Chapter-8
THE STORY OF CREATION

THE EXPANDING UNIVERSE

We are not to imagine or suppose, but to discover, what nature does or may be made to do. (Francis Bacon)

8.01 INTRODUCTION

Our Grand Nature emerged into its present vastness after millions of observations, first through naked eyes, then through instruments like optical telescope, spectroscope and radio telescope. It emerged into present realities only in this 20th century only by men of science. No amount of philosophical foresight or religious sagacity could do it to this end.

It is interesting to note that our known world continued to grow larger at every epoch as our knowledge increased. Earlier we thought our world simply a part of solar system. Later it became larger enough to include the whole solar system. Our World further unfolded beyond the solar system into our galaxy, then into space beyond our galaxy and finally into one expanding Universe. Strangely the big Universe was there all the time but remained unknown to us. How the World unfolded to its present vastness? How we learnt this Great Creation?

8.02. CEPHEID STARS

It is easy to measure a mountain but not heavens. How we are to scale the vast space where we cannot set our feet. All heavenly objects were measured initially by parallax method. The method works only within a short range. Some higher scale is required for measuring longer distances. In early 20th century, a new method of scaling the Universe emerged through discovery of a typical star known as cepheids.

Magellanic clouds were observed in 1521 AD by the Portuguese explorer Ferdinand Magellan. The cloud is a nearby companion galaxy. Where that cloud would be located with respect to our Galaxy? The job was undertaken by two American astronomers Pickering and Leavitt.

Edward Charles Pickering (1846-1919) was born in Boston, USA and taught in MIT. He became Director at Harvard and was responsible for several new catalogues of heavens. In 1895, he picked up a deaf woman, **Henrietta Swan Leavitt** (1868-1921). Her job was to study variable stars from photographic plates obtained from Peru observatory. Among those, some are twin stars orbiting around each other. Some stars would pulsate, swell up and shrink in regular cycle. There are another kind of variable stars that varied in brightness. They were named *cepheids* from the star Delta Cephei in the constellation of Cepheus. The star was noted by **Goordricke** in 1784 AD. Brightness of these kind of stars varied in a regular way and each would repeats a pattern of variation over a definite period. True brightness and variation period were found intimately linked. If its period could be measured, its true brightness could also be known. Then the distance of the star could be determined.

Leavitt identified 2,400 variable and 4 exploding stars (novae) and published her findings in 1912. She identified cepheids and took notes of length of each cycle and its average apparent brightness. Some twenty five cepheids were located in the Small Magellanic Clouds. From these data, she worked out a relationship between luminosity and time-period of varying cepheids (*period-luminosity curve*).

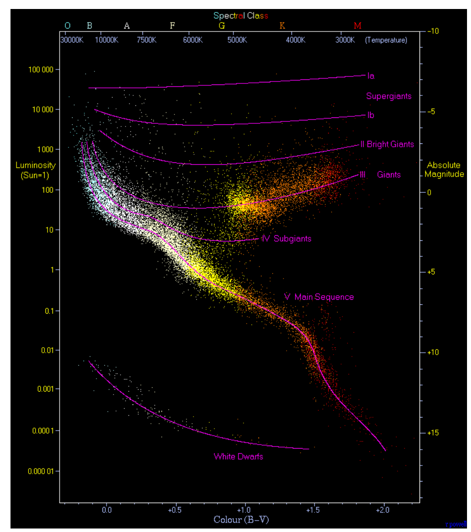


Fig:8.1. H-R Diagram

From this, cepheids turned out to present a way of measuring relative distance of stars within our Galaxy. If real distance of one cepheid could be measured, distances of all cepheids with different luminosity would be calculated. Cepheids became a very useful yardstick yet to be calibrated.

Our nearest cepheid is the pole star, Polaris. The star has a period of 3.97 days with large range of brightness between 2.08 and 2.17 magnitude.

