10. Universe

Introduction

Universe means all existing things i.e., the whole creation. The branch of the science that deals with the study of universe is called astronomy. The astronomers have worked hard to understand the nature and behaviour of the heavenly objects visible in the sky. The astronomers had put forward geocentric model of planetary motion in which earth was assumed to be stationary and all the heavenly objects revolved around it. This was widely accepted but Copernicus gave the simplified model of solar system according to which, the sun was at rest and all the planets revolved around it. Kepler's laws help to understand fully the planetary motion. Solar system is just a very small part of our galaxy called milky way. The milky way is one of the billions of galaxies constituting this universe.

10.1 The constituents of universe

The three main constituents of universe are (i) Solar system, (ii) Stars and (iii) Galaxies.

(i) Solar system

The part of the universe in which the sun occupies the central position of the system holding together all the heavenly bodies that revolve around it, is called solar system.

The solar system consists of nine planets. They are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. They revolve in elliptical orbits around the sun. In solar system, only the sun has its own light; the other planets appear bright by reflecting of the light falling on them from the sun. The planets have got heavenly bodies called satellites (also known as moons) revolving around them. Mercury, Venus and Pluto do not have any satellite. The Earth has one, Mars and Neptune-two each, Uranus-five.

Satum-ten, Jupiter-twelve. In addition to the sun, nine planets and their satellites the solar system also contains thousands of irregularly shaped bodies called asteroids, comets and meteors.

(ii) Stars

The sun is the nearest star to the earth. The heavenly bodies which shine like the sun due to their own energies are called stars.

A star looks bright because it is intrinsically bright. On a clear night about 5000 stars can be seen in the sky with naked eye are such stars called naked eye stars. The bright stars in the sky have been named as Sirius (Vyadha), Canopas (Agasti), Spica (Chitra), Arcturus (Swati), Polaris (Dhrura), etc. After sun, Alpha Centauri is the nearest star to earth.

In addition to the brightest stars, many groups of bright and faint stars called constellations can be seen in the sky. A few important constellations are Aeries (Mesha), Taurus (Vrishabha), etc. There are sign of Zodiac or Rashis. Great bear (Saptarishi) and Southern Cross (Trishanku) are other constellations near the north and south poles. The modern astronomers have divided the whole sky into 88 constellations.

(iii) Galaxies

A large group of stars is called a galaxy. The galaxies are the building blocks of the universe. There are billions of galaxies having different sizes and regular and irregular shapes. The shapes of regular galaxies may be elliptical, spiral and barred spiral.

We belong to a galaxy called milky way (Akash Ganga). It consists of about 10^{11} stars. Andromeda is the nearest major galaxy to earth and can be seen with naked eye. This galaxy is 2×10^6 light years. (Light year is defined as the distance travelled by the light in one year and is equal to 9.46×10^{12} km) away from our galaxy. It appears as a fuzzy patch of light.

10.2 The study of solar system

Copernicus, in sixteenth century, gave his heliocentric theory according to which the sun is at rest at the centre of the solar system and the nine planets revolve around it. In seventeenth century, Kepler by analysing the work of Tycho Brahe, put forward his three laws that govern the motion of the planets around the sun. The Kepler's laws of planetary motion and Newton's law of gravitation help us to study the various physical properties such as distance,

size, period of revolution, mass, surface temperature and atmosphere of planet in solar system.

10.3 The sun

The sun is an extremely hot and self-luminous body made of gaseous material (mainly hydrogen). It is a fixed star in solar system and is nearest to the earth. Its mass is about 1.989×10^{30} kg, radius is 6.95×10^{8}m and distance from the earth is 1.496×10^{11}m. The light from sun takes 8 min to 20 sec. reach the earth. The gravitional force of attraction on the surface of the sun is about 28 times that on the surface of earth. It rotates about its own axis. It takes different time to complete one revolution as it is made of gaseous material. At pole, the period of revolution is 34 days whereas at the equator it is 25 days.

