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CREATION OF THE COSMOS

PART 1 - SPACE AND TIME

"In the beginning", long before all worlds  
Or flaming stars or whirling galaxies,  
Before that first "big bang", if such it was,  
Or earlier contraction, back and back  
Beyond all time or co-related space  
And all that is and all that ever was  
And all that yet will be; Source of the whole,  
"In the beginning was the Word" of God.

Faith and Thought, 1975, 102, 182

*How Big is Space?*

When Abraham looked up at the stars as he heard God's promise about the multitude of his descendants, he could probably see a couple of thousand points of light. If he had waited the year through he might have picked out six thousand unless for some reason his eyesight was different from ours today. For three millenia the 7mm diameter iris of the human eye remained the only aperture through which the information laden rays of light from the Cosmos reached man's consciousness and invited his interpretation. During much of this time, under the influence of Aristotelian thinking, the "fixed" stars, as distinct from the planetary wanderers were thought of as embedded in a "Caelestiall Orbe" or crystal heavenly sphere and so they were all thought to be at pretty much the same distance from the Earth.

With the invention of the telescope (Galileo 1609, Newton 1670), the prototypes of the huge optical telescopes of this century were born and the numbers of stars perceived increased in a way that has given a special meaning to the adjective "astronomical". Today, although we cannot see them all because of obscuring interstellar dust clouds or because some are intrinsically too faint, we know that our galaxy contains some  $10^{11}$ . I speak of *OUR* galaxy. Not so long ago it was called our Universe and thought of as the whole, though of course no-one knew how far it might extend. It was Thomas Digges who suggested in the century before Galileo that perhaps the stars should be thought of as distributed throughout space. But his idea taken with the ever increasing number of stars seen with bigger and bigger telescopes gave rise to a famous paradox ascribed to Olber

(1826). Olber pointed out in effect that given a large enough Universe of perfect transparency, any line of sight must terminate on a star and so the sky would be seen bright all over as the surface of an average star. Not only would this mean that the sky would not be dark at night, it would imply an intolerable and obviously unreal illumination of our Earth.

Olber's paradox was resolved just a century later by the work of Hubble who made two important and very relevant discoveries as a result of some careful observations. He was studying with the giant 100 inch telescope at Mount Wilson certain fuzzy patches of light called 'nebulae' (from a Latin word meaning 'mist') which were thought to be components of our galaxy. This was natural enough as no-one knew of anything else. These patches, of which the nebula in the constellation of Andromeda is perhaps the best known, being just visible to the unaided eye, were shown by Hubble to have distances far greater than the most distant stars in our galaxy. It is not surprising that for a while they were popularly known as 'other' or 'island universes' though it is probably best to keep the word 'Universe' for 'the whole'. This gives it much the same meaning as 'Cosmos' though the latter has classical overtones of order as distinct from disorder (chaos).

Throughout the Universe, galaxies are distributed with a profusion matching that of the stars in our own galaxy. Typically, a galaxy contains ten thousand million stars though ours has perhaps ten times more, and the number of galaxies in our 'visible universe' is of the same order.

The mention of 'visible universe' introduces the second of Hubble's great discoveries. These distant galaxies are moving away from us. What is more, they are moving away with speeds increasing on the average with their distance from us. It is in fact this that is the real solution to Olber's paradox. The mere recognition that our galaxy is finite brings short lived relief from the paradox, for we soon realize that the same argument could be applied to the galaxies themselves so that everywhere we looked we would see a galaxy and although the more distant ones would appear fainter this would be exactly balanced by our seeing more in each square degree of sky. There are only three possibilities apparent. Either space is not transparent — we have good reasons for knowing that while that is true of certain localities it is an inadequate explanation of the paradox — or the Universe may be finite; this may well be the case but we cannot be sure. The reason we cannot be sure is Hubble's great discovery of the recession of the galaxies, but this itself brings a resolution of the paradox. The Doppler effect is a familiar phenomenon. For light as for sound if the distance between an observer and a source is decreasing rapidly the frequency is increased, the light appears blue-er. If the distance is increasing,

