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RECENT THEORIES OF THE ORIGIN AND NATURE OF THE UNIVERSE

By W. E. FILMER, B.A.

THE VICTORIA INSTITUTE
22 DINGWALL ROAD, CROYDON, SURREY

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SYNOPSIS

Several independent lines of evidence point to an age of the universe in the region of 4,000 million years. Gamow's theory that the universe began at this date as a very hot and dense neutron gas, although highly speculative, does appear to provide a better explanation of the relative abundances of the elements than any other current theory. Einstein's general theory of relativity, originally put forward as a statement of gravitational law, allowed for a cosmic force of repulsion. It still remains an open question whether or not this force exists, but it is no longer necessary to invoke it to explain the observed recession of the galaxies. Hoyle's theory of an expanding universe is superfluous for the same reason. Hoyle's theory of continuous creation implies that the large scale appearance of the universe should be the same at all times and in all places; but the Stebbins-Whitford effect indicates that the more remote elliptical galaxies appear different from near ones, and this can be explained as a result of the time lag in our seeing them. It is concluded that a steady state universe is not supported by the balance of scientific evidence.

The last twenty-five years have seen a tremendous advance in our knowledge of the nature of the universe. On the one hand the giant 100-inch and 200-inch telescopes in America have enabled astronomers to extend their exploration of space to a distance of more than 1,000 million light-years, while on the other discoveries in atomic physics have increased our understanding of the nature of matter and energy. All this fresh knowledge forms the raw material from which have been woven new theories about the origin and nature of the universe.

The 100-inch telescope at Mount Wilson made possible the discovery that stars are grouped together into galaxies, originally called nebulae on account of their misty appearance. Each galaxy consists of from 10 to 100 thousand million stars, and may range in size from a few thousand up to two hundred thousand light-years across. The sun is a star of average size situated about two-thirds of the distance from the centre to the outer rim of a large spiral nebula called The Galaxy. The misty belt of stars, known as the Milky Way, which extends across the sky, constitutes the spiral arms of The Galaxy; to right and left of the Milky Way the density of stars falls off rapidly as we look out between them into relatively empty space.

The distances of other galaxies are so great that they cannot be measured by the ordinary parallax, or range-finding method, but have to be estimated from their brightness, or from the brightness of individual stars and other objects in them. This depends on a knowledge of the actual brightness of similar stars in our own galaxy which are near enough to us for their distances to be measured accurately. Recent observations have led astronomers to revise their estimates of the distances of the galaxies, and this revision is likely to have an important bearing on our assessment of current theories.

The Expanding Universe

One of the earliest discoveries made with the 100-inch telescope was that most of the galaxies appear to be moving away from us and likewise from one another—the whole universe appears to be in a state of expansion. The speed of a star or galaxy moving along the line of sight can be measured from the change in colour of the various spectral lines which are characteristic of the spectrum of each element when it becomes incandescent—a deviation towards violet indicates a compression or shortening of wave-length due to the approach of the star, and a shift towards red, a lengthening of wave-length due to recession. All the more remote galaxies show a shift towards the red, and the shift increases the further away the galaxy is situated. Although suggestions have been made to account for this in some other way, a number of reasons can be given why these introduce more difficulties than they seek to solve, and in the theories considered in this paper it is accepted that the red shift is a true indication of velocity.

When the Mount Wilson astronomers, Hubble and Humason, began measuring the distances of the galaxies and calculating their speeds from the red shift, they were soon able to formulate what is now known as Hubble's law, which states that the speed of recession is proportional to the distance of the galaxy. We might compare the situation with one in which a number of cars are moving out along several main roads diverging from a central city. We observe that each car that is 10 miles from the city is going at 10 m.p.h. and each one 20 miles out is going at 20 m.p.h. and so on. If each car had been moving at a uniform speed for the past hour, a simple calculation would show that all of them set out from the city at the same time one hour previously. Of course we cannot be certain that they have been moving at a constant speed, but one thing is clear: at some time in the past they must all have been crowded together in the city. In the same way we may reasonably conclude that at some time in the remote past all the galaxies in the universe were gathered together in a small space.

