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COSMOLOGY AND THEOLOGY*

In the centuries following the birth of science much was learned about motions of the planets, the constitution of the stars and the structure of the galaxies. This was made possible by the development of ever more powerful telescopes, by spectroscopic analysis and by Einstein's general theory of relativity. For the first time the entire universe, spread out in space and time, has become the subject of scientific investigation. More recently, by applying our knowledge of nuclear and elementary physics, we have learned how the universe has evolved from a fiery singularity about ten billion years ago.

If we read about these discoveries in scientific articles and books we seldom find any references to theology. And yet, as Chesterton once remarked, "religion means something that commits man to some doctrine about the universe" Since everyone has some religious beliefs, explicit or implicit, it is nor surprising that, just as theology was of vital importance for the birth of modern science, so it continues to influence, in many subtle ways, the continuing development of our knowledge of the universe. Much more obvious is the popularity of books on cosmology containing accounts of the latest discoveries, frequently linked with speculations about creation and the Big Bang, and how it all leads us to religion and a knowledge of the mind of God, or to atheism, depending on the inclinations of the author.

Before describing these discoveries it is necessary to recall a qualification that applies to all science, but especially to cosmology. By experiments in the laboratory we attain some knowledge of the laws of nature, and then we extend them to the realms of the very small and at very high velocities, and this led to quantum mechanics and special relativity. How then can we be sure that our present understanding is adequate to discuss what happened billions of years ago? Very small changes in the laws, quite undetectable by us, could have large effects when applied to the whole universe. Yet in spite of this difficulty, we must extrapolate the laws of nature, because we have no alternative, but it is important to remember the

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provisional character of all our knowledge of the distant past, as this sets severe limits on, or even excludes, any possibility of drawing theological conclusions.

The traditional philosophical arguments for the existence of a Creator do not, of course, depend on particular scientific theories of the universe. They are based on simple everyday experiences of order in the world, and of the dependent nature of material things. Nevertheless the desire to integrate our scientific and our theological knowledge into a coherent whole often provides an extra-scientific criterion for preferring some theories of the universe more than others. Thus if we believe from Revelation that the universe was created at a particular instant of time, we must notice that this is more plausibly brought into coherence with scientific theories that describe the development of the universe from a unique beginning than with those that maintain that the universe has always existed. Thus Christians might be expected to favour such theories, while those who wish to do away with the need for a Creator might prefer the alternative steady state or oscillating universe theories.

Such preferences run as hidden, and sometimes not so hidden, threads through all the scientific discussions of the origin of the universe. When they do surface they are mentioned as feelings rather than as argued conclusions. Thus Hoyle remarks: "In the older theories all the matter in the Universe is supposed to have appeared at one instant of time, the whole creation process taking the form of one big bang. For myself I find this idea very much queerer than continuous creation" He also found the big bang theory unacceptable on scientific grounds because it postulates an irrational process that cannot be described in scientific terms, and on philosophical grounds because it lies in principle beyond the realm of observations, irrespective of its success, "it simply cannot be a good scientific theory. Under no circumstances ought anything that sounds like a cosmic beginning be acquiesced in by the scientist" Another cosmologist, Harrison, recoiled from the evidence that the universe will keep expanding forever as a "horrible thought" that "would make the whole universe meaningless" Marxist-Leninist writers naturally reject the notion of an absolute beginning as fundamentally incompatible with the principles of dialectical materialism. Thus Sivderski rejected the big bang theory as an "unscientific popish conclusion"

This does not imply that it is legitimate to argue from a scientific theory to a theological conclusion. Although some Christians have indeed used the big bang theory as evidence for Creation, others have been more cautions, notably the originator of the theory, the Belgian Abbe Lemaître, a Catholic priest. Modern Christian writers on cosmology realize very clearly that it is quite unwarranted to argue from a scientific theory, however successful, to a theological belief. It is always hazardous to make links of this character, as has been found every often in the development of science. Science is concerned with the relation between one state of the world and another; it can never provide evidence for an absolute beginning.

The real connection is rather different; it is that the basic beliefs of the time tend to encourage or discourage different types of scientific theories, and these may or may not raise different theological questions. Thus the big bang theory inevitably raises the question about what happened before, whereas the continuous creation theory does not.

Now that Christians have realized it is unwise to argue from the success of big bang theory to the fact of Creation, and agnostics have seen the steady state and oscillating theories subjected to severe criticism on scientific grounds, the arena of argument has shifted. Some theists point to the specificity of the universe as suggesting that it was created purposefully, while agnostics tend to emphasize either its necessary or its random character, and therefore its lack of need for a Creator.

I. COSMOLOGY AND THEOLOGY

Cosmology, or the study of the heavens, played a central role in the development of science. The regularity of the movements of the stars and of the seasons provided an impressive witness to the power and reliability of the Creator. The power of the Creator is emphasized in the words of Yahweh to Job:

> Can you fasten the harness of the Pleiades
> Or untie Orion's bands?
> Can you guide the morning star season by season
> and show the Bear and its cubs which way to go?
> Have you grasped the celestial laws?
> Could you make their writ run on the earth?
> Can your voice carry as far as the clouds
> and make the pent-up waters do your bidding?
> Will lightning flashes come at your command
> And answer "Here we are"
> (Job 38,31-35)

Yahweh also demands:

> Where were you when I laid the earth's foundations?
> Tell me, since you are so well-informed!
> Who decided the dimensions of it, do you know
> Or who stretched the measuring line across it?
> What supports its pillars at their bases?
> Who laid its cornerstone?
> (Job 38,4-7)

The doctrine of creation is the most basic of all Judeo-Christian beliefs. It affirms that God made the world out of nothing, that He is absolutely distinct from His creation, and that all creation depends completely on Him.

