Chapter-3

THE OBJECTS IN THE SKY

THE MICROWAVE BACKGROUND RADIATION

Fifteen billion years ago there was no Universe. It came into existence through a cosmic explosion- the Big Bang, two words coined by the astronomer Fred Hoyle, eventhough he did not believe in the theory .How do we know what happened billions of years ago?Yeh! It's very simple, just watch it, see it using a telescope. We can see any objects when the light from them reach us. Only thing is that, the farther away an object is, the longer it takes. For example, for light to travel from the brightest star Sirius to travel to earth it takes only eight years! Do you know the meaning of this? It means that we are actually looking at it as it as it was eight years ago. You know it takes 50 million years for light to reach us from the Virgo cluster.

Figure 3.1

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This means we are looking at an object when human beings are not on Earth. Stellar objects in addition to light they emit other types of radiation, like radio waves. Using radio telescopes, these can be detected and using that we get a fuller picture of the universe [See figure 3.2]. We know Universe contains galaxies, star clusters, planets, moons etc. By studying the density of the Universe scientists concluded that in addition to the visible matter there are non-luminous matter and energy called dark matter and dark energy. Dark matter is assumed to be made of a certain kind of neutrinos. Virtual particles are the source of dark energy. There are photons which include radio waves, microwaves, infrared waves, visible light, ultraviolet, X-rays and gamma ray, emerging from galaxies, interstellar clouds and stars [see Figure 3.3]. In addition to all these there is microwave background radiation.

Figure 3.2

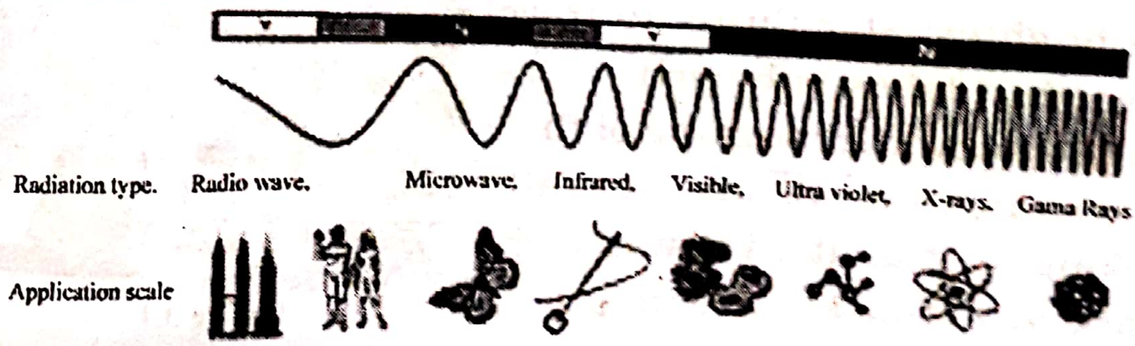

Figure 3.3

3.3 Arno Penzias and Robert Wilson were working on communication satellites and radio astronomy using Radio telescope. One day they found that their telescope was unexpectedly noisy. They studied the details of the noise and found that it was formed by the cosmic background photons. They found that these radiations are coming equally from all directions. At the same time George Gamow suggested if we are living in an expanding universe and when we go back in time we should get the early Universe. If this is correct then we should be able to see the glow of the early Universe, from distant objects. Penzias and Wilson detected this background radiation and were awarded Nobel Prize in 1998.The cosmic Background explorer (COBE) Satellite investigated the radiations from the early Universe. These radiations provided the evidence for the Big Bang theory .The variation of the intensity of the background black body radiation as measured by the COBE experiment is as shown in figure. The spectrum of the microwave radiation is that of a black body radiation at a temperature of 2.735 K.The radiation remaining from the Big Bang is redshifted to the microwave region.