the shift is to the red. Distant galaxies appear reddened and the most distant ones which are receding at velocities approaching the speed of light are so reddened that they seem (but only seem) relatively dull and cool. Thus the paradox is removed. There is a distance at which any galaxy would be moving away at the velocity of light. This sets an absolute limit to the boundary of the 'visible universe'. So much then for the extent of the 'visible universe'. It is incomparably greater than earlier ages supposed and it is of finite size though we cannot exclude the possibility that it might be changing in size. We must remember that we cannot actually see as far as it stretches, for the technical reason that the energy from any object at its limit would be red-shifted to become infinitesimal. In practice, of course, we can only see part of the way, about half, though we are slowly increasing that fraction. We have to remember that 'visible' in this context means 'in principle visible' if we had infinitely powerful telescopes.

We will set down some numbers to help us to get some sort of feel for the magnitudes we are thinking about. We will use the popular unit 'light year' — the distance travelled by a pulse of light in space in a year — rather than the parsec which because it is more directly related to observable quantities is usually used by astronomers. A parsec is in fact 3.26 light years and a light year is just less than  $10^{13}$  kilometres ( $5.91 \times 10^{12}$  miles).

*Some Numbers, Distances and Times*

(orders of magnitude)

Number of atoms in an insect	$10^{22}$
Number of stars in our Galaxy	$10^{11}$
Number of galaxies in 'visible universe'	$10^{10}$
Diameter of the disc of our Galaxy	$10^5$ light years
Distance to Sun	8 light minutes
	$10^8$ miles
Distance to nearest star ( $\alpha$ - Centauri)	4 light years
Diameter of the 'visible universe'	$10^{10}$ light years
Total number of stars	$10^{20-21}$
Age of the Universe probably	$10^{10}$ years

*How long is Time?*

The introduction of the unit 'light year' reminds us that space is associated with time. If we see a celestial object  $10^9$  light years away, then we are seeing what was going on  $10^9$  years ago. When we say that the Crab nebula (the term 'nebula' is used for any celestial 'mist'. This time it is in our galaxy) is the remnants of a

star that exploded in 1054 we mean that that is when the light of the explosion reached the Earth, on 4th July actually. The explosion itself occurred hundreds of years earlier.

Consider a distant galaxy or one of those strange objects known as quasars which are much denser and incredibly bright having masses equivalent to millions of suns (i.e. comparable with galaxies) but dimensions much smaller than that of a galaxy (almost comparable with a giant star) and suppose our observations of its red-shift show it to be getting on for  $10^{10}$  light years away. Obviously this implies that the Universe must be at least that number of years old. Now one of the intriguing things that is emerging as we look back in cosmic time is that what we see then is not quite the same as what we see in our neighbourhood — the nebula in Andromeda for instance which as a close neighbour we see as it was a mere two million years ago. Quasars seem to have been more common earlier in the life of the Universe. This suggests very strongly that the Universe is growing; perhaps we should say growing old or evolving.

The same idea is strongly hinted at by the recession of the galaxies. If they are all moving away from one another with a velocity increasing with their separation, then they surely used to be closer together and presumably there was a time when they were packed in what has become known as the primeval fireball or big bang. If one accepts, as any scientist must in order to pursue his craft, the basic pre-supposition of the Uniformity of Nature, there is only one plausible way of escaping the 'big bang' idea as necessarily implied by the recession of the galaxies. That is the steady state model of the Universe. This supposes that matter is continuously created to take the place of that lost from the visible Universe by galaxies passing out of sight. This picture is now virtually extinct because of the evidence for an evolution of the Cosmos, that it differed in the past from how it is now.

It seems almost certain therefore that there was a big bang to start with. Whether there was an "earlier contraction" would seem to be beyond the power of science to discover. What we don't know yet, though we may hope to find out, is what is likely to happen in the future. One possibility is that the Universe will go on expanding for ever albeit the expansion rate getting slower. Another is that it will slow down, reverse and start to contract, possibly oscillating on like this for ever. Recondite as such ideas might seem, they are by no means beyond our ultimate discovery providing we can take the Principle of Uniformity as valid. It is really all a question of how much matter there is in the Universe. If it contains enough matter, even the most distant and truant galaxy must eventually slow down and return, responding to the gravitational pull of all the other matter in the Universe.

