A Chronicle of Modern Physics

Book III

Soaring on the Wings of Genius

If I have seen farther, it is by
standing on the shoulders of giants.

Isaac Newton (1676)

Dr. Andrew Worsley

First edition 2006

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Cover, *Angel of Enlightenment* by: John and Bridget Wren Potter and Peter Ingram. Adapted from an original by Gustave Doré (1832-83)

Back cover by: Gemma Worsley.

Technical drawing: Joseph Worsley

Dedicated to:

Beauty and Wisdom

Beauty, the eternal spouse of the Wisdom of God and Angel of His Presence throughout all creation.

Robert Bridges (1844-1930)

Acknowledgements

This work is supported by the WWK Trust, whose aims are to promote worldwide ecological, scientific and cultural human development, by the sharing of knowledge.

The work of the late Prof. Paul Marmet, Professor of physics in Canada, in the field of general relativity is acknowledged.

We gratefully acknowledge the assistance of Dr. Nikolaos Mavromatos, King's College London, for his scientific support and discussion.

My gratitude also to my wife, Carolyn, a total non-physicist, my brother Marek Koperski and Alistair Ready for their helpful comments and for making this book an enjoyable read.

Table of Contents

Forward

All the properties of matter are so connected that we can scarcely imagine one thoroughly explained, without our seeing its relation to all others, without in fact having the explanation of all.

Lord Kelvin (1824-1907)

Like all great breakthroughs in science, it is often an unexpected result, which spurs the science community into rethinking how the Universe works. Recently, at the end of the twentieth century just such a discovery was made, which may revolutionize the way we understand the workings of the Universe. It is probable that this discovery is the crucial clue for which mankind has unbeknownst been waiting. This clue has the potential to allow science to unravel the mysteries of the physical Universe.

So important is this discovery that it leads us not only to an understanding of the properties of matter, but also compels us to re-examine the nature of energy and space and time itself. When the discovery was first made, it was greeted with much scepticism by the scientific community. But gradually as more and more evidence has accumulated it has gained wider acceptance. The problem is that science has no real explanation for the phenomenon.

So what exactly is this phenomenon? This new finding affects the entire Universe and came as a complete surprise to most cosmologists. Specifically the entire Universe is not only expanding, but it is expanding at an ever-faster rate.[1] This acceleration in the expansion of the Universe strongly implies one very strange thing. One that scientists are struggling to understand - that there is energy in empty space. Not only that, but it would appear that the energy contained in empty space, far exceeds all the other forms of energy in the entire Universe.

However, this phenomenon is not just a puzzle that requires an answer. In coming to explain this phenomenon it is possible to understand how all the other aspects of the physical Universe arise from a single exquisitely fundamental quantum. The problem is that whilst physics is in effect bound by what has previously been assumed to be correct, it is unable to make the quantum leap of thought required to break the code that is the mystery of the Universe. Ironically, the answer has lain before us for over a hundred years, since the discovery of one of Nature's most fundamental constants, known as Planck's constant. In effect all that is required to unravel these mysteries is an open mind, pure logic and intuitive thought.

In doing so we find a connectedness between everything, which allows an explanation of all the properties of the physical Universe. The last of the known mysteries of the Universe has begun to reveal itself, in such a way as to lay open a window of knowledge so utterly beautiful that it transcends imagination.

Andrew Worsley (July 2006)

Chapter 1

Introduction

The Universe is unfolding as it should

Edwin Hubble (1889-1953).

In the time of the ancient Greeks, the Earth was the centre of the Universe. Around the Earth rotated the Sun and the planets. Even in Aristotle's time (384-322 B.C.) they were able to detect 5 of the other 7 classical planets, but the order they were put in was wrong. To maintain the Earth at the centre of the Universe Ptolemy had to put the planets and the Sun in the order of: Earth, Mercury, Venus, Sun, Mars, Jupiter and Saturn. Each of the planets was treated as if it was embedded in a transparent crystal sphere, which rotated about the Earth, with Earth in the centre. As the distant stars and patterns of constellations, such as Pisces and Virgo were fixed, these were also treated as if they were embedded in a flawless crystal of the outermost sphere of the Universe. This last sphere was placed just outside the orbit of Saturn, and also rotated around the Earth. In effect the orbit of Saturn was the size of the Ancient Greek Universe.

So how did the Greeks estimate the size of their Universe? Remarkably, the Greeks had been able to calculate the circumference of the Earth to a good degree of accuracy. This was done by a Greek scholar of the name Eratosthenes (276-194 B.C.) who lived in Alexandria in Egypt. He was able to observe that a rod cast no shadow, when the Sun was at it's zenith. So in his experiment he placed a rod at a location known as Syene and waited till it cast no shadow. Concurrently a rod placed in Alexandria about 780 km due north, cast a shadow at 7 degrees. Given that a circle has 360 degrees, he calculated the circumference of the Earth as approx. 39,600 km, about 22 thousand miles, whereas the actual circumference is 40,008 km. He had based his workings on valid and logical assumptions and thus achieved a very good degree of agreement.

The Greeks were also able to estimate the distance to the moon as 59 Earth radii, which was also about right. Similarly they estimated the distance of the Sun at some 1200 times the radius of the earth. Taking these deductions together this would have made the distance to the Sun approx. 7,500,000 km, about 4 million miles. An underestimate, but nevertheless, this gave them a basis for estimating the distances involved in astronomy. Thus using their model, this was then the order of the size of the ancient Greeks' Universe.

This model was the accepted model for almost 1500 years. That was until in 1543, when the famous Polish scientist, Copernicus came along and placed the sun at the centre of the Universe. This changed the order of the solar system to the correct order, which is: Sun, Mercury, Venus, Earth, Mars, Jupiter and Saturn. It also implied that the Universe was larger, for if the Earth was now moving around the Sun, in order that the constellations stay in a fixed pattern, they would need to be more distant. Nevertheless, Copernicus still viewed the stars as embedded in the outer most crystal sphere of the Universe.

Tycho Brahe (1546-1601), was the first renaissance astronomer to estimate the distance to the sun, but his estimate of approx. 8,000,000 km, about 5 million miles, was not much better than that of the Greeks. Later Johannes Kepler estimated it at 24 million kilometres, about 15 million miles. In actual fact we now know the distance to the Sun is about 150 million kilometres, or 93 million miles, so Kepler's result was still a considerable underestimate. It was not until 1672, that Giovanni Cassini was able to calculate the distance to Mars and in turn that gave him a good estimate of the distance to the Sun of 140 million kilometres, about 87 million miles. So in the space of 100 years or so, the known Universe had it seemed, expanded some 20 fold.

It was not till the seventeenth century, however, that it was generally accepted that the stars themselves were actually very distant suns. This concept was made all the more possible, because of Galileo and his refinement of the telescope. Nonetheless, the church was very resistant to these new ideas, after all the Earth should be at the centre of the Universe and the Sun and the Earth were considered unique. Fortunately, logic and reason triumphed over religious dogma.

However, the single realisation that stars were in fact very distant suns, had in one fell swoop made the Universe a much, much bigger place. In actual fact the very nearest star to ours is some 268,000 times greater, than the distance of the Earth to the sun. They were unable to measure the distances involved at the time, but today we do know that the distance to the very nearest star (Proxima Centauri) is some 40 million, million kilometres or 25 million, million miles. So with that single realisation the Universe had got at least 270,000 fold larger.

So the Universe, as was then known, did not contain just one Sun but had very many similar suns and had grown again. Both the ancient Egyptians and the Mesopotamians believed in a Universe that would fit within the orbit of the moon. The ancient Greeks lived in a Universe that could fit within the orbit of Saturn. By the sixteenth century the Universe was still very small. However, by the seventeenth century, the Universe, which was until Galileo's time still very small and homely, had suddenly expanded outwards and become a vast and incomprehensible place. Here was another example of the Copernican principle, that asserts that humans hold no special position in the Universe.

The next breakthrough in the understanding of the Universe came from observations of the Milky Way. This is a band of stars in the sky, which is particularly dense. If you look at the stars with the naked eye on a very clear night, this dense band of stars seems to cross the entire sky. It took many years for astronomers to realise that each star in the Milky Way was actually a sun, not dissimilar to our own Sun. By the end of the eighteenth century an astronomer called Sir William Herschel working with his sister Caroline Lucretia Herschel had classified some 2,500 of these star like objects. He mapped out these stars and had placed the Sun somewhere at the centre

But far more was yet to come. Only when it was actually discovered that one half of these suns were travelling in one direction and the other half were travelling in the opposite direction, did the penny start to drop. So what exactly was the Milky Way? Well it turns out that it is a very large collection of stars gathered into a disc, which is itself rotating. This is called a galaxy. This took astronomers to the next level of understanding. Our Universe, it appeared, was a very large group of stars gathered into a giant disc called the Milky Way Galaxy, which is rotating. What's more as our knowledge of the galaxy grew it was realised that our sun was not even at the centre of the galaxy it was some two thirds out towards the edge of the Milky Way.

At the end of the 19th century the total number of stars in the galaxy was being estimated. Taking the average number of stars within a certain area of the Milky Way Galaxy, led to an estimate of the total number of stars. Each star itself was equivalent to a very distant sun. The number of these stars in our galaxy turns out to be enormous. The number was not thousands as thought in the end of the eighteenth century it was not millions, but it is actually hundreds of billions.

The universe itself had again grown enormously. Instead of the night sky being viewed as a backdrop of a pastiche of a few thousand stars, some 25 million, million miles away; it was now appeared that the Universe had become many hundreds of thousand of times larger than this. Rather than Earth being at the centre of the Universe, the Earth was merely a small planet rotating around the centre of our solar system, where the sun lay. Rather than the sun being at the centre of the Universe, our sun was just one of hundreds of billions suns within the galaxy. The physical Universe had grown again to be the size of the galaxy, which was an enormous rotating body of stars in the emptiness of space.

This was the picture of the Universe at the end of the nineteenth century. But even prior to this time astronomers had noticed a few small cloud like structures, which they could not fully resolve with their telescopes. These at the time were called "white nebulae". Astronomers merely speculated that these were clouds of dust somewhere distant within our galaxy. Some, however, thought that they may even be clouds exterior to our galaxy. Fortunately, in the beginning of the twentieth century our telescopes suddenly became far more powerful and photography was developed so that one could get lengthy exposures of these nebulae, which would give a far better picture of what they actually were. Despite having relatively good pictures of these "white nebulae" the debate as to what they actually were, raged for nearly twenty more years. Even in 1920 an astronomer called Curtis was unable to persuade the scientific community what these nebulae actually were. He calculated the approximate distance to these "white nebulae". He also compared what the nebulae looked like, to what our own galaxy would look like from the outside. He argued that what had appeared to be a small disc shaped cloud of dust was not a cloud of dust at all. He argued that they were other very distant galaxies.

We know today that these are other galaxies and some of these are as enormous as our galaxy, but so far away that they had only appeared as small clouds of dust. The distance to these galaxies would be many thousands of times farther than the size of our own galaxy. So these white nebulae were in truth other galaxies. The real question is, why had they taken so long to realise that they were distant galaxies? In actual fact the first sighting of the nearest galaxy, the Andromeda galaxy was made in 964 A.D. by a Persian astronomer named Al Sufi, although the credit usually goes to the renaissance astronomers. As early as 1755 an astronomer and philosopher named Emmanuel Kant had speculated that these were other "island Universes". In 1785 William Herschel had postulated that "our sidereal system" meaning the Milky Way, had a lot of similarities to these nebulae and that they probably lay outside our system. In 1850 one astronomer called Huggins had noticed that these cloud like structures, then called "white nebulae", had the same colour spectrum as that of stars. But even as late as the 1920's some scientists had put forward data to suggest our galaxy was bigger than it was, so that these nebulae could still fit within it. The strange thing is when we analyse this scientific data of the early twentieth century today, it is quite clear that using their own data that our galaxy was smaller than estimated and that the distances to the nebulae were enormous. Clearly some scientists found it difficult to accept that there was more than one galaxy.

From the Earth being the centre of the Universe, we had already been relegated to being a minor planet, orbiting an ordinary sun. An astronomer named Shapley, had led the almost Copernican task of relegating our sun from the centre of the galaxy to some two thirds towards the outside of our galaxy. Ironically he was also one of those astronomers that were convinced that there was only one galaxy. At the time the galaxy was thought to contain thousands of millions of suns, but at least before there was only one galaxy. Now we were relegated to being part of a group of some thirty or so galaxies, in a Universe, which had very many more galaxies in it. Here was another example of the Copernican principle; we were not the centre of the Universe we were not even at the centre of the galaxy, and now there appeared to be very many galaxies in our Universe.

By 1925 the debate was definitively resolved by a man who was to later to revolutionize our view of the Universe - enter Edwin Hubble. When the resolution of telescopes was further improved he could see that the "dust" in these nebulae were actually stars themselves. Our galaxy that had long been thought to be the only one, was now one of very many. Hubble wrote his findings to Shapley who was convinced that there was only one galaxy in the Universe. Upon reading the letter Shapley is reported to have said:

"Here is the letter that destroyed my Universe"

The upshot was that as soon as one of these nebulae had been identified as a galaxy, then there must have been many such galaxies in the Universe. A lot of these nebulae had long since been observed. By the 1920's tens of thousands of these "white nebulae" had been identified. Because of the huge distances between these galaxies the Universe had effectively suddenly become another hundred thousand times bigger.

However shattering this was to some, Hubble then made an even more important discovery in 1929. Until this discovery, the bedrock of astronomy was that the Universe was in some sort of steady state.

Specifically it was relatively static. However, the really interesting thing that Hubble discovered was that the Universe was rapidly expanding. Specifically the distance between the galaxies was expanding. Hubble studied the light spectra of 46 galaxies and showed, by measuring the light from them, that the galaxies were actually racing away from each other. So the Universe was not only absolutely huge but it was also actually rapidly expanding in size. Interestingly the further away the galaxy was, the more rapidly it would appear to be racing away. The standard analogy is to imagine a balloon with dots on it, so as you blow up the balloon the dots appear to be moving apart, and the further they are apart the quicker they will appear to move from each other. The main difference is that you have to imagine the dots are interspersed inside the balloon.

By no means were all scientists happy about these developments. Nor were the consequences of these findings fully understood. If we look at the data, the implications of an expanding Universe is that the Universe would, at one point in time had to be very much smaller in size. By implication the early Universe must have been very hot and very dense. In fact a French mathematician Lemaitre had in 1927, two years before Hubble's discovery, made exactly this prediction from Einstein's equations of gravity (otherwise known as general relativity).

However, to counter this, the steady state theorists, invented a model where matter would continuously be created to fill the spaces that the expanding Universe created, so as to keep the Universe in some sort of steady state. The debate raged amongst scientists who were equally split for over thirty years.

The main protagonist of the steady state theory, which was first proposed by Herman Bondi, was a very respected astronomer Sir Fred Hoyle. In fact it was Hoyle who in the 1950's coined the term Big Bang, as an off the cuff remark, about the rival Big Bang theory of the origin of the Universe.

The fact that scientists were willing to accept the concept of the spontaneous generation of matter from nothing, which clearly violated the law of conservation of energy, attested again to the intransigence to change in science. The thought of a Universe, which was constantly changing was difficult to imagine Even Hubble himself was not entirely convinced by the data. In a 1936 paper he wrote of the hot dense view of the early Universe:

" The high density suggests that the expanding models are a forced interpretation of the data".

Nevertheless Hubble's work had transformed the view of the Universe. Hubble did eventually receive a Nobel Prize for his efforts. But because the Nobel committee did not initially recognize Astronomy, he had to tirelessly campaign for the subject of Astronomy to be included in with the Physics Nobel Prize. He was eventually awarded the Nobel Prize in Physics posthumously in 1953, two weeks after his passing.

The steady state theory itself survived, in contention, for some years more. It was not till 1964 that the debate was finally settled by the discovery of what is known as the cosmic background radiation. The presence of this radiation had been predicted, as a consequence of the Big Bang, as far back as 1948 by a genius scientist called Gamov. He was even able to predict the temperature of this remnant glow from the Big Bang. So when this relic of heat turned up at the right temperature, the issue was finally settled. It would appear that we and much more importantly everything else in the physical Universe had originated in a Big Bang. When more and more evidence confirmed this, the discoverers Penzias and Wilson, were subsequently awarded the 1978 Nobel Prize in Physics for this most crucial of discoveries.

In the meantime by the late 1970's the size of the Universe had grown yet again. Astronomers now realised that galaxies occurred in groups of up to fifty, and that these groups were then gathered into clusters of galaxies, which contained several thousand or so galaxies. Astronomers were now studying superclusters of galaxies each supercluster containing many clusters of galaxies. The Universe was becoming an ever vaster place. Each supercluster was effectively up to many tens of thousands of galaxies huddled together. These superclusters themselves were interspaced by absolutely vast tranches of empty space. Filaments containing a relatively small number of galaxies interconnect these superclusters of galaxies. So the structure of the Universe is like a delicate tracery of galaxies with voids in between.

In hindsight this was the first evidence for what was to come later. The presence of these voids could not be readily explained. Hubble himself had previously thought that the distribution of galaxies was relatively even; although this was later found not to be true, nobody expected to find these large voids. This was the prelude to what was later to be discovered, specifically that the expansion of the Universe was accelerating. So the size of these voids were getting bigger and bigger. Now if we imagine an explosion of any sort, following an initial burst of energy the pieces begin to slow down. This was inherently what scientists were expecting to happen after the Big Bang. The gravity of the Universe should have at least made the expansion slow down. But somewhat surprisingly in 1998, Saul Perlmutter found that the expansion of the Universe was accelerating. By no means was everyone happy with these findings and all manner of different explanations were come up with to explain away the data. But the co-discovery of the same findings later in 1998 by Alex Filippenko, working independently, added much weight to these findings. The explanation for this continued expansion came as a big surprise, there had to be energy inherent in empty space that was pushing this expansion outwards at an ever faster pace. Moreover most of the energy in the Universe consists of the energy that exists in empty space. This is one of the great mysteries of modern Physics.

In the meantime the study of the remains of the heat from the Big Bang, the cosmic background radiation, today is still revealing incredible secrets about the most fundamental aspects of the Universe. The study of the remnant of the hot ashes of the Universe, the background radiation, has eventually identified the age of the Universe. Additionally with the use of the Hubble telescope to look at the far reaches of the Universe, scientists even believe they can estimate the number of galaxies in the Universe along with the size of the Universe.

Now when we talk about the concept of size then the distances we are used to considering as large, normally a few thousand miles, are totally inconsequential. Even the distance to the sun, 93 million miles is miniscule. The distance to the nearest star, which is 300,000 times more distant than that, is a mere hop away. In fact to get any meaning of distance we have to go to use a much larger scale entirely, or else the numbers become ridiculously large, so we use the distance that light travels in a year (circa. 6 thousand billion miles). Distances to the nearest galaxy have to be measured in hundreds of thousands of light years. Today scientists claim to know the size of the Universe and it is inconceivably large at 13.7 billion light years in each direction.

Additionally, by using the Hubble telescope, astronomers are looking back at the very distant reaches of space and have identified that that there are some, 10 million superclusters of galaxies, equivalent to 125 billion galaxies in the Universe. So, it would appear that we are on a minor planet orbiting an ordinary star sitting about two-thirds the way out from the centre of the galaxy. The galaxy itself contains hundreds of billions of stars. Each galaxy is only a small part of a supercluster of galaxies in a Universe itself, which contains 125 billion galaxies.

This then is the epitome of the Copernican principle- or is it? *True* the age of the Universe is correct, at some 13.7 billion years. But in actual fact the size of the Universe we measure is only the distance that light has travelled in that time. What we can see is only the "observable Universe". The most crucial question is how vast is the actual Universe?