The Danish chemist astronomer, **Ejner Hertzprung** (1873-1967), was the first to estimate the distance of a cepheid close to us (1913). A cepheid of absolute magnitude -2.3 showed a period of 6.6 days. Based on this information and using Leavitt's period-luminosity curve, distances to other cepheids were estimated.

From all these data, Hertzprung calculated the distance of Small Magellanic Cloud to be 30,000 lyr away against modern estimate of 205,000 lyr (or 63,000 parsecs).

Hertzprung developed a curve relating luminosity of stars, spectral class, colour and/or surface temperature. The same curve was made by the American astronomer **Henry Norris Russell** (1877-1957) in 1913. They are now known as *H-R diagram*. It shows different evolutionary stages of stars. [refer ch-14]

1 A.U.	= 149.6 million km	= 8.3 light-minute	
1 lightyear	= 9.46×10^{12} km	= 63,240 A.U.	= 0.306 parsec
1 parsec	= 30856 billion km	= 3.26 lightyear	

8.03. UNIVERSE OF OUR GALAXY

Meanwhile several powerful telescopes were made by one great telescope-builder of USA, **George Ellery Hale** (1868-1938). His first one was a 40" Yerkes telescope, at University of Chicago. It was a large refracting telescope built with the help of a wealthy businessman, Charles Yerkes. Hale was the moving spirit, fund-raiser for the observatory and first Director. It was larger than 36" Refracting telescope of the Lick observatory on Mt. Hamilton near San Jose, California.

Then Hale built one 60" reflecting telescope at Mt. Wilson in California (in operation since 1908). His next one was the 100" Hooker Telescope at Mt. Wilson with the fund provided by businessman John D. Hooker. It was completed in 1918.

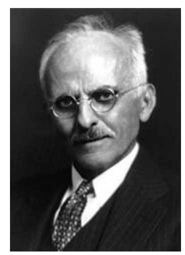
The 200" Mt. Palomer telescope in California (also known as Hale Telescope) was funded by Rockfeller Foundation and came into service from 1948. From 1969, twin observatories at Mt. Wilson and at Mt. Palomar came to be known as Hale Observatory.

The American astronomer **Harlow Shapley** (1885-1972) was posted to newly-built Mt. Wilson observatory and began to study the Milky Way Galaxy using cepheids from 1918. He was born in Missouri and studied there but got Ph. D. from Princeton in four years ago.

Globular clusters are spherical groups of stars found in one part of sky. Shapley identified some variable stars within these globular clusters and estimated their distance. At the centre of larger clusters, stars are packed with density 500 per 10 cubic parsec compared to 1 per 10 cubic parsec in our neighbourhood. From these observations, the globular clusters appeared to be the centre of our disc-shaped Milky Way Galaxy. The Sun and solar system are located away towards its edge. The overall diameter of the Galaxy, according to this estimate is some 300,000 lightyear across.

We know now that the Milky Way Galaxy is a flat disc, 100,000 lightyear across, and the Sun is 40,000 lightyear away from the centre. Shapley in fact overestimated the size of the Milky Way. He was also wrong to include Magellanic cloud within our Galaxy.

But one point he correctly observed. We are not in the centre of our Galaxy, rather reside at an edge. Does this make our existence insignificant? Not at all.



Another American astronomer **Heber Doust Curtis** (1872-1942), concentrated on spiral nebulae some time after 1909. Curtis was from Michigan of USA and came to Lick observatory in 1902. He observed that a nebulae is a galaxy like our own. S. Andromeda within the great Andromeda Nebula seen by him, is far away beyond our Milky Way.

Shapley argued against this view. He said that Andromeda would be part of our Galaxy. The argument was based upon observational result of rotating Andromeda nebulae at a measurable speed by the Dutch-American astronomer **Adriaan Van Maanen** (1884-1946).

Who was right? If it be Curtis, the Universe would be quite large with many galaxies within it. If it is Shapley, the whole Universe would be our Galaxy.

To resolve the issue, a great debate (26 April, 1920) was arranged in the Baird auditorium of the Smithsonian Museum of natural History between two astronomers in presence of great Einstein. Curtis was found winner as regards the size of our Universe.

