God and the Universe
Transcript

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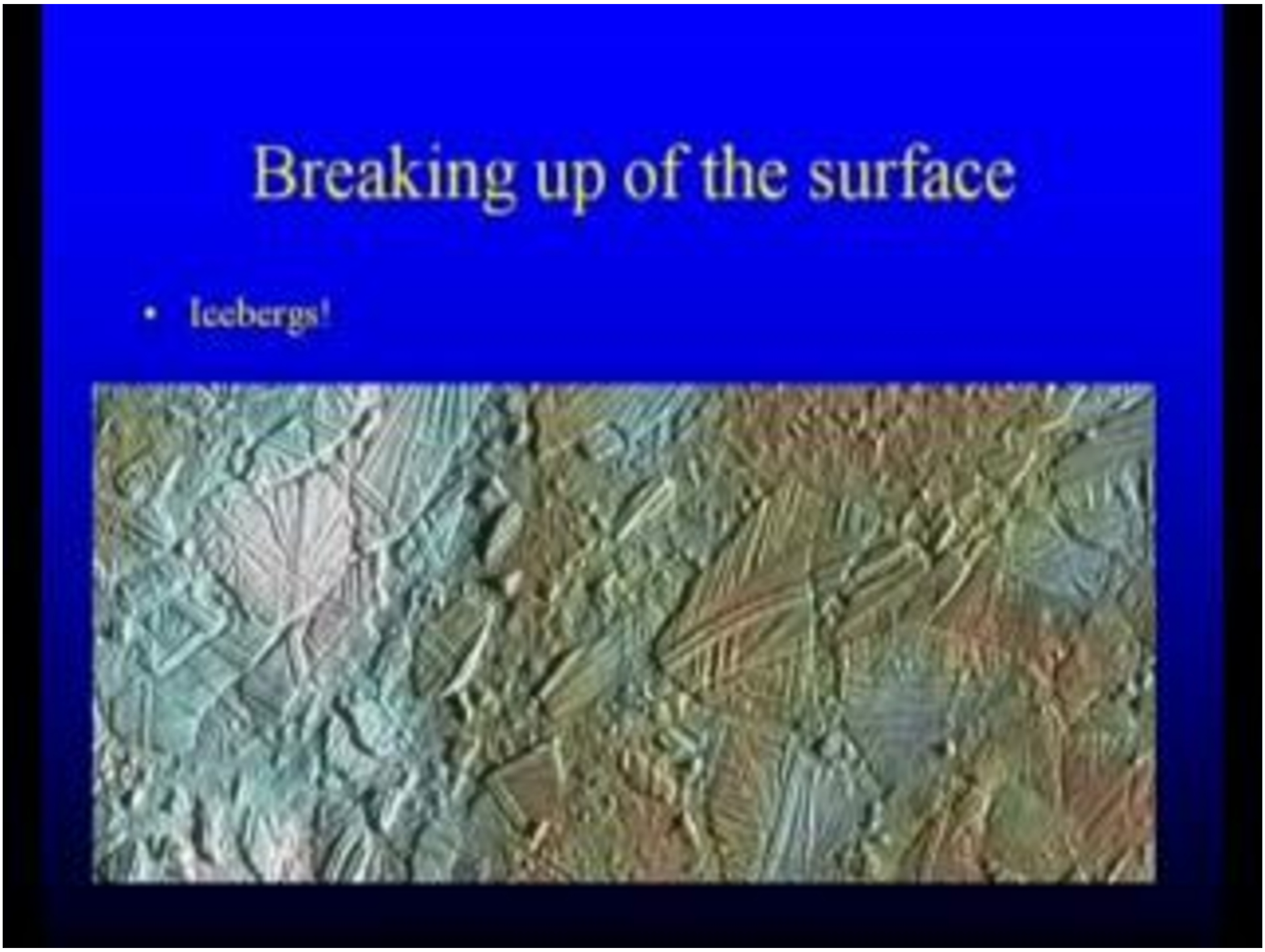

GOD AND THE UNIVERSE

Professor Ian Morison

The Celestial Sphere and Constellations

Looking up at the heavens on a clear night, we can imagine that the stars are located on the inside of a sphere, called the celestial sphere, whose centre is the centre of the Earth.

