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THE ORIGIN AND NATURE OF THE UNIVERSE

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1. The Scope and History of Cosmology

Cosmology, the branch of science concerned with understanding the Universe as a whole, has its origin together with astronomy away back in antiquity with the Babylonians and Egyptians. It was, of course, mixed up with religious ideas and with astrology and arose from man's effort to understand his environment and his relationship to it. The accumulated data of observations was fitted by the Greeks into a mathematical, that is to say rational, symbolical scheme, but understanding in terms of physical law as we know it today was entirely absent. Indeed it was characteristic of Greek thought to look for *final* (i.e. purposive) causes while modern science eschews these and considers only *efficient* (i.e. mechanistic) causes.

Until the sixteenth century, when Copernicus enthroned the Sun instead of the Earth at the centre, the thinking was not only purposive but homocentric and the storm of Galileo's struggle with the Roman church is well known. Unfortunately the lesson of this blow to man's pride was not well learnt. His centrality in the Universe was perforce surrendered but the desire to base his uniqueness on the physical dies hard, as the echoes of the evolution controversy still show. So strong was the instinct to put Man at the centre that the Greeks were prepared for endless complications in the mathematics to meet their philosophical presuppositions, to 'save the phenomena' as they put it. The phrase itself is eloquent of their attitude—an attitude not wholly absent today. One is reminded of the German professor of theology who, on being told that his theories were not entirely in accord with history, is said to have replied, 'So much the worse for history'. But the empirical attitude eventually prevailed and today, whatever might be his practice, every cosmologist would claim, like Huxley, to 'sit down before the facts like a little child'.

The facts, indeed, have confirmed the appropriateness of such humility, for bit by bit the world of the Chaldeans, in which astrology was at any rate not patently absurd, has given place to a cosmos so vast and so regular and so subject to mathematical analysis that the problem today is to convince men that they have any significance at all. Psalm 8 stands out as a balanced and sober appraisal amidst these excursions of the philosophical pendulum.

In less than a century from Copernicus further cracks began to appear in the 'Caelestiall Orbes' as Thomas Digges replaced the sphere of fixed stars by an infinity of bodies extending throughout an infinite universe.

Kepler and Newton completed the demolition of the spheres, and the latter established the rule of physical (that is to say causative) law in the heavens as on earth.

The dethronement of the Sun became total, as with the great telescopes of the nineteenth century the Milky Way was resolved into individual suns and our location was found to be far from central in this galaxy (or Universe as it was then called). Just fifty years ago our galaxy itself lost all claim to physical uniqueness as many luminous nebulae were found to be complete 'universes' like our own Milky Way.

To understand the task and ethos of cosmology it is useful to remember the tremendous step that Newton took. Tycho Brahe, the last great astronomer to observe without the aid of the telescope, had obtained with immense labour data on the positions and motions of the planets, and Kepler had found a pair of empirical mathematical relationships that the motions satisfied. Now all of this is pure description. Nothing apart from an aesthetic sense suggested that the motions *ought* to follow mathematical law, and nothing enabled the particular laws to be predicted. But the Newton myth (if that is the word) tells how Newton seeing an apple fall (and a scion from a true pip is still to be seen in the National Physical Laboratory grounds!), and noting that the Moon moved in an orbit instead of shooting off into interplanetary space, perceived a causal connection. The terrestrial event (the fall of the apple) and the celestial phenomenon (the course of the Moon) were both to be attributed to a common and *universal* force (the force of gravity). Thanks to Kepler's work Newton was soon able to show that the same force accounted for—caused—the motion of the planets.

It is this idea that the history and phenomena of the heavens are to be accounted for in terms of terrestrial physics that is the basic presupposition and task of cosmology.

It is noteworthy that this task has nothing to do with ultimate origins or final causes, nor indeed are teleological arguments relevant. It could be true that iron occurs as it does in the universe in order to make our technology possible, but the cosmologist in common with other scientists wants to know not 'why—for what purpose?' but 'how' in the sense of 'how come?'.

Cosmology is an observational, in one sense an historical, rather than an experimental science and we shall see that its presuppositions are less uniformly held and so less deeply buried in the subconscious than those of other sciences.