Spectrum of the Cosmic Microwave Background

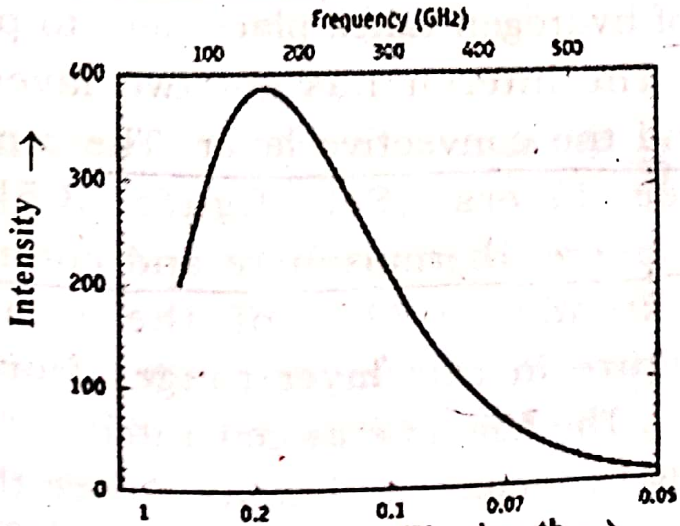

Figure 3.4

THE SUN

Sun burns 700 million tonnes of hydrogen in its core every second and converts about 5 million tonnes a second into pure energy. So far the great fire of the sun has burned for about 5000 million years without any break or stop. We receive only one hundred millionth of the sun's vast energy. The rest of the output of heat and light vanishes beyond the planets and into space. Sun is composed of almost 75% hydrogen and 25% helium plus much smaller amount of oxygen, carbon, neon, nitrogen, magnesium, iron and silicon. The Sun and stars produce energy by nuclear fusion. There are two processes involved. One is proton-proton chain and another is carbon cycle. The net result is the fusion of hydrogen nuclei to form a single helium nucleus. Sun has higher temperature and produce energy mainly by the carbon cycle. The gamma rays produced interact with free electrons and lose energy while trying to emerge from the sun's surface. Since the photons are absorbed and then emitted a number of times, it takes one millions years for a photon to reach the sun's surface.

The diameter of the core of sun is about 450000 km and its temperature is 15 million°C. The thermonuclear fusion of hydrogen takes place here to produce the sun's energy. The interior has got two layers; the radiative layer and the convective layer. The atmosphere consist of three layers [See figure 3.5] photosphere, chromosphere, thermosphere and corona. The radiative layer extends to 70% of the sun's radius. The temperature in this layer ranges from 2 million to 7 million°C. The heat energy generated in the core is carried outwards by means of photons. Above the radiative layer

4,50000 km 4,5000km
4,5000km

15 million

is the convective layer. The radiative layer is from 170,000 km to 590,000 km, while the convective layer is from 5,90,000 km to 6,95,500 km. This layer convects and

450000 km.