Some scientists argue that only the "observable Universe" is relevant, as we can know little of the Universe outside that. Indeed some of what we are observing today is some 13 billion years old. Almost certainly, the picture we have is not a true picture of the entire Universe, which is most probably immensely larger than we can observe. We cannot resign ourselves to only knowing the observable Universe.

The answer to the true size of the Universe may be in knowing what the mysterious energy is in empty space. In knowing this not only may we be able to find what the real size of the Universe is, we may be able unify physics.

Chapter 2

The Substance of the Vacuum

People are very open-minded about new things as long as they're exactly like the old ones.

Charles Kettering

Throughout the history of science, people have been resistant to change. In ancient times it was believed that the Earth was flat and that if one ventured too far then one would fall off the edge of the Earth. It has been said that Alexander the Great's relentless march forwards was to find the edge of the World. We now know today that the Earth is round, or more precisely a sphere. The scientific proof is enormous- we have even seen pictures of the Earth from outer space and it *is* a sphere. Yet even today there exists a Flat Earth Society, its ironic motto is "*Deprogramming the masses since 1547*". It is unwilling to jettison the idea that the world is flat.

If we are to unify the physics of the Universe, some of the old ideas about physics, must also be jettisoned. Logically we cannot hope to retain the same ideas about how the laws of nature work, because these laws at present do not represent a unified approach.

So what is the necessary quantum leap to unite physics? Einstein was very close to making it when he penned his famous equation $E=mc^2$**.** Translated into English, this means the energy of a system is equal the mass of a system multiplied by the speed of light squared. Again this equation has been proven time and time again. What it hints at is that there is link between not only space and time, but between space and time and matter and in turn energy. So this gives us a vital clue to the quantum leap required.

Ironically, the first clue to this leap came well before this, over a hundred and forty years ago in 1864. An eminent scientist called James Clerk Maxwell, with a brilliant talent in algebraic mathematics and geometry, was the first to come upon on this important clue. He showed that the speed of light, had its origins in two other fundamental constants. These constants were the electrical and the magnetic constants, and importantly these constants described the electrical properties of a *vacuum.*

But wait, how can a vacuum of empty space have any electrical properties? Well it *does* and this has been known for a long time, but its implications have been overlooked. These constants were until recently known as the permittivity of free space and permeability of free space. Now they are considered so important they have now been renamed as the electric constant and the magnetic constant respectively. Crucially these are actual electrical constants, which are present in the vacuum and can be separately measured. Each vacuum constant individually has the dimensions of length and time, but also dimensions of Amps and mass. Interestingly, when multiplied together the mass and amps cancel out to give length per unit time, specifically giving the speed of light in a vacuum (see Box 1).

However, when measured separately they do have dimensions, which include the dimensions of electrical current and mass (see Box 1). So it would appear that the very fabric of space-time, has components, which have elements of an electrical force and mass. As an electrical force has energy, then the origin of the energy in empty space is now becoming clear.

Box 1

Vacuum Constants' Dimensions

$$c^2 = 1/\mu_0 \varepsilon_0$$

Dimensionally

$\mu_0 = [L^{-3} M^{-1} T^4 A^2]$

$\varepsilon_0 = [L M T^{-2} A^{-2}]$

$$c^2 = 1/[L^{-3} M^{-1} T^4 A^2] \times [L M T^{-2} A^{-2}] = [L^2 T^{-2}]$$

$$c^2 = [L^2 T^{-2}]$$

where c is the speed of light, ε_0 the permittivity of free space, μ_0 the permeability of free space, L the dimension of length M the dimension of mass, T the dimension of time, and A is Amps.

A far more recent discovery gives us an even stronger pointer to the fact that energy is inherent in empty space. That is the revolutionary discovery that the expansion of the Universe is accelerating (it is increasing in its velocity).

Saul Perlmutter concluded, that there is energy in empty space, when he discovered that not only was the Universe expanding, after the Big Bang, but it is now continuing to expand at an increasing rate.[1] On the face of it this finding makes no sense, because even after a very large explosion the pieces of that explosion will eventually slow down. But the brave and correct conclusion is, this continued expansion will happen if there is energy inherent in empty space-time.

Many scientists in the first instance questioned the findings, but the evidence for it has become increasingly strong and even some of the most sceptical have come to accept the findings and the conclusions. Nevertheless, this has left scientists reeling - what is this strange energy in empty space. The answer to this question is not trivial for as we shall see the answer to this leads us directly to an entirely new unified picture of the Universe.

The necessary quantum leap, or the paradigm shift, to allow this unification, is that space and time and energy are linked to form one fluidic system of :

space-time-energy

What is the evidence for this I hear you say? Well to recap, there is the link between mass and space-time and energy present in Einstein's energy formula $E=mc^2$. Then there are the equations Maxwell discovered for the vacuum, which suggest the vacuum has electrical properties and properties of mass (see Box1). There is also the recent strong cosmological evidence for presence of energy in empty space, due to the accelerated expansion of the Universe. There is further evidence, which we will also elaborate in the next chapter. Suffice to say that the recent discovery of the presence of energy in empty space makes a paradigm shift almost *de rigueur.*

Now this is where the story of the dimensions of the electric and magnetic constants and the energy inherent in space-time gets very interesting. By all accounts, evidence for the presence of vacuum energy had been there for some time. It is just that, when taken together the two electrical components of electricity in space-time cancel out. It is a bit like an atom the outside is negatively charged and the nucleus is positively charged and together they cancel and the atom as a whole is electrically neutral.

The question is what is this energy? Conventionally if we take, force *x* distance *x* time, we get the equivalent of, energy *x* time. Enter Planck's constant, whose dimensions are actually also equivalent to energy *x* time. The presence of Planck's constant has been known since 1900.[2,3] It was first discovered from the study of light, but then became applicable to the equations for the behaviour of matter.[4-7] There is thus very good reason to believe that Planck's constant may also account for the energy of space-time itself.

In actual fact Planck's constant represents the smallest component of energy and is the essential energy component of the *new quintessence*†. This is not the old quintessence described by the eminent

† For a thorough mathematical treatment of how the new quintessence can account for the equations of quantum physics see Book I of the series. For a thorough and accurate account of how the new quintessence can account for particle physics see Book 2.

physicist Lawrence Krauss, but an entirely new quintessence (see Book I and II). It is possible to show that this new quintessence can be used to explain the existence of energy inherent in space-time.

Let us first recap on what the new quintessence is. Imagine a single photon of light, lets say a photon of ultraviolet light. Now a single photon is a very, very small entity, however, it is also a wave, which vibrates at an enormous frequency. In this case ultraviolet light has a frequency of 8 hundred thousand billion cycles per second (800,000,000,000,000 Hz). Now, imagine if we divide that photon by eight hundred thousand billion (800,000,000,000,000), then we have a *single* quantum of our tiny ephemeral new quintessence.

The same applies to matter. The interesting thing about matter at the quantum level is that it also acts a wave. Equally, take the smallest particle that we can measure the mass of, a particle known as an electron. In order to explain its behaviour at the quantum level, it has to have an enormous (estimated) frequency of one hundred billion, billion (100,000,000,000,000,000,000 Hz). If we divide that electron by one hundred billion, billion, again we have the same ephemeral quintessential quantum (for detailed proof see Books 1 & 2 of the series). The interesting thing is the value for the energy of the quintessence quantum, is that it comes out exactly the same whenever we apply this principle. This is the important bit, however we do the calculation (and whatever units we use) the answer effectively comes out exactly the same. †

† See technical notes 1and 2

This is at least in part because on a small enough scale *energy-space-time* are interlinked, This might perhaps have been clear before. This is because on small enough scales at the quantum level everything in the physical Universe can act as a wave, even matter.[4-7] So it is well accepted at the quantum level that matter will not only have mass but also have a wavelength and a frequency, provided you look at it at a small enough scale.

So how small is the scale of the quintessential quantum? Well if we literally and metaphorically liken the electron to be like a large cloud in the sky, then the new quintessence, would be equivalent to a tiny droplet of mist that makes up our cloud. The new quintessence is one hundred billion, billion (100,000,000,000,000,000,000) times smaller than an electron. That is how small the energy of the new quintessence is compared to the energy of an electron. Because of the smallness of the size of this new quantum, it is now small enough to also account for the very fabric of space-time

Now on a more technical level, if we have energy in empty space that energy, by Einstein's energy formula, $E=mc^2$, will have an effective (non rest) mass and strictly speaking momentum (which is just mass x velocity). This is similar to the way that light has energy, and in turn has an effective (non rest) mass and momentum. Mathematically we can derive this fundamental mass quantum in two ways, both methods corroborate the validity of the other method for the derivation. If this quantum is travelling at the speed of light it will nevertheless have a fundamental (non rest) mass. The first method of calculating this (non rest) mass in a self-evident way uses Einstein's standard energy mass relation formula $E=mc^2$, to calculate the quintessential quantum mass. (see Box 2).

You might say to yourself this is obvious, and surely it is. The answer to the conundrum has been staring us in the face for over a hundred years. The irony of it is that had Planck, when he discovered his energy constant, known of Einstein's formula he would probably have got the mass equivalent straight away. But without Einstein's little formula, he instead developed a totally different Planck mass, which was far too large, and did not match his own energy constant. This is largely because the dimensions of his constant were in *energy x time*, but when he developed his Planck mass he constrained himself to produce a value which had the dimensions of *mass* only. This took him in the wrong direction. He should have been aiming at a Planck mass with the dimensions of *mass x time* to match the dimensions of his new energy constant.

So the new quintessence does have exactly the dimensions of *mass x time* to match Planck's constant, which has the dimension of *energy x time*. This is perfectly O.K. because everything in the Universe on a small enough scale also has a frequency. Thus if we multiply *mass x time* by the frequency, which has the dimensions of *1/time* we end up with the dimensions of *mass*, which gives us the correct result. In actual fact we can use this observation to make some very powerful observations about the quantum world[†]. So what is this fundamental quantum mass? Well in the first instance

[†] See also books 1 & 2 of the series.

it is entirely possible to determine this mass from the standard equations of physics (see Box 2 & 3).

> Box 2.
> Quintessential Mass Quantum (m_q)† + Momentum (p_q)
>
> *As* $E = mc^2$, then $m = E/c^2$
>
> substitute
> E for h,
> then
>
> $$\boldsymbol{m_q = h/c^2} \tag{1}$$
>
> if the velocity is c then the momentum p is given by:
>
> $$\boldsymbol{p_q = h/c} \tag{2}$$
>
> where, h is Planck's constant, c is the speed of light. *For dimensions, please see technical note 2.*

To corroborate this, there is a second method for the calculation. This uses values of the original Planck mass, multiplied by the standard Planck time to give the equivalent quintessential quantum mass, again with dimensions of *mass x time* again to match the dimensions of Planck's constant *energy x time.* This also demonstrates how close Planck was to finding the right answer.

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† Dimensionally m_q = [M.T] multiply by n, which is the number of quanta *per unit time*, with the dimensions of $[T^{-1}]$ we get the dimensions $[M.T] \times [T^{-1}] = [M]$. The same principle applies to the momentum.

Box 3.
Quintessential Mass Quanta (m_q) an Momentum (p_q)‡

m_q =Planck mass x Planck time

$$\boldsymbol{m_q} = \sqrt{(hc/G)} \times \sqrt{(hG/c^5)} = \boldsymbol{h/c^2} \qquad (3)$$

If the velocity is c then the momentum p is given by:

$$\boldsymbol{p_q = h/c} \qquad (4)$$

where √ is the square root, h is Planck's constant, c is the speed of light and G the gravitational constant. *For dimensions, please see technical note 2*

Both methods elegantly give the same value for the quantum mass. At the same time this mass value then puts the fundamental quantum mass on the same footing as Planck's constant itself. Both Planck's constant and the quantum mass are equivalent in size. Planck's constant has a time function as part of it's energy component. Now the standard mass quantum has a time function as part of its mass component.†

Once we have this parity between mass and energy in the quantum world, then the unification of physics, becomes feasible, and results in a greater understanding of the fundamental constants of Nature (see Book II) and the fundamentals of gravity.

‡ Dimensionally m_q = [M.T] multiply by n, which is the number of quanta *per unit time*, with the dimensions of $[T^{-1}]$ we get the dimensions [M.T] x $[T^{-1}]$ = [M]. The same principle applies to the momentum.

† For a fuller treatment of the quantum mass please see Book 1, Chapter 7 Quintessential mass quanta. Please also see technical notes 1 and 2.

Now the real irony here, was that once there existed a Planck mass, even when Einstein's energy equation came along some five years later, scientists had already accepted the original Planck mass. They were not eager to reanalyse the original Planck mass. The real problem today, is that the old Planck mass is commonly used in the new string theory. But the old Planck mass is far too big which is what makes string theory so difficult to use mathematically. So much so that this actually begins to alter the standard equations for quantum physiscs.[8,9]

So how small is this new ephemeral quintessence compared to the original Planck mass? Well if the old Planck mass would have the weight of an entire galaxy, that is equivalent to the mass of a billion solar systems, then this new quantum would be the equivalent to the weight of a pinhead. That is how small the true quintessence mass is compared to the original Planck mass.

Now in string theory everything is based on the old quantum Planck mass. This leads us directly to the accepted concept, that everything in the physical Universe can be made of the same quantum. But in the new paradigm this quantum is the *new quintessence* mass. This idea, that the new quintessence could make up energy and matter and space-time and the forces of Nature, were first published in April 2001.[10†] It appears that you and more importantly everything else physical in the Universe, is made of the same stuff as space-time. Today some eminent physicists are now seriously studying this proposal that we are made of

[†] See reference 10. This 1 page reference, refers to a 93 page document, that contains the complete mathematical calculations.

space-time. Recently a paper by Lee Smolin, Markapoulou and Bilson-Thomson was placed on the internet, stating pretty much this.[11] The problem is they haven't as yet found the true quantum mass. Yes they have arrived at a three-dimensional model, but they haven't been able to use this to derive the fundamental mass of the particles they predict. The fundamental quintessential mass defined here, has previously allowed the derivation of the mass of the fundamental particles, and a lot more, from first principles (see Book I & II of this series).

A truly unified theory, should be able to explain everything in the physical Universe, on the basis of a single primary substance, and this is exactly what the new ephemeral quintessential quantum does exquisitely well.

Chapter 3

The Space-Time Matrix

"To deny ether is ultimately to assume that empty space has no physical qualities whatsoever."

Albert Einstein 1920.

The turn of the twentieth century was indeed a most ironic time for science. When scientists at the time thought they knew just about everything that could be known, a scientific revolution was about to occur. But in dealing with that scientific revolution they literally threw out the baby with the bathwater. Some of my learned readers might have already noted that the recently discovered energy present in empty space, is a form of rebirth of what was then known as the "ether". Let us be clear, this is not the same as the old ether, but a new form of energy inherent in empty space. One that increases with the distances involved.

Just to recap, the old ether, was a 19th century concept of an all-pervading substance in space, through which light travelled. This is a bit like sound waves that are produced by disturbances in the air, these require air as a medium to travel through, but cannot travel through a vacuum. (In space, no-one can hear you scream.) Similarly, light reaching us from the sun was presupposed to travel through a "luminiferous" ether. Doubts about the existence of the ether appeared at the end of the 19th century. In 1887, two famous scientists Michelson and Morely had discovered that whether we were approaching the Sun or going away from it, the speed of light appeared to be the same. This constancy of the speed of light, irrespective of the direction and speed you were going, put in question the very existence of the ether. It was Einstein's special theory of relativity, which seemed to put the final nail in the coffin for the ether in 1905 [12] (see also Book I, Chapter 4). Even in today's physics lecture theatres, it is taught that the ether does not exist – despite the recent discovery of the energy, which is inherent in empty space.

Perhaps this points to one of the greater ironies of early 20th century physics, (and of early 21st century physics). Once the ether had been banished no one, it seemed, could bring it back - not even the man who had banished it. But by 1920 it is clear from his own lectures that Einstein strongly believed the ether existed. Of the ether Einstein wrote:

" *More careful reflection teaches us, however, that the special theory of relativity does not compel us to deny ether*

We now know (and did then know), that empty space does have physical qualities. The first clue came as early as 1864, when it was discovered that the speed of light itself, was determined by two constants which describe the electrical properties of the vacuum (now known as the electric constant and the magnetic constant, see Box 1). The major stumbling block to the re-introduction of the ether, was not knowing what speed to give the ether in order to keep the speed of light a constant.

To this end Einstein also wrote:

"We may assume the existence of a ether, only we must give up ascribing a definite state of motion to it"

This approach clearly did not gain favour amongst the science community, even though Einstein himself had proposed it. The ether was banished for over a hundred years. Even today science is most reluctant to recall the name of the "ether". The energy in empty space is variously called: dark energy, quintessence, the space-time lattice or the Cosmological constant.

We have previously called it the *space-time matrix* (see Book I of the series). Let us propose that the individual constituents of that matrix, are the *new quintessence* (see Box 2 & 3). We again stress that this *space-time matrix* is not the same as the old ether and that the energy contained in the matrix increases with increasing distances, as you would expect. The first question you might ask is: would our new quintessence quanta fulfil the requirements for a space-time matrix? Firstly, these would need to be extraordinarily ephemeral in order to compose the space-time matrix, a substance, which cannot be directly detected even today. Secondly, the constituents of the space-time matrix would need to have some inherent energy.

Well with regard the size of quintessence, it *is* an exceedingly ephemeral quantum. It is so small that it has a tenth of a thousandth of a trillionth of a trillionth, of the energy of a single (gamma ray) photon, which itself is an extremely tiny entity. So there would be 10^{28} quanta (100,000,000,000,000,000,000,000,000,000) contained within a single tiny (gamma ray) photon.

The space-time matrix would be composed of energy of these exquisitely small quanta, according to Max Planck's famous equation *E= hf,* which forms the bedrock of quantum physics. *†* So the energy comes in packages of the discreet energy levels 1*h, 2h, 3h, 4h,* and so on.‡ Effectively the space-time matrix would largely be of only a single quantum of this ephemeral quintessence. These would form a virtually seamless three-dimensional space-time matrix as the quanta interweave to form the very fabric of space-time in a breathtakingly aesthetic way.†

It is with the presence of the ephemeral quantum, that we will show that the energy in empty space and in turn the Universe as a whole can be more logically explained. We will show that this quintessential energy, relates to non other than Planck's constant itself and that the energy contained in space-time matrix conforms to equation *E= hf.* ‡

When this equation was first discovered it was thought that it solely governed the behaviour of light.[2,3] Indeed not only is light governed by the equation, but scientists, somewhat surprisingly, later discovered that matter is also governed by the very same equation.[4-7] If we are to succeed in unifying physics, it is only logical to suppose that the energy in empty space is also governed by the same equation. Hence logically, then all the varied constituents of the Universe are then

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‡ Actually the energy equation $E=hf$, can be replaced by the equation $E=hn$, where n is the number of quintessence quanta present per unit time. (see Book 1, Chapter 12)

† As the Planck energy *h*, is given in *energy multiplied by seconds*, the frequency must also be *per second* (please see technical note1).

‡

governed by the very same equation *E=hf.*† Hence by logical reasoning and aesthetic design we will derive an incredibly elegant solution

The real irony is that this solution could have realised over 100 years ago, shortly after the discovery of Planck's constant in 1900. If they had just applied Planck's equation to the existence of what was then known as the ether, then all the pieces of the jigsaw would have fitted in to place. But before the truth could even be contemplated, the ether was discounted in 1905. The timing was unfortunate indeed. Just three years after the discovery of Planck's constant in 1903, there seemed to be a glimmer of realisation. Even before this a physicist named Lord Kelvin had suggested the possibility that the electron has its origins as " smoke rings" of the ether. One of the eminent physicists who had discovered the constancy of the speed of light, Michelson in 1903 wrote:

""We arrive at what may be one of the grandest generalisations of modern science……namely, that all phenomena of the physical universe are only different manifestations of the various modes of motion of one all-pervading ether.

