# Chapter-2

# ASTRONOMY

Astronomy is coined from the two Greek words 'Astron', meaning star and 'nomos' meaning law. It is the Science of celestial objects, space and the physical universe. Our great grand 'fathers' studied astronomy. It is called classical astronomy. During those times, efficient physical instruments like large telescopes, measuring instruments were not available. Now-a-days, we use all latest and ultramodern equipments like hubble telescope, new generation telescope etc and study the nature of celestial bodies and their

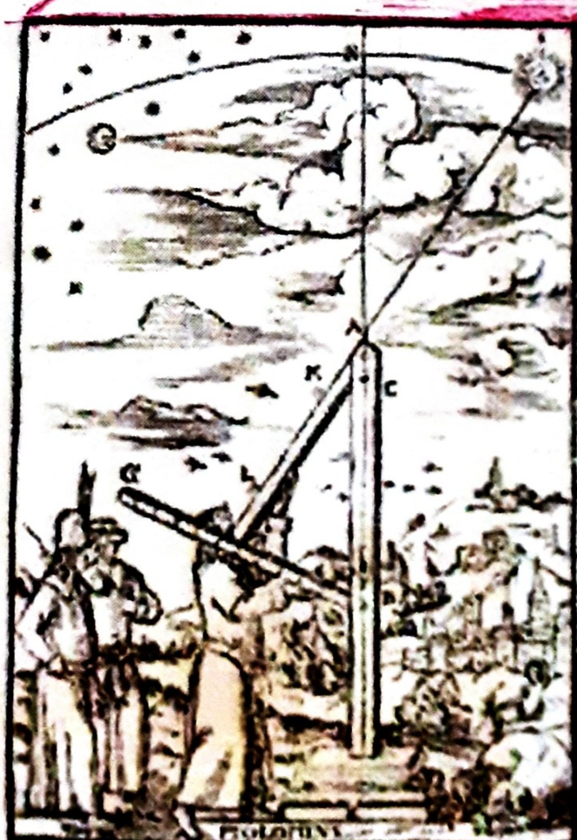

Figure 2.1

structures applying the laws of Physics. We cannot do anything to control the motion of celestial bodies. So Astronomy is an observational Science.

## BIRTH OF THE UNIVERSE

Universe is everything, you can see and think of. It includes all existing matter, the Galaxy, Stars, Planets, Satellites, Animals, we the great people and our belongings and the empty space in between them. Modern scientists say, it is now accepted, that the space contains dark matter and dark energy. According to Einstein, there was no happy birthday for our universe, he said it is static. It is called steady state theory. According to that, new materials were created continuously, and hence there will be no change in the universe. But Edwin Hubble showed that the theory was incorrect. He showed that galaxies are moving away from the earth. Now most of the scientist believe that, there was a date of birth for our universe. Before its birth there was nothing. Universe

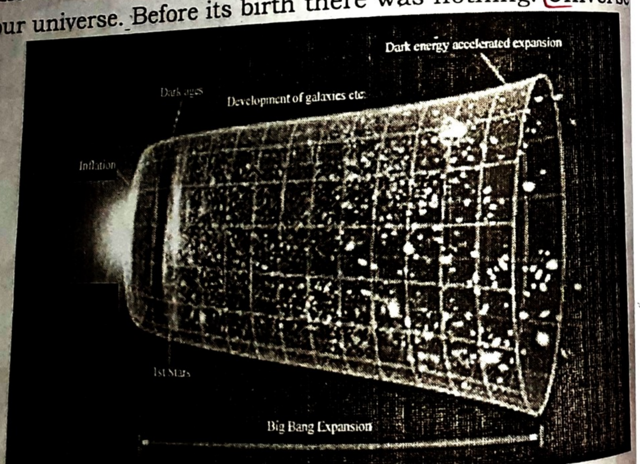


**Figure 2.2**





was born around 15,000 million years back. During time t=0 the universe was very small and very hot. It came into existence in a cosmic explosion called the BigBang. Everything was converged to a point – all the mass and energy of Universe in indistinguishable form called the ylem of the Gamow. In a single second it expanded from nothing to two billion billion kilometer wide; it is still expanding. George Gamow, Arno Penzias and Robert Wilson have the evidence.

Our Sun was born only 8,000 million years ago, after the Big Bang. Our earth and planets emerged from the debris.

Within a single second after the bigbang, the building blocks of matter were created. But the first stars and galaxies were born after 2 billion years, when the time was $3\times10^{-10}$s, only radiation was present. The temperature is given by $T=1.5\times10^{10}\times t^{-½}$ where t is the time, T is temperature in Kelvin. This means, at time t=0 the temperature was infinite. A unit of length is Planck length=$1.616\times10^{-35}$m. The time taken by light to cross a distance of one Planck length is called Planck time. The range of the first aeon of cosmic time is called the Planckian is from 0 to $5.39\times10^{-44}$ s. When the time was about a Planck time, the Universe expanded rapidly, filled with radiation in the form of mostly heat and light. Also gravity appeared as a force. At $10^{-32}$sec the expansion slowed down. The smallest known particles called quarks appeared and they started to continue to form larger subatomic particles. At time $10^{-5}$S, after the bigbang the subatomic particles, combined to form protons and neutrons. The temperature was one billion degree

Celsius, after 100s, when the whole space was filled with protons, neutrons and electrons. For the next 32,000 years, the protons and neutrons fought with the background radiation to form the nuclei of Hydrogen and Helium. The universe became transparent and the temperature dropped to 4000°C after one billion years. The first clumps of matter formed through the gravitational attraction of the atoms.

When the time was $10^{-43}$s, the temperature was around $10^{31}$K, the gravitational force between the particles were as strong as strong force. At this temperature all the four forces were indistinguishable. As the universe cooled, the gravitational force weakened and all forces were separated as, gravitational force, electromagnetic force, weak force and nuclear force.