ANATOMY OF THE SUN

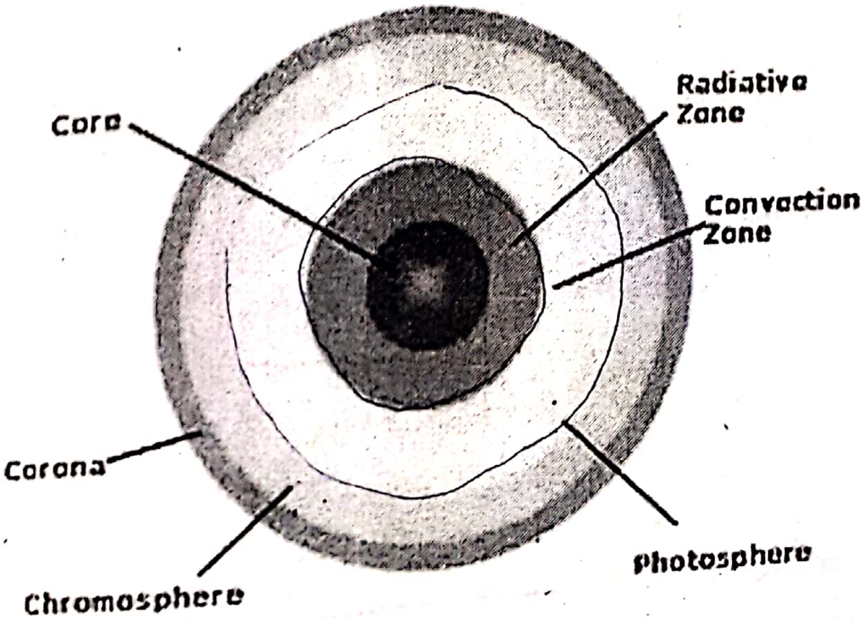

Figure 3.5

15° mill
4,5000km

energy is transferred outwards. The temperature ranges from 2 million to 5500°C. Both the layers consist of about 72% H, 26% He and 2% heavier elements. The average density is 1.4 gm/cm^3. The surface layer which we see is called photosphere. In this layer the gas swirls and bubbles about, giving the sun a mottled look. Photosphere is 450 km thick having a temperature ranging from 8000K at the bottom to 4000 K at the surface. Density is 10^{-6}g/cm^3. At this temperature most of the atoms are neutral because there is no energy to ionize hydrogen. Photosphere emits most of the energy as light and heat. At a particular temperature all the photons need not have the same energy. The distribution of power per unit wavelength with wavelength is as shown in figure 3.6].

4,5000 km

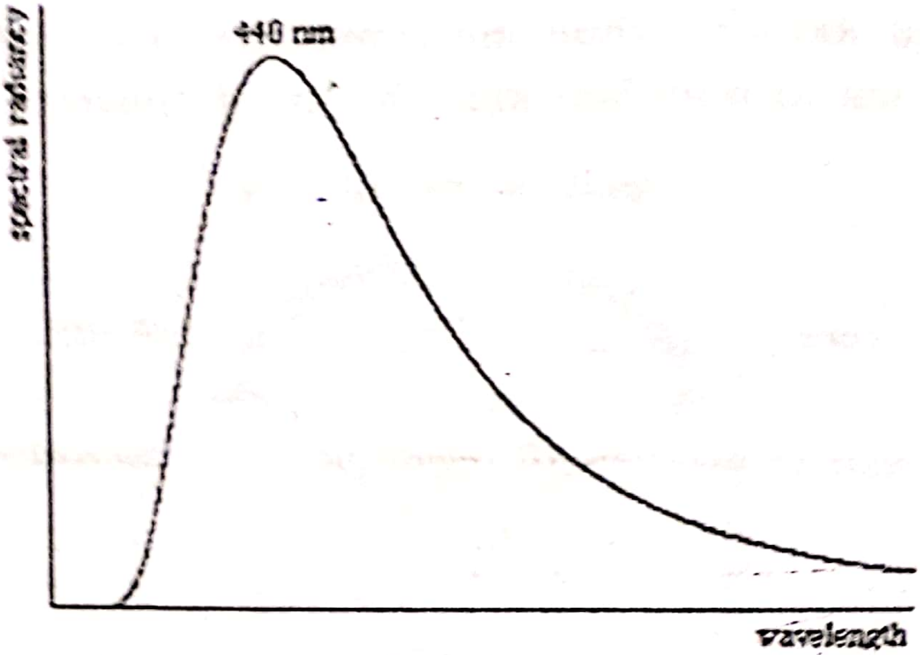

Figure 3.6

The peak power emitted is at a wavelength of 480nm and it is in the blue region.The power emitted is less at longer wavelengths as well as shorter wavelengths. The graphs obtained for a black body by Planck is as shown in figure 3.7. Thus the solar spectrum outside the terrestrial atmosphere approaches that of a black body at the same temperature.