How right he nearly was, however, the new space-time matrix is not the same as the old ether, the new space-time matrix is based on quantum physics. Again the quantum leap was too large for science to make at the time. However, there is now a new paradigm shift,

† Actually the energy equation *E=hf*, can be replaced by the equation *E=hn*, where n is the number of quintessence quanta present per unit time. (see Book 1, Chapter 12)

Einstein's relativity showed that space and time were interlinked to from *space-time*. In this new paradigm energy is linked to space-time, so that we now have *energy-space-time*. This allows an harmonious and unified approach to the entirety of physics. Not only that, but it has previously led us directly to a new Universal energy equivalence formula. ‡

The most beautiful overall solution is, that the space-time matrix, which is composed of quintessence, are one and the same as the ephemeral quanta that make up the photon, the other forces of Nature and matter itself (see also Book 1 and 2) so that *everything* in the physical Universe is made from the very same fundamental quantum.

But a question remains, what is the speed of the components of the space-time matrix? The real answer regarding the speed of a space-time matrix, is quite astonishing. Indeed the results of relativity provide the very answer. The aesthetic answer is that the individual fundamental ephemeral constituents of the space-time matrix, quintessence, are themselves travelling at the speed of light. The question, what velocity would the individual essences of the space-time matrix need to have, to remain constant, is answered. Specifically, it is itself the speed of light, which is constant - so elegant.

The solution itself, is thus the constancy of the speed of light and the individual quanta of quintessence, as they themselves are travelling at the

‡ Actually the energy equation $E=hf$, can be replaced by the equation $E=hn$, where n is the number of quintessence quanta present per unit time. (see Book 1, Chapter 12)

speed of light, will have the same velocity whatever the velocity of the object moving through them. So the solution to special relativity, is to look even deeper into special relativity. We will explain a more logical notion of the motion of quintessence, and a deeper meaning of relativity in the coming chapters of this book. The solution nevertheless turns out to have exquisite symmetry.

The next question is: what is the "*mode of motion*" of the space-time matrix? Our eminent readers would say, if our quintessential quantum forms the very fabric of space-time it must conform to a set of equations known in quantum physics as "field equations" which effectively describe the mode of motion. Indeed there are some field equations, and this is where Maxwell's equations come in to play again. Pretty much at the same time as Maxwell had realised that the speed of light was essentially the product of the electric and the magnetic constant of the vacuum, he had come up with a set of field equations that described the "mode of motion" of light.

To explain this you need to imagine, what a photon of light actually is. Imagine a wave in the sea, this is a two-dimensional wave. So whilst the wave is going in one direction (assigned the x direction) it is undulating in the up and down direction (assigned the y direction). Now light itself, is a three dimensional wave. If you imagine the wave to be travelling in the x direction, then it is oscillating in the y direction *and* in the third direction, the z direction. The effect of the oscillation in the y direction produces an electrical impulse (or the charge density). The vibration in the z direction produces a magnetic field, but because in a normal magnet, the poles of a magnet exactly balance each other, the net effect of the magnetic field is to cancel. This gives the field equations we see in Box 4.

This mode of vibration appears to be the most straightforward mode of motion of quintessence and in keeping with this, the quintessence in space-time merely follows this pattern of motion. The major difference is that that a photon of light is composed of trillions and trillions of these ephemeral quanta bound together; whereas space-time is composed of a three dimensional latticework of single quanta, all going in different directions (although these quanta may transiently combine to form two three or several quintessence).

Of course there would be other modes of motion of the quintessence and these would describe the other forces of nature. Such another force, is the strong nuclear force, which is the force that holds the constituent parts of the nucleus of an atom together (see Book II, Chapter 10). This mode of motion of quintessence is best described by what is known as the Yang Mills equation, after those that first described the mode of motion of the strong force. This is a force, which has characteristics, that lead the particle, that mediates the strong nuclear force (the gluon), to be closed in upon itself. So the mode of motion, which determines the force characteristics of matter can also be deduced from quintessence (see Book II, Chapter 6 & Chapter 10). The crucial thing is that these modes of motion arise from the same overall pattern of motion. There is one directional vector and two vibrating vectors to account for the modes of motion of the new quintessence. This gives three principal options for the motion, and this accounts for the mode of motion of each of the three forces of nature (electroweak, strong force and gravity). Indeed this is exactly why there are essentially only three forces of nature. The question is why are there three forces of Nature is answered and in this case it is essentially the same answer as why the charges come in multiples of 1/3 the charge of the electron, why do particles themselves come in an arrangement of three tiers, and for the same reason there are three real dimensions.

In the case of the *space-time matrix* the mode of motion is the same mode as the photon. This is the simplest mode of motion, with the photon going in the x direction and vibrating in the y and z direction, So the field equations turn out to be pretty much exactly the same as that of light (see Box 4). Moreover, this perhaps is why what was the old quintessence has been described as a "tracker field". In the case of the new quintessence this also appears to track the field equations, which are the same as for light itself. Having said this, unlike the old quintessence the new quintessence in its role as the *space-time matrix*, will only track the light field equations. In its other modes of motion, the new quintessence can behave as the other (force) fields do, such as the forces that govern the matter field (see Book II) and the gravitational field (to be introduced later in the Book). So now we have a fundamental quantum that can both describe the characteristics of both light and the *space-time matrix*. The principle difference being that the quintessence of space-time travels, as it were, singly. Whereas the photon consists of many billions or even trillions of quintessence joined together.

Box 4

<u>Characteristics of Space-time Quintessence</u>‡

Energy: $h = 6.62603 \times 10^{-34}$ J.sec

Mass: $m_q = h/c^2 = 7.373 \times 10^{-51}$ kg.sec

Momentum: $p_q = h/c = 2.2104 \times 10^{-42}$ kg.m.

Wavelength: $\lambda = c\, x\, \text{sec} = 2.99792458 \times 10^{8}$ m.

Wavelength radius: $r\lambda = \lambda/2\pi = 4.77134515 \times 10^{7}$ m.

Field equations:

$$\nabla \cdot \mathbf{E} = 4\pi\rho$$
$$\nabla \cdot \mathbf{B} = 0$$

where h is Planck's constant, c is the speed of light, E is the electric field, B the magnetic field, ρ is the charge density and ∇ is the divergeance.

Additionally in the other modes of motion quintessence can account for the other forces of Nature and the characteristics of matter (see Book II). So in the case of gravity the mediator of that force is (considered by most) as the graviton, which also operates on the

† Dimensionally m_q = [M.T] multiply by n, which is the number of quanta *per unit time*, with the dimensions of $[T^{-1}]$ we get the dimensions $[M.T] \times [T^{-1}] = [M]$. The same principle applies to the momentum.

same principle that there is one direction vector and two vibrating vectors. So we have an entirely unified approach derived directly from the same primary quantum of the Universe.

The key to this unified quantum approach was to take the next quantum leap in our understanding of the Universe. Specifically that *energy-space-time* are interlinked. This leads us directly to a single new quintessential quantum. It is the very presence of this quantum that lays open a window of knowledge on Nature's utterly beautiful design.

Chapter 4

Quantum Relativity

Space by itself, and time by itself are doomed to fade away into mere shadows, and only a kind of union between the two will preserve an independent reality.

Albert Einstein

Einstein spent many years looking for a unified approach to physics. It was Einstein who had made the necessary leap of understanding to discover what is known as the theory of relativity [11]. To do this he had to unite the dimensions of space and time, so that *space-time* were almost fluidic in nature. That in itself was an enormous step forward at the turn of the 20th century, but in order to truly unify physics one has to take the next quantum leap of understanding.

The first leap of uniting space-time, taken by Einstein, had enormous effects on our view of the Universe. This fluidity between space and time means that when one increases one's velocity then both space contracted and time slowed. In relativity this results in the manifestation of time, where the faster one goes, the less time seems to pass (and yes this actually happens!). This occurs along with length contraction, where the faster one goes the shorter one's length gets. So the closer one gets to the speed of light, the length of the object appears to get shorter and the less time appears to pass. Or to put the time aspect more directly –moving clocks go slow.

The relativity concept seemed so counterintuitive to every day experience that it was not initially well received. In the early years after his discovery of relativity, many people rejected the theory. Max Planck who allowed its publication in 1905, in the now famous journal, *Annalen der Physik,* was much chided for publishing "such unnecessary work".

Even today it is tempting to reject what is known as special relativity theory as being illogical. Nevertheless, it has been scientifically proven in millions of experiments, you just need to get close enough to the speed of light for these effects to become noticeable. Interesting special relativity (and general relativity) is now used in one commonly available technology, specifically satellite navigation. Corrections in the system are necessary to account for the effects of the actual speed of the satellite in calculating time. So the theory is not only well tested scientifically, but it is in common usage today.

There is, however, one thing that was not adequately explained by the merging of the dimensions of space and time in relativity. This is the strange effects of the speed of an object on its mass. In relativity the faster an object goes, the greater its mass becomes. That is, as one approaches closer to the speed of light, the total *mass* of an object also becomes greater and greater. So as a solid object approaches the speed of light, its mass will approach infinity. This is why the apparent cosmic speed limit, for a solid object, is the speed of light.

Again, this increase in the mass of an object as it goes faster, has been experimentally proven time and time again, but in reality this effect is not fully explained solely by the "union" between space and time. Indeed the real quantum leap necessary to explain this effect is the linkage between *energy-space-time.*

In truth the effect of speed, in increasing the mass of an object, was another clear hint that energy *was* inherent in empty space, a discovery, which has recently been confirmed. In reality nobody had properly asked the question why does the mass of an object increase with increasing speed? So now that we *do* know, from recent experiments, that energy is inherent in empty space, there would appear to be two possible logical causes for this mass effect:

1). Firstly, increasing speed could increase the "friction" between a moving object and space-time, thereby increasing the apparent mass.

2). The second possibility is that an object speeding along would acquire mass, as more of the actual substance of space-time would pass into the mass, at increasing velocities.

So which of these explanations is actually correct. The first reason does not explain why the actual mass and in turn energy contained within a mass, goes up with velocity. This is known as kinetic energy. This is not apparent energy but actual energy, and as we know, when two objects collide at speed there is a lot of energy released. The second explanation does a better job of explaining this concept of kinetic energy, because the actual amount of space-time substance actually passing into an object would increase its mass. The important thing to stress here is that the additional quintessence contained within the matter is no longer acting as space-time but it is actually acting as matter. The implication of this explanation is that space-time would have to have not just energy, but an effective mass, and (most) scientists accept it is the actual increase in this mass in relativity that results in an increase in the kinetic energy of an object (see Box 5). After all we all know of the constancy of the speed of light, so it is the actual mass that must be increasing.

Box 5
Relativistic Kinetic Energy.

$E_K = \gamma m_0 c^2 - m_0 c^2$

where m_0 is the *rest* mass of the electron, $\gamma = 1/(1 - v^2/c^2)^{1/2}$.

So we know that the real mass of an object increases with greater velocity, and that this increase in mass results in a further increase in the resistance to changes in motion. So how does an increase in mass increase the amount of resistance to motion? The correct answer is that both explanations are needed, because an increase in actual mass would also increase the friction with space-time.

However, the deeper corollary to this increase in mass at greater velocities, is that the substance of space-time must be made of the very same stuff as matter. Otherwise increasing the amount of space-time contained in matter would not increase the mass of an object. The important thing is, that an object increases its mass as it travels faster and faster through space-time, specifically by acquiring more mass from the actual substance of the space-time matrix. Now everything becomes self-explanatory. Space-time impedes changes to velocity and by the same token the energy of space-time adds (or is subtracted) to a mass when its velocity is made to change. Hence the laws of motion of physics are explained at a fundamental level.

Moreover, the crucial thing here is that we can quantise both matter, and space-time using exactly the same quanta. As a result the equations for relativistic mass can be quantised (see Box 6). The relativistic equations have effectively changed, in that there is a minimal increase in mass, which is determined by the mass of the quintessence quantum (see Box 2, 3 & 6). So by defining the minimum mass quantum we can alter the equations for relativity in a direct manner. If we take the equation for relativistic mass for instance, we can deduce the quantum function of standard relativity in such a way that it relates to the quintessence mass (see Box 6)

In relativity the amount that the mass of an object increases, is itself due a factor (known as gamma), which increases with greater velocity. In fact this factor can now be made into a quantum function, dependant on the quintessential quantum mass. So effectively the mass of an object can only increase incrementally, and that incremental amount is none other than the new quintessential mass (see Box 2 & 3). As the quantum mass is in effect many trillions and trillions of times smaller that the smallest thing we can measure, the electron, then the increase in mass will still appear smooth even though it is incremental.

Box 6
Quantum Special Relativity‡

Conventionally

$m' = \gamma m_0$

where

$\gamma = 1/(1 - v^2/c^2)^{1/2}$

in quantum relativity γ *increases only by increments of* m_q/m_0, *such that*

$\gamma = (1 + n.m_q/m_0)$

or

$\gamma = (1 + n.h/E_0)$

where, h is Planck's constant, m_0, is the rest mass of an object, E_0 *is* the rest energy, m_q is the quintessence mass, n is an integer, v the velocity *c* is the speed of light.

In practical terms, because the quintessential mass is now on the same terms as Planck's constant, this quantum relativity turns out to be just a restatement of what is famously known as Heisenberg's uncertainty principle.† As Heisenberg's uncertainty principle has been scientifically proven experimentally on very many occasions, then this is just a common sense modification to relativity.

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† Dimensionally m_q = [M.T] multiply by n, which is the number of quanta *per unit time*, with the dimensions of $[T^{-1}]$ we get the dimensions $[M.T] \times [T^{-1}] = [M]$.

† $p.x \geq \hbar/2$

Not only can we readily and logically quantize relativity, but we can begin to understand the uncertainty principle and a lot of other quantum weirdness to boot. Just to recap, the uncertainty principle states that if know the exact position of something you cannot know its exact momentum (mass x velocity). Equally well if you know its exact momentum you cannot know its exact position. Needless to say, the amount of this uncertainty is based on Planck's constant. When the principle was first espoused, it was thought by many that this was merely a limitation to the accuracy of their experiments. It turned out in fact that it was a real limitation imposed by Nature.

The answer is now plain to see, Heisenberg's uncertainty principle was yet another clue to the new paradigm shift, linkage between *energy-space-time.* The crucial thing is that matter and space-time are made of the same thing and space-time has the same quantum unit of energy as matter does. So the position of an object cannot be determined to a level smaller than the size of the space-time quantum. Equally, knowledge of the momentum of an object is constrained by the equivalent minimum mass quantum.

Additionally, because matter and space-time are made of the same thing, in effect matter and space-time become interchangeable. This is what produces the weirdness we see at the quantum level. For instance, phenomena like quantum tunnelling become clear. This is where a (subatomic) object can metaphorically go through a brick wall spontaneously. In this instance the explanation is that, at the subatomic level, the object can literally transmute itself into space-time and traverse the brick wall. Indeed many of the strange antics at the quantum level can be explained by the inter-changeability of the substance of matter and the forces of Nature, with the substance of the space-time matrix.

The key to this unified quantum approach was to find a discrete quantum of mass, which would be equivalent to the quantum of energy, which Planck had found. For it to account for space-time itself, this quantum mass would need to be exquisitely ephemeral. It is the very presence of this ephemeral quantum mass that will guide us to a greater understanding of special relativity, gravitation and quantum physics in a truly unified Universal design.

Chapter 5

Introducing Relativistic Gravity

When forced to summarize the general theory of relativity in one sentence: Time and space and gravitation have no separate existence from matter.

Albert Einstein

Before Newton arrived on the scientific stage, scholars had thought that the gravity on the Earth and the gravity in the heavens were largely different entities. The genius of Newton was to realise that the gravity that made the apple fall to Earth, was the same gravity that made the planets revolve around the Sun. The first clues to this realisation came from the work of Copernicus, Galileo and Kepler. Kepler in particular noted that the orbits of the planets were not quite round but elliptical (slightly longer in length than width). So in Newton's gravitational terms, the planets orbiting the Sun would experience a force of attraction acting towards the Sun. However, in the planets case they would fly by the Sun and be then pulled back again to form an elliptical orbit. Actually, the real genius of Newton was that he was able to come up with an equation, which would explain this force of gravity very nicely (see Box 7).

Newton's formula for the most part remained the accepted formula for over 250 years. In truth it is still used for most practical purposes today, because it is easy to use (even by NASA). Nevertheless, towards the end of the 19th century a few minor discrepancies started to appear.† Along came Einstein flush from the masterful successes, of the special theory of relativity [12] (see Chapter 4), and the very famous equation $E=mc^2$. [13] These famous papers had appeared in 1905, and not long after this he started to work on a new formula for gravity. This was not at all easy, his next significant paper did not appear till 1911.[14] In this paper he describes the theoretical bending of light, from a distant object, due to the gravity of the Sun. According to his calculations this bending of light would be greater than that predicted by Newton's theory. Interestingly, Einstein, at the end of his 1911 paper, wrote:

It would be a most desirable thing if astronomers would take up the question here raised.

However, testing the hypothesis was interrupted by the commencement of World War I. This was perhaps slightly fortuitous in that his 1911 paper was slightly incorrect. His next major paper was published during WW I in 1916. This was perhaps the most genius of all, in it he finally penned the new theory of gravity, known today as the *general theory of relativity*.[15] This time it appeared to be the correct equation. However, his work, which was published in the German language during WWI, went largely unnoticed at the time.

It was not till after WW I that a famous British astronomer called Arthur Eddington, tested the hypothesis by observing the bending of light by the

† See technical note 3.

Sun. In order to do this he had to wait for the total eclipse of the Sun, because otherwise stars in the line of sight of the Sun would be outshone. This he was able to do in May 1919 with a total eclipse over the island of Principe near Africa. His work, published in English, almost immediately led to Einstein's theory of general relativity being heralded as a breakthrough in physics.

General relativity did not ascribe the effects of gravity to a direct force between two bodies of matter, which Newton had done. What it did do was to ascribe the effects of gravity to the curvature of space-time itself. In the words of the great physicist John Wheeler, matter tells space-time how to curve and space-time tells matter how to move. So in general relativity a mass such as the Sun acted by altering the curvature of space-time itself, and the curvature of space-time is what bent the light from distant stars and made the planets move around the Sun. But how did this apparent force act? Well like all forces it acted thorough a force mediating "particle", in this case called the graviton and it was this graviton release, which in turn caused the curvature of space-time.

What Einstein did first was to develop an equation, which described Newton's gravity, not in terms of a force acting on two bodies, but in terms of the action of a mass on causing the curvature of space-time (see Box 7). This curvature would then cause a planet to orbit an object like the Sun, in an almost circular orbit. For various mathematical reasons, and because Einstein needed to take into account that the actual increase in curvature of space-time would effectively increase the actual density of a mass like the Sun, he then fine tuned his equation, which gave his general theory of relativity an enormous degree of accuracy (see Box 7).

What had initially led Einstein to his theory was a realisation he made in 1907, which he refers to as "*the happiest thought of my life*". This was the realisation that a body undergoing acceleration, just like a car accelerating (i.e. increases its velocity), was the same as the acceleration that a body experienced due to gravity, like the apple gains speed as it falls. Perhaps this was to be expected, because the value of the mass that is affected by motion (inertial mass), is exactly the same as the mass which gravity acts upon (gravitational mass). The real question is not, is this true, but *why* is this true?

