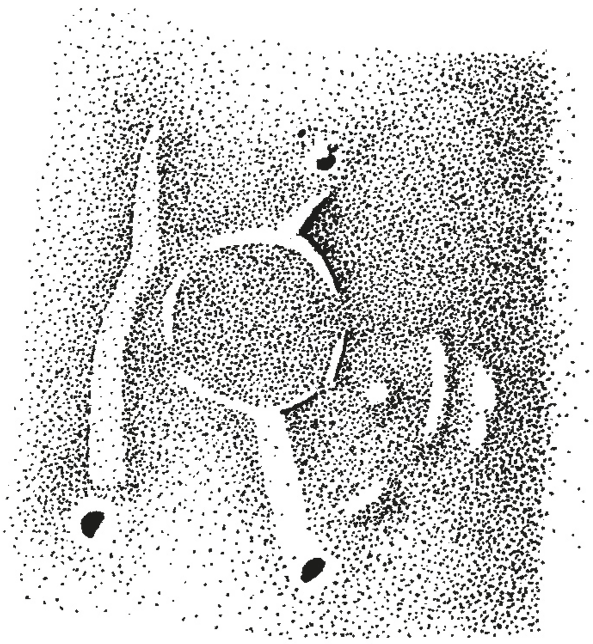
MIRA

Christmas 2005
Number 73
Price 50p

The Journal of the
Coventry and Warwickshire Astronomical Society
http://members.fortuncity.com/cavwas/

Drawings by Vaughan Cooper



The remains of an ancient flooded crater on the floor of Mare Nubium at 26°S 22°W. It is around 44km in diameter and the shallow walls about 2,500 feet high will only catch the sun at sunrise and sunset, This shows how much the look of the lunar service will change in only a day!

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Mind Games

One of the things I like about astronomy is the games you can play in your mind with all the new stories and information in recent articles. Such as this gem from a recent magazine…

The Moon orbits the Earth in 27.5 days at a distance of around 385,000 km and with a mass of only 1/27 of Earth, the Moon pulls the centre of gravity of the Earth/Moon system about 3,000 miles off centre. This means that the point at which the Earth and Moon revolve around (the centre of mass of the Earth/Moon system) lies well under the surface of the Earth. If both bodies were the same mass (but not necessarily the same size) the point at which they orbit each other would be located in space in the centre of the system.

So what happens when a strange binary star system turns up called EF Eridani, a White dwarf star not much larger then the size of Earth. And completing this system is a Brown dwarf companion orbiting around 500,000 km away, 1½ times the Earth Moon distance. The Brown dwarf has 50 times the mass of Jupiter but with not that much greater diameter; it makes you think what the conditions on its surface must be, if it has one!

The White dwarf is the remains of an old burnt-out core of a star which has a magnetic field *14 million* times stronger than our Sun's. The Brown dwarf like object has a surface temperature of 1,700ºK and is made of strange stuff, like stellar-core material rich in nitrogen. But to me the most amazing thing about this pair is that they orbit each other in an astonishing fast time of only 81 minutes!!! Each is deep in the others gravity well and each must be rotational locked together. Both must be egg shaped has they whistle around; 81 minutes to go over 3 million km! Get to Mars in a day when it's close. *Anywhere* in our solar system in a couple of months. *That's moving.*

I suppose most members will have seen *Star Trek* on TV at some time with the *Enterprise* whizzing past lots of streaking stars. But the sad fact is, it wouldn't look like that at all! The faster you go the more the stars in the forewords hemisphere start to group together in the direction the ship is travelling so at almost light speed all the stars are blue shifted into a small area ahead of the ship. No stars would be visible at the sides and looking rearwards would be the other hemisphere red shifted into a small area. Navigation would be tricky to say the least as you can't see where you are going. If its speed you're after think about what it must be like near a black hole. Because they are so small (relativity so (sorry)) and have so much mass, any gas or dismembered stars approaching is speeded up in the increasing gravitational strength the nearer it gets. Most black holes, it is suspected, will be of the Kerr type. They have spin but no charge, so the Event Horizon will be a flattened sphere around the spinning black hole. The faster the spin, the flatter the sphere forcing the inflowing gas into a flat torus. The nearer the gas gets to the event horizon the faster it moves until it is approaching the speed of light and the temperature soars to millions of degrees by the friction of the gas molecules on each other. By now the gas is emitting hard radiation and x-rays as the atoms are ripped apart.

But according to Einstein the faster you go the slower time goes by for the observer, so does the universe suddenly speed up for the unfortunate gas atoms as it speeds around and around and into the black hole??? Does the universe end before it drops in? If you are an observer can you see gas disappearing into… what? Is the edge of a black hole BLACK? Or does it just fade away into blackness as more light is sucked in? Or is it shine with a brilliant light like a sun as the gas spins around it, and how does the black hole generate such powerful jets shooting away from it at its poles if it has such a powerful gravitational force? I should imagine that you would need a pretty fast spaceship and plenty of shielding to be anywhere within a few light hours of a black hole. And be careful of not getting in the way of those jets.

One day when we have better telescopes with thousands of times the resolution of Hubble we may be in a better position to understand what is going on near a black hole. To be able to see and measure the speeds and composition of the infalling material and how it is shredded in the gravitational pull near to the event horizon will no doubt cause many more problems for physics.

Most of the above is totally unknown, even if physics gives an answer of some sort is it correct? The answer to one question often opens up a lot of related questions which again need answers. This is how science operates; find the answer to a puzzle and you seem to get 10 more things you don't know. But you can play with the ideas and imagine what things may be like and who can say with certainty that your ideas are worse than anyone else's. Astronomy is now one of the only scientific subjects left that the amateur can join in and contribute to with some success after many hours hard work and dedication.

Ivor Clarke

It's all Dark up There

by Paritosh Maulik

Many cosmological phenomenon can be better explained if there was more observable mass in the Universe. There have been some suggestions what the missing mass could be, and still there is a lot unknown; hence calling it Dark Matter. Also the Universe is expanding at a rate faster than expected, this has been explained due to the presence of an unknown energy called Dark Energy.

Here is an attempt to describe these is a short general terms.