If it is almost beyond scientific dispute that the Universe has an evolutionary history, it is even more certain that stars are born, grow old and die and almost as sure that planetary systems are born, evolve and eventually collapse into their parent sun unless disrupted by some stellar encounter. Moreover, the question of where stars go when they die may have a bearing on whether the Universe is *open* or *closed*, whether the expansion will go on indefinitely or be slowed down and stop, probably to be followed by a contraction, since dead stars must contribute to the unobserved mass of the Universe.

### *The History of Stars and Galaxies*

Galaxies are composed of stars many of them being second generation. By this we mean they have been formed from matter that was previously part of other stars. We can tell this from their optical spectra which declare their chemical composition. When we find many and varied heavy elements like iron, rather than just light gases like hydrogen and helium, we know that these have come from the cores of an earlier generation of stars since it is in stellar interiors that heavy elements are synthesized. Indeed, it is the fusion or "burning" of hydrogen or helium to give heavier elements that is the source of a star's energy.

Stars condense from clouds of interstellar dust and gas where some irregularity occurs giving a density greater than average. This irregularity with its greater density of matter results in a gravitational mutual attraction which draws the matter together. To start with, the greater density makes the radiation of the energy acquired by the infall easier but soon the rising temperature and density oppose the gravity and quasi-equilibrium is reached in which the protostar continues to shrink getting more massive and much more dense than the surrounding dust and gas cloud as it captures matter from it. As the process proceeds, the centre becomes very hot since heat is generated by the infalling matter but increasingly prevented from escaping by the blanket of surrounding material. Eventually, a temperature of a million or so degrees (K) is reached and thermonuclear "burning" starts. This is a new situation. Both the radiated heat and light (mostly X-rays) and the pressure of the immensely hot gas oppose gravity, prevent further contraction and the system stabilizes.

At some time during this process some of the circumambient material may condense to form planets but the process is normally screened from terrestrial eyes and instruments by the huge dust clouds in which it is going on. Quite often, perhaps more often than not, two or more stars condense close enough to be bound to each other gravitationally and to orbit each other as a binary sys-

tem. If they are very close, they will exchange matter between themselves in a way that affects their future.

The life of a star depends on many factors; its speed of rotation, encounter with interstellar material but most of all on its mass which may be in the range  $10^{-1}$  to  $10^2$  times that of the Sun. Less massive objects would never start up nuclear fusion, never light up that is, and so never become visible. Of course, in that case they would represent some hidden mass in the Universe. Heavier objects would tend to become unstable and blow off material until the stable size is reached. Strangely, the heaviest stars have the shortest lives — about a million years. If the history of life on Earth is anything to go by, and in this the scientist has nothing else to go by, the heaviest stars are unlikely to have biologically populated planets. The environment is changed too rapidly for evolutionary processes by slow adaptation. The same would seem to be true *a fortiori* of mutually orbiting double stars. Of course, there may be a "biology" quite distinct from anything of which we have experience and adaptive processes very different from biological evolution as we know it. It is probably reasonable to assume from this that only a small fraction of stars equipped with planets are suitable suns for highly organized creatures to dwell under. The evidence of our solar system would suggest that most planets are quite inhospitable even when they have well behaved suns. Moreover many whole galaxies seem unsuitable homes for biological systems. Even so, with  $10^{20}$  or more stars in the Universe, other inhabited planets could be very likely even if only one in a billion stars were hospitable.

As a star consumes its nuclear fuel of light elements, dramatic changes take place. The Sun may be expected to swell until it engulfs the Earth. Instabilities occur both in size and brightness. (The two are of course related.) For many stars, especially the more massive, a dramatic and highly disruptive explosion ultimately occurs, blowing off the outer layers and exposing an unimaginably hot and bright core which collapses to almost inconceivably huge densities. In any event, the dying ember of a star resembles nothing in our more direct experience and is probably often the centre of events that can reasonably be called bizarre.