10.4 The planets

There are nine planets in the solar system. Mercury, Venus, Earth, Mars, Jupiter, Saturn had been known from ancient times. Uranus, Neptune and Pluto were discovered only after the advent of telescope. Mercury and Venus are called inferior planets as their orbits are smaller than that of earth. The other planets are called superior planets whose orbits are larger than that of earth. Compared to the sun they are very small and relatively cool. They revolve in elliptical orbits around the sun. Mercury is nearest to the sun, while Pluto is farthest from the sun. Then the size of the solar system is equal to the radius of the orbit of Pluto which is about 5.6×10^{9} km. The distance of earth from the sun is 1.496×10^{8} km and is called are astronomical unit (AU). The planets are not self-luminous but appear bright by reflecting light falling on them from the sun.

10.5 The distance of a planet

The distance of a planet from the earth can be found in the following methods.

(i) Parallax method

Let O be the planet whose distance D is to be measured from the surface of earth. Let the planet be observed from two points E_1 and E_2 on the surface of earth at the same time The distance between the two points i.e., $E_1 E_2 = b$. and is called *basis*. The angle

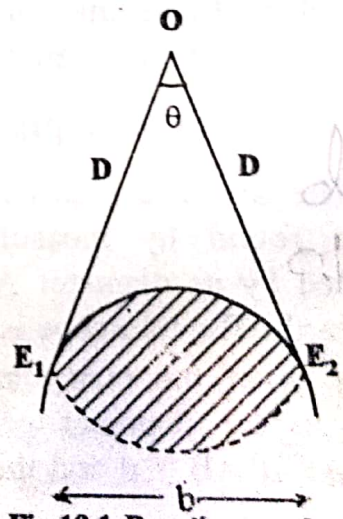

Fig.10.1 Parallax method

(ii) The average speed of the molecules

The value of average speed of gas molecules on a planet is given by

$$\bar{v} = \sqrt{\frac{8kT}{\pi m}} \qquad \ldots(12)$$

where T is the temperature of the planet, m is the mass of the molecule and k is Boltzman's constant. If the planet is hot then due to large value of T, the average speed of molecules may be much higher than the value of escape velocity on it. Again the gas molecules will leave the surface of such a planet and will have no atmosphere.

By studying the absorption spectrum of the light from planet, the chemical composition of the atmosphere of the planet can be ascertained. The dark lines in the absorption spectra lead to the identification of the gases present in the atmosphere of the planet. Jupiter reveals the presence of hydrogen, helium, methane and ammonia gases.

The reflecting power of a planet to reflect the light helps to estimate the atmosphere on the planet. Clouds are good reflectors of light and hence if a planet is surrounded by clouds, its reflecting power will increase. The reflecting power of a heavenly body is called albedo. For example, the albedo of mercury is 0.06, mercury reflects only 6% of the incident light. It implies that mercury has practically no atmosphere. On the other hand, albedo of Venus is 0.85. It indicates high reflecting power of the planet and the presence of a very thick atmosphere.

10.10 Other objects in the solar system

(i) Asteroids

Asteroids are believed to be the pieces of a much larger planet which broke up due to the gravitational effect of Jupiter. The density and chemical composition of asteroids are very much like that of the moon.

(ii) Comets

Comets consist of small particles of rock like material surrounded by large masses of easily vapourised substances like ice, water, ammonia and

methane. They move in highly elliptical orbits and spend most of their time far away from the sun. A comet has a nucleus of about 10 km diameter which is not visible most of the time. When a comet is far away from the sun, it has no tail. As it moves along its path and heads towards the sun, it begins to become elongated in the direction away from the sun thus forming a tail. The tail always points away from the sun regardless of the direction in which the comet travels.

The tail formation is due to radiation pressure. As the comet approaches the sun, some of its substances get vapourised due to solar radiation, which are then forced away from the comet by the pressure of light from the sun.