2. The Structure and Age of the Universe

We saw that Thomas Digges suggested that the 'fixed' stars were not in fact set in a sphere but distributed through an infinite space like currants in a bun. This idea raises an interesting question: 'why is the sky dark at

night?' If one supposes space to be perfectly transparent (and indeed it does appear to be very nearly so in most directions) then Digges' infinity of stars would necessarily reveal a star ultimately wherever one looked. They would not of course all be resolved but every line of sight would ultimately terminate on a star just as every line from the centre must encounter a currant if the bun is large enough. Such a universe would be incredibly bright, looking something like a sphere whose inner surface was like the surface of the Sun.

Arguments such as this lead to the idea that the visible Universe cannot consist of a uniform population of stars stretching to infinity. That the visible Universe is finite is shown by another related line of evidence. If we look at the light from very distant sources we find it to be reddened. The only satisfactory explanation for this reddening that has been advanced is that these distant galaxies are receding from us at tremendous speed and the light is suffering a shift to lower frequency, analagous to the so called 'Doppler shift' in the pitch of the whistle of a receding train. The observations are consistent with the speed of recession being proportional to distance, and this fixes a radius for the visible Universe since no light can reach us from beyond that distance at which the speed of recession is equal to the speed of light. This distance is known as the 'Hubble radius' and has a value of about three-thousand million light years.

It is to be noticed that we have been speaking of the visible Universe. Physics is concerned with that which is observable and strictly speaking matter beyond the Hubble radius is no concern of physics, but it is impossible completely to shrug off the philosophical or aesthetic considerations involved in the concept of a Universe which is infinite although only a finite part of it is in principle open to investigation. However, as we shall see, we do not necessarily have to accept this concept.

Astronomical figures are notoriously unimaginable, but it may be helpful, if only to engender a right reverence, to set some down.

Some Numbers, Distances and Times

Number of atoms per cu. cm. of water	3.3×10^{22}
Approximate number of stars per galaxy	10^9 - 10^{11}
Approximate number of galaxies in 'visible' Universe	10^{10}
Approximate diameter of our galaxy	10^5 light years
Distance to nearest star	4 light years
Diameter of 'visible' Universe	7×10^9 light years
Age of Earth	3×10^9 years
Age of 'visible' Universe	Less than 10^{10} years

The Universe contains an enormous range of temperatures and densities of matter. In the hot interior of stars the elements so vital for life and

industry are manufactured under conditions we are, at present, quite unable to reproduce.

If we work outwards from the Earth, we find that the Universe contains a considerable variety of bodies. The Earth is one of a very varied collection of nine planets orbiting the Sun, which itself is an unspectacular star situated well away from the centre of our Galaxy. The galaxy itself is a member of a cluster of galaxies.

To this fairly straightforward list of celestial objects we must add others, some long familiar such as comets, meteors and asteroids, which together with natural and artificial satellites are members of our solar system, and some only recently discovered such as the quasi-stellar objects, quasars, which seem to have some star-like some galaxy-like properties. Between these relatively large objects, which are in fact far more varied than their classification implies, space is populated by dust and gas and traversed by light visible and invisible and by energetic particles, all of which may be far more important than their unobtrusiveness would suggest.

3. Relativity

I have said a good deal about space, but we must always remember time is just as much part of God's creation; just as *given*, as is space. Until the dawn of the present century time was thought of as an unchanging aspect of existence. It was quite unaffected by anything man could do and quite unrelated in its actual flow to either the psychological state of the individual or the place in the Universe where its flow was observed. However, certain experiments on the speed of light showed up a more complex situation. Speed is a quantity relating space and time (the distance in space traversed in unit time) and the intriguing thing about the experiments was that they showed the speed of light always to be the same, whether measured by someone moving in the same direction as the light or in the opposite. A moment's thought will show that this is very queer. It is certainly not the case for the speed of sound or of cannon balls for example.

To make sense of this it became necessary to recognise a certain interchangeability between space and time so that if one observer were to measure the distance and time interval between two events the values measured for the same two events by another observer moving with respect to the first would be found to be different. This implies that simultaneity is purely relative. I may observe two events as occurring at the same time at two different places in the Universe, another may observe them as occurring at different times and separated by a different distance. (This is a real difference, not just an apparent difference due to the fact that any signal takes a finite time to travel from the event to the observer.)