When the time was between $10^{-33}$ S and $10^{-32}$ S, there was period of inflation during which the radius of universe changed from $3\times10^{-25}$ to 10cm. The increase in radius of 10cm took place in a time of $9\times10^{-33}$s. So there was a radial expansion of the universe at the rate of $10^{+32}$ m/s. A point inside the sphere of radius 10cm can see through a distance of $3\times10^{-24}$m, which is the distance travelled by light in $10^{-32}$S. The volume of a spherule having a radius $3\times10^{-24}$m is $1.1\times10^{-70}$m$^3$. A sphere of 10cm contains $3.8\times10^{67}$ spherules. According to inflation theory there is an increase in radius of each spherule inside large sphere and each of them becomes a universe. Our spherule has radius of 15 billion light years, which is known as the visible universe. Thus the inflation theory says that our universe is one among the $3.8\times10^{67}$





universes, and that the universes cannot be connected even by light. Inflation theory can explain several things which the standard model cannot explain, as given below:

(i) In space in all directions, there is the leftover of the big bang called the microwave background radiation and is the same in all directions neglecting the red shift-blue shift due to the motion of the solar system.

ii) The matter in the universe is distributed in an irregular manner in the form of galaxies, stars etc.

iii) A universe which keeps on expanding is called an open universe. A universe whose gravitational force is sufficient to stop the expansion, reverse it and produce a final cosmo crunch is called a closed universe. The average density of matter in the universe is $0.9 \times 10^{-30}$ g/cm$^3$ is close to the limit between open and closed universe.

iv) The universe contains not just radiation but matter.

According to the standard model, the universe started expanding at the speed of light at time t=0, from the big bang onwards, and so there was no time to reach thermal equilibrium. But according to inflation model between t=0 and t=$10^{-35}$ s the universe was small enough so as light to reach across it and thus thermal equilibrium was attained. Due to this radiation density was uniform, radiation condensed into matter and stars and galaxies were formed. Formation of matter is through x-interaction. Between the Plank time and the inflation time, energy was converted into matter and antimatter and vice versa. During inflation of the universe the temperature decreased. For each $10^9$ antiquarks $10^9$+1 quarks were created. Thus the ratio of material particles to photon in the visible universe is in the ratio 1:$10^9$. This matter forms the visible matter in the universe. The first to stabilize was top quark, which has the maximum mass and greatest energy and later other quarks like strange, up and down quarks and so on. From the quarks, protons, neutrons and mesons were formed at $10^{12}$K. Then came $^3H$ and $^4He$ nuclei. By this time the particles were very far apart and the energy was low enough to form other nuclei. In addition to this, $^5He$ blocked the formation of other heavier elements, as $^5He$ is unstable. The atoms became stable at a temperature of about 3000K and 800,000 years after the big bang. The universe became transparent to radiation when electrons were captured.

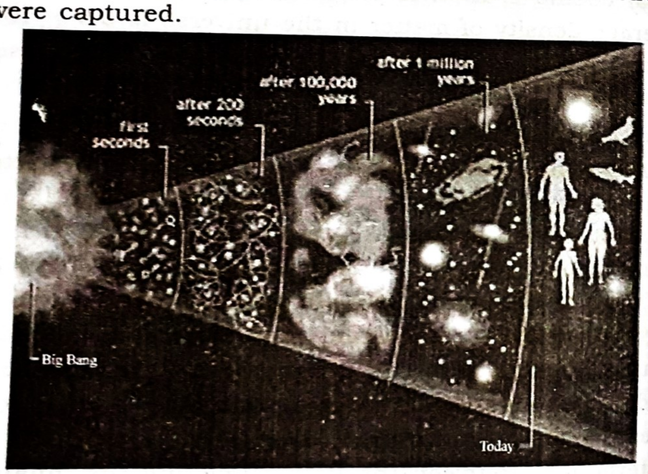


**Figure 2.3**

Massive particles consisting of isolated north or south magnetic poles only are called magnetic monopoles, would have formed in large numbers in the initial formation of





the universe. But according to inflation it is not possible because there are $10^{67}$ different universes and one universe may contain only a few monopoles.

The space – time flatness of the universe can be explained using the inflation model. Before inflation the universe was ultradense and the space time was highly curved. But the inflation flattened the space- time curve and thus the average density of the universe is close to the critical density.

During the continued expansion of the universe, gravity centres were formed. They attract mass and strengthens and this led to the formation of stars, grouping of stars into galaxies and then into galactic clusters. There are about $10^{11}$ galaxies in the visible universe with an average star density of $10^{11}$. This means we need not be alone in the universe because 16% of the stars are spectrally similar to the sun.

**ANCIENT ASTRONOMY**

When humans first looked at the sky, space exploration began. The only way people could observe the universe was to look at it using their eyes (see figure 2.4), because there was no telescope. Ancient sky watchers noted the position of the moon and the patterns of stars. People from different walks of life tried to speculate about the universe. Scientists, engineers, imaginative writers took astronomy from the realms of the theologians to make its basics a matter of everyday understanding. The first astronomical records were kept in Mesopotamia 4000 years back with much accuracy. But these records were used more for astrology than science and for planning of

**Figure 2.4**

war. The Greek questioned this belief on th supernatural. They tried to measure the size of the Earth Moon and the Sun. They were not completely successful Eratosthenes was the first to measure earth. H measured the angle between the earth's axis and th normal to the earth's orbital plane as $23.5^0$, which is th latitude of the tropics. He also measured th circumference of the earth. Another Greek philosophe Poseidonius measured the polar circumference of th earth as 27,300 Km. The circle of maximum size aroun the earth was called a Great Circle. The degree on th great circle was taken as $\frac{27,300}{360}$ = 75.8 Km. Gree astronomer Ptolemy accepted this value. Making use o





this idea, Christopher Coulombus tried to arrive in Japan, but discovered America. Hipparchos was the first to measure the distance to the moon. He used the method of parallax. He also determined the diameter of moon.