(iii) Meteors and meteorites

One can see a meteor, otherwise called as a shooting star on a clear moonless light. Meteors are not stars but small pieces of rocks or metals. Meteors are formed due to breakage of comets, when they pass very close to the sun. When the earth's orbit crosses the orbit of the comet, these meteors fall on the surface of the earth as a shower. Thus a meteor is a relatively small body that has become incandescent because of the heat of friction in passing through the earth's atmosphere. Most of the meteors are small and generally get completely burnt in the earth's atmosphere due to friction. The larger meteors may survive the heat produced by friction and may not be completely burnt. These blazing objects which manage to reach the earth are called as meteorites.

The biggest meteorites form craters on the surface of the earth. The formation of craters on the surface of the Moon, Mercury and Mars is due to the fact that they have been bombarded by large number of meteorites.

10.11 Space exploration - Extra terrestrial life - A search.

What is the aim of all space probes

The aim of all the space probes has been to gain knowledge about the constituents of the solar system and to search for the possible existence of plant and animal life similar to the one that exists on earth. Let us know whether the recent findings using space probes have given any indication of life on any planet other than earth.

The following conditions must hold in order for plant and animal life of the kind with which we are familiar, to exist:

3. Novae and super novae.

In a galaxy, there are only a few single stars like the sun. Majority of the stars are either double stars (otherwise called as Binaries) or multiple stars. The binary stars are pairs of stars moving round their common centre of gravity in stable equilibrium. An intrinsically variable star shows variation in its apparent brightness. Some stars suddenly attain extremely large brightness that they may be seen even during day time and then they slowly fade away. Such stars are called novae. Super novae is a large nova. So far about 100 novae have been recorded. The most brilliant nova was observed by Tycho Brahe in 1572.

10.15 Stellar evolution

A star is born, lives for a certain length of time and eventually dies like everything else in the universe.

(i) Birth of a star

Stars are born out of gas and dust that may exist within a galaxy. A star is believed to form from a condensation of interstellar matter, which collects by chance and grows by attracting other matter towards itself as a result of its gravitational field. This initial cloud of cold contracting matter is called a protostar. Every atom in a protostar is pulled towards the centre of gravity. The protostar builds up an internal pressure as a result of its gravitational contraction. Correspondingly temperature also raises tremendously. At this temperature thermonuclear conversion of hydrogen to helium begins. The loss of energy from the outer surface is then just compensated by the total nuclear energy production within the whole interior of the star. When this stage is reached, the star is said to have reached the main-sequence. The star is now considered to have formed; it is no longer a prostar. The sun has total life of about 10 billion years, out of which nearly half is already over.

(ii) Death of a star

During the period the star remains in the main sequence, the release of nuclear energy at the centre balances the inward gravitational force. Eventually, however, this period of stability comes to an end, because the thermonuclear energy generated in the interior is no longer sufficient to counterbalance the gravitation contraction. The helium formed by fusion collects at the centre. The helium core collapses until a sufficiently high temperature is reached in a shell of unburnt hydrogen round the core to start a new phase of thermonuclear

reaction. This burning of the shell causes the star's outer envelope to expand and cool. The temperature drop changes the colour from white to red and the star becomes a red giant or a supergiant if the original star was large. The core now contracts reaching a temperature of 10^8K, and the helium in the core acts as the thermonuclear energy source. Helium nuclei start fusing into carbon through the triple-alpha process. But a star of low mass relatively soon runs out of helium and the core collapses into a white dwarf, while the outer regions drift away into space. Larger stars have sufficient helium for the process to continue so that heaviest element can be formed with the production of energy. When the helium has all been consumed there is a catastrophic collapse of the whole massive structure, resulting in a supernova explosion. Thereafter the burnt out remnants become neutron stars and black holes. Thus the star finally becomes a dead ball of highly compressed matter, lost from sight for ever.