Within about 100 years of Newton's work of gravity, it was being suggested that heavenly bodies such the Sun and the planets form by condensation of matter under gravity. James Jean tried to put some mathematics to explain the process. As the matter condenses under gravity, it faces friction from neighbouring matter and eventually friction increases. Friction causes the mass to heat up and this heat causes expansion, which in turn opposes the process of collapse.

However, if the expansion is removed, the process of condensation can continue. Jeans's calculation defined a parameter called Jeans Length. It is the minimum size of a gas cloud, which will collapse, on its own accord under the influence of gravity. This condensation process is dependent on the density of the gas cloud. From this calculation it also possible to calculate the time to collapse. If a gas cloud has the density of the present universe, the time needed to collapse is about the age of the universe. This is the reason that no new galaxies are forming today.

Jean's original calculation was based on classical Newtonian theory and it had to be modified to take into account of the relativistic nature of the universe near Big Bang. According to this refined model, Jean's length changed with the size of the horizon. By horizon we mean two regions of the Universe which have exchanged light since the Big Bang. In terrestrial terms it means the farthest we can see. The universe is expanding. The early universe was dominated by radiation rather than matter. Jean's length associated with density rich areas, under such conditions was larger than the horizon and Jean's length increased with increase in horizon. So when such areas formed, it started to gather material to increase in density. But soon Jean's length increased to a very high value; the density fluctuation remained locked in and it could not grow.

This process continued till recombination. The temperature of the Universe is now about 3000°K; electrons and photons are separate from each other. Electrons can combine with protons to from neutral Hydrogen atoms. Photons are free to travel and the Universe is transparent. At this point Jean's Length shrinks to a very low value and the high density areas now can contract to form galaxies. It is to be remembered that these high density areas or fluctuations had to work against the expansion of the Universe. It has been estimated that at the recombination era, if the fluctuation was about 0.3% above the background, we could reach the density distribution as present now.

By around 1970, the temperature fluctuation of the microwave background (radiation leftover from the Big Bang) was reasonably well understood. These works suggested that galaxy formation by gravity acting alone on these density fluctuations is highly unlikely. Some suggestions were put forward such as

1) The radiation was smooth, but the matter was clustered together in places, the objection to this hypothesis is that non-uniformity in radiation would appear soon.

2) The density of matter was high and that of radiation was low; this was considered to be possible, but unlikely to have occurred.

3) The explosion compressed gas to collapse; in the case, the nature or the origin of the gas is not explained.

In order to overcome these difficulties, it was proposed that perhaps during recombination era, there was high fluctuation in the distribution of matter, but the nature of the matter was such that, it did not interact with radiation. Since this matter in question was a kind of an undefined matter, it was termed as dark matter.

It was suggested that one of the fundamental particles called a neutrino might possible be a candidate for this dark matter. At the recombination period the dominant matter of the Universe was neutrinos. Neutrinos did not interact with photons like electrons did with photons and were free to travel.

When particle physicists first predicted the presence of Neutrinos, it was reported to have no mass and is therefore capable of moving (closely) at the speed of light. However some recent experiments indicate that Neutrinos may have mass.

It is assumed that neutrinos have a very small mass (mass on an electron $9.109*10^{-31}$kg and that of Neutrino is one twenty thousand that of an electron). The early universe was dominated by neutrinos; at that era also present were photons and other particles, the latter collectively known as baryons. In such an Universe, only large masses, of the order of 1000 galaxy masses, can start to collapse. This is because, since neutrinos can move very fast, these can leave low density regions. The picture emerges from this scenario is that giant clusters of galaxies form first -> these then collapse to form flat surfaces -> gases get very hot -> these radiate heat -> cools down -> and instabilities form galaxies.

However computer simulation could not replicate such a picture that giant structure formed first and then it gave rise to smaller structures like galaxies. Computer

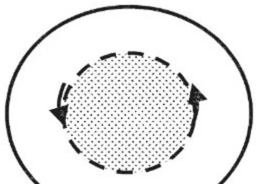


***Fig.1** The gas cloud is within the galaxy and is moving along the broken line.*

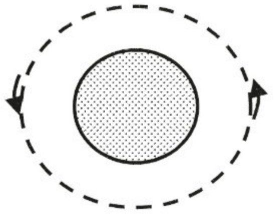


***Fig. 2** The gas cloud is outside the galaxy, (shaded area) and moving along broken line, the whole mass of the galaxy is attracting the cloud.*

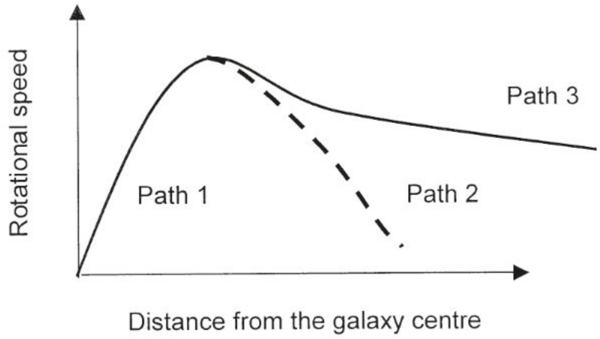


Fig. 3 *If matter is concentrated mainly in the centre the rotational speed should follow paths 1 and 2. If there is plenty of matter present at the outer edge the rotational speed follows path 1 and 3*

simulations suggested that if the giant structure were to form first, one should expect large scale structures to be more common. Observations indicate that large scale structures such as clusters of galaxies, do exist, but it amounts of about 10% of galaxies and rest are in loose groups.

If the neutrinos are the dark matter and since these particles are capable of moving closely to the speed of light (at relativistic speed), these were termed as hot dark matter. The high speed of neutrinos will cause these particles to cluster only at large distances. In short distance scale, cold dark matter will cluster to galaxy size scale structures and once the baryonic matter is free, following the recombination era, baryonic matter will be attracted to these dark matter aggregates. When we look at a galaxy, the baryonic matters form visible part of the distribution as stars and gas; these are embedded in a matrix or halo of cold dark matter. It is generally assumed that dark matter mainly reside in the haloes of the galaxies. Computer simulations also agreed to this model.

