THE ORIGIN OF THE UNIVERSE

AUGUSTINE WALLACE, O.P., AND MARK JOSEPH DAVIS, O.P.

PART I—THE SCIENTIFIC ACCOUNT

THE PAST FEW YEARS have seen a growth of interest in scientific theories concerning the origin of the universe. This interest has been manifest both in articles appearing in technical journals for scientists themselves, and in more or less popular articles in magazines addressed to the general reader. Although the technical articles refrain from any mention of the parallel scriptural account or the theological implications in their theories, several popular articles have indicated a trend that is rather surprising to those who have always seen a conflict between modern science and religion. The surprising thing is that it is not infrequent now to see an allusion to the account of the creation of the world in Genesis as confirmatory of modern scientific theories of the origin of the universe. It is difficult to ascertain the source of this new attitude. It might be that it has not come so much from scientists as from those who are interested in effecting a *rapprochement* between science and religion; but it is significant that scientists are not opposed to this linking of what hitherto had been regarded as irreconcilable accounts of the same event. The effect of this endorsement, tacit though it be, has been to produce a reaction among the common people that is, on the surface, a good one: modern science confirms the truths of religion. "Good," says the average Catholic, "that's just what we always thought—if they worked at it long enough, they'd find that the Bible was right after all." And to one who knows little about the Church's interpretation of the account in Genesis, and even less about modern scientific theories, this naive view is satisfying and conclusive.

But what of the educated Catholic, the college or university student who has the intellectual endowment to afford an opinion in these matters? What is he to think of an attempt to link up any scientific theory with the divinely inspired account of the creation of the world in Sacred Scripture? The Bible is not a textbook of science, all are agreed on that. Yet the Biblical ac-

count of creation is not a fairy-tale either; according to the responses of the Pontifical Biblical Commission[1] and the recent encyclical, *Humani Generis*,[2] the first eleven chapters of Genesis pertain to history in a true sense. If so, it appears that both Sacred Scripture and modern science have reference to the same historical event. But how can the modern technical terms of any scientific description be reconciled with an historical account written thousands of years ago for a primitive people? Is the account in Genesis to be taken literally, giving the words the same sense as modern English? If not, what do the words of the inspired writer mean? Or, approaching the problem from the other viewpoint, can a Catholic have a scientific opinion that conflicts in any way with the Bible? Can he think one thing as a scientist, and believe the opposite as a Catholic? Or, if he senses a conflict, must he refuse to entertain any opinion at all, and simply close his mind entirely to any scientific thought about such a question as the origin of the universe?

These are difficult questions, and no simple answer to them can be given. But there is a real problem here, and it is a problem that can be clarified by discussion. With this end in view, therefore, we intend to outline the main points that must be taken into consideration in any attempt at an intelligent solution. As the reader will understand, it is necessary to come down to particulars, so we have selected a recently proposed theory of the origin of the universe for our detailed discussion. Before presenting this theory, however, a survey of the developments of modern science that preceded and led up to it will give a background for a better understanding of the problem.

THEORIES OF THE SOLAR SYSTEM

It is common knowledge that the first serious rift between the teachings of scientists and those of Sacred Scripture came about as a result of the Copernican revolution. Galileo became involved in serious difficulties because he strongly advocated the heliocentric theory, which was believed by theologians of his day to be opposed to the description of the universe contained in the Bible. After him, a pronounced dichotomy began to appear be-

---

[1] Cf. Letter of J. M. Voste, O.P., late Secretary of the Biblical Commission to Cardinal Suhard. Eng. trans. in *Homiletic and Pastoral Review*, vol. 48 (1948), p. 572. Also replies of the Commission, 30 June, 1909; Denz. 2121-2127 (E.B. 332-338).