Our Galaxy does not comprise the whole Universe but a small part of it. The whole Universe unfolded to be quite bigger than our Galaxy. The sky and the heaven is no longer confined within the narrow solar system as believed by early astronomers. The Sun is just an ordinary star in a galaxy. There are many stars in our Galaxy as well as in other galaxies beyond ours in this grand Universe.

In 1922 Estonina astronomer **Ernst Julius Opik** (1893-1985) supported the theory that Andromeda Nebula is a distant extra galactic matter.

But then how big our Universe would be? How we came to know that?

8.04. COSMOLOGY

Astronomy is meant for studying stars and other heavenly bodies. Cosmology is about the whole cosmos or the Universe. After presenting General Theory of Relativity, Einstein sent in February, 1917 the paper **"***Cosmological Consideration on the General Theory of Relativity*" to Berlin Academy of Sciences on general relativistic cosmology. It describes our existence in a typical ordinary region of the Universe. *The view we get, is just the same, on average, as the view anyone would get from anywhere else in the Universe.* This is known as the *Cosmological principle* we are to follow in our understanding of the universe.

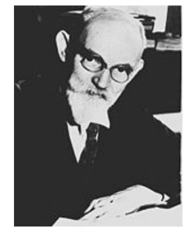
Around 1917, the popularly known universe was the Milky Way Galaxy, more or less a kind of permanent collection of stars where some stars wandered and some were born or died, and perhaps a void beyond. Andromeda nebulae beyond our Galaxy was not confirmed. When Einstein applied his mathematics, the Universe appeared quite unstable. The World was dominated by the gravitational force and would be a contracting one. It cannot remain in any eternal unchanging state.

When his theory indicated a non-static universe, its inventor thought it otherwise against his own theory. Einstein intuitively intrigued for that idea. While formulating his model of the World, he considered a Cosmological constant (λ). This cosmic repulsive force (λ-factor) would balance the gravitational attractive force (G-factor). He argued that the cosmological "*term is necessary only for the purpose of making possible a quasi-static distribution of matter, as*

required by the fact of the small velocities of the stars"(quoted from 'In Search of Big Bang' by John Gribbin, p-91).

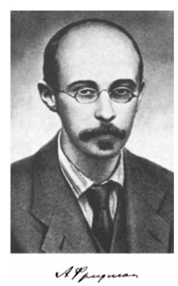
The greatest scientist could not depend on his great equations to predict one of the greatest predictions of the century. Abraham Pais wrote later in his book '*Subtle is the Lord'* (refer to p-285), *in the paper itself, he mentions the 'indirect and bumpy road' he had followed to arrive at the first cosmological model of the new era, an isotropic, homogeneous, unbounded but spatially finite static Universe*.'

By introducing the cosmological constant, Einstein deduced a static Universe, compatible with the spirit of Divine Creation. Most other scientists did the same to avoid arriving at a non-static universe except Friedmann. At the fag end of his life, the great Einstein categorically submitted that the Cosmological constant introduced in the General Relativity Theory was "*the biggest mistake*" of his life. The honest admission is exemplary.



Willem de Sitter (1872-1934), the Dutch mathematician-astronomer, made another solution to GTR. He studied mathematics at Groningen, got Ph.D. (1901) and became Professor at Leiden University in 1908. He was the man who passed the news of Einstein's General Relativity to Arthur Eddington in London.

In 1917, he sent a paper to Royal Astronomical Society in London to show that the solution to Einstein's equations may result into a different model. It would be static like Einstein's model but with no matter in it. It would be nearly empty. Therefore total gravitational attraction (G-factor) would outclass cosmic repulsion (λ-factor). According to Eddington, Einstein's universe thus contain matter but no motion. de Sitter's universe contain motion but no matter. It was not so with Freidman's model which appeared non-static with several solutions.