But larking in the background there was an observational problem. Astronomers were measuring the rotational velocity of galaxies by using optical and somewhat recently by radio telescopes. As early as 1930, it became apparent that rotational velocity of galaxies does not correspond to the observable mass. Let us assume that there are two possible types of distribution of gas in a spherical galaxy and this gas cloud is moving about the galaxy centre according to Kepler and Newton's law. In **Fig.1** the gas cloud is concentric and inside the galaxy and is moving along the broken line. The attracting mass is within the diameter of the galaxy and in **Fig. 2** the gas cloud is outside the galaxy, moving along broken line and the whole mass of the galaxy is attracting the cloud. It was expected that if the situation was like **Fig.1** The rotational speed would increase with increasing distance; path 1 in **Fig. 3** and then drop like path 2. But when measured, for most of the galaxies the variation of the rotational speed from the galaxy centre turned out to follow path 1 and 3, that is, the observed speed does not change appreciably with distance from the galaxy centre.

If the rotational speed of the dark matter distribution were to follow the paths 1 and 2 the darkmatter distribution should be expected to be as in **Fig 4a**, but in reality the speed follows path 1 and 3; this indicated more sprayed out distribution of dark matter, **Fig.4b**.

This suggests that there is plenty of material at the outer edges of the galaxy, which is being attracted by the centre and this attraction is sufficiently high to counteract the centrifugal speed of the motion of the stars at the outer edges. This keeps the stars and gases, present at the outer edges, moving without appreciable drop in speed.

But this observation does not help us to identify the cold dark matter. One suggestion has been that there are dark stars in our galaxy like white dwarfs. These are dead leftovers from stars like the Sun, in which hydrogen has been exhausted. These have not been directly detected, but have been inferred from gravitational microlensing experiments. Stars from a nearby galaxy have been observed to brighten up due to possible alignment of a heavy object, perhaps by dark matter present in our galaxy. On the other

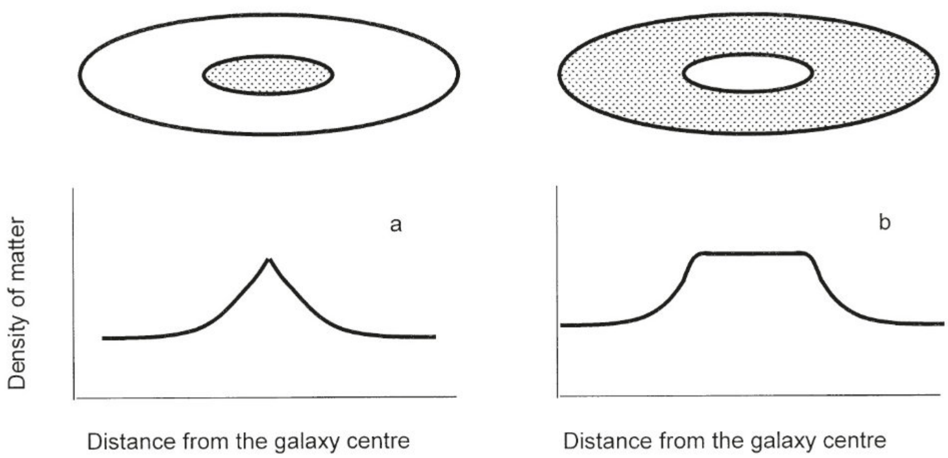


Fig 4a & Fig 4b *If the rotational speed follow the paths 1 and 2 in Fig 3, the density of matter is expected to be ike 4a, manly near the centre, however in reality the matter is more spred out like 4b* hand, it has also been shown that this brightening can be explained by microlensing a star present in the near nearby galaxy.

Baryonic mass of all the galaxies been estimated. This has been done by

i) determine the ratio of starlight to the mass of the Milkyway,

ii) determine starlight of all the galaxies in a cluster,

iii) calculate the total mass of the cluster from the values in step i) and ii).

In this calculation mass due to super hot gasses emitting x-ray has also been added and then from the rotational speed of galaxies in the cluster, the total mass of the cluster can be determined. This indicates the contribution of baryonic or ordinary matter to the overall mass is of the order of about 25% – 35% and the rest to be some sort of dark matter. The nature of this dark matter is not yet known. Several hypothetical particles have been suggested. These have been termed as **W**eakly **I**nteractive **M**assive **P**articles (WIMP). These do not react with matter, but under certain conditions, they may weakly interact with matter and this interaction can be recorded. This has led to a series of underground observatories. These observatories are placed in several kilometre deep underground to shield them from background radiation. These observatories essentially consist of a large tank of fluid and array of detectors. The concept being, WIMP's travelling unimpeded through the earth, hit the fluid and this causes a light emission. This is picked up by the detectors and from this the nature of the incoming particle is detected. There is one such set up in the UK, Balbly Potash mine.

During 1980s from infrared satellite survey three dimensional distribution of galaxies was determined. This result did not agree well with cold dark matter model. COBE results suggested that density fluctuation occurred on large scale. To explain these results, one group argued the presence of a non-zero cosmological constant and another group suggested dark matter is perhaps consists of two types of matter, cold and hot dark matters. As discussed briefly one possible candidate for the hot dark matter may be neutrinos and underground observatories are trying to detect the presence of such hot dark matter.

There is a term called density parameter, Ω (please be patient and put up with it for the time being). It is the ratio of actual density to critical density of the universe. It gives us a measure of the ratio of gravitational energy to the kinetic energy of the universe. The former is equivalent to gravity and the latter is associated with the expansion of the Universe. If Ω Is greater than 1, the density of all the matter is sufficiently high and with time, the universe will stop expanding and will eventually collapse. On the other hand, if Ω is less than 1; there is insufficient matter in the universe and the universe will go on expanding. If $\Omega =1$, the universe will expand but with a progressing slower rate. We know that there is a term called cosmological constant to take into account of this expansion and this term (allegedly) keeps the Universe in a steady state. We shall come back to it another day and for the time being let us stay with the term Ω .