The history of galaxies is much more uncertain and possibly more diverse. Exactly how the condensation of primordial matter from the 'big bang' is related to the obscure conditions prevailing in the first moments of the Universe is not known. Our experience of science would lead us to seek some rather general understanding in which no special properties of the 'big bang' need to be invoked to account for the irregularities that gave birth to galaxies, clusters of galaxies and even clusters of clusters. However, while the 'big bang' seems certain; we can even detect the remnants of radiation

emitted as the so-called 3 K microwave isotopic background (i.e. corresponding to radiation from a body at 3 K); the events spanning the expanding fireball to the expanding system of galaxies are obscure. We know there are active galaxies in which immensely energetic processes are occurring. Some show huge jets or blobs of matter apparently shot out for millions of light years. Some show very hot and turbulent cores. Some emit radiowaves or X-rays in vast quantities. Some have as their cores the superstellar quasars which seem to have been more common earlier in the life of the Universe and which may be a stage in the life history of many a galaxy. It seems not unlikely that these contain gargantuan Black Holes. But now we must turn to consider some of the theological implications of all this.

*In the Beginning was the Word*

"Before all worlds". These are the familiar and ancient words, translated into English, with which in 325 AD the Council of Nicea sought to formulate the eternal character Jesus. The Council wanted to be true both to the way the Bible speaks of Christ and to the understanding of that teaching which had grown up in the Church with its Greek and Roman cultural background and superimposed Old Testament world view. It was also, and most immediately, trying to deal with the views of the heretical bishop Arius.

"Before all worlds", "world view". I wonder what the word conjures up in our minds today and whether it is anything like what was meant by the biblical authors or by that fourth century Council. Modern cosmologists speak of a world-line meaning a path in space-time which is no doubt quite different again. The word most commonly used in the Greek of the New Testament and translated "world" in the "King James Version" of the bible is *kosmos* which, in its modern English meaning, is widely current amongst astronomers and cosmologists today. It is now really synonymous with Universe - the whole of material existence. Another word often translated "world" which was doubtless in the minds of the deliberators at Nicea is *aión* which is just our word "aeon". If 'cosmos' seems primarily to convey the idea of the whole of space, 'aeon' certainly speaks of time, literally ages.

Now what the Nicene Creed says, based no doubt especially on the first three verses of the "Letter to Hebrews", is that God the Son precedes "all worlds". The Bible gives us a picture of a Universe and everything in it dependent on God for its existence. It was not just started off by God, or sorted out, order from chaos, but the whole from beginning to end (if it has a beginning and end) comes from Him whom St. John the Theologian calls the Alpha and Omega



(Revelation 1.8). In fact the word *aion* seems to include orders of spiritual being as well and is translated "all orders of existence" in the New English Bible version of Hebrews 1.2. The idea of God the Son having both priority over and creative and sustaining responsibility for all things is central to Christianity which before all else is theistic. "He exists before everything, and all things are held together in Him" says St. Paul in Colossians 1.17. But the thought (I would rather say revelation) is much older. It impregnates the Old Testament, is the strength and glory of Judaism and, separated from the sensitive human sympathy of Jesus, leads in the Muslim faith to the awesome and distant majesty of Allah.

The magnificent fortieth chapter of Isaiah with its rhetorical, "To whom then will you liken me, whom set up as my equal? asks the Holy One" is saturated with it. The Psalms are full of it too. (Psalms 8, 19, 104 and 139 to mention examples only.) So is that much older story in the book of Job. But of course the bible opens with God's priority. The Gospel of St. John repeats it. The First Letter of John echoes it and the Book of Revelation closes Holy Scripture with an anthem on the theme. It is thoroughly biblical to say, "Source of the whole". "In the beginning was the Word of God".