As an aid to remembering the stars in the night sky, the ancient astronomers grouped them into constellations; representing men and women such as Orion, the Hunter, and Cassiopeia, mother of Andromeda, animals and birds such as Taurus the Bull and Cygnus the Swan and inanimate objects such as Lyra, the Lyre. There is no real significance in these stellar groupings - stars are essentially seen in random locations in the sky - though some patterns of bright stars, such as the stars of the 'Plough' (or 'Big Dipper') in Ursa Major, the Great Bear, result from their birth together in a single cloud of dust and gas.

A chart of the constellation Orion as drawn by Helvelius. It is seen from the outside of the celestial sphere.

The Orion nebula, seen in the Sword of Orion in the image below is a region of excited hydrogen gas. The gas is excited by ultraviolet light from a group of very hot stars at its heart. Such regions are stellar nurseries where stars, like our Sun, are being formed.

Orion, showing the Orion Nebula in the Sword of Orion hanging below his belt.

Energy form the Sun

Up to the late 1800's, scientists could not understand how the Sun could create so much light and heat. Had the Sun been entirely made of something like coal (along with the oxygen it would need to burn) it would burn itself up in about a thousand years! Since the Sun had been providing heat and light for at least several thousand years a chemical source of the Sun's energy was clearly impossible. Around 1870, Hermann von Helmholtz realised that if the Sun were contracting in size, energy, derived from potential energy, could be released. He knew, from the derivations given above, the mass and size of the Sun and also knew how much energy the Sun is continuously creating and sending out into space. He calculated how much the Sun would have to reduce in size to provide its observed output, and deduced the Sun would be able to sustain its energy output for around 20 million years. In the late 1800's people were quite happy to assume that the solar system was less than 20 million years old, so his idea was almost universally accepted as the likely way that the Sun creates its energy. (Note: Jupiter is radiating into space almost twice as much energy as it receives from the Sun - the excess comes because Jupiter is slowly contracting in size and so potential energy is being converted into heat.)

However, during the late 1800's, geologists established that many Earth rocks and the fossils within them are definitely millions of years old, so Helmholtz must have been wrong. In 1905, Einstein published the famous $E = mc^2$ equation as part of his Special Theory of Relativity. One could thus surmise that, as the velocity of light, c, is very large, a tiny amount of mass (m) might be converted into an enormous amount of energy (E). By around 1925, physicists had determined the mass of a proton (a hydrogen nucleus) and had also determined that an alpha particle (a helium nucleus) has a mass slightly less than that of 4 protons. They realised that four hydrogen nuclei might be able to "fuse" together into a helium nucleus (called fusion) and the mass that apparently disappears could be converted into energy.

This is difficult! Since the hydrogen nuclei are each positively charged protons, they repel each other. In order to overcome this mutual repulsion, the protons must be moving toward each other at nearly at the speed of light - and even then quantum mechanical tunneling must be invoked. They can only do this if it is very hot - of order 10 million K. Due to the great mass of the Sun, the pressure at its centre (called its core) must be very high to oppose the mass of the overlaying layers that form the greater part of the Sun and calculations show that the core would reach and exceed the required temperature. Thus the source of the Sun's energy is a nuclear fusion reactor within the core of the Sun. As the dust and gas that made up our Sun collapsed under gravity, the temperature at the centre increased and the protons began to move faster. When the temperature exceeded ~10 million K, the protons' kinetic energy became sufficient for two protons on a collision course to get sufficiently close to allow an effect called quantum mechanical tunnelling to come into play. This allows one of them to overcome the potential barrier due to the electrostatic force between them.