4. Presuppositions

It is insufficiently realised that all kinds of knowledge start with some kind of act of faith, with some presupposition. The mathematician

presupposes the rationality of thought and the scientist believes in the uniformity of nature. That is to say he believes that the laws of physics, applicable in one place and time, will apply in another place and time. In particular he believes, and there is no other word for it, that the Sun will rise tomorrow, though he cannot prove it, and that kettles will not boil on ice and freeze on the fire though he cannot prove that either.

Now when one comes to cosmology this principle of uniformity assumes great importance for we do not know to what extent, if at all, the laws of physics are dependent on the configuration of the Universe at any given moment. For example do we suppose that the velocity of light (or indeed any other important physical constant) is quite independent of the size or age of the Universe? Generally speaking the attitude taken by cosmologists is that we must assume more than we have adequate evidence for or else give up cosmology. If after that the picture calculated on these assumptions tallies with observation our belief in the presupposition is strengthened. This, of course, is no different in essence to the attitude taken in every branch of science, but confidence about sunrises and kettles is easier because of their frequency. The Universe is, for us at any rate, unique.

The two most commonly held forms of the principle of uniformity held by cosmologists are (1) the narrow cosmological principle, which is the belief that there is no preferred place in the universe—no centre—but the broad features, including the physical laws, are the same from whichever point in the universe the (hypothetical) observer makes his observations. (2) The wide cosmological principle which includes the narrow but considers the broad features to be the same not only at every place but also at all times.

5. Kinds of Cosmology

Now the amusing thing about it is that if one assumes the wide cosmological principle it leads by logic alone to continuous creation, for since the universe is observed to be expanding, only by continuous introduction of new matter can its mean density be the same at all times. This is not physics. It is more like mathematics or philosophy or aesthetics. Nevertheless if the observations could be shown to be consistent with the continuous creation model most physicists (including myself!) would find the concept acceptable.

Until recently those who only accepted the narrow cosmological principle favoured the idea that the Universe started as some sort of huge primordial atom which exploded and the receding galaxies are the remnants of that vast expansion. In principle it should be possible to decide between these two views by observing the way the galaxies thin out with distance, but the observational problem is immense and there are many complications.

However, the recent discovery of the quasars has thrown cosmology into such turmoil that it seems best for plain men (including honest physicists!) to wait for the dust to settle. At present there seems to be a swing away from the continuous creation idea towards come sort of oscillatory picture in which the universe is thought of as first contracting and then expanding.

6. Creation

I am very conscious that I have done the universe scant justice in what I have written, and most cosmologists will feel I have done them scant justice too. Cosmology is a difficult branch of science, and aesthetics and ideas of fitness do play a prominent role, but it is an important activity and one that must move the Christian to worship.

There are those who think cosmology to be of theological significance, that the question of physical origin in time is relevant to theistic belief or unbelief. For my own part I see no such relevance. The idea of spontaneous creation of life was widely held until the time and work of Pasteur. If matter or energy or life could be shown to occur spontaneously (i.e. without traceable cause) then it would just be a fact like any other fact, neither more nor less mysterious than the more familiar facts of our world.

The mystery of being is neither heightened nor diminished by ideas one way or the other about an origin in time. Relativity helps me to understand God as the Eternal—the Giver of space and time, by Whom all things hold together.

I am no Hebraist but my impression is that the idea of creation *ex nihilo* which seems to be invested by many Christians with some kind of mystical significance, is not really a Biblical idea. The word *bara* seems to be used for the preparation, forming or introduction of something new and often it is clear from the context that God used matter already existing. Thus God created man from dust, woman from man. Indeed Psalm 104 depicts continuous creation, for it says of the *creatures* of the field 'Thou sendest forth Thy Spirit, they are created (*bara*)'.

If one looks carefully at the first chapter of Genesis, one will find that it is giving a picture of the way God prepared the Earth as a domain for the *imago dei.* And the picture is from a man's point of view, just as it would have appeared to a human observer. Reading it alongside the book of Nature as I read it as a scientist it goes like this.

First the Earth and its atmosphere congealed from the surrounding debris. It was dark and the Earth was featureless (like Venus today?). Next light broke through and the atmosphere cleared of much of its moisture. Land appeared and from the earth vegetation was formed. The clouds scattered and the orbs of heaven appeared. From the waters every kind of animal evolved.

All this God did, and without the Son was not anything made that was made, and it was very good. Hallelujah.