This revelation was first given to the Israelites, and their acceptance set them apart from the surrounding idolatrous and pantheistic tribes. The Bible is saturated with the belief in creation from the powerful words addressed to Job to the confident matter-of-fact acceptance by the mother of the seven martyred brothers in Maccabees.

We cannot understand the creation of the universe. It is difficult enough to understand creation when it is applied to our own activities. How does a painter create a picture? He has an idea, but to realize that idea he re-orders existing matter. But God created the universe out of nothing. When the painter has finished his work, the picture remains, even if he forgets about it. But the universe depends utterly on God not only for its initial creation but for its continuance in being. Without God's sustaining power it would instantly lapse into nothingness.

The belief that the universe had a beginning is strikingly different from those held by most of the nations of antiquity. Almost without exception they believed in a cyclic universe. The Hindus believed in a Great Year, after which everything would be repeated again. Such a belief is intensely debilitating, and played no small part in preventing the rise of genuine science: why should we strive to improve our understanding, if everything that happens has already happened many times before and will happen many times again?

This belief was decisively broken by the unique incarnation of Christ. Writing on the doctrine of the Great Year, the French physicist Pierre Duhem said: 'To the construction of that system all disciples of Hellenistic philosophy – Peripatetics, Stoics, Neo-Platonists – contributed; to that system Abu Masar offered the homage of the Arabs; the most illustrious rabbis, from Philo of Alexandria to Maimonides, have accepted it. To condemn it and to throw it overboard as a monstrous superstition, Christianity had to come.'

As Jaki has remarked, religions fall into two categories: In one there is the Judeo-Christian religion with its belief in a linear cosmic story running from 'in the beginning' to 'a new heaven and earth' In the other are all pagan religions, primitive and sophisticated, old and modern, which invariably posit the cyclic and eternal recurrence of all, or rather the confining of all into an eternal treadmill, the most effective generator of the feeling of unhappiness and hoplessness. Concerning that treadmill, Chesterton has remarked: 'I am exceedingly proud to observe that it was before the coming of Christianity that it flourished and after the neglect of Christianity that it returned.'

The medieval philosophers actively discussed the nature of the universe. They made full use of Greek philosophy, but did not hesitate to depart from it, if is was contrary to their Christian faith. Along with other Greek philosophers, Aristotle believed in an eternal, cyclic universe, and this was rejected because it is contrary not only to the Christian belief that the world has a beginning and an end, but also to the belief in the unique Incarnation of Christ.

Aristotle's speculations, particularly his belief in the eternity of the world and on the difference between unchanging celestial matter and corruptible terrestrial matter, prevented the rise of science in ancient times. They were broken by the Judeo-Christian beliefs in the creation of the universe by an all-powerful God, totally distinct from his creation. The creation of the universe out of nothing transformed a circular view of time to a linear one, and implied that celestial and terrestrial matter, being both created by God, obey the same laws.

Christian theology provided the belief in the orderliness of nature that is the essential basis of all science. Our philosophy of the material world is absolutely crucial for the development of science, and it has its root in theology. We believe that God created the world out of nothing by the free exercise of the creative power that belongs to Him alone.

The created world has its own intrinsic nature, given to it by God. Normally it continues to exist, sustained always by God, and to behave in the way determined by its nature. The material world, the universe, defined as the totality of consistently interacting things, is thus a totally determined system. If we knew exactly its initial state, and the laws of its nature, we could calculate exactly how it would subsequently behave. This is not of course possible in practice because we cannot know the present exactly, we do not know the laws well enough and we cannot do the calculations. This determined development is not however a logically necessary development, in the sense that it could not be otherwise. God always has the power to intervene, to override the development otherwise determined by the intrinsic nature of the material world.

Throughout the preceding paragraph we are speaking only of the material world, not of man. Man is made in the image of God and has freedom of action and so is not wholly part of the universe as defined above.

This account of the material world specifically excludes other possibilities that are widely held and are inimical to the development of science:

1. It excludes the concept of the world as immediately dependent on the will of God, who determines its behaviour from instant to instant. On this view the world is like a cinema picture, a series of disconnected flashes that appear to have continuity but in fact have none, a world that is re-created continually from one instant to the next. It denies the idea that things have their own intrinsic natures that normally determine their behaviour. This view of the world stresses the freedom of God at the expense of His rationality.

2. It excludes the concept of the world held by deists. This is the idea that God created the world like a clock, wound it up and then let it go so that thereafter it inevitably develops according to its intrinsic design. This idea stems from the concept of God that stresses His rationality at the expense of His freedom.