Different groups using different surveys such as Infra Red, X-ray, come up with different values of Ω_{total} ranging from about 0.3 to 1. Some recent experiments have found the evidence of super-hot gases in the x-ray range, which were not accounted before. Despite taking into account of these unaccounted mass before, there is a shortage of matter, collectively known as baryonic matter, to account for the missing mass. The current estimate is dark matter accounts for about 0.97 of the total mass and baryonic matter about 0.03; and if there is indeed hot dark matter, it is about 20% – 25% of the total dark matter. Now to sum up

Ω total=Ω baryonic matter+Ω cold dark matter+Ω hot dark matter

Theorists have a very good estimation of the baryonic matter, but yet we do not know the exact nature of the dark matter. There appear to be some fundamental particles), however are other options as well and here is a shot list of possible nature of the dark matter..

1) Strong or Weak Interacting : If dark matter consists of particles which strongly interact with other matter, then it would create shock waves as the matter collapses, leading to the formation of galaxies. Result of this condensation process, would be spherical. But most of the galaxies are elliptical and so also the nature of the halos around the galaxies. This seems to suggest that dark matter reacts weakly with other matter. Dark matter can react strongly with each other. Future studies on the distribution of dark matter will hopefully determine the nature of the interaction between the dark matter and the baryonic matter.

2) Hot or Cold Dark Matter : If the dark matter is cold, the theory predicts high concentration of dark matter near the centre of the galaxy, but observation suggests diffused distribution of dark matter. Some of it we have discussed before. If the dark matter is entirely consists of hot dark matter, clumps of matter would grow slowly and the early universe will contain too few galaxies. Jury is still out, but this does not preclude the presence of some hot dark matter.

3) Decaying Matter : Dark matter is a type of particle which decays like radioactive particle with time into photons and neutrinos and other particles and this process will spread out the high density of dark matter as discussed in Fig. 4. Since these are decaying in nature, these were high at early universe and decreasing with the ageing of universe. The high concentration of these particles in the early universe will make the early structures small. If these particles disappear with time, binding force of the galaxies will weaken and will spread apart.

4) Ultra-light Particle : Some unknown particles of exceeding small mass and according to uncertainty principle, being of small, the position of these particles are not well defined. These would be present only as diffused cloud spanning several thousand light years across and hence will not be present areas of high concentration.

5) Self Destructing Particles : Nature of particles are such that these particles destroy on contact with each other and hence these, particles are not found concentrated in one area, such as centre of galaxies. If these are sprayed out, mutual interaction stops and this prevents self destruction as in the case fig.4b. The problem with this idea is that nature of these particles are difficult to model.

6) Defect structure : After Big Bang when the universe was cooling down, the structure was not smooth, but had some defects. These defects are somewhat similar to the defects present when liquid freezes into solid, say water to ice crystal or molten metal to metal crystal. Such crystals contain some defects and are not perfect. One such defect is a string, like a very thin wire. Vibration of the string determines it properties. Strings can form network and as these moved around, these helped to condense matter to create galaxies. This is a very contentious topic and better left alone.

In short, the amount of matter in the universe is higher than we can account for from the visible matter. We can not detect this missing mass; all we can think of it is as some type of fundamental particles produced within the first few seconds of the Big Bang as high energy photons lost their energy and converted particles.

There is a group of galaxies called Low Surface Brightness galaxies. As the name suggests these are dim galaxies, irregular in shape and full of hot blue stars. These contain hydrogen gas, but the rate of star formation is much slower than galaxies with higher surface brightness, such as the Milkyway. The size of these LSB galaxies may vary from fraction of the size of the Milkyway to about 10 times grater and there are more than 3000 of them. The density of hydrogen in the LSB is low and theoretically star formation should not take place, yet these galaxies harbour young stars. All the details are not known, but it has been suggested that dark matter present in the core and halo of dwarf galaxies attract hydrogen and this causes the galaxies to spin and merge with others to form large galaxies.

Recently Jodrel Bank Radio telescope has detected a large galaxy without any stars. Changes in the electronic configuration of hydrogen gives off radio emission and this can be picked up by radio telescope. From this radio data, the rotational speed of the galaxy can also be measured. The object detected by Jodrel Bank is essentially a galaxy size cloud of hydrogen in the Virgo cluster of galaxies, the Arecibo Radio telescope has also confirmed its presence. Similar phenomenon has been observed before, but on optical examination with powerful telescopes, such objects have been found to contain stars. However this new object, when viewed optically, seems to be devoid of stars. The explanation given is that the presence of hydrogen cloud alone can not explain the rotational speed, there is more mass in the system, which for the time being has been classed as dark matter.

It seems it is the first reported evidence of a galaxy consisting of mainly dark matter and hydrogen and no stars.

Dark Energy

According to gravitational theory, we should expect that if every constituent of the universe stands still for a moment, it should attract each other and will collapse; only an explosion can hurl matter away from each other. With this scenario it is difficult to explain a steady or static universe.

There is another problem, gravity can not move faster than light; it can move as fast as light, but not faster and hence instantaneous interaction is not permitted. Since the maximum allowed speed of gravity is that of light, time to collapse on a short distance scale like the Solar system may be short, but on a larger scale like that of the entire Universe, it will be definitely long.

Einstein modified Newton's theory of gravitation and applied it to the Universe. His calculations suggested that the matter in the universe should collapse and only way to keep the universe in a steady state, is to have a repulsive anti gravity effect to balance the attraction due to gravity. The equation he came up with had two terms, gravitational attraction and cosmic repulsion called cosmological constant, both of which increased with distance and these two forces just balance each other and any small deviation can have a catastrophic effect; either the universe will collapse or expand.

Now a little more about the cosmological constant: according to the classical Newtonian theory gravitational attraction is dependent on mass and distance. But according to the theory of relativity energy is equivalent to mass and therefore, increase of energy say by heating, will in effect contribute to the mass and hence increased effect on attraction due to gravity.

By squeezing a spring, we can increase its energy and this increase in energy adds to its mass, which, in turn has a positive effect on gravity. Conversely, if we relax the spring, there is a drop in energy and the net result is negative effect on gravity; the negative of gravity is repulsion. If this applies to a spring, it should apply to the Universe as well. Stretch the Universe, increase its repulsive behaviour. Therefore positive pressure is attractive gravity and negative pressure is anti gravity or expansion. The proper way to say this is :- positive pressure adds to the gravity field. We are to remember two facts

1) Increase in energy and hence gravity by squeezing the spring is insignificant compared to the effect on gravity due to its mass alone and this is true for common or baryonic materials like the electron, proton etc.