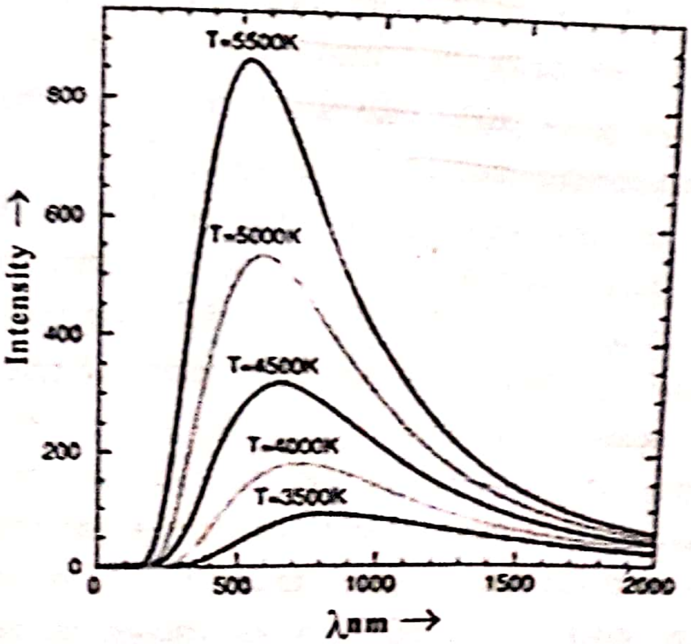

Figure 3.7

3.7 The graphs shown in figure 3.7 are for a black body at different temperatures. The solar spectrum is similar to that of a black body at an effective temperature of 5770K.The curves are asymmetric. Stars whose temperature is less than that of Sun have their peak value of the power shifted towards the longer wavelength region and hence they appear reddish .At the same time stars hotter than sun, their power peaks are shifted towards shorter wavelength region and they appear blue in colour]

When the K shell of an atom contains two electrons the shell is complete.In normal hydrogen there is only one electron so if free electrons are present hydrogen capture one and becomes H^-. During this capture, the free electrons lose energy. This forms the solar spectrum. The free electrons have different amounts of energy. So the wavelength emitted will be wide and varied. The different colours combine to form the white light. (The photosphere is broken by sunspots. They are dark patches which appear as pairs or groups on the sun's surface, around the Sun's equator. Sunspots are the region where the magnetic field of the sun is stronger) [See Figure 3.8]. These spots last from one hour to six months depending on size and the larger ones live longer.

Figure 3.8

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Surrounding the photosphere is an unseen layer of gas called chromosphere, from 2000 km to 3000 km. It is visible as a pink or reddish layer during solar eclipses. The layer got its name from the wavelength of the colour emitted when an electron makes a transition from the M shell to L shell. The wavelength lies in the red region of the spectrum. At the surface of the chromosphere there are jets of hot gases shooting upto a height of 10,000 km with a speed from 20-30 km/s, called spicules.