Box 7

Gravitational Formulae.

Newton's Gravity

$$F = \frac{G\,Mm}{r^2}$$

Provisional General Relativity

$$R_{ab} = -4\pi G\,T_{ab}$$

Final General Relativity

$$R_{ab} - \tfrac{1}{2}R\,g_{ab} = -\frac{8\pi G}{c^4}\,T_{ab}$$

Where F is the force of gravity, G the gravitational constant, R_{ab} the Ricci curvature tensor R the curvature scalar, T the energy-momentum tensor and g_{ab} the metric tensor.

So the final general relativistic equation was born in 1916. What is apparent is that with this equation Einstein had changed how we view space-time. What is also interesting is by 1916, Einstein was beginning to be a little critical of the concepts of space-time and even of his own earlier paper on special relativity, which he wrote in 1905. In his 1916 paper he was critical of special relativity more than once, in particular he wrote:

"In classical mechanics, and no less in the special theory of relativity, there is an inherent epistemological defect…"

Epistemology is the branch of philosophy dealing with knowledge. Maybe Einstein was beginning to question the apparent nothingness of the vacuum and the rejection of something called the ether. It appears the reason why Einstein had such difficulty in formulating the theory of general relativity (apart from the fact that the maths is fiendishly difficult) was the absence of any substance to space-time. After all if you are going to ascribe gravity to the curvature of space-time, it is difficult to treat space-time itself as nothing at all. By 1920 Einstein was very clear when he wrote:

"According to the general theory of relativity space without ether is unthinkable."

It was all too late, the ether had already been banished. The irony is that, despite the absolute genius of the theory of general relativity, Einstein's' battle to reintroduce the ether fell on deaf ears. Not only that, but his arguments appear to be lost in the mists of time, few now seem to realise that Einstein had actually shifted his stance back towards the existence of the ether.

The other ironic thing is that because of this Einstein himself was not able to fully unite what is special relativity and his gravitational theory of general relativity. After all if you are going to unify physics at any level, it is important to unite at least these two aspects of physics as part of the manifestation of the same underlying process. That is precisely what we are going do in the next paragraphs and at the end of the Book we will reveal a quantum version of general relativity based on the beauty of Newton's and Einstein's equations and quintessence.

But, first we must stress that the *new quintessence* is not the same as the old ether. In contrast to the ether, as you would expect from the characteristics of space-time quintessence (see Box 4), the amount of energy in space-time increases with distance. This is because the very substance of space-time has inherent energy. Moreover, it turns out that this energy is in very good agreement with the characteristics of the *new quintessence* given in Box 4. More on this will come later (see Chapter 6), in the meantime we will first need to unite special relativity, at least conceptually, with general relativity on a quantum basis.

The first stage is to understand the nature of space-time. With the discovery of energy inherent in the fabric of space-time, we need to alter our conceptual idea of space-time. Space-time is no longer a blank canvas of vacuum nothingness - it also has a substance. This is again due to the characteristics of quintessence. The beauty about *new quintessence*, is that it has two components. These components are very similar to the components of light. There is the directional component of motion (or real component) and the two vibration modes of motion. These are just the same modes of vibration as we have with light, but unlike light, which is made of very many quintessences, each quantum of space-time is made of a single quintessence. Crucially, while it remains as a single quintessence then its *wavelength* will remain pretty much exactly the same and this is the "unchanging" part of the substance of space-time (see Box 4). This itself arises from the very constancy of the speed of light.

Just to recap these quintessence are themselves travelling at the speed of light. They are incredibly small. Each quintessence itself would have a trillionth of a trillionth of the energy of a single (X-ray) photon. The fundamental physical characteristics of space-time are given in Box 4. The question is how should we conceive the physical or "changing" part of space-time. Well space-time is best conceived as a substance, which *resists motion*. The less substance part of space-time there is present, the less real space there appears to be, thus the space will get smaller or contract. Less space in this case results from the fact that there is less resistance to motion, so that the distance travelled will appear less. Equally well the less space-time there is the less time will pass. The important thing is, that however much the amount of the substance of space-time changes, (in this case the number of quintessence) then the standard wavelength stays unchanged. This means the essential blank canvas (topology) of space-time remains the same. We can now relate this new concept of space-time to actually what is going on in special and in general relativity (gravity).

Many in science may not have noticed that special relativity and general relativity are not conceptually very well united. Yes they both do depend on the concept that space and time are united to give *space-time*, but the theoretical basis and the maths appears dissimilar (compare Box 7 & 8). The fact is that both special and general relativity are actually both a mathematical representation of Pythagoras's theorem.† This is quite easy to see in the equations for special relativity (see Box 8) where we effectively are working in two dimensions (length and time). But actually quite difficult to see in the case of general relativity, because we have to start working out Pythagoras's theorem in four dimensions (3 of space and 1 of time). In actual fact we have to start thinking in terms of volumes (where we require spherical coordinates). The fact is though, that the mathematical principles are very similar, so the mechanism by which they arise should also be very similar.

The problem till now has been a lack of understanding of space-time itself. Space-time is in a sense *both* a blank canvas of a vacuum, and undeniably also a substance with inherent energy. The blank canvas is represented by the wavelength of a single

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† The square of the hypotenuse is equal to the sum of the squares of the sides, of a right angled triangle.

quintessence, which remains unchanging irrespective of the gravitational field. This forms the fundamental (topological) metric of space-time, which arises from the constancy of the speed of light. The substance component, the number of quintessence per unit of volume, is that which changes in a gravitational field.

Box 8

Special relativity

Lorentz-Einstein Transformations

1. $l = l_0 (1 - v^2/c^2)^{1/2}$

2. $t = t_0 (1 - v^2/c^2)^{1/2}$

3. $m = m_0/(1 - v^2/c^2)^{1/2}$

where m_0, t_0, l_0, is rest mass, time and length respectively, c is the speed of light.

By beginning to understand the true nature of space-time we can begin to combine special relativity and general relativity. This is where the paradigm shift is again necessary, there is a need to view space and time not just as *space-time* but in fact *energy-space-time*. This results in a greater understanding of the heart of the matter, now everything in the physical Universe can then be built up from the same exquisitely fundamental quantum, in the most elegant way. This then explains why matter has wave-particle duality (a particle can also behave as a wave); this explains why the forces of nature behave as a particle and a wave, and why energy is contained within space-time itself. Now we can begin to understand in a unified way how the effects of gravity are exerted.

We will start at the conceptual level and move on to the explanation of the mathematical level in the later chapters. Let us suppose, as most scientists now do, that gravity is mediated by the force particles known as gravitons. (In truth these gravitons themselves will also be made of quintessence, but their mode of motion will be different). It is also clear that in general relativity, it is the graviton that mediates the force of gravity, by imparting the force required to "bend" space-time. Equally well the bigger the mass, the greater the number of gravitons produced, hence the bigger the gravitational effects.

We also know that gravity is governed by the same distance law as applies to light, that is that the strength of gravity diminishes (more or less) in accordance with square of the distance (see Box 7, Newton's gravity). That is, as the distance is increased the force diminishes by the distance squared.†

So let us imagine gravitons emanating from a large mass like the Sun. In the same way light is an outward force mediated by the photon, the force of gravity is an outward force mediated by the graviton. But the graviton acts on the substance of space-time itself. So, the best way of thinking about the graviton is to conceive it as being able to *repel space-time*.† As with light this force will diminish, the further away we get.

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† This derives from the formula for the surface area of a sphere, $A = 4\pi r^2$

† Light acts a repulsive force and in the case of the Sun this keeps it from collapsing,, like light, gravitons form a gauge field, which is also repulsive.

The greatest effect will be closest to the Sun's surface. Now under these circumstances the gravitons will act by repelling space-time and this will lessen the amount of the substance of space-time at the surface of the Sun. This will in turn lessen the amount of space. Equally well, it will lessen the amount of time that passes, effectively slowing down time. (Yes, we know this actually happens, because we have to take into account these effects when using Satellite navigation systems). The maximum effect on time will be at the surface of the Sun, gradually diminishing with distance. In principle this will cause a gradient effect, where the further we go out the substance of space-time will become denser. So the number of quintessence per unit volume will increase. This fundamental unit of volume (or blank canvas) is caused by the constant wavelength of quintessence, (which itself comes from the constancy of the speed of light). The substance component the number of quintessence (per unit blank canvas volume) is that which changes in a gravitational field. The fundamental feature of quintessence is its very duality, one feature arises from the direction of motion in which quintessence is travelling, and the other from its (constant) vibrating qualities. Indeed the question, which is taken as the basis for special (and general) relativity, why is the speed of light a constant, can now be answered. *The speed of light is constant, because the energy of vibration of quintessence is constant.*

To summarize, in effect it is this density gradient of space-time, which causes the effects gravity. An object in a gravitational field is effectively been pushed toward a gravitational object, such as the Earth, by the density gradient of the very substance of space-time (see also Chapter 9). If an object is stationary with respect to the Earth, like the apple, it will fall to the ground. If it is moving with respect to the Earth, like the moon, it will orbit it at the appropriate distance according to the density gradient of space-time and the moons velocity. Thus the overall effect, of gravity on the substance part of space and time will be to lessen it, more and more, the closer we get to the gravitational object, to produce an *energy-space-time* density gradient.

So how does this apply to special relativity? In actual fact this will be almost the same way that space and time contracts in special relativity (see Chapter 4). However, in special relativity the length only contracts in one dimension (in the direction of motion) whereas in gravity, the substance part of space, contracts in all three real space dimensions, so it is the actual volume that appears to contract. Notwithstanding this, this view of gravity provides us with exactly the link from general to special relativity.

Now, we know from special relativity that the mass of an object will go up as the speed of an object goes up (to recap please see Chapter 4). So it is fairly clear to see that as the mass of an object goes up so will the graviton release. This provides us with the very link we need, for like gravity, the greater the mass the greater the graviton release. So for an object travelling at increasing velocity, the greater the mass and the greater the graviton release. As a result the smaller space becomes and less time passes, which is exactly what we see in special relativity. So, there is no need to invoke two different perspectives when examining these two aspects of relativity.

To further summarise, in accordance with conventional special relativity, as the velocity increases the mass of an object will go up (for a further explanation see Chapter 4). In accordance with the standard physics of gravity, as the mass goes up the release of gravitons (also made of quintessence) will rise. So the same sort of effects that gravity will have on space -time will also operate as the speed of an object rises as in special relativity. This result concurs with what we see in special relativity (as explained in Chapter 4). So, as the emission of gravitons increases the amount of space-time quintessence diminishes. As a result the passage of time will lessen and space will get smaller.

The next question is, why exactly should the mass rise in a moving object? Well as the velocity rises the amount of space-time quintessence going through any body (also made of quintessence) will rise. The mass of the body will as a result rise, until a new equilibrium is reached. To restore the balance, the amount of quintessence entering a body should equal the amount of energy leaving it. So the amount of quintessence released is released in the form gravitons, whose release consequently rises. So the quintessence input and output balance is restored. This in turn results in the effects of gravitons on space-time in almost exactly the same way that gravity has on space-time. The only difference is that the gravitons in special relativity are preferentially released in one direction (of least resistance). This happens in such a way that only the length in the direction of motion is contracted, which is exactly what you would expect. So here it is, the mechanism that explains both effects of special and general relativity on the same logical basis.

Voila, the link between general relativity (gravity) and special relativity are conceptually established. This depends once more on the concept of the fundamental quantum of the Universe from which all the elements of the physical Universe are made -that wonderfully unifying quantum the *new quintessence.*

Chapter 6

Quantum Space

It can no longer be maintained that the properties of any one thing in the Universe are independent of the existence or non-existence of everything else.

Lee Smolin (1997)

One of the Holy Grails of modern physics is to find a theory of gravity that not only works, but works on a quantum level. Far better still if we can find a theory of quantum gravity that not only works on a quantum level, but one that connects with the other physical properties of Nature. Moreover, we should be able to begin to connect quantum gravity not only to constants like the Gravitational constant, but also to *the* most fundamental constant of quantum physics, Planck's constant. In order to bring a greater understanding to the nature of space and time we should also be able to deduce its physical characteristics and then connect those characteristics with the other constants of Nature.

In Chapter 3 it was possible to determine some of the fundamental quantum characteristics of the *new quintessence* and define them in terms of these fundamental of the constants of Nature (see Box 4). It turns out that because matter and everything else in the physical Universe appears to be composed of the same new quintessence in the most elegant way, we *can* connect all these characteristics. Thus the fundamental characteristics can also apply to matter, electrical charge and the forces of nature, the equations of quantum physics, and the very nature of particles that inhabit our subatomic world (see Books 1 & 2). One important piece of the puzzle remains missing how do we relate all these characteristics to quantum gravity and indeed the gravitational constant.

Enter Max Planck once more, having come up with his constant, he then used that to formulate some basic fundamental quantities. We have extensively discussed the formulation and indeed reformulation of the Planck mass to form the quintessence mass (see Book 1, Chapter 7 & Book 3, chapter 2). It is the reformulation of this Planck mass that revolutionized our view of the Universe. But what about the other dimensional components, the Planck length and Planck time? In actual fact these Planck quantities turn out to be reasonably accurate estimates. Indeed we can use his conventional formulae as a basis on which to calculate the real Planck length and time. Moreover, these quantities do in fact turn out to have fundamental importance in quantum gravity. However, what Planck lacked, to ensure his length and time parameters were accurate, was one vital quantity. He did not know the *amount* of energy that is present in "empty" space.

Indeed, modern science is in a very fortunate position to be able to calculate pretty well the amount of energy that is present in empty space, which gives us a very good handle on exactly what the Planck length and time should be. Now if we divide the average amount of energy that is present in one cubic meter of empty space by Planck's constant we get a very large number, 1 followed by 25 zero's (10,000,000,000,000,000,000,000,000). More usually the density is calculated on a mass basis, so equally well one would need to divide the average mass density by the quintessence mass. Indeed we get exactly the same answer, 1 followed by 25 zero's, or 10,000,000,000,000,000,000,000,000 (= 10^{25}, see Box 9). Now this might seem like an awfully large number of quanta per cubic meter of "empty" space but it's not really given the smallness of the quintessence quanta. Equally well you have to remember that this is the number of quanta going through a cubic meter at any one point in time. What we actually need is the number of quanta going through a cubic meter per unit time, in this case the second. This is because in the case of Planck's constant and the quintessence mass the unit of time is the second.† Thus we have to calculate the number of quanta travelling through any cubic meter of space per second.

Now imagine that quintessence is travelling at the speed of light. So over a period of a second, some quintessence will leave our cubic meter and others will enter it. In effect, over a period of a second we will need to multiply the number of quanta actually present in our cubic meter by the number of meters light travels in a second (300,000,000 m = $3x10^8$m). So now we get an even bigger number contained in our cubic meter that is, 3 followed by 33 zeros, or 3,000,000,000,000,000,000,000,000,000,000,000 ($3x\ 10^{33}$). So this is how many quanta there effectively are in each cubic meter of empty space-time.

From here we can estimate the true Planck length, through straightforward deductive reasoning.

† Irrespective of what time unit we use, we actually get the same answer, see technical note 1 & 2.

What we have to do is consider the nature of quintessence and that of space-time.

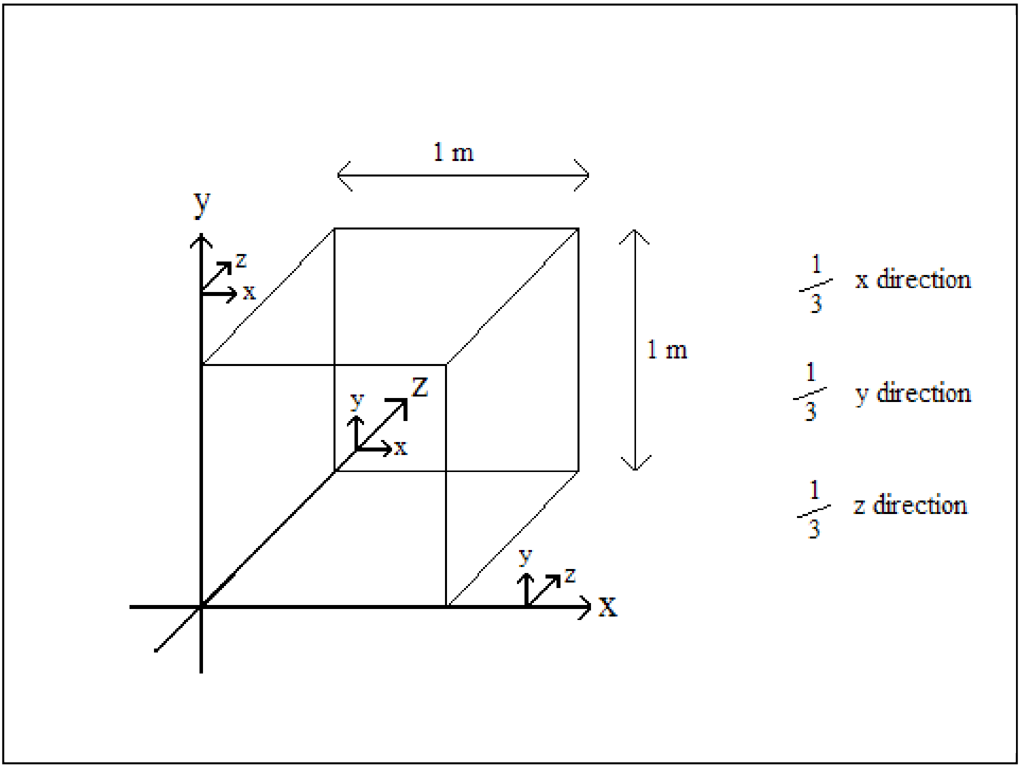

Figure 1. The number of quintessence contained within a cubic meter of space-time can be multiplied by 3, those whose major vector is in the x, y and z vectors respectively. Each quintessence is going in one vector and vibrating in the other two.

What Planck did not know when calculating his unit of quantum length is he had to take in to account the dimensional nature of space-time. To recap, there are three real dimensions (x, y and z), which we can feel and touch. Then there are the vibrating dimensions, two for each real dimension, which we are largely unaware of (mathematically based on imaginary numbers). So for a quintessence travelling in the x direction there will be an additional two vibrating dimensions in the y and z direction, in a very similar way to which light vibrates (see Figure 1). For each of 3 real dimensions there are two vibrating ones, which makes a total of 9 dimensions. Thus we directly multiply the original Planck length, by 9 and we get the total number of quintessence passing through our cubic meter. This gives 3 followed by 33 zero's, or 3,000,000,000,000,000,000,000,000,000,000,000 (3×10^{33}). So the Planck length (that is effectively the length of each quintessence), is 1 divided by the number of quintessence going through our cubic meter, which is 1/3,000,000,000,000,000,000,000,000,000,000,000. Now if Planck had known this he would have pretty much come to the correct answer, which turns out to be some 9 times the original estimate for the Planck length. Because we today we know the mass density of the (observable) Universe, we can arrive at a more correct answer without have to take too big a leap of faith (see Box 9).

From here the calculation for the unit quantum of time, known as Planck time, is pretty much the same again, with the multiplication of the standard Planck time by nine. This gives a quantum value in the order of 1 second divided by one followed by 42 noughts or 1/1,000,000,000,000,000,000,000,000,000,000,000,000,000 ,000, (10^{-41}sec). Now this is an awfully short period of time, but again as with the Planck Length and the new Planck mass described here it pretty much matches the smallness of Planck's constant itself, which is the crucial thing to understanding quantum physics.