3. It excludes the idea that God was obliged to create the world in a particular way, so that it is a necessary world. Such a belief also stresses the rationality of God at the expense of His freedom. It denies that the world is contingent and so destroys science by removing the need for experiment. If the world is a necessary world we might hope to find out about it by pure thought.

4. It excludes pantheism, the idea that the universe is an emanation from God or a part of God, because Christ is the only-begotten Son of God. The universe was made, not begotten.

5. It excludes any form of dualism, the idea that different part of the world were created or are controlled by different spirits of gods. All creation takes place through Christ and is therefore wholly dependent on God.

6. It implies that the world, though contingent, is completely orderly. This again is necessary for science, for if the world was not orderly science would be impossible. God could not create an chaotic world.

7. It denies that there is any intrinsic indeterminism in the world, and thus excludes the misuse of the word chance as if it were a causative agent. Chance is simply a word that indicates that we do not know the determining causes.

The science made possible by Christian theology has repaid the debt by revealing God's creation in ever more detail.

II. THE DISCOVERY AND EXPLORATION OF THE UNIVERSE

It is one of the most astonishing achievements of man that he is able to probe the extremes of the very small and the very large, the recesses of the atomic nucleus and the vastness of cosmic space and time.

The observations of the nineteenth century astronomers showed that our sun is a rather ordinary star in one of the spiral arms of a galaxy of about two hundred thousand million stars that we see in faint outline as the Milky Way. Billions of similar galaxies are visible in all directions, and Hubble found that the frequency of the light from them is shifted in a way that shows that they are all moving rapidly away from us. Furthermore, the greater the distance from us the faster they are receding. In other words, all the galaxies are moving in just the way we would expect if they had all come from a mighty explosion at a time that we can calculate to be about fifteen thousand million years ago. This figure is subject to considerable uncertainty, not only due to inevitable difficulties of measurement, but also because it assumes that the expansion is uniform. It has also been suggested that in the early stages was a period of more rapid expansion.

A deeper understanding of this expansion of the universe was provided by Einstein's general theory of relativity His cosmological model was shown to lead to the observed expansion, and Lemaître derived from it the measured velocity of recession of the galaxies. For the first time the universe as a whole became an object of scientific study. Thus theory and experiment combine to support the idea that what we now see is an ageing universe, the scattered ashes and sparks remaining from the compressed incandescence of its fiery beginning.

Although we see the galaxies flying away from us with velocities proportional to their distance, this does not mean that we are in a specially privileged position. Every galaxy is receding from every other galaxy, so that a being on any of the other galaxies would see just the same recession. More subtly, we must not think of the galaxies as flying apart into an already-existing infinite space, but rather that the space itself is expanding. We cannot imagine this, but the analogy of particles on an expanding balloon may be helpful.

Several other lines of evidence, such as the motions of clusters of galaxies and the relative proportions of various types of nuclei also give about the same result for the time when all the matter of the universe was concentrated in a small volume. We can apply the laws of physics to understand many of the processes occurring during the expansion of the universe from this initial compressed state, but at present there seems no possibility of finding out by scientific means what happened before the expansion began. It seems to be the ultimate limit of science, a limit that some have ventured to call the Creation.

It must however be emphasized again that this is not a scientific inference. It is not possible to show scientifically of any state that there can be no antecedent state. We cannot exclude the possibility that there was a previous state, perhaps one of contraction. It has been suggested that the universe is eternal, either remaining always more or less the same on a sufficiently large scale, or perhaps alternately expanding or contracting. These theories will now be discussed in more detail.

III. THEORIES OF THE UNIVERSE

As already mentioned, several lines of evidence indicate that the universe has expanded from a compressed state about fifteen billion years ago. This suggests that the development of the universe is a continuous progression from an explosive beginning to a silent end. The processes occurring in the first few instants of the expansion have been reconstructed in considerable detail, making use of the latest knowledge of nuclear and elementary particle physics. The details are highly technical and still somewhat speculative for the very earliest times, namely the first fraction of a second. The evolution of the universe from about one hundredth of a second from the beginning of the expansion are better understood (Weinberg, 1977).

At that time the temperature of the universe was about a hundred thousand million degrees and consisted of matter and radiation in very close interaction. It was expanding rapidly, but the interaction was so strong that it remained essentially in a state of thermal equilibrium. The most abundant particles were electrons and neutrinos and their anti-particles, and also photons. There were also some nucleons in the proportion of one neutron or proton for every thousand million photons, electrons or neutrinos. These protons and neutrons were in constant interaction with the electrons and neutrinos so that the numbers of protons and neutrons remained the same. There was no possibility of forming more complex particles as the temperature was so high that they would be broken up as soon as they were formed.

As the expansion continued the temperature fell and soon it became slightly easier for a neutron to interact to form a proton than conversely. By the time a tenth of a second had elapsed there were about twice as many protons as neutrons. The density and temperature continued to fall, and after one second the temperature was about ten thousand million degrees. At this stage the neutrinos no longer interacted appreciably with the other particles, and so play no further part in the story, except in so far as their energy contributes to the gravitational field of the universe.