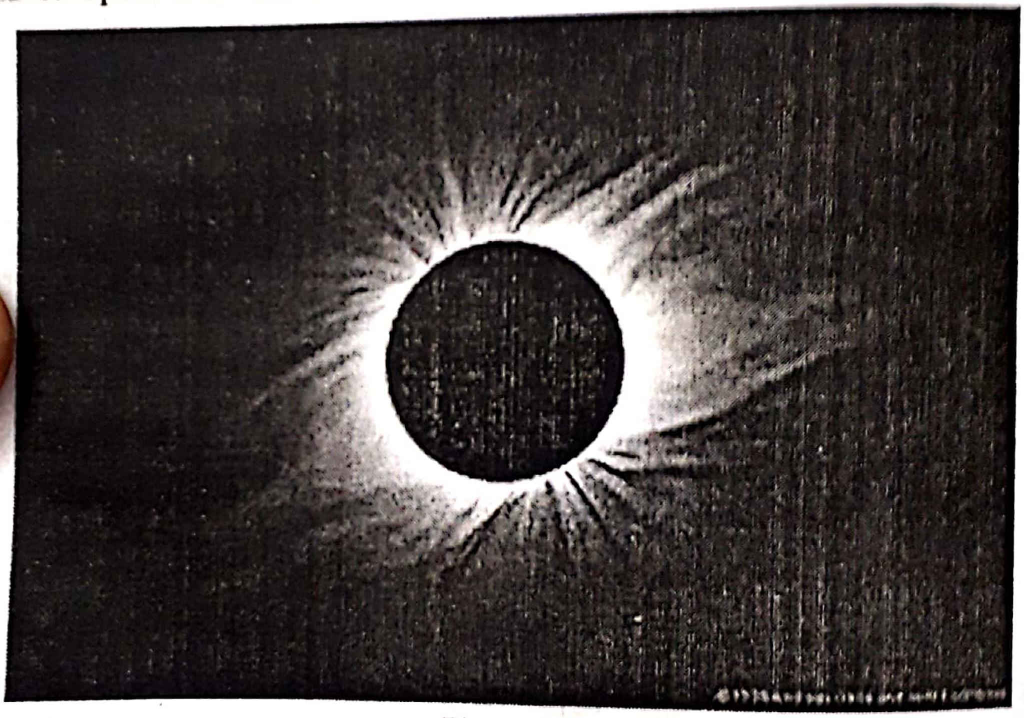
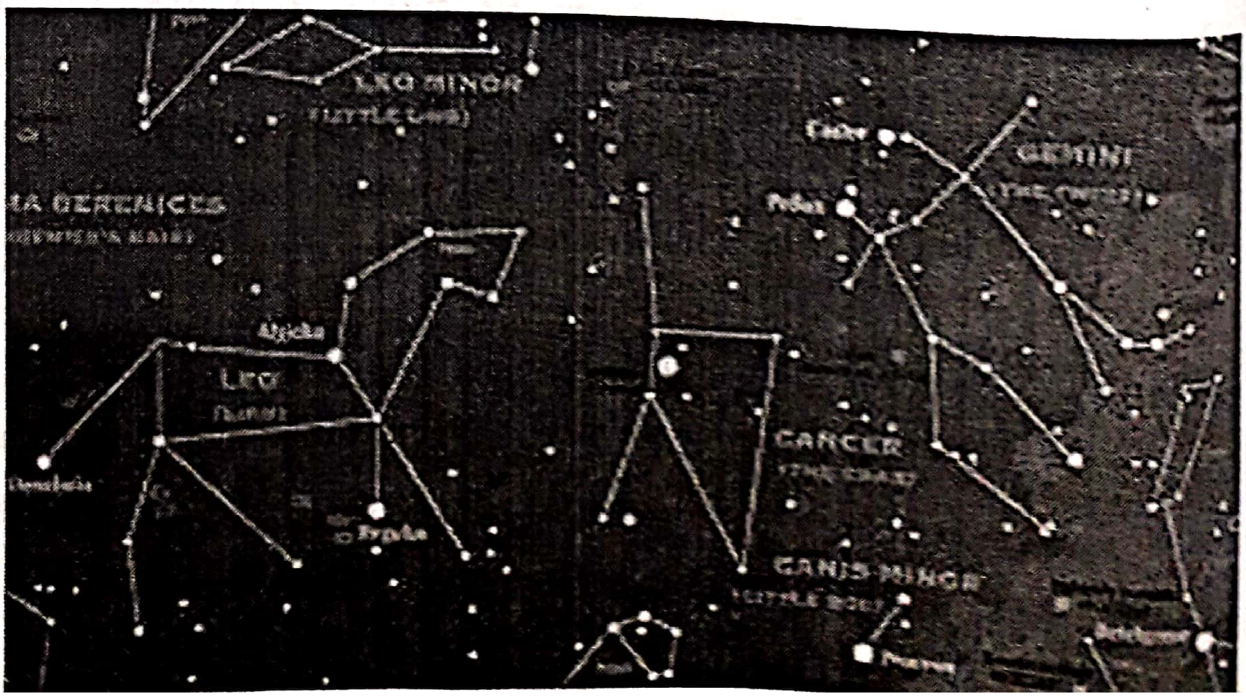