2) Pressure is not same as gravity, it may aid gravity.

In this way Einstein showed that attractive gravity of the common matter can be overcome by the repulsive energy coming from vacuum or nothing. This would keep the Universe in a steady state. This repulsive force increase with distance and it is small over a small scale such as solar system, but over a large scale such as the Universe, it would be very large.

The attractive term depends on density, but the repulsive term does not. If there is a small increase in density, it may lead to localised collapse and thus formation of galaxies. Same amount of matter when close together exerts a smaller net gravitational force compared to if is spaced out uniformly. Therefore, following this argument, once the galaxy formation started, the universe could be expected to expand. This sounds attractive because, we do not need any Big Bang; a static universe will expand as the galaxies began to form. As matter collapse, it gets hot and it would like to expand and the expansion goes on. But this argument has a problem. In fact, this heat increases the energy; and energy is equivalent to mass; which in turn aids gravitational collapse. Thus the collapsing process continues. This point has been verified both theoretically and by observation. So the universe does not expand but collapses.

There have been other models, which pointed towards the possibility of Big Bang. One such model was suggested by Friedman. He did invoke Einstein's theory of relativity and realised that the Universe should collapse due to gravity. He assumed that since there is no obvious evidence of collapsing, there must be something, which is preventing the Universe from collapsing. Let us assume a region of a space is spherical and it is expanding, **Fig.5.** Now divide the matter in this sphere in concentric shells and each shell is expanding. No matter is added or destroyed, the mass remains the same. Each shell has two components of energy, kinetic and gravitational potential energy. The sum of these two is fixed and one can grow only at the expansion of the other. The kinetic energy comes from expansion.

When everything is at the centre of the sphere, its kinetic energy is zero and its gravitational potential energy is highest. Potential energy is generally considered as a negative energy. We know that

Density = mass ÷ volume

When the sphere is small, volume is also small; the density is also high, mass remain constant. So, when the volume approaches zero, density is very high indeed, the moment of Big Bang. The outcome of this model does not depend on the scale of the sphere (or the size of the universe), but on the time; the fate of this growing shell can be roughly expressed as

-{k } = {kinetic energy} – {potential energy}.

k is a factor defining the difference of two energies; parenthesis *{ }* indicates a loose form of expression.

When solved, there appeared to be three possible values of k. The value of k determines the shape of the shell under consideration. The above picture of the shell is also true, if we assume the shell to be the whole Universe. There are three possible shapes, expressed in two dimensions for simplicity, turned out to be

1) Sphere; the surface cycles between expansion and collapse with time

2) Saddle, the kinetic energy is too high, it overcomes gravitational collapse and goes on increasing forever.

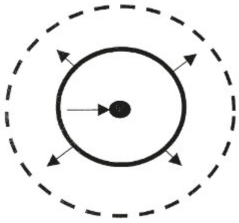


Fig.5 *Expanding shell of matter, outward movement causes increase kinetic energy which is gained at the expense of potential energy, when everything was at the centre.*

3) Flat surface; this surface will expand, but will slow down with time. This is the accepted shape of the Universe.

Since this model obeys Einstein's theory, mass gives rise to the curvature to the above surfaces. Both of these theories were proposed before Hubble's observation confirmed the expansion of the Universe.

While working out his equation for expansion, instead of using a given value of distance, Friedman used a term called expansion factor or scale factor, R. It is an indication of expansion with time. For example, if the initial separation between two objects is r_{inital} and after a time it is r; R is expressed as, R = r/ r_{inital}; when R = 1, there is no expansion. This factor R gives a physical interpretation of Hubble's law :

*Relative velocity between two objects, v = Hubble constant * relative separation of the objects (r).* $v=H_0*r$

As the relative separation changes with time, the objects are moving apart. In reality, since gap or the space between the objects is increasing, the far away objects appear to be moving faster. Thus according to Friedman's model the universe is allowed to expand and its fate depends on the state of the matter.

Now if we rearrange Hubble's equation H_0=v/r= (distance/time)/distance, the unit of H comes out to be 1/time. Time, t_0, corresponding to H_0, is called Hubble time. It is a measure of the rate of expansion of the Universe. If the galaxies move apart without any force acting on them, Hubble time would be same as that of the age of the Universe, but if gravity is the only force trying to slow down the Universe, the age of the Universe will be smaller than the Hubble time.

For his calculations, Hubble used nearby galaxies and H_0 was very high; consequently Hubble time came out to be about $2*10^9$ (2 billion years). But soon from radioactive dating, the age of the earth was estimated to be around 4 – $4.5*10^9$ years. However present data using far away galaxies, suggests a smaller value of H_0 and the age of the universe appears to be around $13*10^9$ (13 billion years). Now we have a theoretical base to estimate the expansion of the Universe. Now let us take break.

Supernova Explosion; Type IA

A white dwarf star accretes matter from a companion star and when its mass increase to about 1.4* solar mass (Chandrashekhar limit), the star starts the process of runaway fusion between carbon and oxygen, commonly known as carbon burning and the star explodes. In these stars hydrogen and helium are not generally present, and in the spectral signature elements like iron, nickel, cobalt, silicon are detected. Since this process occurs when the mass of the star reaches a critical value, all supernova of type IA have the same energy. The intensity of the light gives the time of explosion (how far away it is) and the redshift of the spectrum gives the expansion of the space. By collecting enough supernovae at different redshifts, it has been possible to calculate the stretching of space with time.

We have seen earlier that the Universe is expanding albeit at a slow rate. At the beginning it did expand at a very high rate and then slowed down. However about 5 years ago two independent groups observed that some of the far away supernovae are extremely faint. The conclusion they came up with was, around 10^9 (10 billion years) ago the expansion of the universe has speeded up; as if the attractive power of gravity has weakened.

The only possible explanation seems to be the weakening of gravity along the arguments of Einstein, the energy due to stretching of space. As we have seen earlier, stretching matter reduces its effect on gravitational attraction. Since the space is essentially a vacuum, as a first approximation, it has been dubbed as Vacuum Energy, energy due to the vacuum of the space; and also since we do not know the details of this energy it is called Dark Energy. Just a quick reminder that the change of energy and its contribution to gravity of ordinary matter by contraction or expansion is negligible and therefore ordinary or baryonic matters are not involved in this mysterious energy.