Alexander Alexandrovitch Friedmann (1888-1925) was born in St. Petersburg of Russia. He studied mathematics, became Professor at Perm University after Russian revolution, and joined Petersburg or Leningrad Academy of Sciences in 1920. In WWI, he fought as a bomber. While working on Einstein's GTR, Freidmann assumed that the Universe looks identical in whichever direction we look into and this would be true if we observe the Universe from anywhere else. From these assumptions, the Universe is not to be expected a static one. Friedmann's expanding-universe solution to the general relativity theory came in 1922. His 1924 paper '*On the possibility of a world with constant negative curvature of space*' was published in *Zeitschrift fur Physik*. He demonstrated that he had all three Friedmann models.

Two key features of his work are fundamental to modern cosmology.

First, there are several solutions to General Relativity equations, each describing a different kind of Universe.

Second, cosmic expansion is to be incorporated in the model.

Space may be uniformly curved like the spherical surface of a soap-bubble. But the curvature changes with time and decreases most probably as the bubble expands. With all these, Friedmann's solutions offered several models of the Universe. In all these, there was at least a period, an interval of time, during which the whole Universe expanded in such a way that it would produce a recession velocity proportional to distance.

At first Einstein could not accept Friedmann's views of the World. He replied in *Zeitschrift fur Physik* that Freidmann made an error in his calculations. A year later, he admitted that his calculations were correct but he preferred to present an alternative model.

Unfortunately, Friedmann's theory remained largely unknown to the world until 1935. In that year, the American mathematician-physicist **Howard Percy Robertson** (1903-1961) and the British Mathematician **Arthur Geoffrey Walker** (1909-2001), discovered independently nearly the same model which Friedmann already discovered. The model of the expanding Universe became more popular after the Hubble's discovery in 1924. Freidmann predicted it earlier.

8.05. EXPANDING UNIVERSE

Significant progress in observational cosmology was made by the application of doppler's effect in spectrum analysis. The credit to this new technique, goes to the American astronomer **Vesto Melvin Slipher** (1875-1969). He was born at Indiana, graduated in 1901 and posted at Lowell observatory. With his Ph.D. in 1909, he became the acting director of the observatory.

Lowell observatory was built by **Percival Lowell** (1855-1916), the wealthy man from Boston. He studied mathematics and graduated from Harvard. In 1893 he decided to live with astronomy and built

his own observatory at Flagstaff, Arizona with a 24" refracting telescope. In 1876, Giovanni Schiaparelli of Italy reported that there existed canals in Mars. Lowell became interested in Mars study. His study on life in Mars, turned out wild speculations. Scientists are allowed to speculate but disallowed to make a fanfare until confirmed and tested. Still people with weak logical base, tend to resort to wild speculations with silly observational support.

Lowell promoted Slipher to find out red shift of galaxies. In 1912, Slipher studied Doppler shift in the light of Andromeda Nebula (M31).

Doppler shift is displacement of bright or dark lines in the spectrum of light coming from a moving object. If the object is moving towards the observer, the shift would occur toward the blue end of the spectrum. If the object is moving away from the observer, the shift would be towards the red end. Further from the size of the shift compared to the spectrum of stationary light-object, the speed of the moving object, called the Doppler speed, can be calculated.

Slipher obtained four pictures of the nebulae (M31) that showed blue-shift. It meant that Andromeda is approaching towards us. It is doing so at a velocity of 300 km/sec. In 1914, his study of thirteen nebulae showed that only two had blue-shift and eleven red-shift. So most nebulae are moving away from us. In 1925, Slipher measured 41 (nebular) doppler shifts excluding 4 done by others. Results of 43 out of 45, showed red-shift. One showed recession velocity to the tune of 1,000 km/sec.

Why most of nebulae are showing red-shift?

Slipher's discovery was very important, but its real significance was not immediately understood. His discoveries led towards the determination of large scale structure of the Universe.

Edwin Powell Hubble (1889-1953) was a great name in cosmology. Born in Missouri, he was a Rhodes scholar at Oxford, a high school teacher, a lawyer and a boxer. He was one of the famous American astronomers in spite of his unorthodox background. In 1919, he came to Mt.Wilson observatory in southern California. The 100" Hooker telescope, biggest in the world, was then just in operation.