**MEASUREMENT OF ASTRONOMICAL DISTANCES**

Celestial objects are quite far away from the earth. Their distances cannot be measured by direct methods. Such large distances are called astronomical distances and can be measured by parallax method.

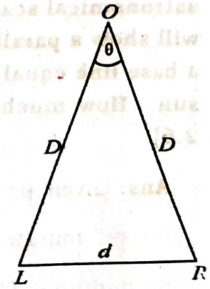


**Fig. 2.5**

**THE METHOD OF PARALLAX-ITS USE**

There is an apparent shift in the position of the object due to the change in the point of observation from right eye to the left eye. This is called Parallax.

The method of parallax is used to measure astronomical distances.

**Principle.** *Suppose an object O is placed at a distance D from our eyes, L represents our left eye and R represents our right eye. [See Fig. 2.5].*

The angle between LO and RO is the parallax angle θ and LR the base line or basis. Let the angle be small.

Then $\theta = \frac{LR}{OL} = \frac{d}{D}$

$D = \frac{d}{\theta}$

Knowing the **parallactic angle** θ and the distance d, the distance of the object D can be found out. In the case of celestial objects, the parallax angle $\theta$ is very small. Instead of taking the distance between two eyes as basis, two points A and B lying at different points on the surface of the earth is taken as the basis.

**A parsec is a convenient unit of length on the astronomical scale. It is the distance of an object that will show a parallax of 1 s of arc from opposite ends of a base line equal to the distance from the earth to the sun. How much is a parsec in terms of metre? [Fig 2.6]**

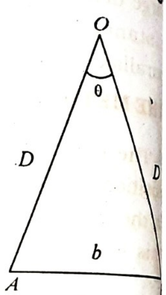

Fig. 2.6

**Ans.** Given $\theta = 1$ s of arc;

60 s = 1 minute

60 minute = 1°; 360° = $2\pi$ radian

$$\theta = \frac{1}{60 \times 60} \times \frac{\pi}{180} \text{ radian}$$

$$= 4.848 \times 10^{-6} \text{ rad}$$

Length of base line = b = Earth to sun distance

$= 1.5 \times 10^{11}$ m (approximately)

Distance of the star from earth = D = ?

$b = D\theta$

$$D = \frac{b}{\theta} = \frac{1.5 \times 10^{11}}{4.848 \times 10^{-6}} = 3.094 \times 10^{16} \text{ m}$$

Thus 1 parsec = $\mathbf{3.094 \times 10^{16}}$ **m.**

## MEASUREMENT OF LARGE DISTANCES - PARALLAX METHOD

*Copernicus method.* By this method the distance of planets (inferior planets) whose orbits are smaller than





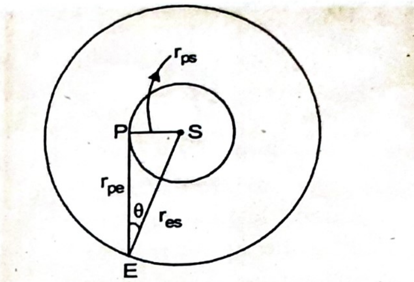

Fig. 2.7

that of the earth can be measured (i.e., Mercury and Venus). It is assumed that the orbits of the planets are circular. In Fig. 2.7 $r_{ps}$ is the distance between the planet and the Sun, $r_{es}$ is the distance between Earth and the Sun and $r_{pe}$ is the distance between Earth and the Planet. The angle between $r_{pe}$ and is $r_{es}$ called the planets elongation. When the elongation is maximum the angle SPE subtended by the Earth and the Sun at the planet becomes 90°. Let $\theta$ be the maximum value of the planet's elongation; then the planet appears farthest from the Sun.

From Fig.2.7, $\sin\theta = \frac{PS}{ES} = \frac{r_{ps}}{1\,A.U.}$;

rps=sin $\theta$ in A.U.

Also $\cos\theta = \frac{PE}{ES} = \frac{r_{pe}}{1\,A.U.}$;

So $r_{pe} = \cos\theta$ in A.U.

The Greeks could not determine the distance of the sun because they could not measure its parallax.

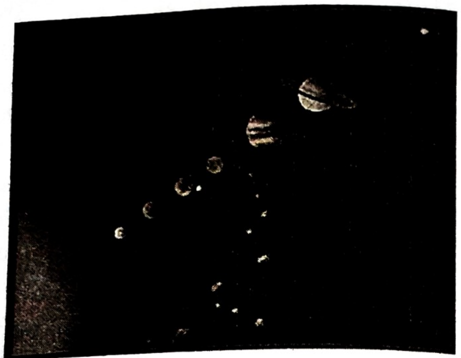

Fig. 2.8(a)

Aristarchos observed that solar eclipse was limited to a small region of the earth's surface. From this he concluded that Sun was larger than the Earth and he proposed that Sun was at the centre of solar system and not the earth. He also suggested that Mercury, Venus, Earth, Mars, Jupiter and Saturn orbited around sun. Uranus Neptune and Pluto were not known then [See Figure 2.8(a)]. The Babylonian and Egyptian astronomers showed that the shortest time period was that of Moon, 27.3 days, followed by Mercury, 88 days, then Venus, 225 days, Earth, one year and so on.

Ptolemy rejected the Aristarchos theory and he kept Earth at the centre, with other planets orbiting around it. Correct conclusions can be arrived at only if the astronomical mea -surements are made precisely using suitable instruments. The Gree ks of Alexandria would have performed in an excellent way in the field of Astronomy, but they were sacked by Christian Zealots who destroyed the Greek scientists and their university library. The remaining part was burned down by the Islamic fanatics in 642 BC.