Box 9

Quantum Unit of Space

Conventional Planck length (l_P)

$l_P = (hG/2\pi c^3)^{1/2} = 1.616 \times 10^{-35}$ m   or

$l_P = (hG/c^3)^{1/2} = 4.051 \times 10^{-35}$ m

Calculated Quantum length (l_q)‡

Known space-time mass density $\approx 10^{-26}$ kg/m^3

Number of quanta/m^3 $\approx 2\pi 10^{-26}/m_q \approx 10^{25}$ sec^{-1}m^{-3}

1/Cubic volume $\approx 10^{25} \times 3 \times 10^8 \approx 3 \times 10^{33}$ m^{-3}

$l_q \approx 1\text{m}^{1/3}/3 \times 10^{33} \approx 3.33 \times 10^{-34}$ m

thus

$l_q = 9(hG/c^3)^{1/2} = 3.65 \times 10^{-34}$ m

where m_q is the quintessence mass, h is Planck's constant, c is the speed of light and G the gravitational constant.

† Dimensionally n, is the number of quanta *per unit time*, with the dimensions of [T^{-1}] .

The beauty of this new approach is that we can now seek to relate the value of the gravitational constant directly to the quantum length on the basis of some physical observations. The quantum length itself is estimated from the known mass density of the Universe. Thus the estimate of the quantum length becomes more than just wishful thinking based on a theoretical quantum unit, but is based on cosmological observation. This means that observations on the largest scale are connected with the measurements on the smallest possible scale.

What evidence do we have we of this value? The answer is that, we can now start to use the results we get from the large scale Universe to determine what happens at the smallest quantum level. The more definitive proof will come when we are able to do measurements on the smallest quantum scale to find the more correct answer. It may be that it will take science a little time to do this. But the biggest clue to the answer may well lay in finding the length of a single photon. Let us consider a photon as a string of quintessence bound together. Like an open string of pearls, the total length will depend on the average size of each pearl, and if we multiply the average size of each pearl by the number of pearls, that will give us the total length. Similarly, if we directly divide the length of a single photon by it's frequency (which is given by the number of quintessence), one would expect to get a good idea of the true quantum length.

Previously, the estimated quantum Planck length was too small and the range between possible values quite large (see Box 9). Our estimate is larger and lies within tighter bounds. Having done this, we have also for the first time derived a reasonably good estimate of the true quantum length, from observational physics. Notwithstanding that this observation is on the cosmological level rather than at the quantum level, it still can be applied. This is because once we know what the fundamental quantum mass is, we can relate this to the mass density of the Universe. Then this can be used to calculate the quantum length. Once we know the true quantum length, we can back calculate what the gravitational constant should be based on the conventional formula that Planck used (see Box 9). Thus we can directly link the quintessential mass in with something that does operate at the cosmological level - the value for the gravitational constant. This could not have been done with the old Planck mass, the answer you would get for the quantum length would be very large (3×10^9m). Somewhat akin to the length of a cosmic string, which has to date not been found.

The elegance of the new quintessence mass is that everything begins to make sense and that the constants of Nature are not picked out of the air meaninglessly. That which occurs on the largest scale interconnects with that which happens on the smallest scale in the most harmonious way.

Chapter 7

Binding Energy

Good binding has no rope or knots, yet cannot be untied

Lao Tzu, in Tao te Ching

When we stretch an elastic band and then let go, it bounces back. What is it that allows the elastic band to do this? In this case, it is the binding energy between the various bonds of the rubber molecules that bind the elastic band together. Equally well when we see a droplet of water, it is the binding energy between the molecules of water, which give it its teardrop shape when it is falling. It is the same binding energy, which gives water its surface tension, which can keep it round when it is on a flat surface like glass.

Equally it is the principle of binding energy, which makes the Earth round or, more strictly speaking, spherical. Now, the beauty of Einstein's work on gravity is that it provided the basis for understanding gravity in the context of the curvature of space-time (see Chapter 5, Introducing Quantum Gravity). Not only that but in doing so it gave us a much better handle on understanding what the gravitational binding energy actually is. Believe it or not, the amount of binding energy of the Earth can be expressed in terms of the slight volume reduction that occurs due to the effects of gravity on the space-time a gravitational body occupies. This is a difficult concept to grasp, but in actual fact there is a standard formula for this volume reduction (see Box 10), which can be derived directly from Einstein's general relativity. This is expressed in terms of the reduction in the radius of a given volume.

Box 10.

General Relativity

Gravitational radius reduction (r′)

$$r' = \frac{GM}{3c^2}$$

where M is the mass of the Earth = 5.9742×10^{24} kg, c is the speed of light and G the gravitational constant.

Now in terms of the reduction in the radius of the Earth we get a very small number. For instance the Earth's radius at the equator is 6,378,137 meters. If we do the calculation we get a miniscule reduction in the radius, which amounts to about 1.47mm. This is one ten thousandth millionth of the original Earth radius. However, we can effectively view this binding energy, as being the amount of matter that is scraped off the surface of the Earth to the depth of 1.47mm - which is quite a lot of earth. Converting that matter in to energy (by the famous formula $E = mc^2$) gives us the gravitational binding energy of the Earth.

Now this concept may not be much of a surprise for some physicists. But what is a surprise, is that most physicists are still using the old Newtonian concept of binding energy based upon the old Newtonian equations to calculate the gravitational binding energy. Not only is the Newtonian calculation of binding energy not based on the same principles of gravity, but also the proof that goes into calculating the Newtonian binding energy is extremely convoluted and time consuming. This is a bit like still using the gas hob to boil a kettle, when the electric kettle has long since been invented. Moreover, Newtonian mechanics become a little bit inaccurate, when you get to the size of masses like the Sun. This is what Einstein proved when he recalculated the bending of light around the Sun (see Chapter 5). It turned out that the Newtonian calculation for this bending of light gave what is generally called a first approximation, meaning that it is only accurate to a certain extent. It turned out that Newtonian physics gives about 3/5 the bending of light expected. Certainly when we go onto calculate the binding energy of things like Black holes we get a little bit twisted in knots if we try to use the direct Newtonian formula for the binding energy.

The first thing to do is to recalculate the binding energy in terms of Einstein's new gravity, we will initially use a demonstration which gives a first approximation, which works well with low mass objects Then we will give a Universal gravitational binding energy formula, which applies to low mass and to very high mass objects. In the final Chapter we will move to make a minor modification to Einstein's general relativity, which will enable us, to move into the realm of supreme mass objects, like the total mass of the Universe. Then we can move forward with the concepts involved in the full realisation of quantum gravity.

Box 11

Earth's Gravitational Binding Energy (E_G)

Mass E = 5.9742 x 10^{24} kg, Radius E = 6,378,137 m, G =6.67 x 10^{-11} .

Newtonian (E_G) = $3GM^2/5r$ = 2.422 x10^{32} J

New Relativistic (E_G)

Radius reduction: $r' = GM/3c^2$

Surface area of the Earth: $A = 4\pi r^2$

Volume "displaced" = $4\pi r^2 r'$

Average density = $M/(4/3\pi r^3)$

Mass "displaced" = $4\pi r^2 r' \times M/(4/3\pi r^3) = 3r'M/r$

Energy displaced = $3r'M/c^2r$

Substituting r'

Relativistic Binding Energy = GM^2/r = 3,737 x 10^{32} J

where M is the mass of the Earth, c is the speed of light and G the gravitational constant.

This calculation does far better than the Newtonian binding energy for objects such as the Earth and Sun, and gives a value for the binding energy, which is some 5/3 time greater than that given by Newton. But in truth it does not suffice for high density mass objects. Like neutron stars and black holes. However, it is possible to arrive at a more general formula, and then calculate the binding energy of a neutron star or Black Hole itself, which shall be demonstrated in the coming Chapters

On an important but technical note, the binding equation for astronomical objects (see Box 11, Energy = GM^2/r) is a useful approximation for calculating binding energies at this mass level without resorting to general relativity, that part of the equation cancels out neatly so that the equation suffices in itself to produce very nearly the correct answer. The equation for the binding energy is accurate for small *and* higher mass objects (Box 11) in accordance with general relativity, but not for high mass density objects.

In addition, the general equation in Box 11 is proof of principle. It also supersedes the Newtonian binding energy equation, by being derived from general relativity itself. The new equation for binding energy is logical and gives exactly the expected result. Specifically that result indicates that in the case of a planet or sun the energy available is dependant on the space-time element that goes in to the formation of the binding energy. Interestingly we can by taking this further, begin to put a maximum on the potential mass of a super-massive black hole. That arises from the fact that the binding energy cannot exceed the total energy available in the mass itself. This will also be discussed in future Chapters. As regards general relativity, this it seems predicts a binding energy from the volume of space-time "displaced". This is a bit like Archimedes principle: the up-thrust is equivalent to the volume of water displaced. So in general relativity it is the volume of space-time displaced, and the matter that would have been contained within that volume, which gives us the binding energy.

Having said this, there is a down side to general relativity and in particular with the concept of a Black hole. As it stands, in theory at least, all the available space-time has contracted to nothing, so that the black hole becomes an infinitely dense lump of matter, known as a singularity. Indeed there is an objection by some scientists regarding this principle of the singularity. This is exactly where quantum gravity comes to the rescue. Knowing the quantum mass and the quantum length allows us to obviate the problem of the singularity, at least in the case of the black hole size objects.

Suffice it to say at this point that if we divide the mass of the black hole by the quintessence mass, that gives us a good idea of the number of quintessence there actually are within the black hole. Lets just recap on how heavy a black hole really is. If we take the mass of the planet Earth and roughly multiply that by a million, that is how heavy the Sun is. When a sun runs out of energy, then it starts to collapse, because it is the outward “pressure” of light produced by the sun that keeps a sun from collapsing under its own gravity. If the mass of the sun is big enough, when the energy runs out, the sun will explode. If the remaining mass is about 1.44 times the mass of our Sun it will form what is known as a neutron star. Now a black hole requires the collapse of a sun with the minimum remaining mass of three our Suns, to be formed. At that point it is so massive it collapses under its own weight into a black hole. So if we calculate the number of

quintessence required to do this, it is an enormous number (but we should be used to dealing with enormous numbers by now). The number of quintessence quanta within a black hole is 1 followed by 81 zeros (10^{81}). That number looks like this: 1,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000.
in actual fact it turns out to be quite a special number for reasons which we will see later. In the meantime, in the previous chapter (see Chapter 6), we were able to calculate the length of each quintessence ($3x\ 10^{-34}$m) and by inference we can calculate the three-dimensional volume (6×10^{-101} m^3). So on this basis, then even in a small black hole there is a residual volume of quintessence, albeit quite small (10^{-20} m^3). This is sufficient volume to introduce a very small correction to general relativity. So by introducing a correction to general relativity based on the quantum mass and length we can avoid that point at which the ordinary black hole become an infinitely dense point. We will go into specific details in the last chapter of the book where a minor modification to general relativity is made, which allows the quantum gravity aspect of space-time to be taken into account.

However, in order to go further with quantum gravity, there is one more important thing to mention. That is what is called the event horizon of a black hole. The reason why a black hole is called just that, is because it has such a powerful gravitational field that not even light can escape its effects. This is called the event horizon, because beyond this point we can no longer see what is happening within the black hole, and no light can exit this limit. The story of the discovery of the event horizon starts in 1916, just a few months after the publication of Einstein's paper on general relativity in 1916. A young physicist named Schwarzschild (interestingly Schwarz in German means black) wrote to Einstein with a solution to general relativity in which the young physicist actually calculated the mass required to overcome the escape velocity of light and more importantly the radius of such a mass. Einstein was impressed by his work and it was soon published. Unfortunately, Schwarzschild died shortly afterward in WW I, nevertheless his publication laid the groundwork for what is now a very important field of cosmology.

What the equation did was cleverly calculate a solution using Einstein' equations, which effectively gave a radius from which a black hole would form. This has henceforth been called the Shwarzschild radius, but its interpretation remains debateable amongst physicists. Some believe it to be the basis of the radius of the singularity and some believe it to be the radius of the horizon for the escape velocity of light and some believe it to be both. To resolve this question we just need to look at the equation (see Box 12)

Box 12

Schwarzschild Radius R_s

$$R_s = \frac{2GM}{c^2}$$

where M is the mass of the Black Hole, c is the speed of light and G the gravitational constant.

A direct comparison of the equation for the relativistic radius of the Black hole (see Box 10) and the Schwarzschild radius (Box 12) shows they are different. The Schwarzschild radius is exactly six times more that the relativistic radius for a singularity. So while the radius reduction, or the "binding energy", of a minimum size black hole is 1.5 km, the event horizon radius is 9km. So it would appear clear that the event horizon is just that, the horizon for the escape velocity of light. We will revisit this concept in the next Chapter upon the actual size of the Universe.

Suffice it to say that the understanding of the quantum world at the quintessence level is an incredibly powerful tool, which allows us to peer outside our "observable" Universe and to make predictions about the origins and structure of the Universe otherwise thought to be beyond the scope of current scientific knowledge.

Chapter 8

The Universe and Beyond

Two things are infinite: the Universe and human stupidity and I'm not sure about the Universe.

Albert Einstein.

In ancient Egyptians times, the universe was no bigger than the orbit of the moon. Virtually all other objects in the sky at night were considered to be some form of roving eternal deity. The most powerful was Ra the sun deity. By the turn of the 20th century all that had changed, the Sun was merely one of many stars in the galaxy and the galaxy was merely one of very many galaxies in the Universe. Indeed a lot of scientists at the time had thought of the Universe as being static and probably infinite. Edwin Hubble again changed that in 1929 when he discovered that the Universe was expanding (see Chapter 1). Today, by studying the remains of the ashes of the Big Bang, we can reasonably accurately estimate the age of the Universe as 13.7 billion years old. Thus it would appear that the Universe is also some 13.7 billion light years across in each direction. Or is it? It turns out that this is not the size of the Universe, this is merely the size of the "observable" Universe.

The question remains, how big is the Universe, is it infinite or finite, and if it is finite how big can it be? Some people would say does it matter, after all the observable universe is all that we can know. Others would disagree, surely our knowledge should extend beyond that which we can merely see.

Now that we know, with reasonable certainty the age of the Universe, then it would appear that we can answer the first question with a degree of logical deduction. Is the Universe infinite? If the Universe began some 13.7 billion years ago, for it to be infinite now, it must have expanded at infinite velocity (at least at some stage) in the past. The evidence we have strongly suggests that this is not the case. From the evidence we do have it would appear that the Universe went through a period of rapid expansion just after the Big Bang and this is called inflation. But there is no evidence that the Universe went through a period when it expanded at infinite velocity. So from what we can deduce the Universe itself is very likely to be *finite.*

Before we go any further, it is of course important to make the distinction between our Universe and what is the entire Cosmos. There is a school of thought, which is gaining increasing scientific support, that our Universe is just one of very many Universes in the entire Cosmos. Thus almost by definition, whilst the Cosmos may well be infinite, the individual Universes that inhabit that Cosmos are very likely themselves to be finite.

The next question is, if the Universe is finite, as appears to be the most likely possibility, just how big is it? Perhaps, before attempting to answer this question we should recap on what *is* known about our Universe. Very briefly, it would appear that the Universe we know, began as a Big Bang some 13.7 billion years ago, it then appears to have gone through a period of rapid (but not infinite) expansion and then slowed down in its expansion. More recently (and this is one of the mysteries) over the past 5 billion years or so that expansion seems to be accelerating.

The size of the "observable" Universe is as you would expect, some 13.7 billion light years in each direction. The generally accepted mass of this "observable" Universe weighs in at some, one hundred trillion, trillion, trillion, trillion metric tonnes (10^{53} kg). The speed of expansion of the Universe, depends on the objects distance away, so the further it is away the quicker it is moving away, this is called the recession velocity. The current recession velocity, for every *million light years* in distance away from us, is approximately 21.5 km/sec.† So if an object is 2 million light years away it will appear to be moving away from us at 43 km/sec, and so on.

So does all this fit together? Well, until quite recently all these facts were in some doubt, so no one has really had a chance to fit all the pieces of the jigsaw together yet. But in truth it does fit together quite nicely, if not in an entirely expected way. Let's, for instance calculate the maximum recession velocity and see what we get. We can do this by multiplying the recession velocity by the size of the observable Universe. If we do this straightforward calculation, then the maximum velocity we get is the none other than the speed of light (3×10^8 m/sec). Quite a few scientists in the field, I am sure, would have expected this result, but it is important to have confirmed it. Indeed, as we know the speed of light very accurately, we can back calculate this figure to get a far more

† The Hubble recession velocity 70km/sec/MPc, has been converted to light years, for consistency.

accurate estimate of the recession velocity, and we can now achieve greater accuracy (21.9km/sec per million light years or 71.4km/sec/Mpc).

Does this then mean that the size of the Universe *is* limited to 13.7 billion light years? After all, the speed of light is the cosmic speed limit, and nothing should be able to go faster than this. The answer is *not at all*, and this is very important, the recession velocity is not the speed that an object is travelling away it is the speed of the expansion of space–time, which can theoretically exceed the speed of light by many fold. So the Universe theoretically could still be an awful lot bigger than the "observable" Universe.

The second perhaps more interesting observation is the radius of the "observable" Universe and its relationship to its calculated mass. You may recall in the previous chapter (Chapter 7, Box12) we mentioned something called the Schwarzschild radius. This is where light itself is unable to escape from gravitational pull because the necessary "escape" velocity, is greater than the velocity of light itself. The Schwarzschild radius is the radius to which the light is confined and is unable to escape, (from a given amount of mass). Now again, perhaps less expectedly, if we use the formula for this light horizon (see Box 12), we find that the known mass of the Universe results in pretty much exactly a Schwarzschild radius of 13.7 billion light years.

This may be a big surprise to some as it is taught that the light horizon or the Schwarzschild radius only applies to black holes. Our visible Universe is certainly *not* a black hole. But it would appear, using the standard formula, that the visible Universe is constrained by the light horizon. This concept has already been addressed in Chapter 7,where it was clearly shown that the Schwarzschild radius (Box 12) was six times that of the radius reduction (binding energy) of a black hole, according to standard general relativity (see Box13).

Box 13.
General Relativity

Gravitational radius reduction of a black hole (r′)

$$r' = \frac{GM}{3c^2}$$

Schwarzschild Radius R_s

$$R_s = \frac{2GM}{c^2}$$

where M is the mass, c is the speed of light and G the gravitational constant.

There seems to be a lot of confusion regarding the light horizon of the Schwarzschild radius, but in realty you just need to do the maths. A calculation such as the light horizon of our observable Universe, is all you need to do to prove the issue. So it *is* possible to have a light horizon without a black hole. Indeed this result should not be such a surprise because this concept of a light horizon is very much in agreement with our cosmological observations. Indeed the light horizon can be far, far larger than the radius of a black hole. This is because general relativity teaches us that the minimum radius "reduction" of a black hole is 1.5km. In general relativity this is the minimum radius reduction that can be achieved for a black hole, otherwise it would appear that time would have to travel backwards beyond this radius. Some will still not be convinced by this logic, but again you just need to do the maths. If you calculate the radius of a black hole with the mass of the our observable Universe, using the equation for the Schwarzschild Radius (R_s in box 12) the black hole would not be much more dense than the vacuum of outer space. Something, which is a total non sequitur in general relativity.

