Baade's recent findings, with the aid of the 200-inch telescope, that distances between galaxies must be at least two or even three times greater than Hubble's former estimates.[37]

Adoption of this new distance scale, along with corrected knowledge of the speeds of galactic flight, has resulted in more accurate measurements. The origin of expansion took place five or five-and-a-half billion years ago.[38] Computations and estimates vary somewhat, but all

[36] Ryle, *art. cit.*, p. 220.

[37] See Abell, "Exploring the Farthest Reaches of Space," *National Geographic* 110 (1956) 785.

[38] Robertson, *SA*, p. 80; Gamow, *SA*, p. 145.

pertain to the same order of magnitude and are accepted by the great majority of scientists competent in the matter.[39]

Allowance has to be made for the probability that relative velocities may have changed in the immense eons of the past. Interactions among galaxies, especially in the earlier stages of their recession, may well have caused variations in their mutual flights. Particularly the pull of gravity should retard their speeds.[40] Yet the figures given are remarkably close to appraisals of the age of the universe arrived at by other methods. In any case, the extreme values admissible for reckonings based on galactic recession range from three billion, a less likely alternative, to six billion years.[41] This time scale represents the duration elapsed since the universe was in a state of high condensation, without implying any chronological forays into the dim region possibly preceding that state. Future researches will undoubtedly achieve greater precision.

THE MAIN THEORIES

Guided by observations, science has shown that the universe is evolving and that some memorable dates mark the beginning of a number of events fundamental to its history. As Kepler, starting with the observations of his predecessors, determined the structure and laws of the solar system, may it not be possible, utilizing facts assembled by more recent research, to reconstitute the world's initial state and fix the date of its birth? A universe in expansion necessarily implies a zero instant which is the point of departure for galactic dispersion, for space, and for time.

State of Primordial Matter

The several essays that have been attempted are dominated by the same directive idea of the profound unity of the universe in space as well as in time. One of the most coherent and widely accepted theories, at least in general outline, is Lemaître's hypothesis of the primitive atom.

[39] Öpik, "The Time Scale of Our Universe," *Annual Report of the Smithsonian Institution* (1955) p. 221, gives 4.5 million years.

[40] Cf. Robertson, *art. cit.*, p. 81.

[41] Öpik, *loc. cit.*

1. **The primeval atom.** On foundations laid by the Russian mathematician, A. A. Friedman, and the American astronomer, E. P. Hubble, Canon Georges Lemaître, astronomer and professor at the University of Louvain, developed his famous theory of the "primeval atom."[42] He proposed that at a point of departure not longer than ten billion, and more probably about five billion, years ago the entire matter and energy of the universe were concentrated in a highly compressed and extremely hot superatom or primeval nucleus with a radius of a fraction of a light-year, perhaps only some ten light-minutes, or a volume equal to that of our solar system. This was "the egg from which the universe was hatched." There were then no chemical elements, no stars, no galaxies. The density, temperature, and pressure of this primordial matter were prodigious.[43]

This monster atom or nucleus was a single thing, without void or separation. It contained all the matter out of which future celestial bodies would be formed, and all the mechanisms that would cause their birth. It existed in a preatomic state, preceding all subdivision into atoms and even, perhaps, into electrons, protons, and nucleons.

Lemaître, Gamow, and others think that the universe emerged from the primeval atom, not by a process of tranquil evolution, but by a colossal explosion. Because of its radical instability, owing to its radioactive constitution, it burst violently asunder and hurled forth its parts into space. A succession of disintegrations followed, resulting in the formation of a gas consisting of high-energy particles. As this matter expanded and thinned out, it gradually, over the ensuing millions of years, cooled down and reaggregated into stars and galaxies, eventually forming the universe as we know it today.[44]

Lemaître's speculations are recommended by their internal coherence and scientific base. The theory accounts well for the observational properties of the universe, such as the powerful rotations that animate celestial systems from the revolutions of spiral galaxies down to the

[42] G. Lemaître, *L'Hypothèse de l'atome primitif* (Neuchâtel, 1946). See also his *L'Univers* (Louvain, 1951).