In quantum theory, particles, such as the two protons approaching each other, can be described by wave-functions, which represent the probability of finding a particle in a certain location. If a particle is adjacent to a potential barrier, its wave function decays exponentially through the barrier, but will have still have a very small amplitude on the far side of the barrier. There is thus a very small probability that the particle can "appear" on the other side of the barrier in which case is then said to have tunneled through it. Quantum tunneling thus allows a particle, in this case a proton, to violate the principles of classical mechanics by passing through a potential barrier higher than the kinetic energy of the particle.

This then (very rarely) allows the two protons to come sufficiently close for the strong nuclear force to momentarily bind them together before one of the protons decays into a neutron, a positron and an electron neutrino (see box below). This leaves a deuteron - the combination of a proton and a neutron which is the nucleus of deuterium. The positron then annihilates with an electron, and their mass energy is carried off by two (sometimes more) gamma ray photons. This is the first step in what is called the proton-proton cycle outlined that, finally, creates one helium nucleus out of four hydrogen nuclei.

This process is on a knife edge: if the reaction rate were significantly faster, our Sun would not have a sufficiently long stable phase for intelligent life to evolve, if the reaction rate were significantly slower very few stars would give sufficient heat and light to allow our existence.

Eventually, the core of the star will be converted into helium nuclei. At this point nuclear fusion stops so that the pressure in the core that prevents gravitational collapse drops. The core thus reduces in size but, as it does so, its temperature will rise. Finally when it reaches ~ 100 million K, a new reaction occurs - the **triple alpha process (3α)** - so called because it involves three helium nuclei which are also known as alpha particles. This is an extremely subtle process. The first obvious nuclear reaction that would happen in a core composed of helium is that two ^{4}He nuclei fuse to form ^{8}Be. But ^{8}Be is very unstable - it has a lifetime of only 10^{-19} seconds - and virtually instantly decays into two ^{4}He nuclei again. Only when the core temperature has increased to 100 million K, does it become likely that a further ^{4}He nucleus can fuse with ^{8}Be before it decays. The result is a ^{12}C nucleus. It is highly significant to our existence here on Earth that there is such a difference in temperature between that (~ 15 million K) at which the hydrogen fuses to helium and that (~ 100 million K) at which ^{12}C can be formed. If this were not the case, and the process could happen at the core temperatures close to that at which the proton-proton or CNO cycles operate, there would be no long period of stability whilst the star remains on the main sequence with a relatively constant luminosity. This, of course, has allowed stable temperatures to exist on Earth for billions of years and so enabled intelligent life to evolve.

During its helium burning phase the core will be compressed to perhaps 1/50th of its original size and have a temperature of ~100 million K with, in addition, a shell of hydrogen burning surrounding the core. The energy so produced, in part by the shell of hydrogen burning, causes the outer parts of the star to also undergo significant changes. The radius of the star as a whole increases by a factor of ~ 10, but at the same time the surface cools to (in the case of a 1 solar mass star) a temperature of ~3,500 K. The star will then have an orange colour and the star becomes what is called (perhaps perversely) a "red giant".

Stars like our Sun may continue to build up heavier elements such as Oxygen and Silicon with the most massive of stars creating elements up to and including Nickel and Iron - the most stable elements.

Eventually the stars become unstable and either blow off much of their stellar material giving rise to a "planetary nebula" or, in the case of the most massive stars, undergo a massive explosion called a supernova leaving behind a neutron star or even a black hole.

In the few seconds of a supernova explosion all of the heavier elements beyond Iron and Nickel are created such as gold, silver and lead.

Planetary Nebula surrounding a white dwarf star.

It is only the fact that stars become unstable and eject heavier elements into space at the end of their lives that has provided the material that have allowed terrestrial planets to form and provided the elements out of which life has been created.

Where might life exist?

The elements, hydrogen, oxygen, carbon and nitrogen which form much of our life-form are the most common in the universe and the element carbon, which forms the basis of our chemistry, has the most diverse chemistry of any element. We therefore suspect that the vast majority of other life-forms will be based on the same chemistry as us and thus would need water to be a liquid. The possible locations for life are thus the surfaces of planets that lie within the "habitable zones" of their star or in oceans beneath an icy crust of a satellite in orbit around a giant planet. Here the water is kept liquid by tidal heating caused by the proximity of the planet.