After about fourteen seconds the temperature had fallen to three thousand million degrees, and now the electrons and their anti-particles the positrons annihilated to produce more photons. This rapidly removed most of the electrons and positrons, and also momentarily slowed down the rate of cooling because of the energy released in the annihilation process. Neutrons were still being converted into protons, though much more slowly, and now there were about four protons to every neutron. At this stage it was cool enough for helium nuclei to form, but this could not happen yet because this can only come about through the formation of deuterons consisting of a proton and a neutron, and then tritons (a proton and two neutrons) and hellions (a neutron and two protons). These intermediate particles on the way to helium formation are much less stable, and so were broken apart as soon as they are formed. However as soon as the temperature fell low enough for the deuterons to survive, the reactions leading to the formation of helium took place very rapidly and all the neutrons combined with protons to form helium.

After about half an hour the temperature had fallen to three hundred million degrees. All the electrons and positrons had been annihilated apart from the small number of electrons needed to provide one for each proton, so that the universe as a whole is uncharged. Most of the nuclear particles were either free protons or helium nuclei (about 25% in weight), with a very small amount of lithium. The period of intense activity was now over, but the universe continued to expand, cooling all the time, and after about a million years the temperature had fallen to about three thousand degrees, sufficient to allow the electrons and the nuclei to combine to form atoms. The disappearance of the free electrons made the universe transparent to radiation, and this decoupling of matter and radiation allowed the atoms to condense into stars and galaxies.

Inside the stars it became possible to build up heavier nuclei. This could not happen before because nuclei with five or eight neutrons or protons are unstable. Inside the stars, however, the intense gravitational pressure allowed the hydrogen and helium to combine to form the heavier nuclei. The nuclear reactions taking place at that time have been studied in laboratories, and so we can calculate the proportions of the different chemical elements in the universe. This is very similar to what is observed, showing that we have as detailed and quantitative understanding of the processes that took place so long ago.

About ten thousand million years later the evolution of living beings took place, among them men who are able to understand and reconstruct the details of the processes that made their existence possible.

How do we know that this story is true? Some parts of it are of course better understood than others, and research is continually providing more details of the various stages, even of the processes occurring in the first hundredth of a second. As already mentioned, the formation of the nuclei is quite well understood, and the results of calculations agree with the measured abundances of the various chemical elements in the universe.

Additional confirmation came from the observation of what is called the cosmic microwave background radiation. At the stage of the formation of the atoms all the electrons were captured by nuclei and thereafter the photons no longer interacted strongly with the rest of the universe. These photons were in statistical equilibrium with each other and their energy distribution is related to their temperature. This energy distribution is well-known from the early days of the quantum theory, and is given precisely by Planck's formula. As the universe expanded the temperature fell, and with it the average energy of the photons. Since we know the temperature at the time when the matter and radiation were decoupled, we can calculate the initial energy distribution of these photons, and also the way that temperature falls as the universe expands. These photons are still present in the universe, and now their temperature is just three degrees above the absolute zero of temperature. Photons of this temperature are in the microwave region.

At the same time as these calculations were being made in Princeton, this microwave radiation was actually observed in 1965 by Penzias and Wilson. These two radio astronomers were hoping to measure the radio waves emitted by our galaxy, but first they had to make sure that there was no spurious noise in their detecting antenna that could mask the signals they were looking for. They found that however they turned their antenna they always detected some radiation, and furthermore it came with equal intensity from all directions and so could not come from our own galaxy. It must come from the universe as a whole. It was then realized that this was probably the radiation left over from an early stage in the evolution of the universe.

It might be asked why the scientists did not actually look for this radiation, since it could have been predicted and to some extent was predicted long before it was observed. Partly this may be the difficulty of the measurements, but it seems that even theoretical physicists sometimes find it hard to realize that their abstract mathematical calculations refer directly to physical reality, that they reach across the vastness of space and time to predict the presence of hitherto unknown radiation, and that if we turn a radio aerial to the sky we find that it is there.

Since that time the background microwave radiation has been studied in detail, and in particular it has been shown to have a spectral distribution closely similar to Planck's formula, and to come almost equally from all directions. It is just what would be expected for the theory of the evolution of the universe, and provides a compelling verification of its truth. The very slight departures from isotropy, found quite recently, are what are needed to allow the formation of galaxies.

Another prediction of the theory that can be experimentally verified is the proportion of helium in the universe. The helium is formed at an earlier stage than the heavy elements, and so its proportion is a sensitive indication of the relative numbers of the nuclear particles and of photons. This ratio in turn fixes the temperature of the microwave background radiation. Thus from the measured temperature of three degrees it can be estimated that the proportion of helium in the matter from which the stars were formed must be about twenty-five per cent by mass. This is just the same as the value for the hydrogen-helium ratio obtained from theories of stellar evolution.

It is worth noting at this stage the extreme specificity of the whole process, a feature that will be returned to later on. In particular the ratio of nuclear particles to photons, electrons and neutrinos must be about one to a thousand million. If there are more photons the number of neutrons and protons will remain about the same, so that as soon as the temperature falls low enough for helium to be formed, they will all combine in this way. Nearly all the nuclear particles will become helium, and then it is not possible to build up any of the heavier nuclei. On the other hand if there are fewer photons the interaction that keeps the number of neutrons and protons the same will cease too soon, and before the helium formation can begin most of the neutrons will have decayed to protons. Nearly all the nuclear particles will then be protons, and so not enough helium can be formed to lead to the production of heavier nuclei. Thus the ratio is exceedingly critical; if it is too large or too small there can be no nuclei heavier than helium, and so no possibility of life.