[43] The astronomer, C. F. von Weiszäcker of Göttingen, similarly supposes that the universe took its beginning from a primitive star (*Urstern*), which had a temperature of 230 billion degrees centigrade, density 40 billion kilograms per cm^3, pressure 760 times 10^{24} atmospheres. Cf. A. Unsöld, "Kernphysik und Kosmologie," *Zeitschrift für Astrophysik* 24 (1948) 24, 296, 302.

[44] G. Gamow, "The Evolutionary Universe," *SA*, p. 145.

gyrations of planets. At the time he proposed it, he remarked that a definite judgment on the value of his arguments could not yet be given; difficult calculations had still to be made and the hypothesis had to be subjected to further experimental tests. He hoped that the great Palomar telescope would furnish new data.

Such data have been forthcoming. Red-shift studies indicate that the universe is steadily slowing down. Since light received from remote nebulae is a flashback to earlier times extending to more than a billion years ago, its red-shift should show the most distant galaxies receding from us faster than those which are much closer to us. For if the universe began with an explosion, its rate of expansion must have been greatest at the start and has been decelerating ever since, because the braking effect of gravitational attraction has been overcoming the original explosive force. Accumulating evidence indicates that this has actually been happening.[45]

2. **Diffuse gas.** A less abrupt beginning of the universe is favored by Arthur Eddington. He represents the primordial state as an extremely diffuse and uniform distribution of protons and electrons, filling all of spherical space, with a density of about one proton and one electron per liter. For an exceedingly long time the vast mixture remained in balance, in spite of its inherent instability. At length slight irregularities developed, and evolution was inaugurated. Condensations formed and ultimately became galaxies; then occurred an expansion which automatically increased in velocity until it is now manifested in the flight of spiral nebulae.[46]

Later versions of the theory explain the process of stellar and galactic formation in greater detail. The universe is pictured as consisting at first of a cold, dilute, but turbulent gas of hydrogen atoms, with ir-

[45] A. R. Sandage, "The Red-shift," *SA*, pp. 170-82. Data contributed by radio astronomy point in the same direction; cf. M. Ryle, "Radio Galaxies," *SA*, pp. 204–20. Einstein's mysterious "cosmic repulsion," a hypothetical force supposed to take over when distance had sufficiently evaporated the power of gravitational attraction and to speed receding galaxies with ever-increasing urgency, has been retired from the cosmic scene. Years ago Einstein told Gamow that the cosmic repulsion idea was the greatest blunder he had committed in his whole life; see the latter's article, "The Evolutionary Universe," *SA*, p. 140.

[46] A. Eddington, *The Expanding Universe* (New York, 1933) pp. 80 f.; 4th ed. (1946) pp. 56–59.

regular density. In some of the denser regions, gravitational force overcame the velocity of expansion which was a property of all matter from the beginning. These accumulations became detached from the rest of the primordial gas and began to develop as independent units or "protogalaxies." Within each protogalaxy the denser lumps of matter contracted into stars; as each star contracted under its internal gravitational force, its interior grew very hot and dense. All the while the systems thus being formed started to rotate in consequence of the intermingling of currents in the original gas; as they further contracted they rotated faster and faster and eventually became galaxies of the various types now observed.[47]

Another possibility is that the universe, starting from the same dilute, primordial gas, contracted more and more throughout its entire range until it reached a state of maximum density, from which it rebounded to an unlimited expansion that will go on to an indefinite future.[48] From the moment of this rebound, the history of the world is much the same as in Lemaître's theory.

The Universe in Evolution

The universe is growing. Its radius has increased over what it was a year ago. Next year it will be still larger. Is the recession of the galaxies to continue indefinitely as the universe expands, associating the expansion of space with that of matter? Is the march to go on forever, unidirectional and irreversible?