[2] N.C.W.C. edition, p. 18, sect. 38.

tween scientific and theological thought on this subject. But scientists continued to elaborate Copernicus' theory of the solar system, and to see in it many implications as to the past and future history of the universe. It is difficult to determine when speculation about the origin of the universe in accordance with this theory began, but historians accord the first development along these lines to Immanuel Kant. Known for his ability as a physicist and mathematician long before he achieved fame as a philosopher, Kant suggested in 1755 that the planets and sun were formed from a single large rotating gaseous cloud or nebula. This nebula, which gives the name of "nebular hypothesis" to Kant's theory, was then supposed to have condensed into smaller rotating parts, and these further condensed into rotating planets with their satellites. No mechanism was posited as an explanation for the rotation and condensation; only a more or less qualitative description was given. But the suggestion was productive of further thought, and in 1796 Laplace, the French astronomer and mathematician, announced an elaboration of the nebular hypothesis that was accepted by the scientific world for over a century. He introduced a fundamental notion from classical mechanics, that of conservation of angular momentum, and prepared the way for placing Kant's hypothesis on a physico-mathematical basis. In the beginning, Laplace said, the gas was hot and the nebula was spinning slowly, but as the gas cooled it contracted, and therefore, being of smaller size, increased its spin in accordance with the law of conservation of angular momentum. As the spin increased, rings of gas were thrown off from the rotating mass by centrifugal action, and these rings finally condensed to form the planets, while the original hot mass became what we know as the sun. So universal was the accord given to this explanation over a long period that it is usually the one found in philosophical textbooks as the modern scientific view of the origin of the universe.[3]

Scientists themselves, however, continued to speculate about the more precise details of the solar system, and by the beginning of the twentieth century, a new hypothesis had appeared that was opposed in some respects to the nebular hypothesis. This became known as the "planetesimal hypothesis," largely because it posited that the earth and the planets were built up by an ac-

---

[3] Cf. J. Gredt, O.S.B., *Elementa Philosophiae Aristotelico-Thomisticae,* Vol. I, No. 361, 3.

cretion of cold particles, or planetesimals, that were moving around the sun under its gravitational attraction. Chamberlin and Moulton, the American scientists who proposed this in 1900, thought that the planetesimals probably originated from a near-collision between another star and our sun. This occurrence gave rise to tidal waves producing great eruptions on the sun, and the ejected solar material later condensed into small planetoids. No consideration was given as to how the sun or the other stars got there originally; the main point was one of explaining the details of the solar system. This explanation, however, would not stand up under physical canons, and it was modified in 1917 by Jeans and Jeffreys, the famous British astronomers, who calculated that such eruptions would not take place unless the intruding star sideswiped the sun, peeling off a long filament of solar material which then condensed into planets. Since this filament would be thicker in the middle than at the ends, it would account for the progression in planet sizes; for the planets, according to astronomical measurements, show a general increase in diameter from Mars to Jupiter, and then begin to decrease again in size. But even this theory had limitations, as H. N. Russell showed at Princeton in 1930, when his mathematical calculations revealed that such a phenomenon would not give the filament sufficient angular momentum to account for the present observed angular momentum of the planets. Spurred on by this development, one of Russell's students, Lyttleton, was led to assume in 1936 that the sun originally had a close companion spinning around it. If this were sideswiped and carried away by a third star, then a filament might be left moving around the sun with sufficient angular momentum. Before this proposal could gain much ground, however, all speculation about the planetesimal hypothesis came to a sudden close when Spitzer, another of Russell's students, calculated in 1939 that any material pulled out of the sun, or any other star, could not condense into planets or planetesimals, but would expand with explosive violence to form a tenuous gaseous nebula. This brought astrophysicists back to the nebular hypothesis, which meanwhile had also developed.

The growth of physical science in the century after Laplace's contribution supplied astronomers with powerful instruments for physico-mathematical theorizing, but it also enormously complicated their theories, and rendered them unintelligible to anyone except those with highly specialized training. For this reason, it will not be profitable for us to trace the exact develop-

ment of the nebular, or gas hypothesis. The highlights of this development, however, were the following. In 1914 a Norwegian physicist, Birkeland, calculated that electrically charged particles shot out from the sun would spiral out in the sun's magnetic field to definite circular orbits, at distances depending on the charge-to-mass ratio of the particles. This was developed in 1930 by the Dutch meteorologist, Berlage, who assumed that the particles were charged atoms and made more detailed calculations. Using the background of these investigations, Alfvén, a Swedish physicist, was able to predict in 1942 that rings of gas, with sufficient angular momentum, would be formed around the sun as the sun moved through the surrounding nebula. Finally, in 1945 Weizsäcker, the German physicist, investigated in detail the vortex motion of a large cloud of dust and gas in rotation about a massive central body like the sun. His calculations showed that while most of the gas would escape into outer space, planets could be formed by the accretion of gas particles over a period of a hundred million years. At the present writing, this theory holds favor with astrophysicists and is believed to be the best scientific explanation of the formation of the planets that make up our solar system. The assumptions are many, the calculations are tedious, but the picture is the best that modern science has to offer.