Figure 3.9

The outermost layer of the Sun is called Corona [See Figure 3.9], constantly changing halo of plums and loops of very hot gases upto 1.6 million km thick. The temperature is around two millions°C. It is visible to naked eye during total eclipse only. Prominences are cool, dense, flame-like clouds in the upper chromosphere and lower corona forming massive arches or loops. They are supported by magnetic fields which gives them the arched shape. They are most common during the solar cycle. Active prominences display rapid motion and are usually concentrated near the equator. But quiescent prominences are arch–shaped, and are concentrated at the poles. They can be tens of thousands of kilometers high and tend to be lasting for several months. Solar flares are violent short–lived bursts of magnetic energy that emit radiation and charged particles into space Flares occur in the lower corona and in the chromosphere. They last for 20 minutes. The longest flare observed was for 13 hours on August 16, 1989. These bursts throw particles into space to form the solar wind. The particles mainly consist of electrons and protons. When they reach the surface of the Earth they are deflected by the magnetic field of the Earth towards the polar areas. At altitudes of 100-200 km, these charged particles ionize the atmosphere gases and form the auroras. At high northern latitudes they are called aurora borealis and at high southern altitudes they are called aurora australis. There are certain temporary bright patches. Patches on the surface of the Sun called Faculae. They are sites of strong magnetic fields and are hotter than the normal surface temperature. Facula appear often before the formation of Sunspots and persists for a several days after the Sunspot have vanished. Sunspots go through a cycle lasting for 11 years. At the beginning, the Sun is free of any spot. A few spots then appear high and low on the Sun's surface. They grow in numbers, then gradually die away. During this time there will be an increase in flares and stronger Solar winds. During these times more charged particles from the Sun reach the Earth. They intensify the effects of the northern and southern aurora. These charged particles can interfere with radio signals can cause surges in power lines and blackouts. Heat flows from hot body to cold body. The sun is hotter on the inside. The edge of the sun called limb in astronomical nomenclature appears darker than its centre. This is called limb darkening.

THE STARS

Stars are a violent, spinning ball of hot luminous gas. The gases inside star are held by gravity. Stars get their energy through the nuclear fusion of hydrogen gas. The amount of gas inside a star influences the gravity, temperature, pressure, density and the size of the star. There are around 200 billion stars in our galaxy alone. Out of these only 6000 are visible with naked eye from the Earth. They display a great range of sizes, brightness, colour and stages of development. Astronomers have grouped the stars into constellations. They divided the stars into groups and draw imaginary pictures around them so that they can easily be remembered. (Figure 3.10).



Gemini Aries Aries, Taurus

Stars display a great range of sizes, brightness, colour and stages of development from red giants to white dwarfs, nebulae to supernovae. The stars closest to Earth are (i) Proxima centauri 4.24 light years away and (ii) Alpha centauri A and (iii) Alpha centauri B, both 4.34 light years away. Next comes Barnard's stars 5.97 light years away. The stars in a constellation are actually unrelated. When observed from the Earth they only make these groups. The stars are so far away that they appear to be at the same distance to move together as if stuck on the inside of an enormous bowl called the celestial bowl [See figure 3.11]. The sun appears to move against a background of stars when viewed from the Earth. The star groups it moves in front of are known as the zodiac. Astronomers use an internationally agreed system of 88 constellations. Twelve of the constellations together are known as the zodiac. Individual stars are identified within a constellation by a Greek letter. The brightest star is Alpha, the next Beta and so on. The 12 Zodiac constellations of antiquity are Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius and Pisces [See Figure 3.12(a)]. Since these constellations represent animals, the name Zodiac is used.