Now one of Newton's laws of motion, which every experiment has shown to be true, states that any object will continue to move with uniform velocity unless it is acted upon by a force. The only force of which we have any definite knowledge acting on the galaxies is that of gravity. This would tend to draw the galaxies together and cause their present movement to slow down, but in actual fact they are now so far apart that the effect is negligible. It is true that in some theories which we shall consider later, a cosmic force of repulsion is assumed which causes the galaxies to fly apart at ever increasing speeds, but it is not sound science to make more assumptions than are necessary to explain the facts, so for the present we shall ignore cosmic repulsion.

Assuming, then, that the galaxies are acted upon by no force other than gravity, it is possible to calculate from their present distances and speeds that they were all crowded together in a small space about 3,500 to 4,000 million years ago. Scientific theory cannot go any further back than a stage in which all the matter in the universe was packed together as tightly as anything we can conceive, and that point in time we may reasonably call the moment of creation.

The Age of the Universe

Having arrived at the age of the universe in this way, Professor Coulson, in a recent broadcast[1], went on to point out that several other methods of estimating its age are open to us. For example, we know of a number of star clusters such as the Pleiades, comprising some 200 members, and it can be shown that these must eventually become scattered under the tidal effects induced in them by the other stars of The Galaxy. It has been calculated by B. J. Bok[2] and others that such clusters could not remain together for more than 3,000–5,000 million years, and if our galaxy were any older than this, such star clusters would no longer exist. In fact several hundred of them are known, so our galaxy cannot be older than 5,000 million years.

A second line of evidence arises from the fact that a great many of the stars we see are really double—they consist of a pair of stars moving round

[1] C. A. Coulson, *The Listener*, 21 May 1953, p. 839.

[2] B. J. Bok, *Mon. Not. R. Ast. S.* (1946), **106** 61–75.

each other in some kind of orbit. As in the case of the clusters, it can be shown that in the course of time pairs of stars of this kind would become more widely separated, so that after a long time there would be very few double stars left. The high proportion of close pairs that are observed puts an upper limit to the age of our galaxy which once again comes out to be only a few thousand million years.

A third clue, quite independent of the others, is derived from our knowledge of the way stars generate the energy they emit by converting hydrogen into helium. It is believed that when their supply of hydrogen is nearly exhausted, they would swell up to an enormous size and become a type of star known as a red giant. From the size and brightness of a star we can calculate the rate at which it is emitting energy, and so arrive at the rate at which it is producing it from hydrogen; we can also arrive at the proportion of hydrogen already used up, and so work out the age of the star. The oldest stars we know, the red giants whose hydrogen is almost exhausted, turn out to be rather less than 4,000 million years old.

Thus by three different methods we are led to the same result for the age of our galaxy, but this does not necessarily mean that all other galaxies are the same age. But when it happens that the age of the universe as calculated from the expansion comes out to the same figure, we must admit, as Professor Coulson pointed out that, "This agreement is too imposing to be treated as a mere coincidence."

But in addition to the astronomical facts about which Professor Coulson was speaking, there is also geological evidence from which we can calculate the age of the earth. Geologists have for many years been using what is known as the radio-active method of dating rocks, and this has become sufficiently refined to show that the oldest known rocks were laid down about 2,000 million years ago. More recently a similar method has been worked out by Professor Holmes of Edinburgh[3] which enabled him to find not only the age of the rocks, but the age of the material from which they were formed. His calculations were based on the analyses of 25 samples of lead ore from different parts of the world, and he arrived at a figure of 3,350 million years as the age of the earth's crust. Doubt was at first cast on this result by Professor H. Jeffreys,[4] who put forward two alternative methods of calculating the age of the earth which gave results differing from those of Holmes. But Holmes later pointed out[5] that one of these methods was wrong in principle, while in the second Jeffreys had made an arithmetical error—when this was corrected the result was consistent with Holmes' original figure. F. G. Houtermans,[6] working independently from the same data, also arrived at the same result as Holmes.

[3] A. Holmes, *Nature* (1946), **157,** 680.

[4] H. Jeffreys, *Nature* (1947), **159,** 127.