## MEDIEVAL ASTRONOMY

For than 1000 years astronomy and much other learning remained dormant. Ptolemy's ideas were revived and they acquired the force of the religious dogma. Powerful forces in the church were keen to insist that the earth was the centre of the universe. They silenced any who argued against them. Polish cleric Nicolaus Copernicus proposed that the sun controlled the planetary system. He was a accused of heresy. Giordano Bruno [See Figure 2.8(b)] was his luckless follower and was burned at the stake. Copernicus withheld the publication of his great treatise Dr. Revolutionibus Orbium Coelestium (concerning the Revolutions of the Heavenly Bodies), until just before his death in 1543. Until 1835, the book remained on the Papal index of forbidden Books.

**Figure 2.8(b)**

The fourteenth century life in Italy was quite different. Very few people knew how to read and write. During that time Dante Alighieri (1265-1321) a Florentine politician and poet wrote a poem La Commedia (The Comedy). He described about Hell, Paradise and Popes. People listened to the poem everywhere. There was maximum propaganda under the leadership of Boccaccio. In the poem priests and nuns were described as saintly pursuits. The church lost much of its prestige People started rethinking which resulted in Renaissance.

## RENAISSANCE ASTRONOMY

Everything changed with the invention of the printin press by Johannes Gutenburg (1397-1468). In 145 Gutenberg's Bible was published. People suddenl developed interest for books. In 1462, a latin translatio of Ptolemy's work was published. Copernicus studied an rejected his arguments about the planetary motion. He spent ten years in Italy studying law and medicine. Then he spent 30 years and put together his great treatise, De Revolutionibus Orbium Coelestium. He was afraid o Pope and he did not publish. His treatise published jus before his death spurred great interest in astronomy.

Tycho Brahe, the Danish astronomer followed th courageous and inspiring work of Copernicus. A observatory called Uraniborg was built up in the island of Ven, sponsored by the King. Tycho was a typical character. He enjoyed making enemies. At the age of 1 he lost his nose during a fight and it was replaced by a metal nose. He died because his bladder was burst due to heavy drinking of beer. But he had a very good assi-stant, an young German Mathematician, Johannes Kepler, by name, It is said that King Frederick II gave Brahe more than one ton of gold

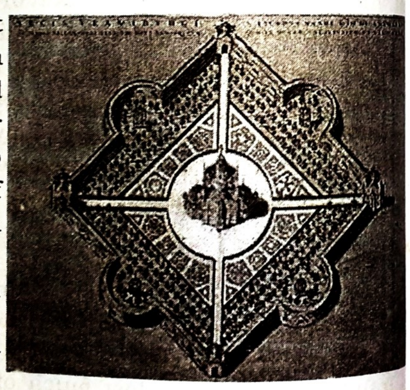

Figure 2.8(c)





to set up the world's first observatory [See figure 2.8(c)]. Dependent basically on the naked eye, Brahe and his assistants recorded precise, planetary positions for more than 20 years. Kepler used these informations and formulated the three laws of planetary motion under his name Kepler published his Astronomia Nova (New Astronomy), in 1609, which overturned the belief that the solar system moves uniformly and in circles. Now, Astronomy became a Science based on Physics.

### KEPLER'S LAWS OF PLANETARY MOTION

**1. The law of orbits: Every planet moves in an elliptical orbit around the sun, the sun being at one of the foci.**

**2. The law of areas: The radius vector drawn from the sun to a planet, sweeps out equal areas in equal intervals of time i.e., the areal velocity of radius vector is a constant.**

**3. The harmonic law (The law of periods): The square of the period of revolution of a planet around the sun is proportional to the cube of the semi-major axis of the ellipse.**

### EXPLANATION OF THE LAWS

1.Planets move around the sun in elliptical orbit. There are two foci for an ellipse. Sun remains at one focus. The other focal point has no special significance. Neptune and Venus move in circular orbit. Circle is a special case of ellipse.

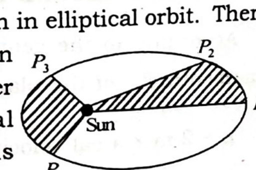


Fig. 2.9(a)

2. According to the second law the area swept by the radius vector joining the planet to sun is equal, in equal intervals of time. When the planet is nearer to sun, during a certain time interval, it travels greater distance from $P_3$ and $P_4$. But at the same time it moves through a smaller distance from $P_1$ to $P_2$ when it is far away. Thus velocity is greater when the planet is nearer to the sun than when it is farther away [Fig. 2.9(a)].

3. To prove 3rd law let us assume circular orbits. Let the planet of mass m revolve round in a circular orbit of radius r with a speed v. The force of attraction between sun and the planet provides the necessary centripetal force.

$$\frac{mv^2}{r} = \frac{GMm}{r^2}, \text{ M - Mass of sun. ; } v^2 = \frac{GM}{r}$$

But $v = \frac{2\pi r}{T}$ where T - is the period of the planet.

$$\frac{4\pi^2 r^2}{T^2} = \frac{GM}{r}; \; 4\pi^2 r^3 = GMT^2, \; T^2 = \frac{4\pi^2}{GM} r^3$$

$T^2 \alpha \, r^3$, because $\frac{4\pi^2}{GM}$ is a constant.

In the case of elliptical orbit $T^2 \alpha \, a^3$ where a, is the semi-major axis of the ellipse.

**KEPLER'S SECOND LAW - PROOF**

According to the geometrical meaning of the angular momentum $\vec{L}$ of the planet is,

L = 2 m × areal velocity

where m is the mass of the planet.





No external torque acts on the planet. So the rate of change of angular momentum is a constant in magnitude and direction.

When $\tau = 0$, $\frac{dL}{dt} = 0$, L=a constant

L = 2m× Areal velocity.

