Soaring on the Wings of Genius

A Chronicle of Modern Physics

Book III

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

Isaac Newton (1676)

Dr. Andrew Worsley

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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)

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Foreword

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?