1. **Expansion forever.** Gravitation is working against expansion, slowing it down. If the velocity of expansion falls below a certain limit, the expansion must eventually be stopped by gravitation, and contraction will set in. In this case, after expansion has attained its maximum, the universe will relapse into its original state of high density. But if the velocity of expansion exceeds this limit, gravitation will have to relinquish its hold and the universe will continue to expand ceaselessly.[49]

[47] J. H. Oort, "The Evolution of the Galaxies," *SA*, pp. 107 f.; cf. Fowler, "The Origin of the Elements," *SA*, p. 88, and "Formation of the Elements," *Scientific Monthly* 84 (1957) 91 f.

[48] Gamow, "The Evolutionary Universe," *SA*, p. 145.

[49] Cf. Öpik, "The Time Scale of Our Universe," *Annual Report of the Smithsonian Institution* (1955) p. 219.

The problem, whether the universe is to expand forever, ought to be capable of solution from the present rate of velocity. For example, if a rocket shot from the earth's surface has a velocity of less than seven miles per second, it can ascend only to a limited height and must then crash back to the earth. But if its velocity surpasses seven miles per second, it will escape the pull of gravitation and disappear into space. The situation of the receding galaxies is similar to that of the rocket, except that billions of them are escaping from one another; and the rate of their flight is seven times more than is required for their mutual permanent escape.[50] Hence we can infer that the expansion of the universe will never come to a halt.

2. **Endless oscillation.** However, this conclusion is subject to a grave reservation. The estimate of the velocity of receding galaxies necessary for mutual escape relies on the assumption that most or practically all the mass of the universe is concentrated in them. If the regions of space between galaxies should contain matter surpassing galactic matter by more then sevenfold, the conclusion would have to be that the universe is pulsating. That is, when it had attained a maximum possible expansion, it would begin to shrink and curl back on itself until it would be reduced to a state of maximum density, such as that of atomic nuclear material, which is a hundred thousand billion times denser than water.[51] After that it would again begin to expand, and so on in endlessly repeated rhythm, passing successively from expansion to condensation and from condensation to expansion in perpetual pulsation or oscillation.

Views concerning this possibility have changed since Eddington's frequently reiterated assurances that he knew of no one who seriously entertained such a theory, which he himself regarded as a nightmare.[52] Present data strongly suggest that the universe is slowing down at such a rate that expansion must eventually stop and contraction begin. This rate depends on the mean density of the world's matter, for the higher the density the more insistent the braking effect it exercises. Matter in the form of hydrogen may be present in intergalactic space and still

[50] Gamow, "The Evolutionary Universe," *SA*, pp. 145 f.

[51] *Ibid.*

[52] Cf. A. Romaña, "The World: Its Origin and Structure in the Light of Science and Faith," in J. de Bivort de La Saudée (ed.), *God, Man, and the Universe* (New York, 1953) p. 67.

have eluded detection, since it is not luminous. So far, however, there is no indication of the existence of such matter, although the great radio telescopes now being built or planned may ultimately discover it.[53]

If present estimates of distances between galaxies are sound, and if tentative findings that the expansion of the cosmos is decelerating should be confirmed, we have reasonable grounds for concluding that we may be living in an oscillating universe.

Steady-state Universe

A major controversy in contemporary cosmology circles around the question whether the universe is evolving or is in a state of eternal equilibrium. Most cosmologists favor the evolutionary view, that in the remote past, some five or more billion years ago, an event occurred which was either the creation of the universe or at least the inception of the present cosmic epoch. But since 1949 a group of cosmologists at the University of Cambridge has advocated a theory of a steady-state universe. Among these, Fred Hoyle takes an approach which is mathematical and develops within the theory of relativity. H. Bondi and T. Gold rely more on a "cosmological principle," according to which the large-scale features of the universe are the same no matter from what point in space or moment of time they may be observed; hence the world has eternally presented the same general aspect as it exhibits today. The mean density of this homogeneous universe has never varied.