Most of this development, of course, took place with very much of an estranged attitude between scientists and those who depended on the Sacred Scriptures for their knowledge of the origin of the world as we now know it. Philosophers and theologians continued to keep an eye on the general picture, however, and while pointing out that the Laplacian theory, with its later ramifications, was strictly hypothetical, and also allowing that the account in Genesis need not be taken literally, for the most part endorsed a limited acceptance of certain aspects of these theories.

THE EXPANDING UNIVERSE

The year 1925 saw the introduction of new evidence that was to work toward a more fundamental reconciliation of the historical opposition between the two viewpoints. In that year, the American astronomer, Hubble, finished detailed spectroscopic study of the spiral nebulae at Mount Wilson Observatory in California, and deduced that the more distant spirals were receding from us more rapidly than the closer ones, and that the speed of their retreat was in direct proportion to their distance from us.

Tracing the motions back in time, he indicated that all the spiral nebulae would have been near our galaxy between two and three billion years ago. This development was taken up by the English astronomer, Eddington, in his theory of the expanding universe. Leaving aside complicated relativity considerations, we may summarize this by saying that he considered that the universe had its origin from the explosion of a cosmic "egg" and that products of this explosion have continued to expand for the past few billion years. This theory is somewhat confirmed by geological evidence, based on relative abundances of lead and helium in uranium deposits at various places in the earth's strata. The analysis of such data indicate that the earth's temperature and atmosphere have not changed radically in the past three billion years. These and subsequent developments have been seen by many interpreters to imply the "creation" of the universe somewhat over three billion years ago. Since that time, it has been expanding from a common point of origin, they say, and has concomitantly undergone a gradual evolution in accordance with the operation of known physical laws.

Up to this point, the existence of stars has been assumed in our discussion of planet formation. Now the question arises: how did the stars get there in the first place? By way of an answer to this, we shall here make brief mention of the theorizing on the subject of star formation. Our own sun, which is a star, is known to be radiating energy at a truly enormous rate. In fact, if the source of the sun's energy is the conversion of four atoms of hydrogen to one atom of helium, as is commonly believed in accordance with the proposal of Hans Bethe at Cornell, the sun could not have been doing this for much over three billion years —a point, incidentally, that ties in with the expanding universe theory. But there are many hot, bright stars, known as supergiants, that are radiating so fast that they could not have existed for more than ten million years. Concern over this problem led Spitzer, in 1947, to propose a theory of star origin that has been accorded general acceptance by most of the moderns. Spitzer showed theoretically that diffuse gas and dust observed in the spiral nebulae could, under some circumstances, be compressed by the pressure of radiation from other bodies, and thus condense into a star. This theory, again based on tenuous assumptions and complicated calculations, suggests a picture of star formation that is regarded as the most plausible account given by modern science. Taken with Weizsäcker's theory of planet

formation, it is complementary to the latter, and furnishes a more or less complete scientific explanation of the origin of the solar system.

Now there was nothing much in these developments that added to the basic difficulty of reconciling the Laplacian nebular hypothesis with the account of the creation of the world given in the Book of Genesis. Yet there was latent in them certain difficulties which prompted more fundamental considerations by contemporary physicists, and led to a theory that has been hailed by some as resolving many of the formerly irreconcilable elements of the scriptural and scientific accounts. The new theory grew out of an attempt to answer the twofold question: what was the material of which the primordial gas or cosmic "egg" was formed, and what mechanism could have resulted in conditions propitious for both star and planet formation? The answer to this, which we shall describe presently, was suggested by Bethe, Gamow and Alpher in a letter to the *Physical Review* in 1948. Although presented originally as a theory for the origin of the elements, it has recently been extended to give a comprehensive theory of the origin of the universe. And, by a strange, unexpected development, it has elements that are somewhat in accord with the description of what happened "in the beginning," as recounted to us by the inspired author of the Book of Genesis.