Here are some the current thoughts on the cause and effect of this Dark Energy:

1) The empty vacuum of the space is not really empty, Quantum theory allows any energy fluctuation to form virtual particles. These can appear and disappear in very short periods. Forces between these particles may give rise to tension. However calculations indicate that the energy involved in such a process would be so great that the whole Universe would explode. With the expansion of the Universe, the density of ordinary matter will decrease and this repulsive energy will gather strength. At the beginning, the opposite was the case. The Universe will continue to expand and eventually objects would be so far that light would not reach from one to another.

2) The Dark Energy is like a fluid filling the space and its nature is such that there is an equilibrium between the dark energy and the energy due to matter. It works on mathematical equations, but does not describe the process.

3) Topological Defects: When something goes through a phase change, say molten metal crystallises in to solid or a crystals form from a solution, the crystals thus formed are not perfect; there are defects present in the crystals. In the simplest case these defects may be a few atoms missing or a row of atoms missing. These are called topological defects. It has been suggested that when things began to cool down following the Big Bang, at certain stages of the process some defects crept in and these are the cause of tension or stretching of the space.

4) Perhaps gravity behaves differently over a long distance.

All these models predict certain values of repulsive energy and the only way to verify the situations is to collect more supernova data. At present the ground based telescopes are continuing to gather data. Reliability of terrestrial based supernova results has been questioned. It is also possible that a distant supernova might have redshifted into the infrared range. The atmosphere of the Earth may interfere with these infrared results and therefore space telescopes are better suited. Such a mission is planned around 2009.

In a recent paper it has been suggested that theoretically black holes should not occur and when sufficiently massive stars collapse, these change into stars with dark energy. The argument goes something like this: at the boundary of the black hole time is supposed to stand still. According to the theory of relativity, time is dependent on the observer and is not universal, hence someone falling into the black hole will continue to fall, but to an observer from a far away they will see the falling person is standing still at the edge of the black hole. Quantum theory, on the other hand, assumes the time is universal and the quantum theory has not been proven wrong. Quantum theory predicts that small fluctuation near the black hole can have strange effects. One of the effects may be, when these massive stars collapse, these become full of dark energy. On the outside there is gravitational pull and inside there is repulsive gravity, throwing out matter. The interaction between matter and antimatter gives rise to high energy bursts and these have been reported to be the signature of black holes. According to this theory fluctuation of spacetime causes the formation of dark energy stars. These are made from undetectable dark matter but have similar gravitational effect as baryonic matter.

If the presence of both Dark matter and Dark are taken into account, the present state of affairs of the Universe since the Big Bang gives a more realistic picture. The consensus seems to be the sum total of the Universe is about 73% dark energy, 23% dark matter and 4% baryonic matter.

Although we have seen that the present thinking indicate a possible dark future (or sky), everything will be too far to observe, it has been suggest after about 18*109 (18 billion) years the repulsive dark energy may change from repulsive to attractive and if that happens, eventually there will be a Big Bang all over again.

Further reading

The Big Bang Joseph Silk, W H Freeman and Co, 2001
The Fabric of Cosmos Brian Green, Penguin, 2004
Just Six Numbers Martin Rees, Weidenfield and Nicolson, 1999
The Nine Numbers of the Cosmos Michael Rowan-Robinson Oxford University Press 1999

The Da Vinci Code and the Venus Pentacle

By Mike Frost

A few months ago, a friend lent me a copy of *"Deception Point"*, a thriller by the American writer Dan Brown. I loved it! It's a wild, no-holds-barred story featuring icebergs, Hammerhead sharks and a giant NASA conspiracy. What not to like?

So I was looking forward to reading Dan Brown's most recent, most famous, biggest selling and most notorious thriller, *"The Da Vinci Code"*. Until the advent of Harry Potter, it was comfortably the best-selling book this year in Britain. Well, I finally read the Da Vinci Code other week. It was a page-turner, certainly – I finished it off in a little over 24 hours – and an entertaining read, though I thought it ran out of steam towards the end. I even managed to decode some of the clues ahead of the protagonists.

Overall, though, I was a little disappointed. One of the things I had been looking forward to enjoying in the Da Vinci Code was the dazzling array of references and diversions. If you want to know about art history, the Knights Templar, the golden ratio, Opus Dei, the Fibonnaci series or the Priory of Sion, you'll find something about them within the pages of the Da Vinci Code. But how accurate is that information? Well, for most of these things, I have no idea. But for the things I do know something about, I found the Da Vinci Code rather misleading.

In particular, there is one astronomical assertion in the Da Vinci Code, and I'd like to deconstruct it for you here. On page 61 of my edition (don't worry, I'm not going to reveal anything of the plot), the hero, Robert Langdon, professor of religious symbology at Harvard, is explaining the significance of the pentacle, or five-pointed star, to Bezu Fache, a French police officer. Langdon, however, is holding something back.

"Langdon decided not to share the pentacle's most astonishing property – the graphic origin of its ties to Venus. As a young astronomy student, Langdon had been stunned to learn that the planet Venus traced a perfect pentacle across the ecliptic sky every eight years. So astonished were the ancients to observe this phenomenon, that Venus and her pentacle became symbols of perfection, beauty and the cyclic qualities of sexual love. As a tribute to the magic of Venus, the Greeks used her eight-year cycle to organise the Olympic Games. Nowadays, the few people realized that the four-year cycle of the Olympics followed the half-cycles of Venus."

Interestingly, I'm told that, in the original edition of the book, the pentacle was said to be traced by Venus in four years, not eight. "Four" was changed to "eight" in later editions, which also explains the rather cumbersome identification of the half-cycle to the Olympic interval. When I read the book, my first reaction was "what is he on about?" Had Robert Langdon gone to the same astronomy class as me? (Answer – No, he's fictional) Or even studied the same subject? Pentacles and Venus just didn't go together, in my book.