This hypothesis does not deny either the principle of degradation of energy, which, however, is reduced to a merely local significance, or the escape of galaxies from our range of observation into infinite space as their speeds attain the velocity of light. Receding galaxies are replaced by new ones which are constantly being formed at a rate exactly compensating for the departure of older galaxies, so that a stable situation is always preserved.[54]

To maintain this equilibrium, new matter in the form of hydrogen atoms must continually be created. Such creation is going on everywhere throughout space, at an average rate of one atom a year in a

[53] Gamow, *art. cit.*, p. 146; Sandage, "The Red-shift," *SA*, p. 180; cf. Öpik, *art. cit.*, p. 220.

[54] F. Hoyle, "The Steady-state Universe," *SA*, p. 157.

volume equal to the dimensions of St. Paul's Cathedral in London. Slow as this rate may seem, the quantity of new material appearing each year is enormous, for it amounts to a hundred nonillion (10^{32} or 1 followed by 32 zeros) tons per second. When sufficient hydrogen has gathered in various regions, condensation begins, and the core of a new galaxy takes shape. The core grows by incorporating atoms that are steadily being created. Stars form within the nebula in the normal way, so that it gradually develops features like those of our Milky Way. The distance separating it from its neighbors increases, for expansion takes place between galactic systems, not within individual galaxies.[55] Thus the universe is perpetually expanding at an undeviating rate, and new galaxies are unceasingly being born. Accordingly the theory of continuous (more exactly, constantly repeated) creation does not suppose either origin of time or initial explosion. Indeed, any question about the beginning of the world is meaningless.

Hoyle alleges in favor of the hypothesis the fact that the universe is composed almost entirely of hydrogen. This would be impossible if matter were infinitely old, for hydrogen is being steadily converted into helium and other elements throughout the universe; if all the material in the world were infinitely old, there could be no hydrogen left.[56] Hence he is led to conclude that the hydrogen we are able to observe originated in finite time and has not yet been converted into heavier elements. It has been created at a constant rate during infinite time and is still being created today at the same rate.[57]

This whole argumentation collapses if the world's hydrogen is not "infinitely old" but was created all at once at the beginning of time, or if the universe is pulsating. Other objections against the steady-state proposal are many and vehement. Theories involving continuous creation are purely gratuitous and lack scientific foundation or support.[58] The continuous creation of matter is a mere possibility, serving no other purpose than that of denying a temporal origin to the universe. Besides, it requires retention of "cosmic repulsion," which Einstein, inventor of this hypothetical force, disowned many years ago, and which is a theoretical superstructure not required by observational

[55] *Ibid.*, p. 158; Hoyle, *The Nature of the Universe* (Oxford, 1950) p. 106.

[56] *The Nature of the Universe,* pp. 106 f.

[57] "The Steady-state Universe," *SA*, p. 158.

[58] P. J. McLaughlin, *Modern Science and God* (New York, 1954) p. 66.

evidence.[59] Moreover, the "cosmological principle" which demands that, on the large scale though not on the small (where it could be tested), every part of the universe must be the same as any other, and that the general appearance of the universe must be eternally uniform, is quite arbitrary. The only reason for supposing the creation of new matter is the necessity of safeguarding this principle, which may not be violated because a few mathematicians would thereby be displeased.[60]

Apart from other reasons, the theory is highly questionable because of the fact that galaxies in our general vicinity seem to be of the same age as the Milky Way,[61] and in particular because elliptical galaxies, consisting exclusively of very old stars, do not exhibit the age variations which the steady-state notion postulates. In his own defense, Hoyle points out that measurements so far made are not sufficiently sensitive to determine the ages of galaxies.[62]

The count of radio sources indicates that the density of galaxies increases with distance from the earth. This disparity argues against the contention of the steady-state hypothesis that the density of matter throughout the universe remains constant; for the radio signals now being received from distant collisions of galaxies started on their way toward us billions of years ago, thus intimating that the universe was then denser.[63] However, the radio astronomer B. Y. Mills in Australia questions this evidence.[64] Perhaps the strongest scientific argument against the steady-state theory comes from the red-shift studies being made by astronomers in California. The most remote clusters of galaxies, well over a billion light-years away, are receding much faster than in proportion to their distances, showing that the universe was expanding more rapidly a billion years ago than it is now. These data indicate that the steady-state model does not square with the real universe.[65] While these findings cannot yet be regarded as definitive, Hoyle himself acknowledges that they constitute "the most serious potential contradiction of the steady-state theory."[66]