Other solar systems are now being discovered at an ever increasing rate, but it is very difficult to detect terrestrial planets and, as yet, no analogues of our solar system have been discovered. However it is already possible to study the atmospheres of a few planets and, if we were to detect the presence of ozone which has an adsorption line in the infrared part of the spectrum we would know that the atmosphere must contain free oxygen. As oxygen is very reactive, we only believe that there could be free oxygen in the atmosphere if it was being replenished by a life-form.

Many extra-solar planets have been found to be "Jupiter sized" close to their star. These would not allow the presence of terrestrial planets.

Our Place in the Universe

The Milky Way

On a dark night with transparent skies, we can see a band of light across the sky that we call the Milky Way. (This comes from the Latin - Via Lactea.) The light comes from the myriads of stars packed so closely together that our eyes fail to resolve them into individual points of light. This is our view of our own galaxy, called the Milky Way Galaxy or often "the Galaxy" for short. It shows considerable structure due to obscuration by intervening dust clouds. The band of light is not uniform; the brightness and extent is greatest towards the constellation Sagittarius suggesting that in that direction we are looking towards the Galactic Centre. However, due to the dust, we are only able to see about one tenth of the way towards it. In the opposite direction in the sky the Milky Way is less apparent implying that we live out towards one side. Finally, the fact that we see a band of light tells us that the stars, gas and dust that make up the galaxy are in the form of a flat disc.

Galaxies, called originally "white nebulae" have been observed for hundreds of years, but it was not until the early part of the last century that the debate as to whether they were within or beyond our galaxy was settled - essentially when observations of Cepheid variables enabled their distances to be measured. They are, of course, objects outside our galaxy and can now be observed throughout the universe. Galaxies can be divided into a number of types and then the subdivided further to produce a classification scheme first devised by Edwin Hubble. As more and more galaxies were discovered, it became apparent that galaxies form groups (up to about ~100 galaxies) or clusters (containing hundreds to thousands of galaxies).

As our telescopes look ever further out into space, we say that we are observing our universe. Assuming that the universe has an origin some time in the past, there is a limit to how far we can see due to the finite speed of light - we cannot see further that the distance light can travel since its origin. As the universe ages, this limit increases. The part of the universe that we *can* see is properly called the "visible universe", but this is normally shortened to simply the "universe". The whole of space, of which our universe is a part, may well extend far beyond - possible to infinity - and the totality of space is often termed the "cosmos", hence the term "cosmology" used to define the study of its origin and evolution.

Most galaxies are found in groups typically containing a few tens of galaxies or clusters that may contain up to several thousand. Our Milky Way galaxy forms part of the **Local Group** that contains around 40 galaxies within a volume of space three million light-years across. Our galaxy is one of the three spiral galaxies (along with M31 and M33) that dominate the group and contain the majority of its mass. M31, the Andromeda Galaxy, shown in figure 8.25, and our own are comparable in size and mass and their mutual gravitational attraction is bringing them towards each other so that, in a few billion years, they will merge to form an elliptical galaxy. M33, whose mass we calculated earlier, is the third largest galaxy in the group. The group also contains many dwarf elliptical galaxies, such as the two orbiting M31 and visible in figure below. M32 is a small, type E2, elliptical galaxy seen to the left of nucleus of M31, just outside its spiral arms, whilst NGC 205 (M110) is a more elongated, type E5 or E6, elliptical that is seen to the lower left of the nucleus of M31. The Local Group contains several large irregular galaxies, such as the Magellanic Clouds, and at least 10 dwarf irregulars to add to the total. There may well be more galaxies within the group, hidden beyond the Milky Way that obscures over 20% of the heavens.

M31, The Andromeda Galaxy, along with two dwarf elliptical galaxies, M32 and NGC 205.