#### *Source of the Whole*

We shall, however, fall very far short of the way the bible depicts God's relationship to the Cosmos if we limit it to an emphasis on the beginning in a temporal sense. First we must take note of the bible's teaching that every event and phenomenon proceeds, as it were, direct from the *fiat* of God. We must heed the teaching of Jesus that God "makes His sun rise ... and sends the rain". This biblical emphasis is all too often watered down in the minds of Christians. It becomes a view that God has so ordered the Universe that sunrise and rain come impartially which misses Christ's point that God, affronted by evil so loves that He still *sends* good and only by so pre-empting ourselves can we, in practice, be His children. God goes on doing it.

The idea of a Universe that ticks on by itself in a wholly autonomous manner and of a God Who occasionally intervenes is a largely pagan concept. It is far removed from Isaiah's picture of a nightly stellar procession which repeats, with no absentee and none out of place, because of God's "great might". It is as far too from the Psalmist's bold use of the Hebrew '*bara*' (= create — as used five times in the first chapter of Genesis) to describe as he does in Psalm 104 v.30 the familiar miracle of animal birth. There is a most admirable effort to recapture this belief in the immanent

and continual activity of God, in the credal statement of the United Church of Christ with its striking use of the present tense:- "He calls the worlds into being, creates man in His Own image and sets before him the ways of life and death" - I wonder why they used "worlds" (Aeons?) instead of "Universe" (Cosmos) there?

The concept of a Universe which is like a self-operating clock with God relegated to the role of clock-maker is deistic. Newton is said to have thought of God like this and the beauty and power of his deterministic scheme of classical mechanics undeniably fits the picture, though in fact even Newton called in God to keep the celestial system in adjustment. (Modern quantum mechanics is less suggestive of a deterministic system.) It was because Laplace, a hundred years later, succeeded in a mathematical analysis of the solar system that left no need for occasional regulation, that he made his famous reply to Napoleon about the absence of God from his thesis:- "Sire, I had no need of that hypothesis". That is precisely what has been going on ever since. No doubt, like Newton, we are still only children playing on the shore of the unfathomed ocean of knowledge, yet every new insight and every fresh understanding declares again that Science has no need of God as a hypothesis. Nor should this surprise us. A God who is only a hypothesis to explain what we do not understand is unrecognisable as the God of the Bible. The biblical idea of God is of One Who is the "Source of the Whole", not was but is or, perhaps better, was, is and will be. There is, I believe, an echo of this in the revelation of the divine Name to Moses at the Burning Bush - "I am what I am", "I will be what I will be" - source of "all that is and all that ever was and all that yet will be."

In talking now about the beginning I therefore insist that the middle and the ending are no less God's work. The interesting and exciting things about the beginning in the temporal sense are scientific not theological. In fact, there is really only one more theological remark that I want to make about the beginning and it is this; I speak of God as "back and back beyond all time and co-related space". Now most cosmologists today believe that the history of the Universe can be traced, at least in broad outline, as we have seen "back to back" to within a minute fraction of a second of a "Big Bang" - a seminal cosmic explosion from which all we now see or detect or infer has been unscrambled. But for a while many cosmologists interpreted the rather scanty evidence then available as suggesting that the life of the Universe extended indefinitely, perhaps infinitely, into the past. Personally, I rather liked this so called "Steady State" theory mostly for aesthetic reasons. There was not much else to go on and it certainly was not because I thought there were any theological pros and cons. There were, in practice, some formidable conceptual problems connected with a rather open-ended proliferation of infini-

tes, but I liked it all the same and half expected the problems to go away when sufficient geometrical genius had been brought to bear. If the Big Bang theory is right, then in its simplest form it suggests that there is a beginning to time, a sort of  $t = 0$  at around 15 thousand million years ago. On the other hand, no-one can be sure that the "Big Bang if such it was", was not preceded by an "earlier contraction", and what is even more merry no-one can be sure which way time was running during the contraction if there was one. (To put it another way; we do not know whether a hypothetical observer living in such a hypothetical contraction would have seemed himself to be living, like us, in an expanding universe because time for him was running the other way. That is to say in a way that we from our position here and now could call backwards.) But let us not complicate it. God, if He is God indeed, is the Giver of the Whole. Space and time are His doing and if in the little time-scale of this Universe He gives infinite space or infinite time, it merely declares his greatness.