ORIGIN OF THE ELEMENTS

In the account of the structure of matter that is at present taught in high schools and colleges, all material things are regarded as made up of various proportions of ninety-odd types of atoms arranged in particular chemical combinations. These atoms, which are the smallest particles of an element exhibiting the properties of that element, are in turn composed of a nucleus and surrounding electrons, and differ from one another in having a characteristic nuclear structure and a particular number of electrons. Recent cyclotron and atom-pile investigations have been directed primarily at finding out more about the structure of the nucleus, and several interesting things have been learned in the past two decades. One is that all nuclei are made up of two types of particles: protons and neutrons. Another is that if one of these type particles, for instance the neutron, is used to bombard nuclei of a particular element at high energies, the nuclei will under certain conditions absorb a neutron and be converted to a heavier element. Thus, by successive neutron absorptions,

referred to as "neutron captures," the nucleus can be made bigger and bigger, and finally, if conditions are suitable for picking up additional electrons, the substance can be transformed into a different, heavier element.

Apart from the studies of this type on the structure of matter, there has also been a considerable amount of work done in ascertaining the relative abundances of elements in the earth, the planets, the stars, and summing up, the universe as we know it. This research has shown that a simple relationship exists between the abundance of an element and its nuclear structure. Without resorting to graphs and technical considerations to give the exact correlation, it may be observed that the most abundant elements are the light ones, and that as the elements get heavier and heavier, and have a more complex structure, they are correspondingly less abundant. This peculiarity, taken in conjunction with the possibility of elements being "built-up" by successive neutron captures, has suggested to scientists a rather startling hypothesis: maybe the present distribution and relative abundances of the elements is not just a freak of nature, but the result of an evolutionary building-up process by which the elements were actually formed. If, for some reason or other, this building-up process were stopped before the majority of elements reached a state of complex structure, there would be a good reason why the relative abundance data are as they are.

The final link in the chain that was to weld the new theory together was the discovery, made in one of the government's nuclear laboratories, that neutrons, as they exist outside the nucleus of an atom, are radioactive, and decompose into a proton and an electron after an average lifetime of about thirty minutes. This fitted in well with other data on radioactivity, a phenomenon that has been found to be associated with the deterioration of nuclei over a period of time. In such radioactive transformations, it has been noted that there are changes in the relative numbers of protons and neutrons making up the nucleus; frequently neutrons seem to be converted into protons, and when this occurs there is observed to be an emission of electrons from the nuclei involved. So if it were possible to conceive of some mechanism whereby primeval neutrons could be partially converted into protons and electrons, and then all three particles regrouped together, so that the generation of various elements and their compounds could be explained in terms of corresponding neutron-proton-electron configurations, there would be left a very

simple evolutionary theory as to the origin of the elements.

Such a mechanism was the one proposed by Bethe, Gamow, and Alpher. In the beginning, they said, the earliest stage of matter was a highly compressed neutron gas. This gas was made up of neutrons, travelling in random directions with great energy and colliding with one another, in a condition described in accordance with the kinetic theory of gases as "thermal chaos." This overheated, neutral nuclear "fluid" at first was radiating only thermal energy, but then it began to expand, or perhaps it would be better to say that it exploded, because the expansion was a violent one. Accompanying the expansion, there was a drop in temperature and pressure which continued until conditions were satisfactory for the neutrons to decompose radioactively into protons and electrons. The first stage of the decomposition lasted for only a few minutes, and in that period a large number of protons, or hydrogen nuclei, were formed. These too were agitated in a state of thermal chaos, and collided both with each other and with neutrons that had not as yet decomposed. When, as a result of the expansion, their average energies reached a point where neutron capture could come about, some of these protons picked up neutrons through collisions, thus forming deuterium (or heavy hydrogen) nuclei. Some of the latter, in turn, also underwent neutron capture, and were converted into tritons. This process continued, with each subsequent neutron capture resulting in the building up of heavier and heavier nuclei. Although this seems to be a lengthy process, calculations show that, at the terrific energies and speeds involved, all the elements that make up the universe as we now know it must have been formed in about one half hour from the beginning of the radioactive decay of the neutron gas. Moreover, the general distribution of the elements, in relative abundance, calculates out to be in remarkably good agreement with present evidence obtained empirically. It must be noted, of course, that this distribution was not attained right away; the building up of heavier nuclei must have proceeded just beyond the range of the stable elements, and the present distribution of various atomic species came only somewhat later, as the nuclei adjusted their charges through subsequent radioactive release of electrons. The electrons thus made available were finally picked up by other nuclei hitherto in an ionic state, and the relative abundance figures we observe ultimately resulted. At the end of the first half hour, however, the element building-up process stopped, partly