[59] Öpik, "The Time Scale," pp. 222 f.
[60] H. Dingle, "Cosmology and Science," *SA*, pp. 234, 236.
[61] Gamow, "The Evolutionary Universe," *SA*, p. 150.
[62] "The Steady-state Universe," *SA*, p. 166.
[63] Ryle, "Radio Galaxies," *SA*, p. 220.
[64] Hoyle, *loc. cit.*
[65] Sandage, "The Red-shift," *SA*, pp. 180, 182.
[66] Hoyle, *loc. cit.*

Radio astronomy, employing new radio telescopes not yet in use, may be able to contribute toward a settlement of the debate by detecting intergalactic hydrogen. Also, the sky survey which is nearing completion will aid science to weigh rival theories; counting clusters of extremely distant galaxies may reveal whether matter is evenly distributed in space or whether its density varies.[67] At any rate, hope that solution of the cosmological problem may be within reach appears to be well founded.

More probing than any scientific argument is the philosophical criticism of a feature essential to the steady-state theory as advocated by its champions. They strongly insist that no cause must be invoked to account for the continuous creation of matter, which "simply appears" or "materializes" out of nothing.[68] No greater act of faith in the sheerly incredible has ever been made. The philosopher, reared on the principle of contradiction, can only shudder at the assertion of an uncaused origin of matter. The very concept of creation becomes utterly unintelligible if God the Creator and the purpose of creating are eliminated.

THE UNIVERSE: TEMPORAL OR ETERNAL?

This brief review of contemporary researches into the origins of the universe brings out the clear fact that the investigation is being conducted by scientific men in a scientific manner. Every year witnesses new developments in the perfection of scientific equipment and apparatus which extend the areas of observation; and observation is indispensable for testing the validity of hypotheses.

As a result of these studies, we know that the universe cannot have existed forever in the form which astronomy exhibits today. A striking convergence of proofs, based on inspection of radioactive elements, our own earth and solar system, meteorites, double stars and star-clusters, the Milky Way, and all the billions of galaxies within the range of our latest optical and radio telescopes, points to an age of some five or six billion years, certainly less than ten billion years, for the cosmos in its present organization. The very convergence of dates, arrived at

[67] Abell, "Exploring the Farthest Reaches of Space," *National Geographic* 110 (1956) 787.

[68] Hoyle, *The Nature of the Universe*, p. 105; "The Steady-state Universe," *SA*, p. 160.

by diverse methods bearing on diverse objects, guarantees this order of magnitude against grave error. All the procedures employed to measure the age of the universe flow together toward an initial hour of time. Reflection on this conclusion leads inevitably to the momentous question: Does this zero hour mark the origin of matter by creation from nothing, or does it signalize only the beginning of the present world?

Adherents of the steady-state proposal do not have to face this question; their hypothesis of continuous creation of matter is able to dispense with a finite duration of the universe. If the theory is exorcised of the metaphysical horror of spontaneous creation so as to acknowledge a Creator, it represents an alternative that does not appear wholly impossible; yet any observational evidence alleged in its favor admits of other, and perhaps better, explanations. In the view of the majority of astrophysicists and cosmologists, our universe had an initial instant. Their studies take them back to a moment when there were no atoms, no elements, no earth, no planets, no sun, no stars, no interstellar clouds, no galaxies. That moment, the ultimate frontier reached by science in its retrogressive tracing of the world's development, defines the start of cosmic evolution.

Is this beginning the emergence of matter from nothing at God's command, or is it only the inception of the present structure of matter? Is the beginning absolute or relative? Science has a right to attempt an answer, for science, when confronted by the insufficiency of a present datum, translates such insufficiency into the affirmation of an antecedent. Back of every state, even that which it qualifies as initial, it searches for another that may go before. Failure to search for it would be a betrayal of the scientific mind. If the initial instant thus far attained turns out to be intrinsically and perpetually insuperable, the scientist ought to invoke God's creative act. If the barrier can be surmounted, the march into the past should be resumed until it is blocked again.[69] We ought not to point to the original act of creation except where it is really to be found.