[5] A. Holmes, *Nature* (1949), **163,** 453.

[6] F. G. Houtermans, *Z. Naturforsch.* (1947), **2a,** 322.

Now the universe must be at least as old as the earth, so once more we are back at the same figure of rather less than 4,000 million years. The fact that so many independent calculations lead to the same age for the universe lends strong support to the idea that about 4,000 million years ago something happened which started the universe off as we know it.

The Origin of Matter: Gamow's Theory

Some idea of how the universe began may be got from tracing the expansion back as far as is conceivably possible to a state in which all the matter was as tightly compressed as the elementary particles in the nucleus of an atom. The most widely accepted theories in recent years have been based on this suggestion which was first put forward by the Belgian physicist Lemaître in 1931. He imagined one gigantic atom which, on account of its size, was most unstable, and exploded, splitting up into ever smaller and smaller fragments until ultimately it had broken down into the atoms as we know them today. The gas or dust originally so formed would condense into stars and galaxies which would continue to fly apart as a result of the original explosion. One of the main objections to this theory was that it was unable to account for the proportions, or abundances of the various kinds of atoms which we find. It would result in too many of the heavier elements and too few of the lighter ones.

Subsequently George Gamow[7] and his colleagues in America suggested that since in the nucleus of an atom the positive and negative particles, the protons and electrons, amalgamate to form neutrons, the universe must have started as a tightly compressed mass of neutrons. For purposes of calculation this could be regarded as an extremely dense gas at a very high temperature. During the first hour of the expansion of this gas all the neutrons would split into protons and electrons, that is to say into hydrogen. But before all the neutrons had split, there would be a mixture of neutrons, protons and electrons which would be ideal for the formation of other elements so long as the temperature and density were sufficiently high to keep them colliding with one another with sufficient force.

Although this chaos of colliding particles may appear at first sight to be hopelessly intractable, it does not, in fact, involve anything but comparatively simple processes which have been studied in the laboratory. Experiments with such high speed particles during the past twenty years provide the necessary knowledge of what the probable result of a collision between any two particles will be, provided their speeds are known. The only difficulty lies in the amount of calculation necessary to discover what the final mixture of gases will contain, when the temperature has fallen too low for collisions to be effective in building atoms. Gamow had the necessary calculations done on an electronic computing machine, and showed that, provided that the temperature and density of the original

[7] G. Gamow, *Creation of the Universe* (1952), p. 57.

neutron gas had certain values, the theoretical amounts of the different elements resulting from this process corresponded remarkably well with the actual proportions found to exist in the universe.[8]

Describing conditions during this first hour as being similar to those existing in the centre of an exploding atom bomb, Gamow points out that an enormous amount of energy would be released in the form of short-wave radiation. This energy, according to Einstein's principle, has mass, and there would be so much of this radiant energy present, that its mass would exceed by a large factor the mass of the ordinary atomic matter. However, as the gas consisting of the newly formed atoms continued to expand, its temperature would become lower and lower, and the amount of radiant energy would become less and less, until eventually a time would come when the mass of the radiant energy would fall below the mass of the ordinary matter. This was a critical stage in the history of the universe, for radiant energy exerts a pressure in the same way as a gas, and once the pressure exerted by the radiation ceased to preponderate in driving the atoms apart, the force of gravity could become effective in drawing them together. The result of this would be that the gas which had hitherto filled the universe uniformly, would break up into separate gigantic clouds. While these clouds would continue to fly away from one another, gravity would prevent each one from expanding any further and it would remain the same size. The continued action of gravity would break up each cloud into globes of gas which would become stars. Thus we have an explanation for stars being grouped together in galaxies which are themselves flying apart.

Gamow goes on to calculate[9] that the amount of matter in each cloud would be enough to form several million stars the size of the sun. Although this number is not quite as great as the number of stars in the existing galaxies, he gives reasons why the calculated value falls short of the actual value, and expects that when these other factors have been taken into account, the figures will agree.