What is a spiral nebulae? Do they exist far beyond our Milky Way? These were important issues awaiting solutions. By 1922, Hubble was studying gaseous nebulae which do not shine with their own light. How do they shine then? There can be two explanations. The nebulae may reflect light from stars which exist within it or close to it; or the energy of the nebulae absorbed from nearby stars, may be enough to make the hot gas glow. Whatever it is, gaseous nebulae associated with stars in our Galaxy, must be part of Milky Way.

Hubble focussed to a group of stars called NGC6822 and took photographs. Some cepheids were discovered there. By Shapley's method, he estimated their distance. NGC6822 appeared to be 7 times further away from the Small Magellanic Cloud.

In 1923, Hubble succeeded in resolving outer part of Andromeda (M31), a huge collection of stars. One cepheid was located there. He discovered two novae and one more cepheid. These cepheids indicated a distance of 900,000 ly. With such a huge distance, it cannot be within our galaxy. More Cepheids were identified in M31 and M33. Gradually a lot of evidences were collected which would enlighten us about the nature of the spiral nebulae. Spiral nebulae are in fact spiral galaxies, existing far beyond our Galaxy. For next five years, the scientist was engaged in analysing the data he collected.

Hubble used super-giant stars to indicate distances. The technique was the same by which we derived the distance of the globular cluster of our Galaxy. Globular clusters acted here like an approximate yardstick. He then made a bold and roughly accurate guess. All galaxies in a cluster are equally bright and absolute luminosity shall be one third of the brightest galaxy or three times to that of the dimmest galaxy. With this assumption, the distance estimates would be limited to within a safety factor of three. The idea increased the span of the Universe to 500 million lightyear with 100 million galaxies occurring within.

As a result of five year long observations, Hubble came to the conclusion that *ours is not the only galaxy in the Universe and there are many more beyond ours*. The Universe is a vast space, constituted of many galaxies.

Suddenly an imaginably vast Universe unfolded before us. Distribution of galaxies within this vast space appear, on the whole, uniform. But when they occur in clusters, distribution is local and appears at random. Two types of galaxies, spirals and ellipticals, usually occur. 75% are spiral type and the rest ellipticals with few irregulars. The curious thing is that most of the galaxies are red shifted. Out of 46 galaxies with known red-shift, he measured

distances of eighteen. He also measured the distance of the Virgo cluster.

From the fact that most galaxies are red-shifted, it appears that, as per Doppler effect, the distant galaxies are moving away from us? The expansion can be visualised from actions of several dots over an expanding balloon. When the balloon expands, it would appear from one dot that all others dots are going away from the observing dot. The same would appear from any other dot. Our Universe resemble like that. If so, what would be the possible explanation? Sir Arthur Eddington proposed around 1931 that red-shifts of galaxies are due to the expansion of the universe.

In 1929, Hubble published his findings in the *Proceedings of the National Academy of Sciences* that red shift size of galaxies are directly proportional to the distance from us. Further a galaxy exists, faster it is moving away from us. The law known as *Hubble's law* is expressed by,

$$\mathbf{z = DH/c} \quad \text{and} \quad \mathbf{v = HD}$$

where, z = red-shift, D = distance, c = velocity of light, v = velocity, and H = Hubble's constant.

The expansion of our Universe is the most important discovery of 20^{th} century. It led to rapid development of the science of the sky, of the Universe and of the Grand Nature. Einstein abandoned the idea of the cosmological term he introduced to get the static Universe.

The Hubble's constant (H) became an important determinant to find out the distance of galaxies. Hubble himself estimated H to be about $1.5x10^{-17}$ per second (i.e. 150 km/sec/mly or 500-530 km/sec/Mpc). Such a value implies that the Universe is only 2 by old. The age is too small as it contradicts the age of Earth calculated geologically.