**Areal velocity is the area swept per unit time**

Areal velocity$= \frac{\Delta A}{\Delta t} = \frac{L}{2m}$ = a constant because L is already a constant. Hence Kepler's second law is proved.

**KEPLER'S FIST LAW - PROOF**

Since the angular momentum is a constant the planet moves in a plane perpendicular to $\vec{L}$. We can prove that the orbit of a body moving under the gravitational force is an ellipse or circle or parabola or hyperbola depending on the initial conditions.

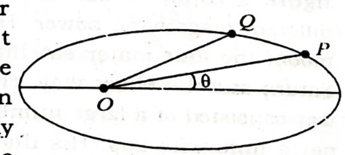


Fig. 2.9(b)

Glass was first manufactured in 3500 BC. But lens was invented only in 1317 by Florentine Salvino degli Armati. But again, nobody knew how two lenses could be put together in the form of a telescope so that distant object could be seen very close, until 1608. Using a convex lens and a concave lens, Lippearshey made a telescope.

Fig. 2.10(a)

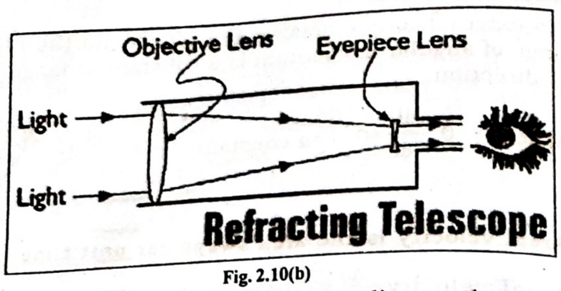


Fig. 2.10(b)

Galileo Galilei, [See figure 2.10(a)] Italian mathematician heard of Lippearshey's invention and he himself built a telescope. He was the first to use the telescope [See figure 2.10(b)] in astronomy. He built telescopes of different magnifying power. He discovered mountains on moon, the four major satellites of Jupiter, the rings of Saturn and the Milky Way. He discovered that the milky way consisted of a large number of stars and so that it is not a luminous gas. His discovery proved that all the planets are orbiting around the sun. He put together all his views in a book with a very lengthy title, which is abbreviated as, 'Dialogo Sopra i. Due Massimi Sistemi del Mondo', and was published in 1632. His ideas were also condensed. In 1633, he was made to 'abjure, curse and detest' before the Inquisition the opinion that the Earth moves around the sun.

**MODERN ASTRONOMY**

Modern astronomy started with the advent of micrometer. Telescope was fitted with micrometers which made more precise angle measurement. The parallax of Mars was measured by Giovanni Domenico Cassin to be $25^0$. The distance to Mars was determined. Distances to other planets and hence the size of the





solar system was known. Next astronomers tried to find the distances to the stars. But there was a problem. The lenses had several image defects. One was spherical aberration due to which the image was blurred and

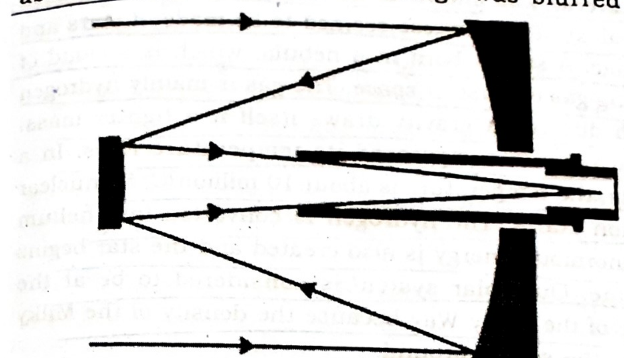

Fig. 2.11(a)

distorted. Another one was chromation aberration due to which an object appeared coloured as well as blurred. So instead of lens mirrors were used [See figure 2.11(a)]. In reflection telescope there was no chromation aberration because it was caused due to refraction of light. To reduce spherical aberration parabolic mirrors were used. The first parabolic mirror was constructed in 1721 by Joln Hadley (1682-1743). At present there are telescopes whose objective, (the lens or mirror facing the object) is 1.016 m across, in university of Chicago, another one 6 m diameter weighing 78 ton in Russia, another one of diameter 5.08 m on Mt. Palmar, California.

In 1838, the German astronomer Friedrich Bessel succeeded in determining the parallax of the star 61 Cygni. He found the heliocentric parallax of 61 Cygni was 0.5″ and that it was 6.5 light years away. The distance of the closest star is Proxima Centauri, which is 4.26ly away.

During the second half of the 19th century the shape of universe was known to be like a flattened disc called the galaxy. The universe seemed to be made of stars and nebulae. A star is born in a nebula, which is a cloud of glowing gas or dust in space. The gas is mainly hydrogen which due to its gravity draws itself it a tighter mass. When a gas is compressed its temperature rises. In a nebula, the temperature is about 10 million°C. So nuclear reaction starts. The hydrogen is converted into helium and enormous energy is also created and the star begins to shine. Our solar system is considered to be at the centre of the Milky Way because the density of the Milky Way is the same allround.

Sun changes its luminosity by 0.1% with a period of 11 years. A few other change their luminousity much more.