because the number of available neutrons had been used up, partly because the expansion of the out-rushing gas decreased the probability of collisions resulting in neutron-capture.

UNIVERSE FORMATION

This, then, is the theoretical explanation of how the chemical elements had their origin. But what about the formation of the stars (including our sun) and the planets? That can be explained, too, say the theorists. All you have to do is follow the above process through millions of years, and apply the speculations of Spitzer on star formation, and of Weizsäcker on planet formation, and everything will be found to come out very satisfactorily. Thus, they continue, the stage following the formation of the elements saw the mass of gas continue to expand more or less violently, while the density of radiation decreased as the temperature of the gas dropped. Ultimately a condition was reached where the density of matter exceeded the density of radiation, and then gravitational effects came into prominence. When this happened, the previously homogeneous gaseous matter began to break up into separate clouds, which were later pulled apart by the continuing expansion. This period probably lasted for about ten million years, and culminated in the formation of matter clouds, or whirling masses of gas that are now known as galaxies. The third stage saw these galaxies continue to rush away from each other for about a hundred million years; as they did this, some of the elements which hitherto had existed in the gaseous state began to condense as cosmic dust, and the presence of this dust and radiation pressure set up the proper conditions for Spitzer's phenomenon of star formation. Thus, at the end of the third period, the stars were formed. Finally, the motion of the newly formed stars, moving through the remaining gaseous matter and dust particles in the galaxies, resulted in the formation of planets in accordance with Weizsäcker's theory, over another period of roughly a hundred million years. The end result was the formation of the entire universe at the end of approximately one billion years. This universe has been expanding for several billion years, in addition to the first billion.

Such is the latest scientific description of the origin of the universe. It is more or less complete, includes the best elements of all theories hitherto offered, and is said to be confirmed indirectly (after the manner of verification of all scientific theories) by experimental data obtained from three or four different

lines of investigation. Moreover, as we shall now see, it can be reconciled with the account of the creation of the world in Genesis in a more satisfactory way than any other similar theory.

Now comes the important question. What is this particular tie-up with Sacred Scripture? How can all this very technical talk about neutrons and protons and expanding galaxies be reconciled with the simple, somewhat anthropomorphic account of the inspired writer? The answers to this that have been given to date have come mostly from popular writers, interested either in showing that there is no conflict between science and religion, or in obtaining a scriptural "confirmation" of a scientific theory. As a result, they lack the scholarship and technical detail of the works of professional exegetes, but at least they give some indication of an interpretation that is being imposed on the words of Sacred Scripture. We shall now picture this interpretation, drawing freely on the proposals of previous writers and occasionally supplying details suggested by their accommodation of the Biblical text to the theory just discussed. The resulting exegesis will be amateurish—one certainly that we do not subscribe to—but it will suffice to furnish the general lines of this new scientific interpretation of the account of creation.

SCIENTIFIC INTERPRETATION OF GENESIS

1. *In the beginning God created the heavens and the earth.* This verse describes the formation of the cosmic "egg" from which the entire universe subsequently evolved. Actually the scientific theory can say nothing about "creation" one way or the other, but the theory presupposes the existence of this primordial mass, and it simplifies things for the scientist to say that it was made from nothing. Reference to the heavens and the earth indicate that everything now in the universe was pre-contained in the "egg."

2. *The earth was waste and void; darkness covered the abyss, and the spirit of God was stirring above the waters.* The second verse then describes the state of the nuclear fluid out of which the "egg" was composed. The state was one of thermal chaos, which could have been represented to the Hebrew mind by referring to the earth as *waste and void* with *darkness* covering the *abyss*. The use of the term *waters* suggests the fluid state of the compressed neutron gas.