So does all this help with determining the true size of the Universe? The answer is yes and no. The answer is no because these observations themselves do not directly assist in helping us decide how big the actual Universe is, we are limited to the "observable" Universe. However, modern cosmologists have, by a complex set of reasoning, determined that we are not entirely restricted to our light horizon. How is this you may well ask? Well the reasoning goes something like this: although a galaxy that was receding faster than light, emitted light say 5 billion years ago, the light which was moving towards us can move into of our light horizon, because our light horizon is continuously expanding with time. Our cosmologists thus deduce, that the Universe is at least 3 times bigger than the observable Universe, with a radius of 42 billion light years in each direction. Is this now the size of our Universe or can we make a better estimate?

The answer is yes, it is possible to do better than this and with fewer propositions. The fact is because we know the mass density of the observable Universe, we can calculate the quantum length (see Chapter 6, Quantum Space). This then gives a very good handle on the actual size of the Universe. Like the ancient Greek, Eratosthenes who was able to accurately determine the size of the Earth, using the right assumptions (see Chapter 1), it will be possible to determine the probable size of our Universe.

To recap the quantum length can be deduced from the mass density of the Universe (see Box 9). So the quantum volume can also be calculated ($\approx 5 \times 10^{-101} m^3$). Now, we have previously introduced the physical concept of a black hole. The minimum radius "reduction" of the black hole turns out to be 1.5 km. This is effectively the binding energy. Thus the maximum volume of the matter in a black hole can also be calculated ($\approx 10^{10}$ m^3). Let us propose (as we did in Chapter7) that the ordinary black hole does not represent an infinitely dense mass, or singularity. We showed that there is small but significant amount of residual volume in which to fit the mass, so the matter in a black hole does not need to be infinitely dense (see also Chapter 10). However, there is a limit to the volume that this mass can occupy in this condensed form. As more and more mass is added to the black hole, the greater the gravitational pull. As the gravitational pull is acting un-apposed, the smaller the actual volume of the black hole becomes. It is important to stress, that the Schwarzschild radius, which actually defines the light horizon, does not define the volume of a black hole. Again if you calculate the radius of a black hole with the mass of the our observable Universe, using the equation for the Schwarzschild Radius (R_s in box 12 &13) the black hole would not much more dense than the vacuum of outer space. Something, which is a total non-sequitur in general relativity, because the black hole forms at a particularly high mass density.

The proposition we suggest is that this volume limit for this condensed matter is precisely the volume limit of the minimum volume reduction (binding energy) of a black hole, ≈ 10^{10} m^3. So the total quantum volume is not allowed to exceed the volume of a maximum volume of matter of black hole, as at this point it *will* have an infinite density. Picture a sphere, now the maximum volume that sphere can have cannot exceed its own actual volume. Just in the same way that the binding energy of the black hole cannot exceed the total energy contained in a system. At this point the universal black hole becomes unstable and explodes and forms the Big Bang, with the release of an awful lot of binding energy.

This set of propositions is more logical than the standard set of propositions that state that there are many, many such infinitely dense black holes in our universe. You would imagine that these black holes would be immensely unstable. In particular what of the super-massive black holes that reside in the centre of virtually every galaxy in the Universe. Surely these are so big that if they were infinitely dense these would be unstable and would be exploding all the time - which they are not. Fortunately there is only the need for one infinitely dense object that is the “Universal” black hole. This is a black hole with the condensed core, condensed to zero space. You see as the black hole grows in mass the actual volume of space left for the mass to fit in gets smaller and smaller. When it gets to zero it does the only thing it can do, which is to explode into the Big Bang.

So what exactly is this "Universal" black hole made of? The answer is: it is made of the *new quintessence.* So does this conclusion tell us how big the Universe actually is? Yes it does, we merely divide the volume of a binding energy of a minimum mass black hole, by the volume of quintessence and that gives the number of quintessence that makes up the Universe. Then we multiply the number of quintessence by the quintessence mass and we have the mass of our Universe (see Box 14). This makes the estimate of the new mass of our entire Universe, some 10,000,000 times larger than the mass of the "observable" Universe.

The real question is does this model help us understand the Universe better? Certainly it does for the design of the Universe becomes far clearer. The *new quintessence* solves the mystery of what the energy inherent in space-time is. (see Chapter 3). Crucially it explains why the big Bang occurred in the first place. It resolves the mystery of the inflation field, which is caused by the release of enormous amounts of binding energy from the explosion, which is the Big Bang (see Chapter 7, Binding energy). It can also explain a lot more than just this.

Box 14

Estimated Mass of Our Universe (U_{mass})‡

Universal number of quintessence (Un_q) =
Volume of a maximum mass Black hole/Quintessence Volume.

Un_q =1.413 x10^{10} m^3/5 x10^{-101} m^3sec =2.8 x 10^{110} sec^{-1}

Mass of the Universe = Un_q x quintessence mass (m_q)

U_{mass} = 2.8 x 10^{110} sec^{-1} x 7.373 x 10^{-51} kg.sec

U_{mass} = 2.06 x 10^{60} kg

The *new quintessence* tells us what the estimated mass of our entire Universe is. Because the entire Universe is estimated at 10,000,000 times larger than our own bit of the "observable" Universe it is quite probable that other parts of the Universe will look different from our corner of the Universe, and we can only begin to predict how those other parts may actually look.

The presence of space-time quintessence also tells us why the new quintessence behaves as a "tracker" field, from the field equations (see Box 4). It gives a good idea why the galaxies were able to form so quickly after the Big Bang. It is now known that Galaxies each have a black hole in their centre.

† Dimensionally n, is the number of quanta *per unit time*, with the dimensions of [T^{-1}] . The quantum volume is cubic volume x unit time with dimensions of [L^3][T]. The quintessence mass is the mass x unit time and has dimensions of [M][T].

Certainly one would expect remnant small black holes as a result of the explosion of the Universal black hole. These would act as a catalyst for the formation of galaxies as the substance of quintessence would re-coalesce to form matter. This in turn tells us why the expansion of the Universe has speeded up in the past five billion years. Because at some stage about 9 billion years ago the distance between galaxies had expanded so much that quintessence stopped coalescing and thus started to exert more outward pressure.

Indeed there are few questions that the new quintessence does not answer logically. One major question remains: If our Universe is expanding what is it expanding into? The standard answer is that the formation of space-time occurred at the point of the Big Bang. The *new quintessence* agrees with this proposition, for quintessence does do exactly that - form space-time. What then lies "outside" our Universe (and possibly other Universes), well it is likely to be a very thin tracery of space-time quintessence. The next question is what then physically lies outside that? The logical answer, is a infinity of absolute physical nothingness. Something physical is very unlikely to be able to be totally infinite as you would need a infinity of that something physical. However, absolute physical nothingness can be infinite. But what is really important is what inhabits that absolute nothingness.

The elegance of the *new quintessence* is that it provides the substrate *and* what is also the blank canvas of space-time (otherwise known as topology). The new quintessence also potentially accounts for and explains everything else in our physical Universe at the same time. In doing so one can begin to explain the existence and laws of Nature that govern the Universe. The sheer beauty and unity of the Universal design shines out in such a way that it transcends human imagination.

Chapter 9

Proving the New Quintessence

No rational argument will have a rational effect on a man who does not want to adopt a rational attitude.

Karl Popper.

String theory was first eked out in the late 1960's, by a scientist called Yoiricho Nambu. Since then it has had a number of very eminent physicists study and write textbooks about it.[16-18] String theory's principle strength is that there is only one fundamental mass string of the Universe. The various modes of vibration can be made to account for the particles and forces of Nature. However, the predictive power of string theory has not been impressive. When asked what string theory predicts, the famous and gifted protagonist for string theory Ed Witten replied that: it predicts gravity. In truth, string theory has done much for quantum gravity, but still very little that is specific can be predicted from it.

The real beauty about string theory is that it is entirely possible that *everything* in the physical Universe is ultimately made of the very same substance, including matter and the forces of Nature. Indeed everything physical appears to be made of the same substance, including also space-time. The other interesting thing about string theory is that it predicts extra hidden dimensions. These elements of string theory are what make it so alluring to physicists. Importantly both these elements are also an essential and alluring part of the *new quintessence* theory, but quintessence theory is able to predict so much more than string theory.

What then does string theory predict or explain, the real answer is, it makes no readily testable predictions. It cannot definitively predict the size of the hidden dimensions, (although there is a tacit assumption that these are in the order of smallness of the standard Planck length). Indeed string theory does not really predict what we already know about physics. Karl Popper the famous philosopher of science, once defined a theory as something that is testable, or falsifiable. In truth string theory does not fulfil this criteria. Interestingly string theorists have a name for those that question the nature of string theory: "popperazzi". Yet is important that any theory be testable and agree with current results and equations. Indeed if anything string theory appears to slightly modify the equations for quantum physics, which have been already thoroughly tested. Yet the allure of having a single explanation for everything, is what keeps scientists fascinated with string theory

Enter the *new quintessence* theory, it can also explain the physical laws of Nature based on a single fundamental quantum. The question is what does it predict? Firstly it predicts the equations for quantum physics from first principles. The reason why the equations for quantum physics exist and are what they are, was answered in Book I of the series.

To give a straightforward example we can *directly* predict the radius of the electron orbiting a hydrogen atom, something that standard quantum physics requires three pages of complex mathematical proof to do. The difference here, between the new quintessence theory and string theory is that the size of the "hidden" dimensions is merely the wavelength divided by 2π. The other difference is that the wavelength depends on the number of quanta present in a single string (see Box 15)†. The number of quanta in a quintessence string theory is directly given by the mass of a quantum object divided by the quintessence mass. This in turn gives the frequency of any quantum object† and by definition can also be used to quantify the wavelength.

> Box 15
>
> Electron Radius Hydrogen Atom (R_H)
>
> Radius = the quintessence mass (m_q) x $c\alpha/2\pi$, divided by the electron mass (m_e)
>
> $R_H = \lambda/2\pi$
>
> equals
>
> $R_H = m_q. c\alpha/m_e 2\pi = 5.292 \times 10^{-11}$m.
>
> Where c is the speed of light and α the fine structure constant

Effectively this gives the size of the "hidden" dimensions of the electron and in turn yields the radius of orbit of the electron around the hydrogen atom (see

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† Actually the inverse of the number of qunta, because the frequency is given by the number of quanta per unit time n, such that *f=n,* where the dimension of n are [T^{-1}]. The energy equation *E=hf*, can then be replaced by the equation *E=hn*,. (see Book 1, Chapter 12

also Book 1, Box 12). So the radius is dependant on the electron completing a circle with the circumference of exactly one wavelength. What could be more direct?

What about the mass of the electron, which we also used to derive the radius of the hydrogen atom, can that be derived from first principles also? The answer is yes (see Box 16). The *new quintessence* theory also predicts much about the subatomic world and the constants that are important in this realm (see Book II). So here goes the mass of the electron can be directly derived from the appropriate light speed harmonic of the quintessence mass.

Box 16

Mass of the Electron m_e in kg.

taking $c^{2½}$ as the number (n) of harmonic quanta/sec

$$^{\dagger}\boldsymbol{m_e = m_q \, x \, c^{2½}/4\pi^{*} \quad = \quad 9.109 \, x \, 10^{-31} \, kg.}$$

where m_q is the quintessential mass quantum, c is the number of speed of light quanta per second, ε denotes the standard electron magnetic moment to Bohr magneton ratio and $* = (1 + 2\varepsilon)$.

The fine structure constant and the charge of the electron can also be derived form the quintessence mass, as previously demonstrated (see Book 2, Box 6). The masses of the principal known subatomic particles

† Dimensionally m_q = [M.T] multiply by $c^{2½}$, which is the number of light quanta *per unit time*, with the dimensions of $[T^{-1}]$ we get the dimensions $[M.T] \times [T^{-1}] = [M]$.

can also be deduced. Even the mass of the neutrino, a particle hitherto thought to have no mass, was predicted. The reason for the existence of these particles in the subatomic world and some of the constants of Nature that govern them was also answered in Book II.

Now some of the most mysterious secrets of the Universe have also been answered in this Book (Book III) of the series. This includes the very nature of the mysterious dark energy that is inherent in empty space, also the Big Bang, the inflation period, and the early formation of galaxies is predicted, all on the basis of the same exquisite fundamental quantum.

To have predicted just about everything we currently know (which is still very little) about the physical Universe on the basis of a single fundamental quantum, would for some still not be sufficient proof. Even if that prediction allows us to understand not only how things work, but why they work, it would still somehow not be a sufficiently rational argument for some. Some would require further predictive proof. Better still if the prediction could be something totally unexpected. Something that was not only not known at this time but that nobody could have guessed, nor would guess in a hundred years.

So here it is, the additional prediction. This prediction is to do with gravity and the two constants of nature, which together make the speed of light (see Box 1). These are specifically known as the electric and the magnetic constants. Perhaps we should no longer be surprised that empty space has electrical properties. The very direct prediction that can be made is that in a gravitational field the magnetic constant of space-time, will decrease and the electric constant will equally increase. This will of course occur in such a way as to keep the speed of light a constant.

The prediction is based on the radius reduction as dictated by general relativity (see Chapter 7, Box10). So in the case of an Earth like planet the decrease in the magnetic constant would be related to the change in radius (see box 17). Prediction is fine, but it is the understanding behind the prediction that is crucial. Now understanding this prediction will enable a better understanding of what is actually happening in a gravitational field. To recap space-time has electrical properties (see Box 1) and gravity may, in theory at least, affect these properties, and as a result affect the geometry of space-time.

> Box 17
>
> Predicted Gravitational effects on Space-time.
>
> Decrease in Magnetic constant
>
> $\mu_0 \quad \alpha \quad r'/R$
>
> =
>
> Increase in Electric constant
>
> $\varepsilon_0 \quad \alpha \quad r'/R$
>
> where r′ is the standard relativistic reduction in radius (see Box 10), R is the radius at the surface of the gravitational object and α is the symbol of proportionality.

In classical general relativity as we approach a gravitational body the distance gets shorter and less time passes, the closer we approach that body. In quantum gravity this translates to a diminution of the density of space-time quintessence (see Chapter 5). In the quantum gravitational model a diminution in the density of space-time quintessence will result in the diminution of the magnetic constant of space-time. So a diminution in the apparent density of space-time quintessence will involve a decrease in the magnetic constant. This will occur in proportion to the actual radius reduction as given by conventional general relativity (see Box 10 & 13). Equally well any decrease in the magnetic constant will result in a reciprocal increase in the electric constant. This will happen in such a way as to keep the speed of light constant (see Box 1).

These observations are fairly self evident when you know that space-time has some electrical properties (see Box 1). In fact this pretty much is another explanation of how gravity really works. The space-time matrix is thinned close to a gravitational object (see Chapter 5, Introducing Relativistic Gravity). In classical general relativity this means that the distance is shorter and less time passes in a gravitational filed. However, notice the dimensions of the magnetic constant of space-time ($\mu_0 = 4\pi \times 10^{-7}$ N A^{-2}). These dimensions represent the force exerted (in Newtons) per electrical charge flow (Amps squared). Thus the force exerted, by the space-time matrix on a charged object, would decrease as one approaches the surface of Earth. So the force acting on a charge would push the object towards the surface of the Earth.

Equally the attractive electrical force associated with the electric constant of space-time would increase the closer one gets to the surface (ε_0 = 8.854 x 10^{-12} F/m). You may notice that the dimensions of the electric constant are capacitance per meter. Just to briefly explain how capacitance works, if you take two electrical metal plates, one side positively charged and the other negatively charged and separate the plates, then this acts a capacitor. Now the further we separate the plates the greater the capacitance. The greater the capacitance the greater an electric charge will be attracted to one of the plates (depending on whether it is positive or negative). In the same way, the further we separate space-time quintessence the greater the capacitance, and the greater the electrical attraction. Effectively, all atoms are ultimately composed of moving positive and negative charge. Thus bodies in the rarefied medium of space-time closer to the surface of the Earth would experience a greater attractive force acting upon them. They therefore would tend as a result of the electrical properties of the space-time quintessence (via the electric and magnetic constants respectively) be both attracted and pushed at the same time, towards Earth.

So is this prediction new, *absolutely it is*. These constants have recently been fixed by physicists, who believe there are immutable. So what sort of effect would we see if we compared the values for these constants on the surface of the Earth compared to outer space? Well the answer is not much. Because the conventional relativistic radius reduction (see Box 10) is very small on Earth, the effect will be very small. It will be in some way *proportional* to the gravitational change in radius, which we see on Earth. The change in radius of the Earth, compared for instance to the radius of the whole Earth is proportional to a change of one ten billionth of the value of the radius of the whole Earth (see Box 10). There is also one caveat, these constants must be measured entirely separately, so the effect that one has on the other does not confound the result.

Notwithstanding this, here is something totally unexpected that we can predict. Suffice it to say that the *new quintessence* predicts and allows us to understand quantum physics at the very most fundamental level.

Chapter 10

Introducing Quantum Gravity

The beauty of Einstein's equations, for example, is just as real to anyone who's experienced it as the beauty of music…..the equations that work have inner harmony.

Ed Witten

Before Einstein arrived on the stage everyone was fixed in the world of Newtonian physics. It was a world where space and time where themselves fixed and the events that occurred, could be mapped upon it almost like clockwork. Indeed it was thought that if one knew the starting position of every thing one could predict exactly how things were going to unfold.

In 1905 along came the special theory of relativity,[12] followed in 1916 by general relativity.[15] Space and time had been united to form space-time and had become at the same moment changeable. In fact the genius of Einstein was to realise that the two types of relativity had their origins in the same sort of mutability. Mathematically (although on the face of it general relativity appears fiendishly complicated) both are based on Pythagoras's theorem. The main difference is that you can treat special relativity as if it were based in two dimensions, one of space and one of time (see Box 8). But in gravitational terms things get a little bit more complicated, because we have to start thinking in four dimensions, three of space and one of time. If we look at the starting point for the maths, however, we can see how Pythagoras's theorem can operate in four dimensions just as it did in two (see Box 18).

Box 18

<u>GR, Four Dimensional Pythagoras</u>

"Flat"space-time

$$ds^2 = -c^2\, dt^2 + dx^2 + dy^2 + dz^2$$

In Spherical (two sphere) coordinates,(t ,r, Θ, φ)

$$ds^2 = -\, c^2 dt^2 + dr^2 + r^2\, d\Omega^2$$

where

$$d\Omega^2 = (d\theta^2 + \sin^2\theta\, d\varphi^2)$$

That is not to say the mathematics does not get more complex even than this, but the principle is the same as Pythagoras' theorem, but in four dimensions. In general relativity we can then translate this in to a volume (R_{ab}). Now we can relate that initial volume of this sphere, as being proportional to the mass enclosed (T_{ab}) in that sphere. This gave a provisional formula for general relativity (see Box19, Eq 1). But as it happens, this gave pretty much exactly the same answer as Newtonian gravity. So it would appear that this provisional formula was actually a representation of Newton's formula, but demonstrated gravity in terms of the curvature of space-time. Where do we go from here, you might ask? This is what took Einstein such a long time to perfect. The answer is, now that the volume in "flat-space-time", has been described, we now need to describe what happens when we start to additionally curve that space-time slightly. To further explain this we can demonstrate what is meant by the additional curvature of space-time. It would be easiest to give a practical demonstration, one which can also be treated as a thought experiment. Take a piece of paper and cut the piece of paper into a circle. Place the piece of paper on to a spherical object, such as a football, and selotape the paper to the surface of the ball. You will notice two things about the dimensions of the paper circle; first if we look from above the radius of the paper will appear smaller than it was when the paper was flat, because it will now follow a curved path. Secondly the actual circumference of the paper will decrease compared to what it was when it was flat. This is similar to the radius and circumference reduction we see as part of Einstein's theory of gravitation, with the circumference reduction according to standard general relativity. This led to the addition of an extra little term to the equation, which made all the difference. So in curved space-time the circumference and the radius will appear slightly less than it should. So all well and good this is pretty much how general relativity works, except we have to work in four dimensions.