By studying certain variable stars called Cepheids [See Figure 2.11(b), a method was designed to measure the distance of the star. The Cepheid is named after the variable δ Cephei in the Cepheus constellation, which changes its luminosity by 178% with a period of 5.2 days. There are stars in Cepheids which have periods as short as one day and as

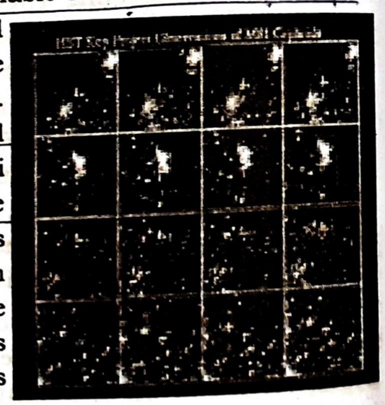

Fig. 2.11(b)





long as 100 days. There are a number of Cepheids in a nebula called the Small Magellanic cloud. It was noticed that the longer the period the brighter the brightness peak was. The power emitted by a star is called the luminosity and the power received from a star is called brightness. Hipparchos designed a unit called magnitude to express the brightness of the star. A star's brightness is affected by distance. A close dim star might appear brighter than a far away bright star. The brightest star is represented by the magnitude 1. A star of brightness magnitude 2 means it is 2.512 times less bright than those of magnitude1. Magnitude 3 stars are 2.512 times less bright than the stars of magnitude 2, and so on. Table 1 shows the brightness of stars as seen from the Earth.

| Star | Constellation (Apparent Magnitude) | Brightness |
|---|---|---|
| Sirius | Canis Major | -1.46 |
| Canopus | Carina | -0.72 |
| Arcturas | Bootes | -0.04 |
| Rigil Kentaurus | Orion | 0.02 |
| Vega | Lyra | 0.03 |
| Capella | Auriga | 0.08 |
| Rigel | Orion | 0.12 |
| Procyon | Canis Minor | 0.38 |

The English astronomer Norman Pogson proposed the number 2.512 which is equal to $100^{1/5}$ to define the ratio between one magnitude and the next. It is called Pogson ratio. It is the ratio between one magnitude and the next. Stars brighter than magnitude zero are given negative values. The magnitude reduced to the distance of 10 parsec is called absolute magnitude. The absolute magnitude of our sun is +4.84. The apparent magnitude is a measure of the apparent brightness as seen by an observer on Earth.

When the star is beyond the limit of the parallax method then the distance of the star can be measured from the motion of the cluster itself. This is done by photographing the cluster at certain intervals, can be years or decades. When a cluster is moving away we feel that the cluster is progressively shrinking to a distant point. This point is called convergent point. If the starts in a cluster is approaching us we feel that the cluster is progressively diverging from a distant point. The angle between the line of sight and the convergent point P is the same as the angle between the line a between the line of sight and the actual velocity vector of the star. The actual velocity v of the star can be determined [See Figure 2.12(a)] by knowing α and the radial velocity $v_r$. Then the tangential velocity $v_t$ can be calculated. From this the distance of the star can be found out. Using this method the distance to galactic clusters which contained Cepheids was determined. Using this method the radius of our galaxy was found to be about 150,000 light years.

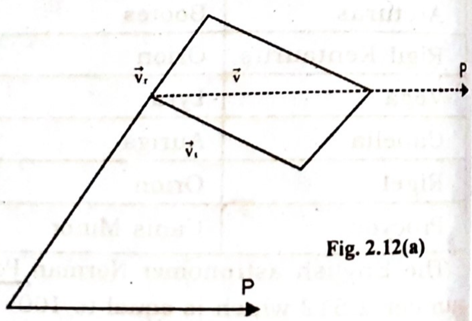


Fig. 2.12(a)





Enter Edwin Hubble was lawyer turned astronomer. He was interested in nebulae. Wth the help of the Hooker telescope in the Mount Wilson observatory near Los Angeles, Hubble told that the universe was not static but was expanding at a fast rate. In 1929 he found that the speed with which a galaxy moves away called recessional velocity from the Earth depends on its distance r from the Earth. This is called Hubble's Law. Hubble arrived at this conclusion through red shift. If $v_r$ is the recessional velocity and r is the distance then $v_r = r\,H_o$. Ho is called Hubble constant [See figure 2.12)b].

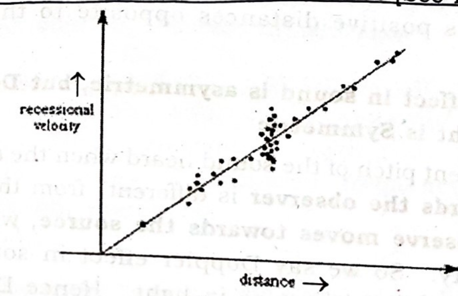


**Figure 2.12(b)**

## DOPPLER EFFECT

**Doppler effect is the apparent change in the pitch of a sound, due to the relative motion between the source and the observer. The motion of the medium also affects the change in the frequency heard.**

Suppose a man is standing on a railway platform and a train is approaching him. As the engine is approaching him the apparent pitch of whistle of the engine increases. When the engine moves away from the man, the apparent pitch decreases. There is similar apparent change in the pitch of sound heard when the source is at rest and the listener moves towards or away from the source. The wind also affects the apparent pitch heard. Doppler effect depends on (i) velocity of source (ii) velocity of listener (iii) velocity of medium or wind. Doppler effect in sound is asymmetric.

For deriving the expression of the apparent frequency it is assumed that the velocity of source and listener are less than the velocity of sound. Distances measured in the direction in which sound travels to reach the listener are taken as positive distances opposite to this are negative.

**Doppler effect in sound is asymmetric, but Doppler effect in light is Symmetric**

The apparent pitch of the sound heard when the **source moves towards the observer** is different from the case when the **observe moves towards the source**, with the same velocity. So we say Doppler effect in sound is asymmetric. But it is not so in light. Hence Doppler effect in light is symmetric.

**Expression for apparent frequency**

Suppose a source S is producing a sound of pitch (frequency) n and wavelength λ. The velocity of sound in the medium is V. Let the source and the listener be at rest. Then the frequency of the sound heard by the listener is $n=\frac{V}{\lambda}$.

Let the source and listener be moving with velocities Vs and $V_l$ respectively in the direction of propagation of sound wave (Fig.2.13).

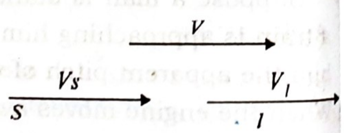


Fig. 2.13





The sound wave propa gates from the source to the listener.