According to Gamow[10] the critical stage, when the original uniform gas broke up into separate clouds, was reached about 30 million years after the creation. He calculates that the density of the gas at that stage was about the same as the average density of matter in a galaxy today, thus confirming his theory that from that time each individual cloud expanded no further. Also, since the average distance between one galaxy and another is today about 100 times the average diameter of a galaxy, the date of separation was about one-hundredth of the present age of the universe; this would give a rough estimate for the age of the universe as 3,000 million years, which is in reasonable agreement with the other estimates we have discussed.

[8] G. Gamow, *Creation of the Universe* (1952), pp. 65–69.

[9] *Ibid.*, p. 77.

[10] *Ibid.*, p. 78.

Theories of The Expanding Universe

The theory of the origin of the universe which we have so far been considering was based on the assumption that the galaxies are moving apart with a speed which has remained constant ever since the initial explosion. From their present distances and speeds we were able to calculate that this explosion must have taken place about 4,000 million years ago, and this was in agreement with the age of our galaxy as estimated by entirely independent means, as well as with the age of the earth. This agreement has, however, only very recently become possible. For the past twenty-five years the distances of the galaxies were believed to be only about half of those on which our calculations were based, and consequently they allowed only half the time for the period of expansion, namely less than 2,000 million years. This was evidently impossible, because it was even less than the age of the earth. In order to get round this discrepancy it was necessary to put forward theories which assumed that the galaxies were moving more slowly in the past: that is to say that instead of moving with uniform speed, they were accelerating, and a cosmical force of repulsion was postulated to account for this acceleration. It so happened that Einstein's general theory of relativity allowed for the possibility of just such a force of repulsion. It is, however, not an essential part of the theory (for the cosmical constant may be zero), but since the astronomical data appeared to demand it, it was incorporated into most theories of the expanding universe.

The Origin of Matter: Hoyle's Theory

One such theory which has received much publicity is Hoyle's theory of continuous creation. He put forward two main objections to any theory such as Gamow's.[11] The first of these was based on the erroneous distances of the galaxies: any theory, he said, which leaves out cosmical repulsion gets into difficulties because the period of expansion comes out less than the age of the stars and of the earth. His second objection was that in the early stages of the expansion the temperature (or the amount of radiant energy) would not have been sufficient to prevent gravity causing condensations of gas whose density would be much higher than the average density of the galaxies.

As we have seen, the first of these objections is no longer valid. Observations made by Alfred Behr[12] in Germany, S. C. B. Gascoigne[13] in Australia and just recently by the American astronomers,[14] have led to the conclusion

[11] F. Hoyle, *Nature* (1949), **163**, 196–7.

[12] A. Behr, *Astron. Nach.* (1951), **279**, 97–104.

[13] Gascoigne and Kron, *Pub. Ast. Soc. Pacific* (1952), **64**, 196–200.

[14] E. P. Hubble, *Observatory* (1953), **73**, 102–3.

that the distances of the nearest galaxies must be doubled, and with them the distances of all other galaxies.

As regards the second objection, Gamow gives a formula[15] for the temperature of space at any moment after the creation. From this formula he calculates that the temperature (and likewise the amount of radiant energy) would, in fact, be sufficiently high to prevent condensations until the density of the original gas had fallen to the present average density within a galaxy. This calculation can be checked, because the same formula also gives the temperature of space today when the universe is 3,000–4,000 million years old. This comes out to be 40–50 degrees absolute, a temperature which Gamow says "is in reasonable agreement with the actual temperature of interstellar space."[16] Here we can see the fundamental difference between Hoyle and Gamow, because Hoyle is not prepared to admit that the temperature is now more than 1 degree absolute.[11]

As a consequence of his second objection, Hoyle is not able to believe that the average density of matter in the universe could have been any greater in the past than it is now. Although galaxies are continually flying out of any given volume of space, he believes that the number within that volume remains the same. This requires that new galaxies must continually be formed to replace the old ones, and that hydrogen is being continuously created to provide the raw material. In this way he avoids the idea of a creation at a particular epoch in the past, and supposes that the universe has existed eternally.