### *Contingency*

The relevant theological doctrine is contingency. The Universe macro- and micro-scopically is His doing and His choice. He does not do it because He has to and He does not do it the way He does because there is no other way. It is not merely dependent upon Him but contingent. If in any sense it has to be as it is, that can only be because He is as He is. It fits, indeed derives from, His character. "The heavens tell out the glory of God". This doctrine of contingency, that the Universe is as it is by divine choice, is basic to theism and excludes the increasingly popular non- or perhaps sometimes sub-Christian doctrine of pantheism. Pantheism identifies God with the Universe — a noble idea but still far short of the transcendence attributed to Him in the Bible. And while I am talking about -isms let me fill out the picture by recalling the no doubt unthinking attitude of some Christians who speak and maybe even act as though there is that which exists of its own right so to speak, not given by God. It is easy to slip into imagining that time or space or more commonly both, exist apart from God, that His relationship to them is not that of Creator, that He inhabits them. The idea that space and time do not derive from God is one form of Dualism. Another more subtle form is the idea that good and evil are two autonomous, self-existing entities. But the Bible will not yield an inch on this either. In the New English Bible, Isaiah 45, 6-7 reads, "I am the Lord, there is no other; I make light, I create darkness, author alike of prosperity and trouble. I, the Lord, do all these things." The Revised Standard Version translates like this, "I make weal and create woe" and it is interesting to note that "create" here is the Hebrew word

"bara" as used in Genesis 1. The King James version is even more uncompromising - "I make peace and create evil".

In theism evil is God's creation as a necessary and in a sense, inevitable outcome of the misuse of delegated freedom. This, surely, is the awesome but so true implication of God "visiting the sins of the fathers on the children", grand-children and great grand-children. Any social worker knows that that is a fact of life, as the Christian would say, of God's world. The fact that we recognize this situation in human society and, try by education and by the compassion and gospel of Christ to ameliorate it, simply illustrates what St. Paul (Romans 11:22) calls "the kindness and severity of God". God creates everything. He creates what to us is an evil as an act of mercy. It starts most often as an act of mercy to an individual, a voice of warning which, unheeded, may eventually be unheard, but which calls then to others - family, fellow citizens, the race. So it is that Amos, that towering prophet of social justice and impending doom says, "If disaster falls on a city has not the Lord been at work?"

All of this will raise questions about what we are to understand by the laws of Nature, by chance (and Providence) and by freedom in the Universe as science sees it today. For the present, having noted that beginning when referred to God's activity has to mean author, giver, source in far more than a temporal action at  $t = 0$  sense we must turn back to the scientific ideas and see what we can learn from science about those creations of God, space and time and how closely 'co-related' they are.

### *Relativity*

One of the great discoveries of the century came with Albert Einstein's insights into the close relationship between space and time as developed in his Special Theory of Relativity and his slightly more speculative development of the relationship between space and gravitation and matter known as the General Theory of Relativity. Again because of Einstein, the idea that gravity can be interpreted geometrically implies not only a relationship between the geometry or configuration of space (or perhaps better, space-time) and matter, but also energy, for no discovery of Einstein is better known than the equivalence of mass and energy expressed by  $E = mc^2$  where  $c$  is the speed of light in a vacuum. Mass here means the prime quality that matter has, to resist a change in its motion - Newton's so-called Second Law. What Einstein says is that this quality of inertia which we customarily associate with matter is really a quality of energy in whatever form it occurs.

For example Einstein's Law implies that a watch would be heavier, have more mass, more inertia when fully wound. Because the factor  $c^2 = 9 \times 10^{16}$  (metres per second)<sup>2</sup> is very large, the effect would be not only quite unnoticed but also undetectable. But it would be there all the same. For far larger amounts of energy than could be stored in the mainspring of a watch, it cannot only be detected but becomes quite important. The increased inertia is nothing to do with increasing the number of atoms and molecules in the watch. However, the subject that treats the basic particles of matter is Quantum Mechanics and Dirac's Relativistic Quantum Mechanics provides us with an insight into the conversion of energy into actual atoms and molecules. Because of the huge factor -  $9 \times 10^{16}$  - that we have already noted, we cannot expect, even if we could master the technology, to make the brass, iron and jewels out of nothing but energy, but in principle it could be done.