Apparent frequency $n' = \frac{V - V_l}{V - V_s} \times n$

**This expression is used when the source, listener and the medium are all moving in the direction of sound.** The direction of source to the listener is taken as positive and the opposite direction is taken as negative.

**DOPPLER EFFECT IN LIGHT**

Doppler effect is observed in light also.

When the source of light is stationary and the observer moves towards the source, the apparent frequency increases. When the source moving away from the stationary observer, the apparent frequency decreases or wavelength increases.

**Red shift**

Suppose a star recedes from Earth with a high velocity. Then the frequency of the light emitted by the star decreases or wavelength increases. Thus its spectral lines are shifted towards the red end of the spectrum. This is called red shift. If the spectral lines are shifted towards the shorter wavelength, it is called blue shift. This will happen when the source of light approaches the observer.

**Applications**

(i) **Discovery of double stars.** Some stars, which normally appear to be single, consist of double stars, called spectroscopic binaries. These stars revolve around each other, such that when one is approaching the earth, the other is going away from the earth. All the lines in the spectrum may look as one line, when one star is covered by the other. When both the stars become visible, on account of the approaching of one and the recession of the other, there is a shift in the spectral lines. They split and show double lines. By this method a number of double stars have been located.

(ii) **Rotation of sun.** Light is received from the eastern and western edges of the sun and the apparent difference in the wavelength between the Fraunhofer lines in the two spectra are studied. The study of the spectra reveals that there is displacement of the spectral lines corresponding to a velocity difference of about 2 km/s and it shows that the sense of rotation of sun is from east to west with respect to earth, about an axis passing through north and south.

(iii) **Speed of planets, stars, galaxies etc.** The spectrum of light coming from planets, stars etc. are photographed over a long period. By observing the Doppler shift, one can conclude whether they are moving towards or away from earth. The light received from stars and galaxies show a red shift, which tells us that they are receding and our universe is expanding.

(iv) **Study of saturn rings.** The Doppler shift of light received from the saturn rings shows that the rings consist of a number of discontinuous satellites.

(v) **Speed of automobile, aeroplane etc.** Short waves emitted from an observation centre are reflected from the automobile. The difference between the incident frequency and reflected frequency is noted. From the the magnitude and the direction of the velocity of the automobile can be calculated.





## EXPRESSION FOR RED SHIFT

If $Z$ is the red shift parameter then $Z = \frac{\Delta\lambda}{\lambda} = \frac{dr/dt}{c}$ where $\lambda$ is the wavelength, $r$ is the distance and $c$ is the speed of light. If $v_r$ is the recessional speed and $H_0$ the Hubble constant then the distance $r$ is given by $r = \frac{v_r}{H_0}$. If

$Z = \frac{\Delta\lambda}{\lambda} > 0$, there is red shift and $r$ is increasing. If

$Z = \frac{\Delta\lambda}{\lambda} < 0$, there is blue shift and then $r$ is decreasing. If

$Z = \frac{\Delta\lambda}{\lambda} = 0$ there is no shift and $r$ is a constant.

Hubble constant has the dimension of $\frac{1}{\text{time}}$. The inverse of the Hubble constant is called Hubble time $H_t$

$$H_t = \frac{1}{H_0}$$

The age of the universe is the inverse of the Hubble constant. Hubble distance $H_r$ is the distance covered by the light during the Hubble time and gives the radius of the visible universe, $H_r = c\left(\frac{1}{H_0}\right)$.

Hubble's discovery that the universe is expanding provides an explanation why the universe does not collapse. This is because the universe is not stationary but it is expanding since the bigbang. Also it explains why the sky is dark at night. Eventhough according to Olber's paradox the sky should be packed with stars.

According to Hubble, the universe within the Hubbl Horizon, which is a sphere having a radius of Hubbl distance are expanding at a rate such that the visibl light is shifted to infrared and beyond. The light emitted by the objects beyond a distance greater than the Hubble distance has not yet reached Earth so far, because the age of the universe is $1.5\times10^{10}$ years.

The equation for red shift contains the recessional velocity of the source. So knowing the red shift its distanc can be calculated. In 1963 the Dutch Astronomer Maarten Schmidt discovered an object with strong radio emissio having a red shift parameter of 0.16, with a recessional speed of 44000 km/S at a distance of $2.5\times10^{9}$ light year away. It was not a star and is called Quasar-Quasi stella objects. Quasars are very luminous objects moving awa from us at great speed. They are thought to be the core of young galaxies, possibly with blackholes at thei centres. A large number of quasars are detected. Th most distant quasar is $15.7\times10^{9}$ light years away with recessional speed of $2.83\times10^{5}$ km/s, having an Z valu equal to 4.897.

There are various other methods to measure th distance of celestial objects. Radar (Radio Detection An Ranging) is used to measure the distance of Moon an other inner planets. Radar emits high power radio pulse which get reflected from the object as echo. Knowing th speed of the radio waves and the to and fro transit tim the distance can be accurately measured. Using rada the surface features of Venus was mapped. Using Lase (Light amplification by stimulated emission of radiatio these distances can be measured more precisely. To g the light reflected from the Moon a mirror was kept. Th distance was accurately determined using the equatio S=c×T where c is the speed of light and T is the tim taken by the light to travel from earth to moon and bac