So we can view the extra curvature of space-time as a slight diminution in the circumference and in turn radius. So in reality there had been a paradigm shift in the way that gravity was treated in terms of the curvature of space-time. Mathematically they also gave slightly differing results. The question for Einstein had been how to move forward. The main clue at the time, had been a very slight shift in the orbit of planet mercury, the closest planet to the sun. This was the clue that would lead Einstein to finding the modification of Newtonian gravity.

Box 19

<u>Standard Gravitational Formulae.</u>

Provisional General Relativity (Eq.1)

$$R_{ab} = -\frac{4\pi G}{c^4} T_{ab}$$

Final General Relativity (Eq.2)

$$R_{ab} - ½R\, g_{ab} = -\frac{8\pi G}{c^4} T_{ab}$$

Where G the gravitational constant, R_{ab} the Ricci curvature tensor R the curvature scalar, T the energy-momentum tensor and g_{ab} the metric tensor.

Nevertheless, this is where Einstein had got a little bit stuck, for several years in fact. The actual maths just did not seem to gel at all. Enter what is effectively the binding energy (see Chapter 7). This time the binding energy represents an additional volume reduction, which occurs in the volume of the gravitating mass itself and in turn on the effects on an orbiting planet. So the volume reduction occurs in the size of the actual planet or star that is generating the gravitational field and in turn on the surrounding space. So the total volume reduction is now the additional gravitational term (Box 19, Eq 2) what, in conventional general relativity, is known as the "pressures" in the material. The addition of this new part of the equation (½R g_{ab}, see Box19, Eq, 2) worked fantastically well. This was the genius of Einstein and it was this slight difference that made the results of general relativity, far more accurate than Newton's equation. Now the slight anomaly in the orbit of mercury was resolved

Fortunately, there is a fairly straightforward standard equation for determining the radius reduction of the actual gravitating mass produced by this additional term. (see Chapter 7, Box 10). Unfortunately, there seemed to be no simple remedy for calculating these effects on the curvature of the surrounding space-time. There was also a slight problem with this part of the equation that effects the actual volume reduction of the gravitating mass itself, which we have previously alluded to. If we squeeze enough mass into a small enough space, then space itself collapses and we seem to get a resulting mass of infinite density, known as a singularity. This problem mathematically appears, in particular with the formation of a black hole (see Chapter 7).

The solution to the problem actually lies in quantum gravity, or more precisely in the understanding of the *new* space-time quintessence described here. We can start with the concept of quantum gravity by considering the work of a physicist by the name of Abhay Ashtekar. The trick lies in the fact that we can split one of the terms involved in describing the "metric tensor" of the gravitating mass down into two. One, which acts as the main part of the equation, and the other part which can be treated as a tiny quantum of space. In fact this is one way accounting for quantum gravity. There is however a much simpler way of doing this.

In the original relativistic equation the volume reduction in the gravitating mass reaches an apparent maximum. This happens when we have sufficient mass to form a black hole. If we squeeze the mass of a (black hole) in to a small enough space, that space then collapses upon itself. This gives us the infinite density, otherwise known as the singularity.

In the new model the space does not collapse upon itself completely, because there is a residual quantum space. The next question is how small is this quantum metric? We can directly quantify this quantum metric as a proportion of the volume "reduction" that occurs in a *minimum mass Black hole.* As it happens the maximum mass black hole has an actual radius of 1.5 km, which gives us a maximum black hole volume. Now to compare this the quantum residual volume we merely calculate the number of quanta in the any particular gravitating body and multiply that by the volume of a single quintessence and we get our answer (see Box 20).

Box 20

Quantum Residual Volume (Vrq)

$Vrq = 5 \times 10^{-101}\ m^3.\ sec \times \underline{nqM}$

$Vrq\ BH = 3 \times 10^{-20}\ m^3$

nqM is the number of quanta contained in a gravitating mass and. Vrq BH is the residual volume of a minimum mass black hole.

Now the corollary to this is twofold. Firstly the *ordinary* black hole does not form an infinitely dense "singularity". This is because the quintessence has a quantum residual volume. Secondly when the black hole reaches the mass of the Universe it does reach a singularity, because the residual quantum volume has reached it's maximum. Clearly the volume of highly dense quintessence mass cannot exceed that of the volume of the (maximal mass) black hole because, the mass of the entire Universe, would then itself have to have an infinite density. This is when the Big Bang occurs.

After the Big Bang, in this model, the quintessence that makes up the Universe, either then forms space-time, or the forces of Nature, or matter. The release of the binding energy, creates what is called the inflation field. Following a rapid period of inflation the Universe then slows. At this point in the history of the Universe space-time quintessence coalesces to start to reform matter again thus slowing the expansion even further. At about 300,000 years after the Big Bang, matter is able to reform into atoms. This means that the light hitherto trapped (by ionised matter), can now shine forth and this light forms what is known as the cosmic Microwave background radiation, the embers of the hot dense Big Bang.

In standard cosmology there is a gap in the account of why these events happen in the Universe. In addition, one of the mysteries that remains is why galaxies seem to form so quickly. In the *new* *quintessence* model, the residual quintessence that still remains in the form of black hole matter, then quickly acts as the nucleus for the formation of galaxies. Further space-time quintessence continues to re-coalesce to form more matter and this process goes on until about 5 billion years ago; the Universe then passes its youth. Because of the continued expansion of the Universe, space-time quintessence is no longer coalescing into matter, the energy inherent in space-time starts to speed the expansion of the Universe up. The Universe then accelerates in its expansion whilst it matures.

What then is the likely ultimate fate of the Universe? Well, there is every reason to believe that it will continue to expand. Equally well there is every reason to suppose that if our Universe is made of quintessence that there will be quintessence outside our Universe. That leads to the possibility that other Universes are also made of quintessence. When our Universal Black hole eventually reaches a critical mass density that would lead to the Big Bang. The Big Bang will be the beginning of time and space for our Universe. Importantly, our concept of space and time is almost reversed by the realisation that space-time itself is a substance, which has inherent energy. In the absence of this substance, there is no space-time to impede motion.

What about different Universes? Some scientists are now seriously publishing work on what they believe other Universes may look like. Perhaps this is a little premature, in truth we can only see a tiny corner of what is likely to be our Universe, and we cannot even predict what other parts of our Universe will look like. One thing we do know a little about is the behaviour of Black holes within our Universe, and this has given us clues as to how big our Universe might be (see Chapter 8). As with ordinary Black holes most are likely to be rotating. Indeed it is quite possible that the Universal Black hole that formed our Universe was probably spinning. Indeed in Latin the word Universe, literally means one (uni) and revolution (verse). In Book II, we posed the question as to why matter, as opposed to anti-matter, appeared to be the predominant form of matter in the Universe? The actual answer may depend directly on which direction the Universal Black Hole was turning. Matter will arrange itself so that on average the outer matter of the atom, the electron, will be spinning in an orientation which relates to the original spinning of the Universe and the inner matter of the atom the protons will be spinning in the opposite direction.

One more major question remains, what are the actual formulae for quantum gravity and does a better understanding of quantum gravity arise from using the new quintessence? The answer is yes, even more than Einstein's equation, there is an equation for quantum gravity, which has the beauty of music and that inherent inner harmony.

Chapter 11

Quantum Gravity Revealed

We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

T. S Elliot, in Little Gidding.

One of the great mysteries of the quantum world remains to be addressed. What exactly are the equations that govern quantum gravity? Many famous authors have written on this subject but the answer remains obscure.[19-22] So what is the answer, well in the previous books of the series and in this book, we have gone a long way to establishing that there is a connectedness between the laws of Nature. This connectedness depends on establishing the nature of the *new quintessence*, particularly on defining its mass (see Chapter 2, Box2 & 3), the quintessence mass. To a lesser extent it also depends on defining the substance of quintessence space-time (see Chapter 3, Box 4). We now have to link these in with what Einstein discovered in 1916 about the form of gravity, known as general relativity. Before revealing the answer, I can only say that whatever the background of the reader is, he or she will most probably be very surprised by the result.

The major problem that arises with gravity, in the form that it is presented in general relativity, is that it is mathematically fiendishly difficult. Indeed for many years only a few solutions were known explicitly because of the difficulty with the calculations. Notably, one of those was the Schwarzschild radius, the radius of a black hole (see Box 12). The mathematics of general relativity has been studied so intensely that even Einstein himself famously once said:

Since the mathematicians have invaded the theory of relativity, I do not understand it any more.

Only more recently with the advent of supercomputers has it been possible to derive more explicit answers. Even some of these answers give more theoretical than physical results. A lot of solutions have no real relevance to everyday physics. The other problem relates to that of two body systems. It is O.K to use general relativity when dealing with the solar system because there is only one major mass, involved, the Sun. When dealing with two major masses, such as two suns orbiting each other, finding exact solutions is almost impossible. Moreover, the problem of the presence of objects like black holes, which appear to have infinite densities or "singularities" still remain.

General relativity predicts some very counterintuitive situations regarding a black hole. Firstly a black hole becomes an infinitely dense singularity in general relativity. Secondly, space becomes zero and all time stops at an event horizon. This means that a person or object, can never appear to fall in to a black hole. Equally well if we tried to lower a person into a black hole the string would have zero length at the event horizon, so the person could never fall in.

In general relativity if we tried to pull a person back from the brink of falling into a black hole we would have to exert an infinite force. Equally well in general relativity it is impossible to say what is beyond the event horizon, some scientists even believe that time may go backwards.

Are we simply to accept these mathematical findings, or find a solution? Well the solution to the problem rests with the Schwarzschild radius. If we use the Schwarzschild radius formula for the event horizon of a black hole, then the event horizon gets bigger and bigger for the black hole as its mass gets bigger. However, something strange emerges when you start to apply the Schwarzschild radius formula to the observable Universe. If you do the calculation for the event horizon for our observable Universe, based on the known mass of the observable Universe, it is exactly 13.7 billion light years across. According to general relativity we should be in a black hole. It is of course clear that we are not in a black hole, and that this radius is clearly just our light horizon. So what is wrong?

Well the reason for the production of these singularities in general relativity, is that the volume "metric tensor" itself depends on the speed of light (see Box18). This is perhaps where general relativity begins to break down. This is because whilst the speed of light limit applies to matter, it does not apply to space-time. But the curvature of space-time is what general relativity seeks to explain. So in reality space-time itself can exceed the speed of light. Now we can see far more clearly what is going wrong. The Schwarzschild radius just describes the light horizon. Effectively, after all the debate, it does just that, describe the horizon for the escape velocity of light.

So can these difficulties and what happens beyond an event horizon be resolved by quantum gravity - the answer is a resounding *yes*. What we have to do first, is to distil out the essential elements of Einstein's general relativity. You may have noticed, that when Einstein was developing general relativity, he developed a provisional equation, which effectively gave identical result to Newtonian physics (see Box 19, Eq. 1). The trick is to reverse the process, with Einstein's full general relativistic equation (see Box 19, Eq. 2). Specifically to translate the equations of general relativity back from describing curved space-time into describing a force. But it has to describe the force in relativistic terms, i.e from the point of view of curved space-time.

Now the genius of Einstein was to develop an equation, where the maths seemed to dovetail exactly the way it should, so that both sides of the equation matched. In doing so, the actual amount curvature of space-time needed to balance the equation, actually dropped out from first principles. Thus this bit of general relativity is a direct result of Einstein's equation. Once we have performed the highly complex mathematics of general relativity we get one straightforward equation. So we can calculate this (extra) curvature of space-time by using direct algebra. It turns out that this bit of the equation is the bit that makes relativity different from Newton, so with a bit of our own ingenuity we may be able to transform the formula back to a formula for a force. Thus obviating the problem of applying a speed limit to the speed of space-time itself. The general relativistic formula for the extra curvature is so important that we will show it again here.

Box 10.
<u>General Relativity</u>

Gravitational radius reduction estimate (r′)

$$r' = \frac{GM}{3c^2}$$

where M is the mass, c is the speed of light and G the gravitational constant.

Now we may recall that this algebraic equation gives the radius reduction of the actual gravitating mass, i.e. the mass that is causing the gravitational field (see also Chapter 7). We can visualize this more clearly, if we return to our experiment, that we demonstrated at the beginning of this Chapter. In that experiment we took a circular piece of paper and selotaped it over a ball. We found that the apparent circumference of the paper was smaller than it was, when we measured the paper compared to when it was flat. Now when we look at the ball from the top, which allows us to see the radius as a straight line, then the radius, has also got smaller. We also find that the decrease in radius, is directly proportional to the decrease in the circumference.

Now we have come to the crucial question, is the decrease in the radius of the gravitating mass, itself related in any way to the decrease in the space-time around it? If it is then, we can reduce the complex mathematics of general relativity relating to the space-time component, down to a direct algebraic formula. We can progress this work relating to gravity, directly into a *relativistic* formula for the force of gravity and then into the field equation of quantum gravity.

The first real clue to this new approach to quantum gravity came in 1991, when the use of supercomputers allowed the accurate calculation of the deviation of the orbit of mercury, using general relativity. A scientist called Straumann had after 75 years,[23] managed to come up with the accurate answer to the problem which general relativity had originally been designed to resolve (see Box 21). The late Professor Paul Marmet later theoretically developed that work further.[24] The calculation of the accurate change in the circumference and in turn orbit of mercury was very revealing because we find that it related in some way to the change in the radius we saw earlier (see Box 10).

Box 21

Known Advance Perihelion of the orbit of Mercury

$$\Delta\varphi = \frac{6\pi \ GM}{c^2 \ a(1-e^2)}$$

where $\Delta\varphi$ is the advance in the perihelion of mercury in radians, M is the mass of the Sun, c is the speed of light and G the gravitational constant, $a(1-e^2) = \ell$, the semi latus rectum.

Now with some relatively straightforward calculations we can work out the change in the circumference of the orbit of mercury and in turn the change in the radius of orbit of mercury. (First we just divide the formula by 2π to change radians to the actual circumference change). For a circular orbit the ratio of the change is exactly that of circumference.† This is just as we did with our experiment, when we saw the change in circumference and radius of a flat piece of paper when we selotaped it to the surface of a ball. Now, very interestingly it turns out this change in space-time radius relates directly to our relativistic change in radius of the actual gravitating mass (see Box 10).

The most important clue to the algebraic realisation of quantum gravity is that space, as we have previously described it, is effectively nine dimensional (see Chapter 6, Fig 1). The answer is then all we have to do, is to multiply the formula for the standard radius reduction in general relativity *by a factor of 9.* Hey presto, a beautiful piece of music, we get our algebraic conversion for the radius of space-time itself (see Box 22). Which as it turns out is exactly the same as the change in radius as calculated for general relativity by Straumann.

Box 22

Relativistic (Space) Radius Reduction (R′)

$$R' = \frac{3GM}{c^2}$$

† For a elliptical orbit, to be precise, the change in the circumference, should be minorly corrected by the formula for the ratio of the average radius of an ellipse compared to the radius of a cicle.

where M is the mass, c is the speed of light and G the gravitational constant,, R' is the relativistic space-time radius reduction.

Yes, this is the radius reduction equivalent of general relativity for the radius reduction of space-time itself and gives the very the same answers as general relativity

Now we *can* go on to develop an equation for the change in the force of gravitation in a relativistic way.

Box 23

Quintessence Gravitational Force Equation (Fq)

$$Fq = \frac{GMm}{R^2}[1 + 3GM/Rc^2]^2$$

For elliptical orbits

$$Fq = \frac{GMm}{R^2}[1 + 3GM/\ell c^2]^2$$

The two body solution

$$Fq = \frac{GMm}{R^2}[1 + 3GM/Rc^2]^2 \times [1 + 3Gm/Rc^2]^2$$

where M is the larger mass, m is the smaller mass, c is the speed of light and G the gravitational constant, R is the distance, (normally taken as the radius) and $\ell = a(1-e^2)$, where *a* is the semi major axis and e is the ellipticity.

Technically this gives answers that are no different than the equations for general relativity. It mathematically gives exactly the same answer as general relativity does for bodies like the planet Mercury (see Box 21). The equation has just been derived from the translation of describing the curvature of space-time back to describing the effective *force* of gravity. Of course if you wish you can spend many years working on the complex maths (known as tensor calculus) involved in general relativity, and waiting many days for your supercomputer to work out the answer. Alternatively one may of course get your calculator out, and get the same answer in about two minutes. In fact, up till now NASA have still been using Newtonian gravity. Now they can use the quintessence equivalent, which will give them the same accuracy as general relativity, but without the mathematical difficulties.

But ease of use, is not the only criteria. Just as Einstein was able to resolve an astronomical mystery using his formula, so should the new formula be able to resolve a gravitational mystery. Indeed there is a mystery, which remains unresolved that relates to the Pioneer and Voyager missions. In each case these deep space probes appear to experiencing a gravitational anomaly. This is only apparent because these probes have travelled so far out in space and they have had constant telemetry. The fact is that, there appears to be an acceleration *towards* the Sun acting upon these probes (8×10^{-10} m/sec^2.) Now in gravitational terms this is tiny but no one has any real explanation for this. Now if you flip your calculator out, you can do the calculation to prove the source of the anomaly, using the equation in Box 23, in under two minutes.

The change in the effect on gravity can readily be calculated by directly plugging the known mass of the Sun and using the net distance an object has travelled in the direction of its trajectory. Importantly we get exactly the right answer for this previously mysterious and unexplained phenomenon (see Box 24).

Box 24

Anomalous Gravity

$a' = 8 \times 10^{-10}$ m/sec^2

$$a = \frac{GM}{R'^2}[1 + 3GM/R'c^2]^2, \quad a = \frac{GM}{R'^2}[1 + 8 \times 10^{-10}]$$

Where a′ is the anomalous acceleration, a the total acceleration, G the gravitational constant, M is the mass of the Sun, and R′ the average distance in the direction of the major trajectory

This quick calculation shows that *quintessence gravity* now neatly accounts for this gravitational anomaly, where no other explanation previously appeared adequate. There have been various explanations for the anomaly, ranging from technical reasons in the probes (out-gassing), and to a modification in Newton's gravity called MOND. First of all, technical reasons are unlikely because the effect seems to apply equally to different probes. Secondly MOND only applies to exceedingly low levels of acceleration and the Sun's gravity exerts far greater accelerations than MOND accounts for.

The fact is that not only does the new *quintessence gravity* give the correct answer, but it does equate to general relativity. The effect on the curvature of space-time in general relativity, has just been directly translated back into an equation for the expression of the force exerted. From that it is a straightforward matter to calculate the acceleration due to gravity. The equivalence of quintessence gravity and general relativity is based on the same principle that Einstein's provisional formula for curvature equated to Newton's formula (Box 19, Eq. 1). The irony is that the gravitational anomaly could have been predicted by general relativity, but the calculations are so fiendishly difficult as to be prohibitive.

The other difference between quintessence gravity and general relativity, paradoxically enters the equations not on the small scale but on the large scale. That scale starts to be important in our treatment of masses of a Black Hole. Firstly a black hole becomes an infinitely dense singularity in general relativity. In quintessence gravity, it has a residual volume, so that infinite density is only reached once the black hole has the mass of the entire Universe (see Box 20 & 14). Secondly, space and the passage of time become zero at an event horizon. With quintessence gravity, as regards space, as there is residual volume there is also residual space and time.

In general relativity if we tried to pull a person back from the brink of falling into the event horizon of a black hole we would have to exert an infinite force. In quintessence gravity, the force required would only be the normal force of gravity, multiplied by 4 (see Box25). In general relativity it is impossible to say what is beyond the event horizon. Using quintessence gravity, we can reasonably calculate the forces exerted inside a black hole. So we now have a very useful equation for general relativity, by translating general relativity back in to a force of gravity. We have got rid of the speed limit imposed on space-time by general relativity, which is where the problem of singularities arose. Effectively the "metric tensor" of general relativity is no longer needed.