Since Hoyle's theory postulates only the creation of hydrogen atoms, he is obliged to give some explanation of the origin of the other elements. There is no difficulty about helium, for it is agreed that this is being formed from hydrogen in the centres of the stars, but for the formation of the heavier elements temperatures of over 1,000 million degrees accompanied by very high densities are necessary, and it is difficult to find anywhere in the universe where such conditions exist. Hoyle supposes that they would be found in the centre of a very massive star when its hydrogen has become exhausted.

It is believed that so long as a star has a supply of hydrogen which can be converted into helium, its internal temperature will remain sufficiently high to keep it blown up to a large size; but once this source of energy fails, the central portion of the star would collapse inwards under gravity. Now at temperatures of several million degrees which prevail in stars the atoms are rushing about at such high speeds that their nuclei are stripped of all their satellite electrons. Consequently when the collapse occurs, a large number of these bare nuclei will pack into a very small space, and the result is an extremely dense star, a type known as a white dwarf.

[15] G. Gamow, *Op. cit.*, p. 142–3.

[16] G. Gamow, *op. cit.*,, p. 42.

According to Hoyle's theory, the rise in temperature and density resulting from such a sudden collapse would be sufficient to convert helium into the heavier elements. At the same time the sudden release of energy provided by the collapse of the core would blow the outer layers of the star off into space. Extremely violent explosions like this are known to occur and such stars are called supernovae. Hoyle suggests that together with the outer layers some of the newly formed elements from the core would also be blown out into space. In the course of time sufficient of these heavy elements would accumulate in the general background of new hydrogen to affect the constitution of any stars which began to form.

A study of Hoyle's original paper[17] leaves one in doubt whether his theory is able to account for the total quantity of elements other than hydrogen and helium known to exist in the stars. As he points out, in any newly formed galaxy the first stars to form would consist entirely of hydrogen, and only after a number of supernova explosions had occurred would there be any other elements available. Such explosions are rather rare occurrences—there being only one in about 500 years in a whole galaxy. But by supposing that each explosion produces a quantity of heavy elements equal to ten times the mass of the sun, Hoyle calculates that after 10,000 million years the amount of these elements would reach 0.1 per cent of the hydrogen present. There is already more than this in the existing stars, although many of them must have been among the first stars to be formed, and so should contain none, or very little of the heavy elements. Furthermore, it seems very doubtful whether each supernova could produce such an enormous quantity of heavy elements in the outer layers, as these would be formed mainly in the central core.

Nor is this the only difficulty with which Hoyle has to contend. He finds that the conditions required for generating the light and medium weight elements would not be suitable for producing the heavier ones. Consequently he is obliged to postulate two different processes which take place in entirely separate stars. As Gamow points out, this " sounds like the request of an inexperienced housewife who wanted three electric ovens for cooking the dinner: one for the turkey, one for the potatoes, and one for the pie. Such an assumption of heterogeneous cooking conditions, adjusted to give the correct amount of light, medium-weight and heavy elements, would completely destroy the simple picture of atom-making by introducing a complicated array of specially designed ' cooking facilities '."[18] Gamow claims that his own theory is capable of explaining not only the general trend of atomic abundances, but even the proportions of each individual element.

[17] F. Hoyle, *Proc. Phys. Soc. London* (1947), **59,** 972–8.

[18] G. Gamow, *Op. cit.*, p. 52.

Consequences of the Alternative Theories

It was pointed out by Professor McCrea in a recent paper read before this Institute[19] that it should be possible to distinguish between a universe which had a beginning when all the matter came into existence at once, and a universe which had no beginning and in which matter is being created continuously. In the former case all the galaxies would be of approximately the same age, whereas in the latter they would range from very young to extremely old—in fact, some would be infinitely old, but it would be unlikely that any very ancient galaxies would be in our own neighbourhood.

Now owing to the time taken by the light from the more remote galaxies to reach us, we actually see them not as they are now, but as they were many millions of years ago. Consequently, if the universe had a beginning, and the galaxies are now all about the same age, the more remote galaxies should appear to be younger than the nearer ones. If on the other hand galaxies are constantly coming into existence, a census of galaxies at any distance or at any time would always contain galaxies of all ages. It would seem, therefore, that to decide the issue between one theory and the other we must have a means of measuring the relative ages of the galaxies.