# MODEL QUESTIONS

## SECTION A

### BUNCH I

### OBJECTIVE QUESTIONS

1) The scientist who showed that the galaxies are moving away from the Earth is
   a) Edwin Hubble b) Einstein
   c) Kepler d) Newton
2) One planck length is
   a) $10^{-34}$m b) $1.616 \times 10^{-35}$m
   c) $1.5 \times 10^{-44}$m d) non of the above
3) The _____ theory our universe is one among the 3.8 x $10^{67}$ universes.
   a) Steady state b) inflation
   c) big bang d) none of the above
4) During inflation of the universe the temperature
   a) Increased b) decreased
   c) remained constant d) became zero
5) The number of galaxies in the visible universe is
   a) $10^{10}$ b) $10^{9}$
   c) $10^{11}$ d) infinite
6) The first astronomer to measure circumference of the Earth was
   a) Erathosthenes b) Copernicus
   c) Hipparchus d) Poseidonius
7) Kepler formulated his laws of planetary motion from the observations made by
   a) Copernicus b) Tycho Brahe
   c) Frederick d) Galileo
8) The man who made the first telescope was
   a) Tycho Brahe b) Lippershey

c) Kepler
d) Bruno

9) Sun changes its luminosity by 0.1 % with a period of _____ years.
a) 1
b) 5
c) 10
d) 11

10) Hubble constant has the dimension of
a) Time
b) 1/time
c) Distance
d) 1/distance

## BUNCH II

### FILL IN THE BLANKS

1) Universe came into existence in a cosmic explosion called _______.
2) Just after the big bang only ______ was present.
3) Gravity appeared as a force when the time was a_______.
4) The first charged particle appeared in the universe was ______.
5) When the temperature of universe was______ all the four forces were indistinguishable.
6) The radius of the _______ from which our universe was born is 15 billion light years.
7) The ratio of material the material particle to photons in the visible universe is____.
8) From ______ protons, neutrons and mesons were formed.
9) Friedrich Bessel succeeded in determining the parallax of the star _____.
10) The ____ is named after the variable star ™ cephei.

## BUNCH III

### TRUE OR FALSE

1) Space contain dark matter and dark energy.
2) Einstein is a supporter of the big bang theory.





3) Einstein told that the galaxies are moving away from us.
4) Our Earth and planets are emerged from debris of the big bang
5) The temperature of universe was zero during the big bang.
6) Inflation theory can explain several things which the standard model cannot.
7) The universe which keep on expanding is called an open universe.
8) Before inflation the space-time was ultra curved.
9) During the continued expansion of the universe gravity centers were formed.
10) Hipparchus was the first to measure the distance to the moon.

## ANSWERS

### OBJECTIVE QUESTIONS

| | | | | |
|---|---|---|---|---|
| 1.a | 2.b | 3.b | 4.b | 5.c |
| 6.a | 7.b | 8.a | 9.d | 10.b |

### FILL IN THE BLANKS

| | |
|---|---|
| 1) The bing bang | 2) radiation |
| 3) planck time | 4) quark |
| 5) $10^{31}$ | 6) spherule |
| 7) 1: $10^9$ | 8) Quarks |
| 9) 61 cygni | 10) Cepheid |

### TRUE OR FALSE

TRUE → 1, 4 , 6 ,7 ,8 ,9,10

FALSE → 2, 3, 5

## SECTION B

### VERY SHORT ANSWER QUESTIONS

1) What is steady state theory?

2) What is ylem of Gamow?
3) When was the sun born?
4) What is Planck length ?
5) What is Planck time?
6) How did the nucleii of hydrogen and helium came into existence?
7) What is a spherule?
8) What is inflation theory ?
9) Distinguish between open universe and closed universe ?
10) What is big Crunch?
11) What is X- interaction ?
12) What happens to energy between Planck time and the inflation time?
13) Why heavy elements were not formed after the formation of helium?
14) How will you explain the space –time flatness of the universe?
15) What is great circle ?
16) How did Aristarchus conclude that sun was larger than Earth?
17) Why did the powerful forces in church kill Bruno?
18) Write a note on Ptolemy's view of solar system?
19) What is the influence of Dante in Renaissance Astronomy?
20) Where was world's first observatory set and for whom?
21) Hoe did Brache record planetary position?
22) Who proved first that all planets are orbiting around the sun?
23) In telescope instead of lenses, mirrors are preferred Why?





24) What is the distance of the nearest star?
25) What are Cepheids?
26) Distinguish between luminosity and brightness?
27) What is 'magnitude'?
28) What is the meaning of saying that the brightness of a star is magnitude 2?
29) What is absolute magnitude?
30) What is apparent magnitude?
31) What is Pogsonratio ?
32) When a star is beyond the limit of parallax how will you determine its position?
33) What is convergent point?
34) State Hubble 's law?
35) What is redshift?
36) What is blueshift?
37) What is Hubble's constant?
38) What is quasar?
39) Name the modern method to measure the distance of celestial bodies?

## SECTION C

## SHORT ANSWER QUESTIONS

1) Write a note on the birth of universe?
2) Describe what happened in the universe during Planck time?
3) Explain the inflation theory?
4) Write a note on Ancient Astronomy?
5) Name the astronomers who contributed much during the medieval astronomy?
6) Compare the contributions of Ptolemy and Copernicus to astronomy?
7) Describe the universe as seen by TychoBrahe ?

8) State Kepler's laws of planetary motion?
9) Write a note on the works of Galileo?
10) Mention the significant discoveries during the modern astronomy stage?
11) How was the distance to stars measured?
12) Mention the names of different types of telescopes?
13) How will you measure the brightness of stars?
14) How will you measure the distance of stars beyond the parallax limit?
15) How will you measure the velocity of distant stars?
16) State Hubble's law. What are the conclusions drawn from the law?
17. How will you determine the distance to moon using laser?

## SECTION D

## LONG ANSWER QUESTIONS

1. Explain the origin of universe based on Big Bang theory
2. What are the discoveries made during the ancient astronomy?
3. Discuss the discoveries made during medieval astronomy and renaissance astronomy
4. a) Explain the different methods used to find the distance of stars during the time of modern astronomy

   b) State Hubble's law

   c) What is Hubble's constant? How is related to Hubble time and Hubble distance?