3. *God said, "Let there be light," and there was light.* The third

verse then relates the beginning of radiation, the first step in the development of the universe. The overheated nuclear fluid formed a black body at high temperature. As soon as it started to radiate energy, its temperature would begin dropping, and conditions suitable for the rest of the process would be brought about. This necessitates taking the word *light* to mean radiation. According to modern scientific analysis, light is one form of electromagnetic radiation—viz., visible radiation; radiation is a term of wider extension, and it includes light as a special case.

4. *God separated the light from the darkness.* The fourth verse describes the radiative expansion of the universe. This would be taken to include the beginning of radioactive decay of the neutrons into protons and electrons, which can be considered as a "separation" of radiation products, or a separation of *light* from matter. Following on this, all of the chemical elements would have been formed in a short period of time. Thus, when separation was completed and radiative capture had immediately followed its natural course, universe formation would have progressed through the origin of the elements.

As chronicled in the fifth verse, this takes the whole process of creation to the end of the first day.

7. *God made the firmament, dividing the waters. . . .* The sixth verse and the seventh verse describe the firmament. This would be interpreted as the space resulting from the formation of the galaxies, and therefore these two verses may be taken as a description of the galactic formation period. Such an interpretation necessitates taking the term *waters* to refer to the fluid state of the expanding gases. According to technical terminology, gases are a special kind of fluid, so the use of "fluid" for "gas" is permissible. But the use of *waters* would have to be explained, in this theory, as a word that would suggest fluid to primitive minds not acquainted with such technical distinctions.

Verse eight records that God called the resulting empty space *Heaven,* and this marked the end of the second day of creation.

9. *Then God said, "Let the waters below the heavens be gathered into one place and let the dry land appear."* Beginning with this verse and ending with verse thirteen, we have the formation of the earth and its adornment with plant life. According to the scientific account, this would have to be placed in the planet for-

mation period. Thus there appears here a discrepancy respecting the order in which parts of the universe appeared. Verses fourteen to sixteen describe the formation to the sun, moon, and stars, after the earth had already been formed. The scientific theory would have the sun and stars formed first, after the galactic formation period and the condensation of the elements, with the planets formed later as parts of solar systems. This is the first ordinal discrepancy between the two accounts.

16. God made the two great lights, the greater light to rule the day and the smaller one to rule the night, and he made the stars. This represents the star formation period which, as we have pointed out, should have followed after the completion of the elements. The second and only other ordinal discrepancy occurs here. The scriptural account places the origin of the moon at the same time as that of the sun (v. 16), after both of which the stars were formed. The scientific account identifies the sun with the stars, and would place the origin of the moon in a planet formation period some time later.

This, then, is the much heralded *rapprochment* between the hitherto conflicting accounts of creation as found in Sacred Scripture and in modern science. Of course, there are one or two obvious discrepancies. For instance, in the chronology, the scriptural account says that both the earth and the stars were formed in successive one-day periods. Mathematical calculations in accordance with the theory being discussed indicate that the stars were not formed until one hundred million years after the beginning of the expansion, and the planets similarly were not formed until one billion years from the beginning. And there are other and more serious difficulties.

Notwithstanding these, however, it must be admitted that there is also a general line of agreement in the elements of the scientific theory when compared with the account of Sacred Scripture. Could it be possible that both accounts are descriptions of the same event, differing in particular details because of the different media through which they are presented to us? Is it conceivable that the inspired writer was given a vision of the origin of the world somewhat according to this theory, and then, to make it intelligible to his contemporaries, described what scientists now know as radiation as *light,* thermal chaos as an *abyss,* nuclear fluid as *waters,* galactic space as *firmament,* etc., etc. ? Or, to get down to the basic problem, was there a foundation in fact,

now being uncovered by physical science, for the account that the inspired writer has given, and could this be reflected in the particular manner in which he describes the events depicted in the opening verses of Genesis? The reader will sense immediately that such questions demand a knowledge of exegesis not possessed by the average scientist or layman. So, before attempting an answer, it will be well to see what modern scriptural scholars and exegetes have to say about the description of the origin of the universe in the Book of Genesis.

(To be concluded)