Well, I was wrong. Or maybe right. Let me explain how the Venus Pentacle is generated. Let's start with how Venus actually moves through the heavens. The first accurate description of its motion was given by Johannes Kepler, in two laws of motion which he published in 1609 (followed by a third law, which doesn't concern us here, in 1619). These are Kepler's two laws.

1/ The planets move round the Sun in ellipses, with the Sun at one focus.

2/ The line joining planet and Sun sweeps out equal areas in equal times.

These two laws are natural consequences of the Universal Law of Gravity, discovered by Isaac Newton around 1666 and published in 1687. Newton's Law of gravity is no longer the most accurate description of reality; it was superseded by Einstein's general theory of relativity in 1915. However the relativistic corrections to the orbit of Venus are negligible and can safely be ignored here.

What is an ellipse? It's a bit like a squashed circle. In the case of both Venus and the Earth, the non-circularity is not obvious (unlike, say, Mercury and Mars, whose orbits are clearly non-circular). For the purpose of this analysis I'll assume that both Venus and Earth orbit the Sun in circular orbits. Kepler's second law then implies that the orbital speed is constant.

So, Earth goes round the Sun once in 365.256 days in a (near) circular orbit. Venus goes round the Sun once in 224.701 (Earth) days, in a (near) circular orbit. What is the significance of the eight year period? Well, 8 years is 8*365.256 = 2922.048 days. 13 Venus years, on the other hand, is 13*224.701 = 2921.113 days. For every eight times Earth orbits the Sun, Venus goes round the Sun – almost exactly – thirteen times. But note that "almost". When Robert Langdon says that the pentacle is "perfect", he's wrong.

Is there any significance to the 13:8 ratio of orbits? The fact that it isn't an exact ratio suggests no – it's just a numerical co-incidence. There are places in the Solar system where orbital "resonances" are exact, however. For example, the orbital periods of three of the major Galilean satellites of Jupiter,

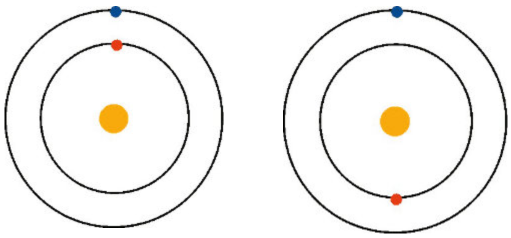


Fig 1 Inferior Conjunction and Superior Conjunction of Venus

Io : Europa : Ganymede, are in the exact ratio 1:2:4. Over the history of the solar system tidal interactions have slowly pushed the Galilean moons into this configuration. However, the mutual gravitational attraction of Venus and Earth isn't sufficient to lock the two planets into a stable resonance.

But what about the pentacle? In a given 8-year period, Venus orbits the Sun five more times than Earth does. So, on five occasions, Venus overtakes Earth in its orbit, lapping it on the inside, so to speak. The moment when Venus passes Earth on the inside is called "inferior conjunction". There's another type of conjunction, superior, where Venus is on the opposite side of the Sun from the Earth (see figure 1.). The last time when Venus and Earth were in inferior conjunction was June 8th 2004, and you might remember that it was a special occasion, the Transit of Venus across the face of the Sun. You might also remember that the reason why we don't get a Transit of Venus at every inferior conjunction is because Venus's orbit is tilted slightly to the Earth's. Because of the 8-year cycle we do get another transit in 8 years time, albeit three days earlier; but the fact that the 8:13 match isn't exact means that there are then no more transits for over a century.

There are five inferior conjunctions of Venus in every eight year cycle, and because the planets' orbital speeds hardly vary, they are spaced pretty much equally through the 8 years, that's to say at intervals of $^{8}/_{5}$ of a year, or around 584 days. Let's consider a series of inferior conjunctions. These occur after $^{8}/_{5}$ years and then $2{*}^{8}/_{5}$, $3{*}^{8}/_{5}$, $4{*}^{8}/_{5}$ and $5{*}^{8}/_{5}$ years. In terms of orbits of the two planets, inferior conjunctions occur:

For Earth after: $^{8}/_{5}$ $^{16}/_{5}$ $^{24}/_{5}$ $^{32}/_{5}$ and $^{40}/_{5}$ (=8) orbits.

For Venus after: $^{13}/_{5}$ $^{26}/_{5}$ $^{39}/_{5}$ $^{52}/_{5}$ and $^{65}/_{5}$ (=13) orbits.

We can throw away the whole number parts of these, to leave the fraction of the orbits, which are the same for both planets (this should not be a surprise). After $^{3}/_{5}$ $^{1}/_{5}$ $^{4}/_{5}$ $^{2}/_{5}$ and $^{5}/_{5}$ orbits.

Figures 2-5 below illustrate successive cumulative inferior conjunctions of Venus. In Fig. 6, I join up the successive inferior conjunction positions, and – ta da! – we get the pentacle. The Venus pentacle is the construction made by joining successive inferior conjunctions of Venus. After five inferior conjunctions, the pentacle joins up and starts again.

But wait a moment! What do the construction lines represent? NOT the motion of Venus, which is happily orbiting the Sun in its circle. NOT the Earth, which also orbits in a circle. What the straight lines of the pentacle represent physically is — NOTHING AT ALL. We are simply joining five snapshots of the position of Venus by the shortest route possible, emphatically not the route the planet actually takes.

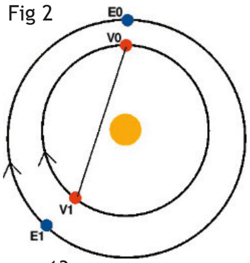
Does the pentacle perhaps represent the apparent route taken by Venus, as seen from Earth? Once again – nope, sorry. From Earth, the motion of Venus is backwards and forwards along the ecliptic, the great circle through the sky along which all the planets move (there are small deviations from the ecliptic because of the three degree tilt of Venus's orbit to Earth's). As Venus moves through inferior conjunction it stops being an evening star, rising before the Sun, and starts being a morning star, setting after the Sun. For a while it sets later and later, then closer to the Sun, before disappearing behind, through a superior conjunction, to re-appear as an evening star.

Because Venus is so bright, and the transition from evening to morning star so obvious, the 584-day period between inferior conjunctions was well known to ancient astronomers, although they didn't necessarily understand how it arose. Some Greek astronomers successfully understood circular orbits around the Sun, but there's little evidence that Mayan astronomers, for whom the 584-day period was important, actually understood how it came about.