Observations of the region lying in Virgo just to the west of Leo show many hundreds galaxies and is thus called "the realm of the Galaxies". Sixteen of these are bright enough to have been catalogued by Charles Messier using a telescope of just a few inches aperture. In this direction we are looking towards the heart of a galaxy cluster containing some 2000 members called, due the constellation in which we observe it, the Virgo Cluster. Two other nearby clusters are the Coma Cluster and the Hercules cluster. Galaxy clusters typically contain 50 to 1000 galaxies within diameters of 6 to 35 million light years and having total masses of 10^{14} to 10^{15} solar masses.

The Virgo Cluster of galaxies.

Superclusters

Small clusters and groups of galaxies appear to make up structures on an even larger scale. Known as superclusters, they have overall sizes of order 300 million light-years (100 times the scale size of our local group). Usually a supercluster is dominated by one very rich cluster surrounded by a number of smaller groups. The Local Supercluster is dominated by the Virgo Cluster. The Virgo supercluster, as it is often called, is in the form of a flattened ellipse about 150 million light-years in extent with the Virgo Cluster at its centre and our local group near one end. In the same general direction, but further away lies the Coma cluster containing over 1000 galaxies. It is the dominant cluster in the Coma Supercluster at a distance of 330 million light-years. Two other nearby superclusters lie in the directions of the constellations Perseus/Pisces and Hydra/Centaurus at distance of 150 and 230 million light-years respectively.

How old is the Universe?

The first serious calculation of the age of the universe was made by Archbishop Ussher (this is spelt right!) who was the primate of all Ireland between 1625 and 1656. He studiously worked out the genealogy of the bible - it provides an unbroken lineage from Adam to Solomon. From the late Age of Kings (Ezra and Nehemiah to the birth of Jesus) no information at all is provided in the Bible and he had to link known events from this period with a dateable event in another cultures.

Using these methods, Ussher calculated that the universe was created on the nightfall preceding 23rd October 4004 BC so now ~6000 years old. I regard this as a totally scientific method - even if his error was smaller that justified! His premises were just not as we would use today.

How far back in time can we see?

It was the American physicist, George Gamow, who first realised that the Big Bang should have resulted in radiation that would still pervade the universe. This radiation is now called the **Cosmic Microwave Background** (CMB). Initially in the form of very high-energy gamma rays, the radiation became less energetic as the universe expanded and cooled, so that by a time some 300 to 400 thousand years after the origin the peak of the radiation was in the optical part of the spectrum.

The Discovery of the Cosmic Microwave Background

Radio astronomers Arno Penzias and Robert Wilson serendipitously discovered this background radiation in 1963, but incontrovertible proof as to its origin had to wait until 1992 when the COBE satellite was able to show that the background radiation had the precise black body spectrum that would have been expected. It is worth telling a little of the Nobel Prize winning story of its discovery. Penzias and Wilson had been given use of the telescope and receiver that had been used for the very first passive satellite communication experiments using a large aluminum covered balloon called "Echo". It had been designed to minimise any extraneous noise that might enter the horn shaped telescope and the receiver was one of the best in the world at that time.

They tested the system thoroughly and found that there was more background noise produced than they expected. They wondered if it might have been caused by pigeons nesting within the horn - the pigeons, being at ~ 290 K, would radiate radio noise - and bought a pigeon trap (now in the Smithsonian Air and Space Museum in Washington) to catch the pigeons. They took them many miles away and released them but, as pigeons do, they returned and had to be "removed" by a local pigeon expert. During their time within the horn antenna, the pigeons had covered much of the interior with what, in their letter to the journal Nature, was called "a white dielectric substance" - we might call it "guano". This was cleaned out, but having removed both the pigeons and the guano there was no substantial difference. The excess noise remained the same wherever they pointed the telescope - it came equally from all parts of the sky.