IV THE STEADY STATE THEORY

As an alternative to the big bang theory, Bondi and Gold, and also Hoyle, proposed the steady state theory. This was based on what they called the perfect cosmological principle, which says that on a sufficiently large scale the universe is always the same, both in space and time. In particular, the number of galaxies in any large volume of space is constant. Since however we know that the galaxies are receding from each other this can only be ensured if new galaxies are coming into being to replace those that are moving away. They therefore postulated that hydrogen atoms continually appear out of nothing and ultimately condense and coalesce to form new galaxies at a rate just sufficient to replace those lost by recession. The rate of appearance of the hydrogen atoms came out to be so small that there is no possibility of ever observing it, just one hydrogen atom per year in every cubic mile of space.

The motivation behind this theory was avowedly to provide a rival to the big bang theory which, although it does not prove that Creation in time has occurred yet seems to be more consonant with it. To do this, they were obliged to postulate what they called continuous creation, and yet they resolutely refused to consider how this creation occurred, or to attribute it to a Creator. It thus seemed to many to be a somewhat gratuitous hypothesis, and yet they were correct to maintain that it is a legitimate scientific theory that stands or falls when its consequences are compared with observational data.

The most direct test of the theory is to see if indeed the galaxies are uniformly spread throughout all space. At first this seemed to be the case; the number of galaxies increased as the cube of the distance, as it should. Then it was found by the techniques of radio astronomy that at very large distances the galaxies start thinning out; there are not enough of them for the steady state theory to be correct.

The observation of the 3 degrees background radiation by Penzias and Wilson provided further evidence against the steady state theory since it shows that the present expansion of the universe started some fifteen thousand million years ago. On the steady state theory we would not expect this background radiation to be there. The red shifts of quasi-stellar objects are also inconsistent with the theory. For these reasons the steady state theory has now been abandoned and scientists reluctant to envisage the possibility of a Creation turned their attention to the possibility of an oscillating universe.

V THE OSCILLATING UNIVERSE

At present the universe is expanding, but the question is whether it will go on expanding for ever, the galaxies and the stars getting colder and colder, or whether at some epoch the expansion will slow down and go into reverse, leading eventually to the collapse of the universe into a very small volume. If the universe is ultimately destined to collapse we can then see the present expansion and collapse as possibly just one of a whole series of expansions and contractions going on for ever, a spectacle that banishes the possibility of a Creation at a particular instant but not, it must be added, the need for a continuing Sustainer of the whole oscillating process.

This question is physically the same as asking whether as rocket fired upwards will escape from the earth's gravitational field or eventually fall back to the ground. We can answer it in two ways: by examining the way the velocity of the rocket is changing after the motors have been switched off, or by comparing the velocity at that moment with the velocity that we can calculate to be sufficient to take the rocket out of the earth's gravitational field. When we apply this test to the receding galaxies we find that we cannot yet measure the velocities of recession at great enough distances to determine whether they are on the road of eternal expansion or the road of eventual contraction. We therefore have to fall back on the second method, which requires a knowledge of the total mass of the universe. We can also calculate the mass that the universe must have if its gravitational attraction is to be sufficient to slow down and ultimately reverse the recessional motion of the galaxies. If this mass is greater than the actual mass, then the expansion will go on for ever, but if it is less, then the expansion will ultimately turn into a contraction.

Present estimates of the mass of the universe show that it is between ten and a hundred times too small to reverse the motion of the galaxies. This has led to a hunt for the missing mass, particularly among those with a vested interest in an oscillating universe. It is possible that there is a halo of unseen mass around the galaxies, and the neutrinos may account for some more, but even then the best estimate is that only about a tenth of the required mass can be found. This is of course open to revision in the light of further research. It is worth noting in passing that it is remarkable that the masses are so closely the same, and this may well have a deeper significance. The relative abundances of the light elements also supports continual expansion.

There are other difficulties with the idea of an oscillating universe, in particular those connected with the second law of thermodynamics, which requires the total entropy of any system to increase continually. As Tolman showed, when this is applied to an oscillating universe the result is that the period of oscillation becomes less and less, so that eventually it all runs down. Thus the second law of thermodynamics appears to exclude the possibility of an oscillating universe (Tolman, 1934).

Thus at the present time there are considerable difficulties with the theory of an oscillating universe, but it cannot yet be entirely ruled out. It is always possible that further developments will weaken the arguments mentioned above. Scientifically it remains an open question.

Philosophically, an eternal universe is open to the objection that if we are in such a universe then everything would already have happened an infinite time ago. The only way to avoid this conclusion is to say that the whole of history is indeed repeated in all its details an infinite number of times. The periodicity of this repetition need not be the same as that of the universe as a whole, providing it is equal or greater. Such a belief in an oscillating universe has indeed often occurred in human history, but in our civilization this idea was rejected because the Incarnation of Christ is a unique event that cannot be repeated. God's plan in history is a linear one, from the beginning to the end, and is incompatible with eternally recurring cycles. That is why the Church has always believed in Creation in time, and conversely it is notable that belief in an oscillating universe is always one of the hallmarks of atheism.