According to the continuous creation theory, the oldest galaxies should be the biggest, because they would be continually accumulating more matter by gravitation. When we come to look at the galaxies we find that they do, in fact, vary in size to some extent, but the variation is not greater that it might have been by accident had they all been formed at the same time. The variation in size is not sufficient to decide the issue.

Another possible clue might be the shape of the galaxies. About one in five is elliptical or spherical and the other four are spiral with a considerable variation in the arms, some being tightly coiled and some very loosely. Whether or not the different types represent an evolutionary series is open to question: some people[20] suppose that elliptical galaxies evolve into spirals, while others believe[21] that spirals develop into ellipsoids. In view of our present lack of knowledge about how galaxies evolve or change their shape, it would seem impossible for any observational evidence at the present time to decide between one theory and the other. Curiously enough an interesting phenomenon has recently been observed which is regarded as providing strong evidence against the theory of continuous creation.

A few years ago the American astronomers, J. Stebbins and A. E. Whitford,[22] began analysing the light from the nebulae by photographing them through six different coloured filters. In this way they found that elliptical galaxies appear progressively redder the further away they are,

[19] W. H. MacCrea, *Trans. Vic. Inst.* (1951), **83**, 119.
[20] G. Gamow, *Op. cit.*, p. 80.
[21] C. v. Weizsäcker, *History of Nature* (1951), pp. 74–88; P. Couderc, *Expansion of the Universe* (1952), p. 41.
[22] Stebbins and Whitford, *Astrophys. J.* (1948), **108**, 413.

but the spiral galaxies do not show this change. For example, they measured the colours of four elliptical and seven spiral galaxies which they knew to be all at approximately the same distance, because they lie in a cluster in Corona Borealis. Only the elliptical galaxies showed the reddening effect—the light from the spirals did not. Similar measurements of light from other clusters of galaxies whose distances are known show that the amount of reddening is proportional to the distance.

This effect should not be confused with the red shift in the spectral lines from which the speed of the galaxies is measured. It is, of course, true that the shift of the whole spectrum towards the red might make a galaxy appear redder, but what is observed is an additional reddening in excess of this. For example, a galaxy in Boötes shows a red shift of 23 per cent in the lines, but the proportion of red light is increased by 61 per cent. Observationally the effect is similar to the difference between the sun at midday and at sunset. The spectral lines are not affected, but we see a greater proportion of red light in the evening because dust in the air cuts out some of the blue light.

Now there can be only two ways of explaining why a remote galaxy looks redder than a near one: either it was emitting redder light, or the light has undergone a change on the way; some blue light, for example, may have been lost due to obscuring matter in space, in the same way as atmospheric dust causes the reddening of the sun. But if the light had in any way been altered on the way, the light from the spiral galaxies would have been affected to the same extent, so this explanation must be ruled out. We are, therefore, left with the only other solution, namely that the remote elliptical galaxies must have been emitting light that was redder than that now emitted by nearer ones.

It follows that whatever theory may be put forward to account for the redder light of the elliptical galaxies, it must in any event be incompatible with a steady state universe of Hoyle's type, for in such a universe the average characteristics of each type of galaxy must be independent of time and distance. If, however, a good reason can be given why the light from the spiral galaxies would not change over a period of several million years, while the light from elliptical galaxies might be expected to do so, then we can be reasonably certain that the effect is an evolutionary one, even though we might not be able to understand fully the evolutionary process causing it.

It has been known for some time that the stars of which the arms of the spiral galaxies are composed differ from those in the central nuclear region, and that the latter are similar to those in the elliptical galaxies. The bulk of the light from the spiral arms is supplied by comparatively few very bright stars, called white or blue giants, but in the nuclear region and in elliptical galaxies most of the light is provided by red giants. The white or blue giants are consuming their hydrogen at such a rate that their life-span cannot be more than a few hundred million years, but as they burn out, they are probably being continuously replaced by new stars forming from the large amount of interstellar gas and dust which exists in the spiral arms. So great is the quantity of this interstellar dust that it completely prevents us from seeing the nucleus of our own galaxy, or seeing other galaxies which lie in any direction near the plane of the Milky Way. Photographs of other spiral galaxies seen edge on show a dark band across the nucleus where the dusty arms cut across it.