10.16 The milky way - size and shape

The milky way is a very large band of stars, having a misty cloud like appearance, extending itself across the sky like part of a great circle. It is thicker in the middle and thins out at the edges (Fig.10.5). The diameter of the milky way is about 10^5 light years. The sun which belongs to this galaxy is situated in its central plane at a distance 27,000 light years from the centre. The thickness of the disc is about is about 5000 light years at the centre and about 1000 light years near the sun and diminishes as we reach the edges. When seen through a telescope, it is found to consist of billions of stars that give it a cloudly appearances.

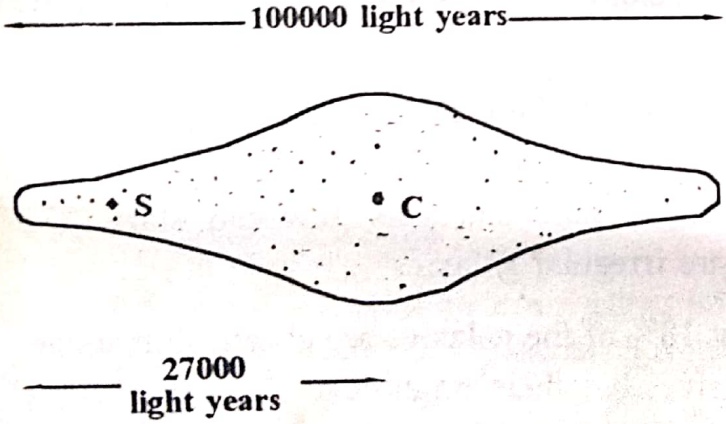

Fig. 10.5 Milky way

There are about 150 billion stars in the milky way. All the stars revolve about the centre. The sun moving at a speed of 250 km/s revolves about the centre of the galaxy in about 220 million years. The milky way is not uniformly bright everywhere. Most of the visible stars lie in the plane of the flat circular disc. When one looks in a direction at right angles to the plane of the milky way, the sky

appears much darker because of thin distribution of stars as compared to that in the central plane of the milky way.

10.17 Galaxies

A galaxy is a large band of stars, gas and dust particles held together by gravitational forces. Stellar systems like our milky way form the major building block of the universe. Galaxies are really complex organisations consisting of millions and millions of stars. There are also galaxies observed with no gas and dust. Billions of galaxies have been photographed by the modern powerful telescopes and they constitute the universe. The farthest of them are about a billion light years away. The size of earth galaxy is enormous. The mass of our galaxy is nearly 3×10^{41} kg. The milky way rotates around an axis passing through its centre. Due to rotation, the milky way appears as a flat disc. In the galaxy, each star revolves around a central nucleus in a circular or elliptical orbit. Galaxies are classified into two broad categories, namely Normal galaxies and Radio galaxies.

1. Normal Galaxies

Normal galaxies are further divided into three groups depending on their shape as spiral galaxies, irregular galaxies and elliptical galaxies.

(a) Spiral galaxies: About 80% of the galaxies are spiral galaxies and have spiral arm structure. Our milky way and the Andromeda galaxies are examples of spiral galaxies. The sun belongs to the spiral galaxy known as the milky way system.

(b) Irregular galaxies: A few percent of the galaxies show no regularity, neither spiral nor elliptical. These galaxies have no well-defined geometric form. They contain mostly young and bright stars and very few old stars. The Magnellanic Clouds, for example, are irregular galaxies.

(c) Elliptical galaxies: About 18% of the galaxies are elliptical in shape. They are relatively large and massive, but their brightness is comparatively small. This is because they contain only old stars like red giants, white dwarfs etc.

The properties of normal galaxies are mentioned below:

(i) A galaxy is a band of billions of stars, travelling together through the vast expanse of the universe.

(ii) The size of each galaxy is tremendous. For example, the galaxy (milky way) to which our solar system belongs is about 100,000 light years in diameter and about 5,000 light years thick.

(iii) All the galaxies can be divided into three groups as regards their shape. Most common of them are called spiral galaxies. Other show elliptical discs on photographs and are called elliptical galaxies. A small per cent have no regular shape and are called irregular galaxies.