Some scientists, who accept the time scale established by the procedures outlined, regard it as the absolute age of the universe, which

[69] Cf. Mersch, "L'Origine de l'univers selon la science," *Nouvelle revue théologique* 75 (1953) 251.

consequently was created out of nothing on the date that has been tentatively fixed. The supposition that matter or energy existed previously in an inert condition and was suddenly galvanized into activity at a definite moment is judged to be groundless. What could have designated that instant in preference to all the other past instants of eternity?[70] What was the cause of the awakening from eternal lethargy?[71] If the cause that had the power to rouse the embryonic world from a dormant state existed forever, it should have been operative forever, for inanimate causes act necessarily; in that case, the expansion of the universe should have begun from eternity, which is contrary to all the findings of science and besides plunges us into an abyss of absurdities.[72] Furthermore, since the neutrons from which the elements were built have a brief life and cannot exist indefinitely in the free state, they must have come into being by a creative act only a few hours before the formation of the elements.[73]

Whatever may be the validity of these views, search into the past guides us to a stage that marks the inauguration of all evolutionary processes at work in the universe. The cosmic event that then occurred need not, in the opinion of reputable scientists, betoken an absolute beginning. Although the nebula of primeval gas, which in Eddington's theory preceded the expansion of the universe, could have existed indefinitely, it could also, and equally well, have been the first thing created from nothing. Lemaître's primitive atom, on the contrary, can perhaps be best explained as the product of creation; but it could also have been the end result of the collapse of a prior universe.[74] In this assumption, the expansion now going on is an elastic rebound that started as soon as the maximum possible density had been effected by contraction, when all the matter of the universe was so compressed that any structural features it had possessed before the collapse were entirely wiped out, so that even atoms and their nuclei were broken up into the protons, neutrons, and electrons that compose them. Since such

[70] E. T. Whittaker, *The Beginning and End of the World* (Oxford and London, 1943) p. 63.

[71] Stein, "L'Universo, donde?", *Civiltà cattolica* 100 (1949) 263.

[72] Romaña, "The World: Its Origin and Structure in the Light of Science and Faith," p. 67.

[73] De Dominicis, "La fisica nucleare e la creazione," *Doctor communis* 7 (1954) 225.

[74] Öpik, "The Time Scale," p. 205.

a process cannot be ruled out, no certain conclusion may be derived about the era preceding the collapse.[75] Although we may penetrate to the cosmic explosion that started the universe on its long history of expansion, we cannot get behind it, and therefore we are not compelled to regard that event as following hard on the creation of primordial matter.

Nothing can be so aptly assigned as the cause of the velocities of galactic recession, which approach and may exceed two-fifths of the speed of light, as an explosion from nuclear fluid, the densest known state of matter. But our ignorance of intergalactic hydrogen blocks a decision between two choices: whether the universe is expanding irreversibly, hence forever, or whether it will return to its starting point when gravitational attraction eventually gathers its fleeing parts together again, only to repeat the process, with the collapsed universe rebounding from the elastic forces of nuclear fluid in maximum compression, to inaugurate a new expansion. This course of events can go on eternally, oscillating forever in alternating expansion and contraction. Such an oscillating universe would lose none of its energy, and so could have an unlimited duration both in the past and in the future.[76]

CONCLUSION

Vigorous investigation of the problem has not issued in a definitive solution. The sciences engaged in studying the origins of the universe have reached a stage at which theory tested by observations on the largest possible scale justify a confidence that the main traits sketched in a rough draught of the evolving cosmos will not have to be erased. Future advances will certainly modify present views and eliminate some hypotheses. In particular, the copies of the Palomar Sky Atlas to be distributed to observatories in every region of the globe within the next year or two will be intensively studied by astronomers. New discoveries will come forth and new avenues of research will be opened.