VI. NECESSARY OR SINGULAR?

With the abandonment of the steady state theory and the uncertain future of the oscillating universe theory, those who are unable to accept the idea of a Creator have turned their attention to developing the concept of a necessary universe, that is a universe that must be the way that it is. If the universe is necessary, then there is no need to enquire why it is the way it is; it could not be otherwise and so there is no need to look for an explanation, in particular no need for a Creator.

The idea of a necessary universe has a long history, going back to Aristotle. As a scientific hypothesis it encourages the idea that it is possible to obtain the whole of science, including even the values of the fundamental constants, by pure deductive reasoning. There is no need to make experiments; physics, like mathematics, may be carried out by thought alone, Strenuous efforts were made along these lines by Eddington, but in spite of instructive insights. he did not succeed in his endeavors. The structure of the universe is far richer and more sophisticated than could ever be imagined by the mind of man.

But even if it is not possible to discover the structure of the world by thought alone, it remains possible that it is a necessary world. Due to the limitations of our minds we need the help of experiments to understand the order of the universe, and then we could realize that it is in fact a necessary order. The experiments serve as intellectual scaffolding that can be discarded when we have reached our goal.

There are indeed many features of the universe that might seem at first to be given, but which turn out on further examination to be necessary. For example the number of spatial dimensions must be three, for otherwise the solar system would not be stable. As science advances, more and more features of the world seem to be linked together and not at all arbitrary. Indeed the aim of theoretical physics is the unification of our knowledge of the world expressed inevitably in mathematical terms. Already the unification that has been achieved is remarkable, and areas of experience that seem to be quite distinct are seen to be but different manifestations of the same underlying order, as for example electricity, magnetism, optics and radio are all governed by Maxwell's equations. Great efforts are being made to unify the four fundamental forces of nature, and important progress has already been made.

It is quite possible that scientist will eventually succeed in developing a comprehensive theory that explains all phenomena and enables the results of all conceivable experiments to be calculated. Even this, however, will fall short of proving that the universe is a necessary one, as a consequence of a theorem of Gödel, who showed in 1930 that no set of non-trivial mathematical propositions can have its proof of consistency within itself, and that there are always meaningful propositions that cannot either be proved or disproved within the system. Thus any scientific cosmology, which is necessarily expressed in mathematical terms must fall short of being a theory that shows that the world must necessarily be what it is. There is always the possibility of the surprising, the unexpected, that points beyond this world for those who have eyes to see.

VII. THE SINGULARITY OF THE UNIVERSE

The more closely scientists study the evolution of the universe the more evidence they find of its extreme singularity. A striking example of this has already been quoted: if the proportion of nuclear particles and photons had been slightly different there would have been nearly all hydrogen or nearly all helium, and in each case no heavier nuclei and so no possibility of life. Again, it has been noted that the universe is remarkably homogeneous on a large scale, and this is the result of the initial conditions. It is very difficult to understand why these inhomogeneities should be so small, and yet if they were any larger the matter of the universe would have collapsed into black holes long ago, while if they had been any smaller, there would have been no galaxies.

The evolution of the solar system is also highly specific. There is still no satisfactory theory of how the system of planets was formed, and in particular how they came to be rotating around the sun in nearly circular orbits, and nearly in the same plane. Yet it is only on a planet of a certain size moving on a nearly circular orbit that life could have evolved. The more this evolution is studied, the more we realize that it is immensely improbable that we should be here at all. We have come to where we are on an exceedingly narrow track.

VIII. MAN IN THE UNIVERSE

We always tend to think that we are at the center of all things. The ancient Hebrew cosmology, the cosmology of the Greeks, and cosmology of the Hindus all put man in the center of the universe. In Genesis man appears as God's supreme handiwork on the sixth day, and all creation is his to dominate. This anthropocentric picture received a crushing blow when Copernicus showed that the motions of the planets can be much better understood if they rotate about the sun, so now the sun is the center, with the earth a rather small planet revolving around it. Man's centrality received further blows when it was shown that the sun, so impressive to us, is a rather undistinguished star near the end of one of the spiral arms of a vast galaxy of billions of such stars, and that this galaxy is but one of many billions of similar galaxies scattered through an unimaginably large universe.

What remains of the centrality of man, and of the world made for him by God? Compared with the vastness of space, we are totally insignificant. We can be filled with awe and reverence, and with the Psalmist we can rejoice that the Heavens show forth the glory of the Lord. Or, with Pascal, we can be terrified by the vastness of space, realizing that "man is but a reed, the most feeble thing in nature. The entire universe need not arm itself to crush him; a vapour, a drop of water, suffices to kill him."

It is true that we can reply, again with Pascal, that man 'is a thinking reed. If the universe were to crush him, man would still be nobler than that which killed him, because he knows that he dies, and the advantages the universe has over him; of this the universe knows nothing.' But how can we be sure even of this? Is it not very likely that around some other stars in far away galaxies there are sentient beings in civilizations immeasurable superior to our own, who know what we are doing and regard our activities in much the same way as we regard those of ants and bees. There are indeed few grounds for pride when we consider our position in the universe. And if there is no other life in the universe, this raises another question, posed by Margaret Knight, a well-known humanist: 'If life is the purpose of creation, what conceivably can be the point of countless millions of lifeless worlds? Or of the aeons of astronomical time before life existed? The Church has glanced uneasily at these questions but it has never answered them' In saying this she was but echoing Maimonides Guide for the Perplexed:

> Consider then how immense is the size of these bodies, and how numerous they are. And if the earth is thus no bigger than a point relative to the sphere of the fixed stars, what must be the ratio of the human species to the created Universe as a whole? And how then can any of us think that these things exist for his sake, and that they are meant to serve his uses?