Table:8.01. Hubble's constant in km/sec/Mpc revised from 1929

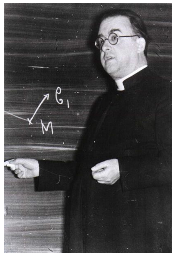
(1929) Hubble = 500-530	(1950s) Baade = 250
(1958) Sandage = 50-100	latest value = 40-100

The constant was thereafter revised by the work of Walter Baade in 1950s, by Allan Sandage in 1958 and by others. It is presently taken as within the range of 40-100 km/sec/Mpc.

Hubble's law continued to be tested in field observations. From 1929, the job was taken up by **Milton Lasell Humason** (1891-1972). Born at Minnesota, he had no formal education and joined as janitor in the Hale observatory in 1917. But he turned out to be a brilliant sky-watcher. At Mt. Wilson, he obtained spectra of dimmer galaxies and measured some 150 red-shifts by the year 1935. The findings showed recession velocity over 40,000 km./sec to most distant galaxies. Greater recession velocity were discovered by late 1950s. They came in the range of 100,000 km/sec when 200" telescope came into operation.

Is it a World of mad galaxies running faster and faster away? What kind of World it would be then?

8.06. PRIMEVAL COSMOS



The Belgian Roman Catholic priest-cum-scientist **Georges Henri Joseph Edouard Lemaitre** (1894-66) undertook the next step towards understanding the universe. Interestingly, he was a civil engineer graduated from Louvain in 1920, became a priest three years later, and came back at Louvain in 1927.

Lemaitre combined red-shift of the galaxy and General Theory of Relativity. His thesis entitled *Hypothise de l'atomeL primitif* (Hypothesis of the primordial atom), was published in a Belgian journal '*Annales de la societe Scientifique'* in 1927.

At 5th Solvay congress at Brussels (1927), Lemaitre submitted some suggestions to the great Master, Einstein, but he was not impressed. Support came from Arthur Eddington who brought him to limelight in 1931 with an English translation of his paper. That is why it is often referred as *Eddington-Lemaitre hypothesis*.

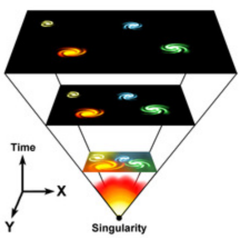


Fig:8.2. Expansion of flat universe from singularity

That was the *first theory of Universe*, the first attempt to offer a scientific explanation of Creation in place of genesis of Bible or others. Lemaitre proposed the value of constant of proportionality in the red-shift-distance relation quite close to the value proposed later by Hubble. His equations put forward basically same solutions as those by Friedmann. But the most important fact is that he offered an explanation of the Creation of the Universe. His hypotheses was later

revised into the Big Bang theory. For this Lemaitre was referred to as the father of theory. What was the hypotheses?

The universe was born from a single primeval quantum of energy or atom. Presently galaxies are moving away from one another. From this fact, we may logically deduce if we care to look back. Expansion can only happen from a smaller and denser state. Some time in the past, the galaxies must be closer together packed into a small sphere having thirty times to the size of our Sun i.e. within say 4,000-5,000 million km. Let this be called the *primeval cosmic atom*. The universe within the primeval atom would be in a super-dense state like radioactive nucleus. Density may be assumed to some 2.5 billion ton/cc. This exploded and broke into fragments to form present day galaxies and stars. So it started from a kind of singularity from where the galaxies were born and began to move away.

Somewhere around 1932 after discovery of Hubble's red-shift, two scientists, Einstein and de Sitter, jointly tried to find another solution and to build up a cosmic model. In this model, the Universe expands and the expanding space is a flat space of Special Relativity. It came out of a mathematical point which was in a state of infinite density, called *singularity*. Lemaitre favoured slightly bigger cosmological constant which would make the initial expansion faster in the beginning and then slowing down towards a static state.

Three years later (1935), the American mathematician-physicist **Howard Percy Robertson** (1903-1961) of USA and English mathematician **Arthur Geoffrey Walker** (1909-2001), developed a model of *homogeneous isotropic Universe*. It was described with uniformly curved space but with a cosmic time remaining same for any observer in the expanding world.