(iv) They are very bright near the centre but gradually get dim towards the edges.

(v) Normal galaxies emit a comparatively small amount of radio radiation as compared to the tota! radiation emitted.

2. Radio Galaxies

2M

These are the galaxies which emit million times more radio radiation compared to normal galaxies. The radio radiation does not come from the galaxy itself. This radiation is found to originate form two large regions situated symmetrically on either side of the galaxy. According to one belief a great explosion occurred in the central galaxy which ejected two clouds of charged particles on cpposite sides.

10.18 Star clusters

Our galaxy has two types of star clusters:

(a) Galactic clusters

2M

The galactic clusters are a group of 100 to 1000 stars bound by mutual gravitational forces. The cluster moves as a whole round the galaxy and each individual member star orbits around the common centre of the cluster.

(b) Globular clusters

2M

The globular clusters are a group of about 100,000 stars closely packed. About 100 globular clusters are known to exist in the milky way, all of them about 20,000 light years from the sun.

10.19 Expansion of universe

The most striking feature of the universe is its expansion. There are millions of galaxies in the universe. When the galaxies are observed through a spectrograph, the light from all of them is found to shift towards the longer

wavelength or the red end of the spectrum which is also termed as red shift. It indicates that all the galaxies are receding away from us. Further, the speed of recession V increases proportionally with their distance R,

i.e., $V \alpha R$ (or) $V = HR$

where H is called Hubble's constant and the relation is known as the Velocity Distance Law or Hubble's Law.

Dividing the distance of any galaxy by its velocity of recession, we get the same number for all galaxies. This number is a time. According to the most recent work its value is about 10,000 million years and represents the characteristic time of the universe, called the age of the universe. The Hubble's Constant H can be expressed as

$$H = \frac{1}{\text{Age of the universe (10,000 million years)}}$$

This relation helps us to determine the distance of distant galaxies and quasars. The recession of galaxies shows as if the entire universe were expanding from some central point. Based on this idea of expanding universe, three main theories have been put forward to account for the origin and evolution of the universe.

10.20 Origin of the universe

(a) The big bang theory

According to the Big Bang Theory, all matter in the universe was concentrated in a very dense and very hot premeval nucleus at the beginning. A cosmic explosion occurred some 20 billion years ago and the matter was thrown out in the form of galaxies. The galaxies thus formed are continuously moving away from each other. The distances between the galaxies will continually increase and space will grow more and more empty. The hydrogen in each galaxy will be gradually used up and the galaxies themselves will become fainter and fainter. Eventually the galaxies will fade out completely. In the end, the universe will be devoid of all matter, energy and life.

The Big Bang Theory explains the following phenomena

(i) The expansion of the universe

(ii) The observed microwave background radiation

(iii) The observed abundance of helium in the universe, formed in the first 100 seconds after the explosion from dueterium at a temperature of 10 K. This theory is now generally considered to be more satisfactory than the rival steady-state theory.

(b) The steady state theory

According to this theory, the universe is unchanging in time. The universe never had a beginning and will never has an end. But the steady state must be squared with the fact that the universe is expanding. For the density of matter to remain constant, new matter must be created at the same rate that the expansion would decrease the density. Only in this way can the density remain the same. According to this theory, new hydrogen is steadily created throughout the universe out of nothing. Due to the creation of new matter, the density remains constant and the steady state is maintained continuously. Because it has failed to account for the microwave background radiation or the evidence of evolution in the universe, it has lost favour to the Big Bang Theory.

(c) The pulsating theory (or) the oscillating universe theory

The Pulsating theory states that when the universe has reached a certain maximum permissible expansion, it will begin to contract. It will contract till it eventually reaches the state of maximum compression of matter. After that it will begin to expand again. Thus the universe alternately contracts and expands.

According to this theory, the calculation indicates that the expansion and contraction repeats itself after every eight billion years. Thus this theory suggests a universe with an outer boundary which moves in and out at regular intervals.