An astronomer, Bernie Burke, when told of the problem suggested that they contact Robert Dicke at Princeton University. Dicke had independently theorised that the universe should be filled with radiation resulting from the big-bang and was building a horn antenna on top of the Physics department in order to detect it. Learning of Penzias and Wilson's observations, Dicke immediately realised that his group had been "scooped" and told them that the excess noise was not caused within their horn antenna or receiver but that their observations agreed exactly with the predictions that the universe would be filled with radiation left over from the Big Bang. Dicke was soon able to confirm their result, and it was perhaps a little unfair that he did not share in the Nobel Prize. The average temperature of the CMB is 2.725K. Thirty years later COBE's measurements were able to show that the CMB had the precise "blackbody spectrum" that would result from the Big Bang scenario. Since then, it has been very difficult to refute the fact that there was a Big Bang.

Arno Penzias and Robert Wilson and the Holmdel Antenna.

Since then, observations by the COBE and WMAP spacecraft, from balloons and high mountain tops have been able to make maps of the universe as it was some 400,000 years after its origin. The structure that we see in this map tells us much about the properties of the universe and helps us estimate its age. The "ripples" that we see in the map tell us of the structure of the early universe that allowed galaxies like ours to form.

All-sky map of the CMB ripples produced by 5 years of WMAP data in March 2008.

Hubble (and later others) plotted the apparent expansion velocity of galaxies against their distance and produced a linear plot. This measures the current rate of expansion of the universe. We do not expect that this relation is actually linear as we know that the universe was expanding faster during its early life. Gravity caused the expansion to slow, but now what we call "Dark Energy" is causing the expansion rate to increase. Taking all this into account we can calculate that the universe was created ~13.7 thousand million years ago. This nicely ties up with the fact that we believe that the oldest stars that we can observe are ~12 to 13 thousand million years old. The universe must be older that anything within it!

Was the Universe created by a GOD?

The very fact that you are reading this book tells us that our universe has just the right properties for intelligent life to have evolved. But why should this be so? As eloquently described in a book "Just Six Numbers" by Martin Rees, there are a number of parameters that have a major influence on how universes can evolve and how stars produce elements that are needed for life. The galaxies formed as a result of fluctuations in the density of the primeval universe - the so called "ripples" that are observed in the Cosmic Microwave Background and shown in the accompanying diagram. The parameter that defines the amplitude of the ripples has a value of ~ 10^{-5}. If this parameter were smaller the condensations of dark matter that took place soon after the Big Bang (and were crucial to the formation of the galaxies) would have been both smaller and more spread out resulting in rather diffuse galaxy structures in which star formation would be very inefficient and planetary systems could not have formed. If the parameter had been less than 10^{-6}, galaxies would not have formed at all! But if this parameter were greater than 10^{-5} the scale of the "ripples" would be greater and giant structures, far greater in scale than galaxies, would form and then collapse into super-massive black holes - a violent universe with no place for life!

One parameter of our universe is so well known that it is barely given a moment's thought - the number of spatial dimensions, 3. But if this were either 2 or 4, life could not exist.

Though we perceive gravity to be a "strong" force (because we are close to a very massive body) it is actually incredibly weak in comparison to the electrostatic forces that control atomic structures and, for example, cause protons to repel each other. The factor is of order ~ 10^{-36}. Let us suppose gravity were stronger by a factor of a million. On the small scale, that of atoms and molecules, there would be no difference, but it would be vastly easier to make a gravitationally bound object such as the Sun and planets but whose sizes would be ~ a billion times smaller. Any galaxies formed in the Universe would be very small with tightly packed stars whose interactions would prevent to formation of stable planetary orbits. The tiny stars would burn up their fuel rapidly allowing no time for life to evolve even if there were suitable places for it to arise. Our intelligent life could not have arisen here on Earth if this ratio had been even slightly smaller than its observed value.