Box 25

Force of Gravity at the Event Horizon‡

$$F_q = \frac{GMm}{R^2}[1 + 3GM/Rc^2]^2$$

$$R_s = 2GM/c^2$$

$$F_q = \frac{GMm}{R^2}[1 + 3/2]^2 = \qquad F_q = \frac{GMm}{R^2} \times 6.25$$

where M is the larger mass, m is the smaller mass, c is the speed of light and G the gravitational constant, R is the distance, (normally taken as the radius)

So what happens to our mass once it goes beyond the mass of the black hole. Well the event horizon will

† With big changes in radius it is important to use the correct equation for the backwards difference operator. Yielding the more correct equation.

continue to expand as with general relativity. But there will to be a continuing volume reduction in the volume of the gravitating mass. The event horizon of the smallest (naturally occurring) black hole is 9km. At this point the radius of the actual matter is just less than 9km and the apparent reduction in radius of the black hole (the binding energy) is 1.5km. As the mass of the black hole rises, the radius of the event horizon will rise. At the same time the pressure of gravity will continue to contract the actual volume of the gravitating mass, so it will continue to shrink.

Of course there is a volume reduction beyond which a gravitating mass cannot go, which is the effective zero volume. That is when the residual quantum volume shrinks to the maximum volume of the mass of a black hole, itself with a radius of 1.5km. All the energy contained in the condensed matter of pure quintessence at that point is binding energy. That is when a true singularity *is* reached. There is no space left, hence the big Bang occurs (see Chapter 8).

In fact using the new quintessence we should be able to go further than general relativity and Newton's laws of gravity. We should *arrive where we started and know the place for the very first time.* We should for the first time see how the acceleration of gravity can be translated most elegantly into the equations for the fundamental quantum of Nature, the *new quintessence.* Because the acceleration due to gravity is the same as the acceleration we get when we apply a force, the two are equivalent.

So what is the equation for the acceleration due to gravity in terms of quintessence. Well the answer lays in the fact that both mass and space-time are made of the same quintessence, so they should interrelate in some way.

Box26

Quintessence Gravity‡

$$a = \frac{GM}{R^2}$$

as, $l_q = (hG/c^3)^{1/2}$ (see box 9)

$R = l_q\, n_{qs}$ and $M = m_q.n$, $m_q = h/c^2$ (see box 2 & 3)

substituting

$$\mathbf{a = cn/ n_s^2}$$

$$\mathbf{F = cn\, m /n_s^2}$$

where n is the number of quanta contained in gravitating matter, n_s is the number of quanta contained in linear space-time, c is the speed of light in m/sec, h is Planck's constant and l_q is the length of quintessence, m is the mass of the accelerated body

Indeed we are not disappointed because the acceleration due to gravity, is now given by the ratio of the number of mass quintessence to the number of space-time quintessence. Equally the force exerted on a

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† Dimensionally n is the number of quanta per unit time , with the dimensions of $[T^{-1}]$, n_s is a dimensionless number, and thus $a = [L\, T^{-2}]$.

body is now given by the ratio of the number of mass quintessence to the number of space-time quintessence (see Box 26).

This is where quantum gravity fits into the equation, if we multiply the length of quintessence by the number of quintessence that make up space we get the linear radius, R. Then there is a direct relationship between the number of quintessence that makes up space-time and the number of quintessence in a gravitating mass (see Box 26). This goes on to account not only for Newton's but Einstein's gravity. All we need to do is take the new equations for gravity (Box23) and translate the physical quantities there into their quintessence equivalent as we have in box 26, with the addition of the extra mathematical term, which accounts for the relativistic gravity.† Again we are not disappointed the relativistic part of the equation is the ratio of the number of mass quintessence to the number of space-time quintessence multiplied by the quintessence length. Not only do we get quantum gravity, these can be corrected in the same way that relativity was able to correct Newton's gravity. These equations for quantum gravity can also now be expressed in terms of quintessence (see Box27). Again the acceleration of a body just depend on the ratio of the number of quintessence present in a mass to the number of space-time quintessence. Indeed these equations show how everything can be made of the same fundamental quantum, the *new quintessence*.

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† $[1 + 3GM/Rc^2]^2 = [1 + 3l_q n/cn_s]^2$

Box 27

Quintessence Advanced Quantum Gravity‡

$$\mathbf{a = cn/n_s^2}$$

$$\mathbf{a} = \frac{\mathbf{cn}}{\mathbf{n_s^2}}[1 + 3l_q n/cn_s]^2$$

where n is the number of quanta contained in matter, n_s is the number of quanta contained in linear space-time, c is the speed of light in m/sec.

Now finally, this shows pretty much exactly what acceleration really is. It helps explain Einstein's realisation that the mass of an object related to acceleration (inertial mass), is exactly the same as the mass that responds to gravity (gravitational mass). Everything is made of the same substance the *new quintessence.*

With the new quintessence we can also explain the conundrum of the energy inherent in empty space. We can solve the strange increase in gravity, which our space probes are experiencing as they leave the solar system. This in turn can help explain the apparent missing mass in the galaxy. Not only is the missing

† Dimensionally n is the number of quanta per unit time , with the dimensions of $[T^{-1}]$, n_s is a dimensionless number, and thus $a = [L T^{-2}]$. Dimensionally m_q = [M.T] multiply by n, which is the number of quanta *per unit time*, with the dimensions of $[T^{-1}]$ we get the dimensions $[M.T] \times [T^{-1}] = [M]$.

mass due to the presence of objects like relativistic neutrino's with mass and primordial black holes, who do not shine, but it is due to the gravitational effects of the new quintessence. Each galactic core contains a super-massive black hole and this mass along the mass at the centre of the galaxy and in its spiral arms and halo is exerting a much greater force of gravity than accounted for by Newton or Einstein (see Box 23).

Additionally, we can even solve the mathematically intractable "two body" problem (see Box 23). Moreover, not only does the two body equation work, but it does have, that inherent inner harmony. Finally we can formulate a most elegant equation for the acceleration due to gravity solely on the basis of quintessence and the speed of light (see Box 26).

So it is clear that everything physical, can now depend on the presence of one fundamental quantum. We can formulate a picture of the origin of the Universe and its evolution and everything physical that lies within it, using a single ephemeral quantum *harmonic quintessence*. The last of the known mysteries of the Universe has begun to reveal itself, in such a way as to lay open a window of knowledge so utterly beautiful that it transcends imagination.

Afterword

Enlightenment will be now the beginning, not the end. Beginning of a non-ending process in all dimensions of richness.

Bhagwan Shree Rajneesh (1931-1990)

In the beginning of this trilogy, it was the manifest beauty and the elegance of the design of the Universe that moved these writings. Since starting writing these books that manifest beauty has become immeasurably greater.

Suffice it to say, that in Book I, it was possible to start by deriving the fundamental equations of quantum physics. The energy equations that go hand in hand with these quantum mechanical equations then just seemed to arise from first principles. At the end of the book it was even possible to derive a new fundamental energy equation that dovetailed in with both quantum physics and the physics of relativity. So it would appear, theoretically at least, that these two branches of physics had become reconcilable. All of this was achieved by finding a quintessential quantum, one that equally befitted relativity and quantum physics.

The next stage came in Book II, it was not only necessary to commence the unison of the two main branches of physics, but to harmonize that with what we know about the subatomic world. Amazingly once the concept of a single fundamental quantum had been developed, more and more of physics seemed to arise from it. It was possible to then continue to ask the question, in which way does quantum physics work, and how and why quantum physics arises in the first place. It would appear that the masses (and wavelengths) of the subatomic particles are all based upon the quintessential quantum and the harmonics of the speed of light and of course pi. The charge of the electron, then appeared out of the mathematics of what was effectively a harmonic light sphere. The most compelling observation was that, not only did one particle appear but the masses of all the principle particles appeared on the basis of the same light speed harmonics, to a high degree of accuracy in each case. Thus the probability for these observations being correct is incalculably large.

The *pièce de résistance* of Book II, was perhaps in the last Chapter, where we were able to better understand, what is probably the most important reaction in the entire Universe. That is the conversion of the neutron into a proton and an electron, and the reverse reaction. In what is known as the "Standard model" of physics this is an inordinately un-wieldy process. This involved a particle that was hugely more massive than the mass of proton and neutron put together. In or new model the decay of the neutron could be readily explained by using the neutron and an electron, which occupied the classical electron radius modified by special relativity (see Book II, Box 21). This realization alone would if properly applied have a huge effect on how we understand physics, and the forces of Nature.

Notwithstanding this, in Book III, something that would have originally seemed entirely unattainable in theoretical physics, has became a reality. Using *harmonic quintessence* it has been possible not just to unite physics, but also to explain three of the greatest mysteries of modern physics, all with one elegant solution. One of these, is the mystery of the energy that is inherent in empty space. This is resolved directly by the presence of quintessence in empty space. It is the energy inherent in quintessence, which forms the very substance of space-time. Remarkably both aspects of space-time, the apparent "curvature" of space-time and the blank canvas of space-time (its topology) arise from first principles using quintessence. Indeed we can start to envisage gravity not as a curvature of space-time, but as a density gradient of quintessence. Entirely, in keeping with general relativity, gravity can be explained by such a density gradient. Moreover, the presence of this density gradient can be experimentally tested. This forms an essential part of any truly viable concept in science, it must pass the Popperian test, a concept must be falsifiable. However, quintessence does far more than just this it explains these mysteries using *a priori* principles.

Indeed *harmonic quintessence* does even more than this, it explains the very most impenetrable part of modern physics. It formulates quantum gravity in a way, which is again in keeping with general relativity, and at the same greatly eases the calculations involved. This leads directly to a solution to the other two great mysteries of modern physics. The first of these is an apparent increase in gravity, which the Sun is exerting on two deep space probes Pioneer and Voyager. The second is the apparent missing mass of the galaxy.

Both these can, at least in part, be explained by an increase in the gravitational field produced by the new quantum gravity. The interesting thing is that general relativity could have gone a long way to predicting these effects, had it not been for the fact that the maths in general relativity is so fiendishly difficult. The new quintessence almost miraculously solves all the major problems of modern physics in one fell swoop.

The next question is what can physics do with this new and exquisitely unifying concept of quantum physics? The answer lays in doing what science should do, that is to unite itself. Indeed there is one crucial and pressing question in physics, which has not been answered, which desperately requires a united front. In the beginning of Book I we alluded to that fact that the environment may be reaching what is essentially a tipping point. Since finishing writing that book, just under one year ago, it is apparent that the world is accelerating towards that environmental tipping point. In fact the future of the world may depend on the answer to this one important question. That is how can mankind produce abundant amounts of safe and clean energy? Yes, science should concentrate on producing the technology for nuclear fusion.

It may come as a little surprise to some environmentalists that the solution to the problem lies in nuclear energy. That is of course *not* nuclear fission, which is dangerous and unclean. Radioactive fission products may potentially contaminate the Earth for another 100,000 years, and lead to widespread nuclear proliferation. On the other hand controlled energy production using nuclear fusion technology, does not lead to significant radioactive waste products, nor can the technology be diverted towards making nuclear bombs. In the meantime particle physicists in particular are competing to build ever more expensive particle colliders to prove the existence of particles that may not even exist. Perhaps one and not two colliders would suffice. Certainly, if and when these particles fail to be discovered (or even before this) it is crucial that funds be allocated into solving the technical difficulties with fusion power. So instead of using billions and billions of funds trying to prove or disprove current theories of physics, science would serve mankind far better by solving the technical difficulties surrounding fusion power. This may enable the continued existence of our species in harmony with other species on this planet.

Having said this, there is also the need for the political will to drive these changes. After all we cannot continue to rely on sunset technologies to take us in to the 21st century. Renewable energy resources, may provide a stopgap, but are themselves limited by the amount of energy production available and the cost. Additionally, the continued dependence on increasingly scarce fossil fuels will only drive the world towards greater and greater conflict. The costs and results of such a dependence have already shown what is in store, if the trend continues.

What then does the series of books contribute to the process of achieving the goal of fusion power? Well as we mentioned earlier, these books shed considerable light on the nuclear reactions, which are crucial to the full scientific understanding of nuclear fusion. In particular Book II describes the decay of the neutron to the proton and the reverse process in detail, and this is crucial to the concept of nuclear fusion. Secondly these books lead us to a far greater understanding of just how and why the Universe is what it is. Because science is potentially no longer locked in the struggle of understanding the fundamental workings of the Universe, it should be able to focus its attention on what is important. This may allow us to use the resources that have been allocated to science more gainfully.

Thirdly and most important, in this third Book, the veils of mystery, which surround such subjects as the energy inherent in empty space and the missing mass of the galaxy, gravity and general relativity have been removed. That is not to say that Einstein was not a complete genius, because without general relativity we may never have stumbled upon the correct answers. Indeed it is these answers, which most strongly indicate the presence of quintessence.

Suffice it to say that *harmonic quintessence* is able to explain some of the deepest mysteries of physics, and in one fell swoop explain just about everything we know, and some things we do not yet know, on the basis of a single ephemeral quantum. Does this knowledge detract from the beauty of the Universe? Far from it, it enhances it greatly.

The possession of knowledge does not kill the sense of wonder and mystery. There is always more mystery.

Anais Nin

Indeed one can, for the very first time, glance at the structure of the Universe and look in complete awe and wonder at the immeasurable beauty and wisdom of the Universe and its exquisite design.

End of Book III

Technical Notes

1). *Frequency*

Common questions arise from this straightforward *a priori* assertion, $f = n$, *the frequency is equivalent to the number of quanta, per unit time,* these can readily be answered.

a.) How can a number have the dimensions of frequency? Well it is actually the number of quanta *per unit time*, so it will have the dimensions of frequency, specifically [T^{-1}].

b.) Another question is what *are* the units of time? Well the units of Planck's constant *h* are given in Joule seconds (J s). Hence the unit of time of the frequency must be given in seconds (s^{-1}).

c.) A much more philosophical question arises, does it matter which units of time you use? The answer is, *no* it does not matter which unit of time you use, provided you are consistent, you get the very same answers.

This is where some people have some difficulty. The fact remains that time *elapsed* is *not* the same as *units* of time. Time can elapse, in this case the more time that time elapses the smaller the energy component of the minimum quantum gets as *h,* which consists of energy multiplied by time, is a constant. Visa versa the less time that elapses the greater the energy component of the minimum quantum is.

Nevertheless, when we change *units* we cannot do this in isolation, for the equation must balance. For example if we change from S.I. units to cgs units, then not only does the meter change to centimetres, but kilograms change to grams and energy changes to ergs. To get the equivalent answer in Joules we have to convert ergs back to Joules and the same answer emerges, provided we use the same actual quantities, whatever the units. The important thing is because we have changed one unit we also have to change other units, we cannot change units in isolation. Indeed the equation $E=mc^2$, must hold.

This aspect is very important, so it is worth staying with the explanation. Lets now change the time unit and see what happens. The fact is if we are using Joules then to balance the equation then if we increase the time unit we would have to increase the either length unit, or the mass unit to balance the units. So what happens when we increase the time unit. Lets say we increase the units from seconds to minutes. If we take the time elapsed for example as 1 second. Then 1/60th of a minute will have elapsed and the energy component of the quantum *h,* will as before appear to rise by 60. But remembering that the length must also change means that the unit of length goes up by 60 also, as length is a component dimension of energy [ML^2 T^{-2}] when the unit length component goes up the energy decreases by 60. So in fact if you change the unit of time T, you have to increase the length L dimension. The two changes balance and you get the same answer *h*, for any new unit of time.

We can do exactly the same with time and change the unit of mass, in this case to balance the units, mass needs to go up whatever the time units went up, but squared to keep the equation balanced. It is not necessary to go through the whole explanation again to see that the two changes balance an you get the same answer *h*, for any new unit of time.

The important thing is for every unit change the equation *E = hf is the same for all time units used.* The main thing to remember when working this all out, is to remember time *elapsed is not the same as units of time.*

This is the absolute conceptual beauty of these observations, so whatever time unit you use *h* is effectively the same , the frequency f is therefore the same, the number of quanta per unit time n is the same, and m_q is the same.

To prove this we just need to work out for example m_q in S.I units and then in cgs and see that we get exactly the same answer.

Box 19
Lets do S.I. units first

$m_q = h/c^2$

$h = 6.626 \times 10^{-34}$ *J s*

$c = 2.9979 \times 10^{8}$ *m/s*

$m_q = 7.373 \times 10^{-51}$ *kg s*

Then lets do it in cgs

$m_q = h/c^2$

$h = 6.626 \times 10^{-27}$ *erg s*

$c = 2.9979 \times 10^{10}$ *cm/s*

$m_q = 7.373 \times 10^{-48}$ *g s* $= 7.373 \times 10^{-51}$ *kg s*

Q.E.D.

It would appear that the Universe is trying to introduce a beautiful new concept, not only is space-time interlinked but energy and space-time are interlinked. We should have guessed this from $E=mc^2$. But now that the science is telling us that there is energy inherent in apparently empty space that's evidence enough to support it. This takes us to the next common question.

2). Dimensionalty

The conventional formula for the Planck mass is dimensionally constrained to give a Planck mass value, with the dimensions of M which is difficult to use in string theory.[7,8] The quintessential mass has the dimensions [M][T], which when multiplied by the frequency with the dimension [T^{-1}], represented by the number of quanta per unit time we resolve the dimension back to those of M. From this result, it is also clear that dimensionally, the number of quintessences (n) is directly equivalent to the frequency, in units of sec^{-1}. Therefore the dimensions of the effective mass of the system, $m = m_q.n$, are entirely consistent with the dimensions of matter.

$$M = [M][T][T^{-1}]$$

These dimensions are also compatible with those of The Planck energy itself whose dimensions are [E][T]such that from the equation $E = hf$.

$$E = [E][T][T^{-1}]$$

It is quite clear that while the Planck energy is the key to understanding energy relations at the quantum level it is equally important to have a fundamental mass, which conforms to the Planck scale.

3). Advance in the Perihelion of Mercury

Technically, as mercury orbits the sun in an ellipse, there will be a point at which it approaches most closely to the Sun. This is known as the perihelion. Just to complicate things, the point of closest distance to the sun is itself very slowly rotating around the Sun. But this rotation is slightly quicker than it should be by about 43 sec of arc per century. This can be readily calculated using the following calculation.

1). Advance in the Perihelion of Mercury (worked example).
change in orbital circumference of Mercury:

$$\Delta_{circ} = \frac{3GM_S}{c^2 a\left(1-e^2\right)} \qquad = 7.987\times 10^{-8}$$

multiplied by the number of Mercury orbits in a century:

$$= 3.316\times 10^{-5}$$

the ratio of circumference to arc second:

$$360°\times 3600 \ = 1.296\times 10^{6}$$

calculated advance in the perihelion of Mercury per century:

$$3.316\times 10^{-5}\times 1.296\times 10^{6} = 42.98 \ \underline{\text{arcsec/cy}}.$$

Equivalent *general relativistic* value per century

$$= 42.98 \ \text{arcsec/cy}$$

Experimentally estimated advance in the perihelion of Mercury per century.

$$= 43 \pm 0.1 \text{ arcsec/cy}$$

where Δ_{circ} is the change in circumference of the orbit of Mercury, G is the gravitational constant, M_S the mass of the Sun, c the speed of light, a is the semi major axis of Mercury 's orbit (in meters), e is the eccentricity.

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