8.07. THREE MODELS OF UNIVERSE

All cosmological models are now based on two basic assumptions – Weyl's postulate and Hubble's cosmological principle.

The German mathematician **Hermann Weyl** (1885-1955) postulated a simplified universe, assuming that galaxies would stream along regular tracks without intersecting one another. Synchronisation of clocks on different galaxies would be thereby possible. On a surface, intersecting all tracks at right angles, the clocks would record the same time. Cosmological principle further simplified the structure. According to this, a typical surface is homogeneous and isotropic. With the above assumptions, we can deduce three possible models of our universe.

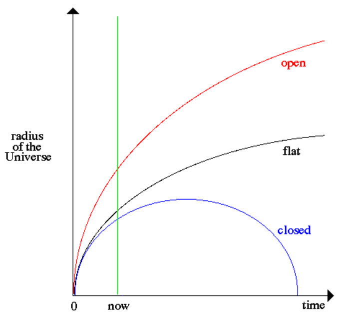


Fig:8.3. Three models of the Universe.

In model-I (closed), the universe began from zero or near zero state at zero time when the Big Bang occurred and would expand. Beginning at first slowly, it picks up its rate of expansion. Gravity between galaxies began to build up at the same time and gradually slows down this expansion rate. Finally its expansion will be stopped completely but gravity would continue to act. The universe would be maximum in size. From then on, galaxies would start to move towards each other and contract. The universe would finally collapse into zero or near zero state at some Big Crunch state. Here everything would be finite in extent and gravity would depend on quantum of matter contained within. This model depends on the highest amount of matter in the universe. Space here is to be bent in itself like the surface of the Earth and must be finite, spherical and closed.

In model-II (flat), the universe, once born, would expand so fast that gravity cannot stop its expansion. It can however slow down expansion rate considerably in later phase. Here the universe would go on increasing forever. It would start from zero at Big Bang to infinity with a slower rate. In this case the space is bent not like the surface of the Earth. It is rather like a saddle with a critical expansion rate so that the space shall come out to be flat and infinite. The universe must be open. Curvature of space shall be negative.

In model-III (open), the universe would be expanding just fast enough to avoid collapse. It would start, like model-II, from zero and shall go to infinity again at a very slow rate. It would not meet the fate of Big Crunch as the expansion rate would be just critical one to escape collapse. Here also the space with critical expansion rate shall be flat and infinite.

Which of these three models really fits in our Cosmos? That depends upon two factors – the rate of cosmic expansion and the average density of matter within it.

The *critical density of the universe* would be just that results in critical rate of expansion. It is reflected in the model-III above. In case of density less than critical, the gravitation will be too weak to halt the expansion and we shall have model-II. In case the density is more than critical value, the gravity will stop the expansion at some time in future and cause the universe to collapse, as in model-I.

The rate of expansion of the universe can be measured by measuring velocities of stars and galaxies. As per our present estimate, the average rate of expansion is 5% to 10% by every 1000 myr.

But it is difficult to find out the average density, as we need to measure the total matter content of the Universe. When we add up mass of all visible matter, it amounts to mere 1% of the critical mass. Is that all the mass we have in our Cosmos? We are then living in an infinite universe. Or is there any other mass still lying beyond our observation?

Scientists think that our galaxies most probably contain a large amount of *dark matter*, dark not in sense of colour. They are so as they remain beyond our observation. Their existence can only be guessed by gravitational influence on orbits of stars. Further, most galaxies exist in clusters. Dark matter exists in inter-galactic space, we guess, from its effect on the motion of galaxies. Adding up all such inter-stellar and inter-galactic dark matter with observable quantity, we arrive at a value of 10% of the critical mass. With such insignificant mass, there is no chance to halt ongoing expansion of the world.

Some scientists think that there possibly exist more matter beyond our guess. If they really exist in large amount, we may expect that the universe may stop to expand further. These are all guess-work. Presently it appears from available information that the universe will go on expanding forever. That's our destiny. Can it re-collapse into Big Crunch? Possibly not. If, for any unknown reason, the Universe happens to re-collapse as per Freidman's model-I, it will not occur immediately. It existed for 15,000 myr and we expect to exist for another period of same span to the least.