Now, when we know far more about the universe, when we begin to understand in a very detailed way the evolution of the very matter of which it is composed, we begin at the same time to glimpse a new truth, that it looks more and more as if the universe was indeed made just for man. At each stage in its development there seem to be many possibilities, and every time the one is chosen that alone leads to a universe that can produce man. Within this perspective the insignificance of man takes on a completely different aspect. We wonder at the vastness of the universe in space and time compared with the smallness and frailty of man. Why this apparent prodigality? Now we see the answer: all this stupendous evolution was necessary in order that the earth should be made as a habitation for man. The process of nucleosynthesis, by which the elements constituting man's body are built up in the interiors of stars, takes billions of years. And in this time the galaxies containing these stars will inevitably move vast distances from their point of formation. So the universe must be as large and as old as it is, in order that it can be prepared as a home for man.

This is why we can say that it is our universe. Freeman Dyson has summed this up in the words:

> As we look out into the universe and identify the many accidents of physics and astronomy that have worked together for our benefit, it almost seems as if the universe must in some sense have known that we were coming.

The idea that the universe has taken just that path in its evolution that leads to man is called the anthropic principle. It must be noted that this principle does not explain why the universe evolved in this particular way, unless we already believe in a Creator who intended this result. Since we are indeed here, then of course the universe must be such as to allow our emergence. If the universe had so to speak taken the wrong turning, then we would not be here to talk about it. Or perhaps there have been millions of different universes in non-interacting spaces, and this is just the one that happened to be such as to allow for the evolution of man. We may or may not think that these arguments are plausible, but they are certainly tenable.

It has sometimes been objected that the anthropic principle is not scientific because it is not testable and leads to no new discoveries. However, Hoyle considered how carbon could be formed, and concluded that if must be by the simultaneous collision of three alpha-particles. The probability of such collisions is extremely small, and so the cross-section can only be appreciable if there is a resonance just above the state in carbon formed by three alpha-particles. He looked at the spectrum of carbon and found that there is indeed a resonance at exactly the required energy.

There is an even stronger form of the anthropic principle that deserves mention. We are accustomed to think of the constants of nature like the velocity of light or the mass of an electron as fixed and unalterable. Now the strong form of the anthropic principle says that the values of these constants are in fact fixed by the requirement that the universe will allow man to evolve. Some rather detailed arguments have been made to support this idea. This raises the possibility that there are many universes with different values of the fundamental constants, and only those with the values we know can produce man. There is however a difficulty with this argument. The number of fundamental constants is about ten, whereas the number of conditions they must satisfy is substantially greater. This implies that it is not possible, even in principle, to fix the parameters so as to ensure the evolution of man; there are not enough of them. The values of the constants cannot be the result of a random process; the universe is our universe, at the deepest level.

It should also be remarked in connection with the anthropic principle that it is possible that when science advances further we shall see that what appear to be arbitrary choices in the evolutionary process are in fact necessary. That, for example, the ratio of nuclear particles to photons must be as it is, and similarly for the other apparently very singular parameters. At an even deeper level, the very values of the fundamental constants as we know them might be necessary values, as indeed Eddington tried to show. This would make it even more surprising that we are here.

Although the emergence of life in the universe seems to be a most improbable process, there are so many stars that might conceivably have planets on which life could have evolved that there have been many speculations that conscious beings and perhaps well-developed civilizations exist in many parts of the universe. This has led to ambitious schemes to detect signals that may have been broadcast by such beings, and plans to transmit signals of our own. However until we have factual evidence the whole subject is highly speculative, serving to distract attention from real and solvable problems.

IX. RANDOM OR ORDERED?

There are two contemporary lines of argument that appear to support the idea of a purely random world, one derived from quantum mechanics and the other from the recent work on chaotic motion.

Quantum mechanics was developed in the nineteen twenties and has been extremely successful in accounting for a wide range of atomic and nuclear phenomena. It is an indispensable part of modern physics. There is however still much dispute about its interpretation, and this is essentially a continuation of the dispute between Bohr and Einstein.

The most important point of difference is that Bohr held that the wavefunction contains all that can be known about each individual system, whereas Einstein held that the wavefunction gives only the average behaviour of a large number of similar systems. Since individual systems behave differently, even if as far as we know they have been prepared in the same way, then according to Bohr they manifest a radical indeterminism. That is what led Heisenberg to say that the law of causality had definitely been disproved by quantum mechanics. He failed to distinguish between the inability to measure exactly and the objective existence of exact quantities. Einstein however would say that the systems differ because they were different from the beginning, and thus it is quite possible that the world is a fully determined system, although we cannot prove that this is so.