Einstein's famous equation, $E = m c^2$, relates that amount of energy that can be extracted from a given amount of mass, so the value of c is obviously fundamentally important. In practice only a small part of the energy bound up in matter can be released, as in the conversion of hydrogen to helium. This process releases 0.7% of the mass of the four protons that form helium - a percentage closely linked to the strength of the strong nuclear force. This parameter, 0.007, has been called "nuclear efficiency". However if this value were too small, say 0.006, the sequence of reactions that build up helium could not take place. In the first of these reactions, two protons form a deuterium nucleus but, given a value of 0.006 for the nuclear efficiency, deuterium would be unstable so preventing the further reactions that give rise to helium - stars would be inert. On the other hand, if this parameter were 0.008, meaning that nuclear forces were stronger relative to electrostatic forces - the electrostatic repulsion of two protons would be overcome and they could bind together so no hydrogen would have remained to fuel the stars. A critical reaction in the evolution of stars is the formation of carbon in the triple alpha process. Fred Hoyle played a key role in the understanding of this reaction and pointed out that even a change of a few percent from the observed value of 0.007 would have severe consequences on the amount of carbon that would be formed in stars - with obvious consequences for life as we understand it.

How can this be so?

So how can it be that all the parameters described above are finely tuned so that we can exist? There are two possible reasons. The first is that our universe was "designed" by its creator specifically so that it could contain intelligent beings, a view taken by some scientist-theologians. A second view is that there are many universes each with different properties, the term "multiverse" has been applied to this view. We have no knowledge of what lies in the cosmos beyond the horizon of "our" visible universe. Different regions could have different properties; these regions could be regarded a different universes within the overall cosmos. Our part of the cosmos is, like baby bear's porridge, just right.

String Theory: another approach to a "Multiverse"

Theoretical physicists have a fundamental problem. Einstein's General Theory of Relativity that relates to "gravity" is a classical theory, whereas the other forces are described by quantum mechanics. A "theory of everything" has yet to be found that can bring together all the fundamental forces. One approach that is being actively pursued is that of "String Theory". The early string theories envisioned a universe of ten dimensions, not four, making up a 10-dimensional space-time. The additional six beyond our three of space and one of time are compacted down into tiny regions of space of order 10^{-35} m in size and called strings. These are the fundamental building blocks of matter. Different "particles" and their properties, depend on the way these strings are vibrating - rather like the way a string of a violin can be excited into different modes of vibration to give harmonically related sounds. As these strings move, they warp the space-time surrounding them in precisely the way predicted by general relativity. So string theory unifies the quantum theory of particles and general relativity.

In recent years five string theories have been developed each with differing properties. In one there can be open strings (a strand with two ends) as well as closed strings where the ends meet to form a ring. The remaining four only have closed rings. More recently Ed Witten and Paul Townsend have produced an 11 dimensional "M-Theory" which bring together the five competing string theories into a coherent whole. This 11th dimension (and it not impossible that there could be more) gives a further way of thinking about a multiverse.

We can think of a simple analogy: take a sliced loaf and separate each slice by, say, one centimeter. On each of these slices add some ants. The ants could survive, at least for a while, eating the bread of what is, to them, effectively a 2 dimensional universe. They would not be aware of the existence of other colonies of ants on adjacent slices. But *we* can see that all of these exist within a cosmos that actually has a third dimension.

In just the same way, rather than being individual regions of one large spatially linked cosmos, it could be that other "universes" exist in their own space-time - hidden from ours within a further dimension.

How often might intelligent life arise in our Galaxy?

Our universe is suitable for life, how widespread will it be? We suspect that the vast majority of life forms will have the same basic chemistry as our carbon based life. The elements that play a major role in our chemistry; hydrogen, carbon, oxygen and nitrogen are those first produced in stars and are thus very common. In addition, carbon has the most diverse chemistry of any element. It is not impossible that other life forms could exist based on phosphorus, arsenic and methane, but these would, I suspect, be far less common.

So, in most cases, we need locations where water is a liquid, such as the surface of a planet in its star's habitable zone or perhaps an under-ice ocean of a satellite warmed by the tidal heating of a nearby giant planet. If we hope that other advanced civilizations such as our own exist then significant periods of time are needed - to allow the simple lifeforms that may arise a chance to evolve.