8.08. BIG BANG MODEL

Hubble's work was further carried out by the German astronomer **Wilhelm Heinrich Walter Baade** (1893-1960). Born in Shrottinghausen of Germany, he received his Ph. D. from Gottingen (1919) and came to USA to work in Mt. Wilson and Palomar

observatory from 1931 to 1958. In 1942 during the war-time blackout, he could make detailed study of Andromeda with 100" telescope.

Inner part of Andromeda galaxy exhibit some hot blue young stars in the spiral ring. This are called *population-I stars*. Large, cooler and redder stars in the globular clusters are called *population-II stars*. Population-I stars are younger than population-II. Further study from 200" telescope revealed that elliptical galaxy and globular clusters are perhaps made up of Population II stars. Spiral galaxies are made up of population-I in its spiral arms and population-II in its background. Population-I stars show different types of cepheids from population-II cepheids. So period-luminosity relation would be different for each of them.

Baade recalculated the distance of Andromeda galaxy as 2 mlyrs away, instead of Hubble's estimate of 0.9 mlyrs. It means our known Universe is increased in size more than twice from Hubble's universe. The estimated age scaled up from 1.8 to 3.6 billion years.

In 1952, the American astronomer **Allen Rex Sandage** (1926-2010) continued observations with 200" telescope at Hale observatory. He brought down Hubble's constant from 250 to 75 km/s/Mpc. Later he advocated for 50 km/s/Mpc, from which our Universe appeared 20 billion years old.

Soon a detail picture of the early universe, was proposed by the Russian-born cosmologist-physicist **George Gamow** (1904-1968) with his students **Ralph Alpher** and **Hans Bethe** in 1948. Gamow was a student of Friedmann and defected to USA in 1934. The trio published a paper known as *alpha-beta-gamma paper* containing the modern version of Big Bang Theory of Creation.

According to them, *the universe came out from a fireball of radiation.* At first, it expanded fast and then cooled down. It was dominated by matter when expanded and cooled below the critical degree. One second after the creation, temperature was 10 billion degree; after 100 seconds it dropped down to 1 billion and one hour after, to 170 million degree. It was also predicted that the radiation

from the hot body of early universe should be still around us with a temperature close to about 5 K.

In the same year, the British astronomer **Fred Hoyle**, and Austrian-born astronomers **Thomas Gold** and **Hermann Bondi** proposed another theory, known as Steady State Universe. According to this, as the galaxies moved away from each other, new galaxies were continually forming in the gaps in between, from new matter that were being constantly created. The Universe would look almost same at all points of space at all times. Rate of creation of matter is about 1 particle/cu.km/year. The theory predicted that the number of galaxies or similar objects in any given volume of space should be same wherever and whenever we look into.

8.09. REMARKS

Once our world was no bigger than some continents and oceans of this globe. Then our planetary globe had become our whole world. Stars and planets decorated only the canopy of the sky. The world expanded further to include some of them into the vast solar system. Soon our world became as big as our galaxy. Soon it grew bigger than that, into many galaxies with some frightening voids in between.

Now the universe appears as large as 10-15 billion lightyear, far exceeding our galaxy, and groups of galaxies. We the mortals, occupy an insignificant space-time in this vast realm. Wherefrom it came? Whereto it would go? Some proposed that the universe is there from eternity with the same distribution of matter. Ideas of eternity fit easily among so many unknowns but that evades real explanation.

In science, popular idea is that our universe evolved from some primeval atom of fireball radiation in some way. It is a big shock that our universe continues to expand at a very fast rate. Why it is doing so? How long it will go on expanding? Where is the end of all these expansion?

There are more questions than answers. We shall come back again on this subject. Before that let us have a look towards the micro-world again. This would explain how things possibly behaved in the primeval era and explain how our complex universe evolved from that simple primeval stage.