The difference between the two views is thus primarily ontological. Einstein held that there is a really existing objective world that we try to study using the methods of science. We do not yet know all that there is to know, and if there is any apparent indeterminacy then we may be sure that there is some underlying determining process that we may one day hope to discover. Bohr, on the other hand, held that "it is wrong to think that the task of physics is to find out how nature is. Physics concerns only what we can say about nature." We see here very clearly how a positivistic stance weakens our grasp on the objective reality of the universe, and leads us to infer a spurious indeterminism. It is not surprising that another fruit of the Copenhagen interpretation is the misuse of the Heisenberg Uncertainty Principle to explain the production of matter out of nothing. Even more bizarre is the claim that the universe can exist only because of the presence of an observer, necessary to collapse its wavefunction.

The other line of thought that has strengthened the general belief in the randomness of the world is that connected with what is called chaotic motion. We are familiar with the idea that if we know the initial conditions, then application of the laws of physics enables us to calculate the subsequent behaviour. If, for example, we know the position and velocity of a planet, then using Newton's laws we can calculate its subsequent motion. Recent studies have however shown that in many systems the motion is exceedingly sensitive to the initial conditions. A very slight change will soon lead to completely different behaviour. For example, if we try to calculate the motion of molecules of gas that are continually colliding with each other, then the motion after a collision depends sensitively on the initial trajectory, and so a very small change may easily determine whether a subsequent collision takes place or not.

The effect of this is that it is impossible to predict the future behaviour of such systems. All measurements are limited in precision, and the imprecision of our measurement is always such that our calculations of the future behaviour of a system very soon become quite unreliable. Once again it is an ontological matter. Because we cannot predict the behaviour of a system it does not mean that the system is undetermined or random.

Thus whenever we hear talk about a process that is described as chance or random, this refers to the way it is described mathematically, not to its intrinsic nature, which is strictly determined. We cannot prove that this is so by the methods of science; we know it from the Christian doctrine of creation, on which all science is ultimately based.

Some attempts have been made to give a scientific account of creation out of nothing by a chance process. By nothing we do not mean just the absence of matter, but also of space and time. At the moment of creation space and time were created together. Chance is referred to as if it is a causative agent, a not as indicating unknown causes. There is a more general difficulty: all a scientific theory can do is to say that if there exists matter with such and such properties that obeys certain equations, then if it is started off in a particular configuration it will behave subsequently in a way calculable from those equations. What it cannot say is whether there indeed exists matter with such and such properties, and how it is put into a particular configuration and no other. As Hawking asked, "what is it that breathes fire into the equations and makes a universe for them to describe?" And who sets the initial conditions? Furthermore, a scientific theory is only reliable in the regions where it has been thoroughly tested; when it is extrapolated to other regions its predictions must be less certain. And what is more unpredictable or more singular than the moment of creation?

Another point worth noticing is the way creation is associated with the very simplest structures: "The creation can generate only the most primitive structures, structures of such simplicity that they can drop out from absolutely nothing." But it must be said that, simple or complicated, small or large, the passage from non-existence to existence is the most radical of all steps. We are being soothed into acceptance by being told that it is only a very small baby. This is totally unacceptable, and no one with any sense of ontological reality could accept it for an instant. However large or small the object may be, the passage from non-being to being is the greatest possible transition. It cannot be glossed over or talked away. We are talking about creation itself, and that is an activity that belongs to God alone.

The story of our attempts to understand the world shows a complex interaction of theological beliefs, scientific observations and theoretical speculations. It is notable that is was Christian theology that made science possible in the first place, and with it all the vast development that has led to our modern understanding of the universe.

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KOSMOLOGIA I TEOLOGIA

Streszczenie

Teorie kosmologiczne ocierają się o tematy, którymi tradycyjnie zajmowały się filozofia i teologia. Fakt ten sprawia, że chrześcijanie na równi z niewierzącymi podejmują czasem wysiłek spojrzenia na religijne prawdy (zwłaszcza doktrynę o stworzeniu) przez pryzmat aktualnych teorii kosmologicznych. Dziś, po wielu doświadczeniach, wszyscy wiedzą o metodologicznych granicach oddzielających naukę od teologii. Wszelako nauka i teologia, choć tak odmienne, mogą się wzajemnie ubogacić. Chrześcijańska teologia – jak wiadomo – stworzyła sprzyjające warunki do powstania nauki, a nauka wpływa na rozwój teologii, opisując coraz dokładniej świat stworzony.

Porównanie aktualnych teorii kosmologicznych między sobą jest również rzeczą pożyteczną. Okazuje się, że tylko teoria Wielkiego Wybuchu wychodzi obronną ręką z konfrontacji z danymi. Sytuacja teorii stanu stacjonarnego i teorii wszechświata oscylującego nie jest tak dobra. Fakt ten przywołuje zagadnienie osobliwości, a przez nie w nowym świetle każe spojrzeć na obecność człowieka we wszechświecie (zasada antropiczna).

Jeśli do tego dodamy słabość argumentów (związanych z tzw. indeterminizmem mechaniki kwantowej i chaosem deterministycznym), mających rzekomo wykazać przypadkowość świata, w którym żyjemy, staje się jasne, że kosmologia w żaden sposób nie przeczy chrześcijańskiej prawdzie o stworzeniu świata i człowieka.