In 1960, Frank Drake, who the previous year had made the first search for signals from an extra-terrestrial intelligence in Project Ozma, gathered a group of eminent scientists to try to estimate how likely it was that other intelligent civilisations existed in the Galaxy and might perhaps be transmitting signals that we could detect by observing programs covered by the term SETI - the Search for Extra-Terrestrial Intelligence.

The Drake Equation

They produced what has become known as the "Drake Equation". It has two parts. The first part attempts to calculate how often intelligent civilizations arise in the galaxy and the second is simply the period of time over which such a civilization might attempt to communicate with us once it has arisen.

Some of the factors in the equation are reasonably well known; such as the number of stars born each year in the galaxy, the percentage of these stars (like our Sun) that are hot enough, but also live long enough, to allow intelligent life to arise and the percentage of these that have solar systems. But others are far harder to estimate. For example, given a planet with a suitable environment, it seems likely that simple life will arise - it happened here virtually as soon as the Earth could sustain life. But it then took several billion years for multi-cellular life to arise and finally evolve into an intelligent species. So it appears that a planet must retain an equable climate for a very long time.

The conditions that allow this to happen on a planet may not be commonplace. Our Earth has a large moon which stabilizes its rotation axis. Its surface is recycled through plate tectonics which release carbon dioxide, bound up into carbonates, back into the atmosphere. This recycling has helped keep the Earth warm enough for liquid water to remain on the surface and hence allow life to flourish. Jupiter's presence has reduced the number of comets hitting the Earth; such impacts have given the Earth much of its water but too high an impact rate might well impede the evolution of an intelligent species. It could well be, as some have written, that we live on a 'Rare Earth'. How many might there be amongst the stars?

In addition, it has been widely assumed that once multi-cellular life formed, evolution would drive life towards intelligence, but this tenet has been challenged in recent years - a very well adapted, but not intelligent, species could perhaps remain dominant for considerable periods of time preventing the emergence of an intelligent species.

When all these factors are evaluated and combined, the average time between the emergence of advanced civilizations in our galaxy is derived. My own calculation came out with the value of 35 million years - this is largely determined by how often I believe that a simple life form will involve into "intelligent" life like our own. If we find it hard to estimate how often intelligent civilizations arise it is equally hard to estimate the length of time over which, on average, such civilizations might survive. In principle, given a stable population and power from nuclear fusion, an advanced civilization could survive for a time measured in millions of years. This length of time is critical in trying to estimate how many other civilizations might be currently present in our galaxy. If, for example, a civilization arose once every 50,000 years - a reasonable estimate - but have lifetimes significantly less than this then we could well be the only intelligent civilization at present in existence in our own galaxy.

When the Drake Equation was first evaluated, the estimates of the numbers of other civilizations were quite high; numbers in the 100,000's or even as high as 1 million were quoted. Perhaps sadly, nowadays astronomers who try to evaluate the Drake Equation are far less optimistic and derive values similar to my own.

The truth is we just do not know. It was once said with great insight that 'the Drake Equation is a wonderful way of encapsulating a lot of ignorance in a small space'. Absolutely true, but an obvious consequence is that we *cannot* say that we are alone in the galaxy.

The author's own belief is that simple life will be widespread in the galaxy, but that few locations will keep stable temperatures for sufficient time to allow advanced civilizations to arise.

Perhaps our human race IS rather special.

Could we be here for a purpose?

In one interpretation of Quantum Theory, the Copehagen Interpretation, particles are represented by wave functions that only take up a particle form when observed at which point the wave function is said to "collapse". If one takes this interpretation to extreme it could be said that the universe would not exist unless it could be observed - in which case the presence of a life form is necessary for its existence!

I do not like this interpretation but one could perhaps argue the following if one believed that our universe was created by a "God". There seems little point for an artist or composer to create a work of genius if it could never be appreciated. If so, perhaps, one role of our human race is to be able to appreciate the beauty of "God's" universe.