The divergencies noted in the views of scientists invite an attitude of reserve. The value of researches, involving that of conclusions, depends on the facts that support them and the methods of deduction that are

[75] G. Gamow, *The Creation of the Universe* (New York, 1952) p. 29.
[76] Öpik, *art. cit.*, p. 223 f.

employed. The facts are not completely known, and the method of extrapolation or extension of physical laws to the entire universe may not be wholly reliable. The farther we get from the area of experience and observation into domains that dim to the vanishing point, the more does the jurisdiction of such laws dwindle. We know for certain that our little earth and the sun and the stars and the galaxies did not always exist, and we have a good idea of their approximate age. But is all this the universe as such, the whole of creation? No one would dream of an affirmative reply. All that we now observe, even with telescopes that project their monstrous eyes and ears to a distance of two or three billion light-years, may be no more than a single metagalaxy, a single unit in a hierarchy of like systems forever beyond our range. We can never be absolutely sure that the expansion we perceive may not be restricted to this great system, with the possibility that conditions outside it may be radically different.

Science cannot answer all questions, and many scientists think that the question about what preceded the origin of the known universe exceeds its competence. Its point of view is not wholly adequate, and its manner of searching and finding is not that of philosophy, still less that of theology. It has not demonstrated the first day of the world. Even the hypothesis of an initial state of extreme concentration, beyond which science has nothing certain to say, fails to demonstrate a beginning. Something behind that state is at least conceivable, for matter may have endured in a state that simply eludes us. Theories pointing to a finite past may well be embraced as most probable, but no rigorous course of reasoning permits science to eliminate all other hypotheses.

Solution of the problem, whether the universe has a finite or an infinite duration, belongs to another order of thought. Is this the order of philosophy? St. Thomas Aquinas did not think so, and throughout his productive career, on seven different occasions, he undertook to show that arguments drawn up to prove a temporal universe are inconclusive; while human reason can prove that the universe was created by God, the fact that it has not existed forever is known to us by revelation alone.[77] Although philosophers who preceded him were

[77] *Sum. theol.* 1, q. 46, a. 2: "Mundum non semper fuisse sola fide tenetur, et demonstrative probari non potest."

confident that they could demonstrate that the world had a beginning, those who came after him have in the main agreed with him.

Without revelation, we could not be sure whether we are living in a temporal or an eternal universe. This verdict harmonizes with the appraisal given by Pius XII in his address delivered November 22, 1951, to the Pontifical Academy of Science in Rome: "It is quite true that the facts established up to now do not constitute an absolute proof of creation in time, in the way that arguments drawn from metaphysics and revelation alike demonstrate creation as such, and those based on revelation prove creation in time." And the reason is that solution of the problem requires an order of "argumentation that of itself is outside the proper sphere of the natural sciences."[78]

However, we do know by means of scientific procedures that a number of cosmic events preceded the formation of our earth. Will that knowledge arouse any religious misgivings? The thought would hardly occur to a theologian, but it seems to have occurred to a scientist:

> Since Copernicus we have not believed our earth to be central in the solar system; in recent times, we have found that our sun is not central in the galaxy. If we accept the point of view of the synthesis of the elements in stars, then we see that the sun and the earth are not central in time—that is, that they did not originate at the beginning of our galaxy. The philosophic and religious consequences of this removal of the last vestige of our intuitive geocentric concepts can be readily imagined.[79]

I am not unacquainted with philosophy and have devoted my life to religion; yet, try as I may, the only consequence I can imagine is simple acceptance of any facts, on any plane of truth, that have been established.

The important religious truth is not the cosmic location of the earth or its age relative to the antiquity of other parts of the world, but the fact that the Incarnation of God's Son, crowning all creation, has endowed our tiny planet with a worth exceeding that of the rest of the universe, and has invested time with the value of eternity.

[78] *AAS* 44 (1952) 41.

[79] Fowler, "Formation of the Elements," *Scientific Monthly* 84 (1957) 99.