So, this is the bottom line. The pentacle of Venus, which Robert Langdon heard about in his astronomy classes, does exist. However the pentacle doesn't quite join up, because the 8-year period isn't exact. The pentacle is a little wonky, because neither Venus nor Earth orbits the Sun in a perfect circle. And the straight lines of the pentacle bear no resemblance whatever to the motion of Venus through the skies. All of which goes to show that Dan Brown is very good at taking an interesting snippet of information, ignoring any inconvenient caveats, and hyping it up way beyond any reasonable significance.

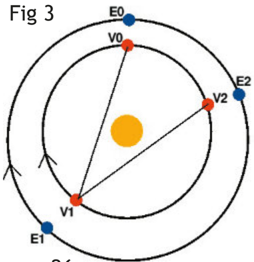
And I suspect he does that with everything else in his book.

Fig 2



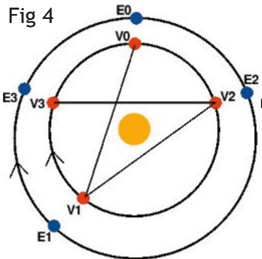
$^{13}/_{5}$ Venus orbits
$^{8}/_{5}$ Earth orbits

Fig 3



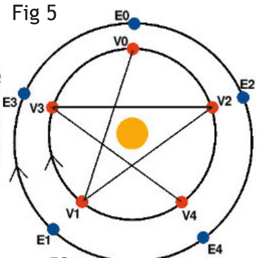
$^{26}/_{5}$ Venus orbits
$^{16}/_{5}$ Earth orbits

Fig 4



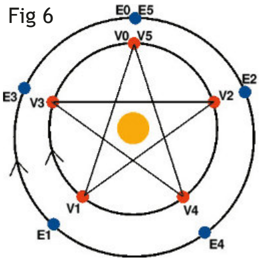
$^{39}/_{5}$ Venus orbits
$^{24}/_{5}$ Earth orbits

Fig 5



$^{52}/_{5}$ Venus orbits
$^{32}/_{5}$ Earth orbits

Fig 6



The Venus Pentacle

Redshift 5.1
Deluxe Edition

The next version of this software tested by Clive Rogers

The new offering from Focus boast an array of features which should be of interest to novice and the more experienced astronomers alike. This software come on 2 CD's with the option of installing all of it which is some 1.4 Gig. When you install all of the software you don't have to have the CD in the drive and this means faster access to the information. The program does require that you register it over the Internet which is quick and easy and no personal information is transmitted. It also comes with a Quick start guide which has some keyboard short cuts printed on it for quick easy use.

After installation you are greeted with the Start up screen which gives you an over view of what this software is capable of from Sky Diary giving you the events of the planets, Lunar and Solar eclipses to Meteor showers. The Guided Tours tells you about the Solar system, Comets and Asteroids through to Spaceflight. The Story of the Universe takes you from the Big Bang through the lives of stars to the history of the Solar System and Time and Seasons.

The Lectures will be a bonus to the budding astronomer giving details of the night sky from a beginners point of view with lots of video accompanied by space music.

Video Gallery takes you through; The Universe, Solar System, Space Craft and the Hubble Space Telescope. Photo Gallery consist of loads of images from all sections of astronomy.

The Multimedia part of this program is well put together and will keep you glued to the screen viewing either images or video footage. I also found that the astronomical dictionary was very good too and will come in handy for the beginner coming across words they have not heard or know the meaning of.

Before you start to use the planetarium program its wise to setup your home location which can be achieved either with a click able map or a database of names. Doing this gives a true image of the night sky for your local time and area.

Here are just a few of the features within the planetarium

20,000,000 stars, 25,000 deep space objects, 9 planets with over 100 Moons, 50 minor planets and 1,500 comets. Some of the star catalogues are the Hipparcos, Tycho 2 and the Hubble guide star catalogue 2.2. If you're not happy with the night sky as it is today then you could always go back in time to some 6,000 ago or even into the future to see what the night sky will look like in your Great Grand children's time.

In use the planetarium is very good. If you have an object you wish to explore then its a simple matter of a mouse click on the object which brings up a menu with more information. Finding objects is also easy with this new software just by right mouse clicking on the screen or choosing the flashlight icon along the top. This brings up a menu that is easy to navigate and find what you are after. I was able to find everything that I wanted to see with just a few mouse clicks. The zoom in feature using the scroll mouse is very easy to use in practice. If you don't have a scroll mouse out in the field then the magnifying glass icon from the top is a nice feature but to zoom out you have to use the Navigation panel then click the view tab then find the zoom feature at the bottom of the list which can be a tiresome.

All in all a very well put together planetarium come teaching tool covering many aspects of astronomy. I only have one small niggle and that is the red screen or night vision effect, this is pinkish in colour and very bright and I found that it is not dark enough for use in the field under observing conditions and does not let your eyes dark adapt to there fullest extent. You can read more on their web site at www.focusmm.co.uk

Having said all that, for £24.99 you really can't go wrong.

See the back page for the special offer until the end of March 2006

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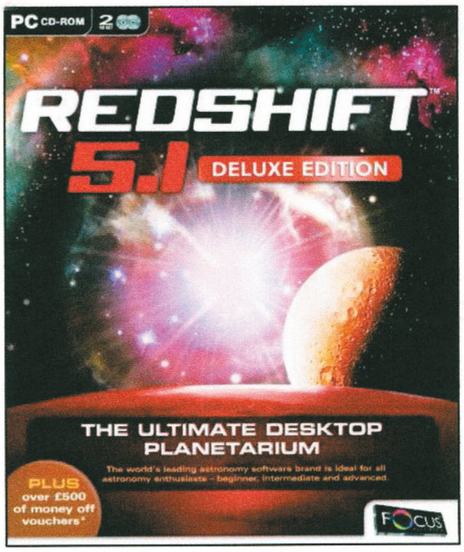
Get the World's Leading Astronomy Software Brand for LESS!



Ideal for beginner, intermediate and advanced astronomers, this powerful software forms the ultimate desktop planetarium.

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