This interstellar dust and gas does not appear to be present in elliptical galaxies, and consequently no new stars can form, so the average age of the stars steadily increases. In the spiral arms the birth of new stars may keep the average age almost constant for as long as there is a supply of material. There is, therefore, every reason to expect an evolutionary change in the appearances of the elliptical galaxies, but not in the spirals.

The explanation put forward at present to account for the redness of the distant elliptical galaxies is that at the time when their light was emitted they contained a larger proportion of red giants than do the nearer galaxies; in the latter a great many are believed to have collapsed meanwhile into white dwarfs. It would appear, therefore, that the first stars to form were those in the elliptical galaxies and in the nuclear regions of the spiral galaxies, and that later new stars have been continually forming in the arms of the spirals where alone the necessary raw material is present.

Summary of Scientific Arguments

We have seen that several independent lines of evidence point to an age of the universe in the region of 4,000 million years: the age of the earth gives a minimum of 3,350 million years, the astronomical facts agree in placing a maximum age of 4,000–5,000 million years, and the latest estimates of the distances and speeds of the galaxies point to a date between 3,500 and 4,000 million years ago when the universe began. In view of these consistent results it is reasonable to suppose that at that time some event did take place which we may call the creation, and that the universe has not been in existence for an infinite time.

To arrive at this remarkable agreement between so many widely different methods of approach it was not necessary to suppose that the galaxies are accelerating under a force of cosmical repulsion. Although the possibility of such a force was allowed for in Einstein's general theory of relativity, it is not a necessary part of the theory. It was invoked to explain a discrepancy which no longer exists. Consequently any theory such as Hoyle's which requires an acceleration of the galaxies is making an unnecessary assumption, and for that reason is scientifically unsound.

As regards the origin of matter, Hoyle's theory does not appear to explain satisfactorily how the heavier elements came to be formed.

Gamow's theory that the universe began as a very hot and dense neutron gas, although rather speculative, appears to provide such an explanation which leads to an agreement with the actual amounts of these elements found in the universe.

Finally the theory of continuous creation requires that the large scale appearance of the universe should be the same at all times and at all places; but Stebbins and Whitford have found that the distant elliptical galaxies are not the same colour as the nearer ones, a fact which can be explained in terms of an evolutionary change with time.

It would be difficult to find a more authoritative, or a more severe condemnation of the continuous creation theory than that delivered by Professor Dingle in his presidential address to the Royal Astronomical Society earlier this year.[23] He said that he had a responsibility as president of one of the foremost scientific societies of the world, because the ideas to which the society gave publicity were accepted as genuine scientific pronouncements, and as such influenced the thinking of philosophers and theologians. When, therefore, it happened that the society had published so-called " principles " which were comparable with the " principle " that all celestial movements are circular and all celestial bodies are immutable, it became his duty to point out that this was the kind of thing that science was created to displace. " It is hard for those not acquainted with the mathematics of the subject," he said, " to credit the fact that the idea of the continuous creation of matter, whether right or wrong, is not a legitimate inference based on scientific observation, but is based merely on the fancy of a few mathematicians who think how nice it would be if the world were made that way."

Philosophical Arguments

Before we consider the philosophical aspects of the subject we must be clear what the word creation means as it is used in the two theories discussed. There is no doubt that in Hoyle's theory he means that hydrogen atoms come into existence from nothing—at one moment they are not there, at the next they are. Gamow states that he does not mean this, but rather a " making something shapely out of shapelessness."[24] However, he is not concerned with discussing how his original neutron gas came into existence, but with describing how, once it was there, it developed into the universe as we know it. If, however, we examine the situation at the beginning of his " creation ", we find a dense gas of neutrons whose origin cannot be explained. It could not, for example, have arisen from a previous compression, like the expansion in reverse, for this would only lead back to a state in which the universe was empty but matter came together at high speed from infinity—a statement which

[23] H. Dingle, *Observatory* (1953), **73,** 46–47.