Dirac's theory, in fact just because it is concerned with the basic particles introduces us to a way of thinking about the properties of space which shows it every bit as "real" as more tangible matter, but we must get back to the bigger scale, broader relationship between space, time and matter implied by Einstein's two theories of Relativity. The mystery of being is so elusive as to call for the utmost humility, precisely that humility that seems to make it easier for great men of Science to enter the kingdom of God than for some others. If a biblical epigram were needed for Einstein's theories and Dirac's and for much else in modern physics it could be, "Judge not by the appearance".

Einstein's Special Theory starts from the observational fact that the speed of light (in a vacuum) is the same for all observers no matter how they may be moving.

The ramifications of this remarkable result are incalculable. One result is that nothing can be accelerated to a speed greater than that of light, another is the equivalence of mass and energy already referred to ( $E = mc^2$ ), a third is that the mass of anything increases as it approaches the velocity of light. (This is really an aspect of  $E = mc^2$ ; as the kinetic energy increases so does the inertia.) Perhaps the most startling result is the discovery that two events that occur at the same instant of time for you may not be simultaneous for me if we are moving rapidly relative to each other. Moreover our measurements of a length will differ.

Perhaps the simplest (and profoundest) way to summarize these effects is to say that it is an observational fact of physics that space and time cannot be treated as distinct entities but are a single whole - space-time.

Einstein's General Theory is, as we have said, concerned with gravitation. From the point of view of mathematical ways of representing our World, it has the interesting property of replacing the Newtonian idea of gravitational forces between masses by a geometrical distortion of space-time itself.

For the path of a particle like a bullet (say) in a gravitational field it operates rather like this. In the absence of air, a bullet's path deviates from a straight line by the fall due to the pull of the Earth's gravity. Einstein replaces this effect by changing the geometry of space-time in which the bullet's path is traced curving it in a way prescribed by the presence of the terrestrial mass. In the geometry of this curved space-time, the path is restored to a "straight line" of geodesic, as it is called by analogy to the shortest path between two places on the surface of the globe - the geodesic or "great circle" along which ships sail or planes fly to accomplish a journey in the shortest time in the absence of winds and currents. There is an analogy in the fact that the path taken by a ray of light passing through a refracting medium, that is, one like water in which the velocity of light is less than its free space velocity, is always the path which involves the shortest time of travel.

The General Theory introduces us to two important ideas. The first of these is that a "curved space-time" allows at least the possibility of a finite yet boundless Universe. Just as the surface of a ball is quite finite and has a definite area given by  $4\pi r^2$  where  $r$  is the radius of curvature so the Universe might turn out to have a finite and quite definite volume. And just as there is no boundary to the surface of a ball as Christopher Columbus demonstrated for the Earth to the confusion of his dissuaders, so the Universe may have no boundary, and for that reason no centre and, of course no place which is farther from the centre than any other.

This concept of a finite but unbounded Universe is interesting in the meaning it suggests for a phrase like "beyond space" for in this case what is beyond space is certainly not space in the sense we normally use the term. To suggest that it was, would be as absurd as suggesting that there must be land and sea beyond the surface of our globe. There is nothing beyond space and if the phrase is to mean anything it must mean "other than space". The Eternal God is surely utterly other than space-time. He creates it and gives it and all within it. He must be "beyond" it.

A second implication of the General Theory is the probable existence of Black Holes with the puzzling concept of inner boundaries or "event horizons" within which the physics would seem to be unknowable.

The General Theory of Relativity and Dirac's Relativistic Quantum Mechanics were early pointers towards the increasing role played by the properties of space in physical theory such that its symmetries and intrinsic characteristics, symbolised mathematically, are the underlying interpretation being given to the varieties and properties of fundamental particles. In the search for a Grand Unified Theory of the basic forces of nature the characteristics of the particles are being subsumed in the characteristics of space.

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