[24] G. Gamow, *Op. cit.*, Preface to 2nd Printing.

seems to be nonsense. Nor could Gamow's neutron gas have existed for any length of time in its highly compressed condition, for as soon as it existed it must start to expand. We must conclude, therefore, that it did not exist before the beginning of the expansion, but came into existence at that moment. If we confine the word " creation " to describe this particular phenomenon, we shall be using it in the same sense as Hoyle.

If the theory of continuous creation is not a legitimate inference based on scientific observation, we may now enquire what philosophical preferences may have lead to its adoption. " On philosophical grounds," says Hoyle, " I cannot see any good reason for preferring the big bang idea. Indeed, it seems to me in the philosophical sense to be a distinctly unsatisfactory notion, since it puts the basic assumption out of sight where it can never be challenged by a direct appeal to observation."[25] But Hoyle's own basic assumptions are equally out of sight: first he assumes the existence of a cosmic force of repulsion which only becomes effective at a range of millions of light-years, and secondly he supposes that one hydrogen atom is created per litre of space in 250 million years. Since he is himself obliged to admit that " it would be quite impossible to detect such a rate of creation by direct experiment,"[26] we cannot take seriously his plea for a direct appeal to observation.

The truth is, as Professor Dingle said, " The authors of this new cosmology seem to be primarily concerned with the question ' How can we conceive that this changing world began.' Tacitly assuming that the universe must conform to their tastes, they declare that there was no beginning and will be no end to the material universe."[23] Now the knowledge that the universe had a beginning in time when it was created out of nothing is not only a very strong argument for the existence of God, but it also provides reason for us to believe that He existed before it began and therefore transcends it. As Sir Edmund Whittaker pointed out, " it implies that God is not Nature, and Nature is not God; and thus we reject every form of pantheism, the philosophy which identifies the Creator with creation."[27]

These theological implications are evidently Hoyle's real difficulty. By concluding his book, *The Nature of the Universe,* with an attack on religion in general and the Christian Faith in particular, he has shown that he strongly objects to the idea of God. Consequently, since he cannot get away from the fact of creation, he is obliged to resort to a novel form of pantheism in which he can reduce the Creator to the status of an automatic machine for the production of hydrogen atoms.

[25] F. Hoyle, *Nature of the Universe,* p. 98.

[26] *Ibid.,* p. 99.

[23] H. Dingle, *Observatory* (1953), **73,** 46–47.

[27] E. T. Whittaker, *Beginning and End of the World,* p. 40.

Historical

The argument about whether or not the universe had a beginning is not new. The ancient Greek philosophers were unanimous in their belief that matter had existed eternally, for this followed directly from their basic axiom that " nothing can come into existence out of what does not exist." When the Greeks spoke of creation they meant nothing more than the bringing of order out of chaos, a condition in which they believed matter to have existed eternally.

The conception of a beginning when God created the heavens and the earth (or space and matter) out of nothing, was of purely Hebrew origin. The early Christians held that this belief was based on revelation, and could not be established independently by rational science, though this did not prevent some of them from devising philosophical arguments to support their view. It was not until early in the nineteenth century that any scientific reason could be given why the material universe should not have existed eternally: it was then that the discovery of the second law of thermodynamics was made, but even then it was many years before this was used to argue that the universe was " running down " like a clock, a fact which implied that at some time, not infinitely remote, it must have been " wound up."

The discovery of the expansion of the universe, far from being evidence against a beginning, provides, in fact, a very strong argument in favour of it, for if the motion of the galaxies be traced far enough back, there must have been a time when they were all crowded together to a maximum degree. Had it not been for erroneous measurements leading to an age for the universe which was less than the age of the earth, it is unlikely that the conception of cosmic repulsion, on which the continuous creation theory depends, would ever have gained favour.

It is interesting to note that by declaring that the universe had a beginning, the Bible anticipated modern science by some thousands of years, and when it is further realized that this doctrine was taught in face of the strongest possible opposition from Greek philosophy, it must be admitted that divine revelation alone can have been the source of that knowledge.

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