Gemini

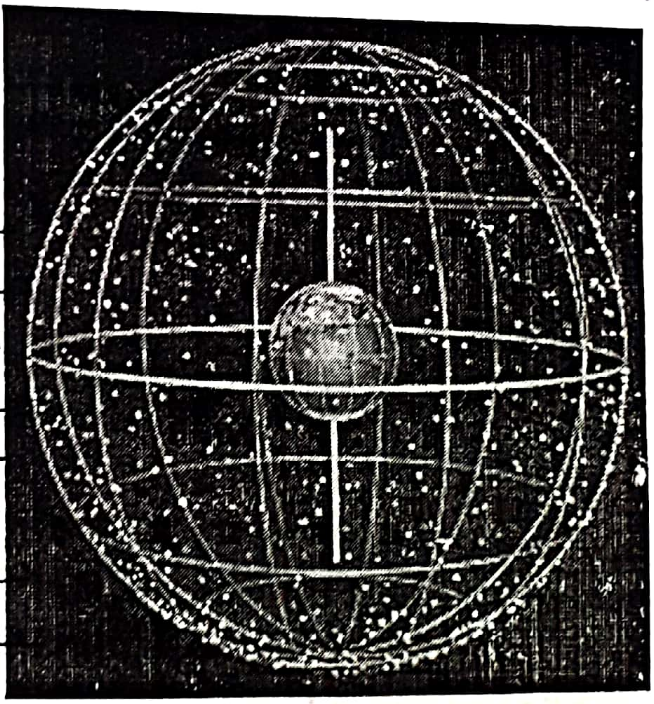


Figure 3.11

Taurus

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Cancer

Aries Taurus Gemini

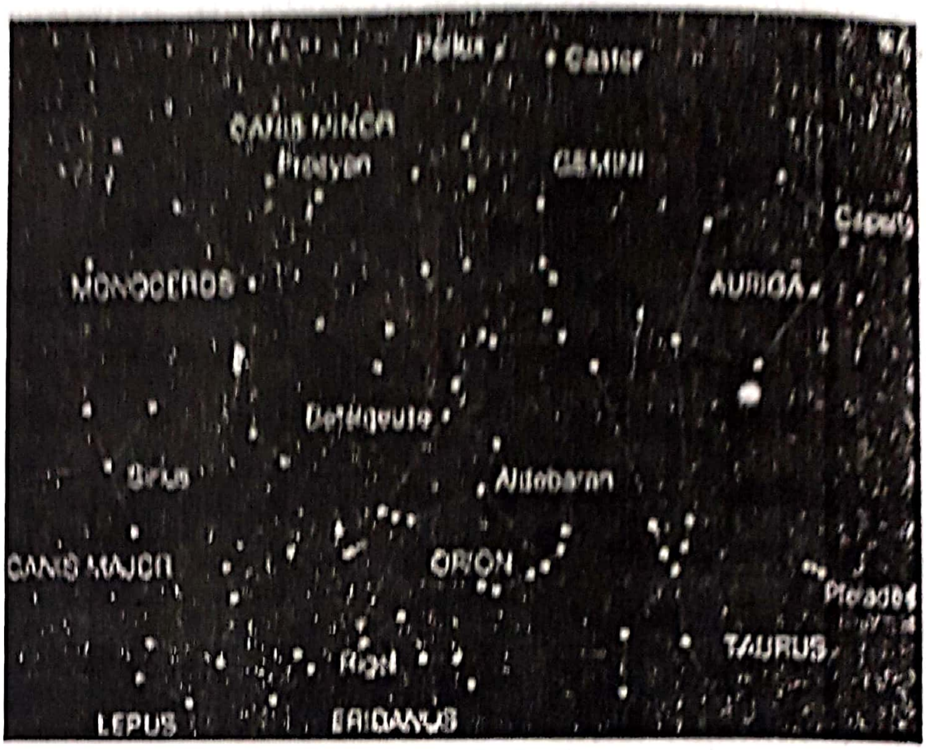

Figure 3.12(a)

Through spectroscopic observations the physical characteristics of stars like temperature, pressure, density and elemental composition can be studied. Based on the spectroscopic observations the stars can be classified. based on the type, strength and number of spectral lines. At first, the spectra were classified in the alphabetical order A, B, C etc. Later it was felt that the classification based on the temperatures of the stars are more meaningful. This type of classification is the basis of Henry Draper catalogue of stars which contains

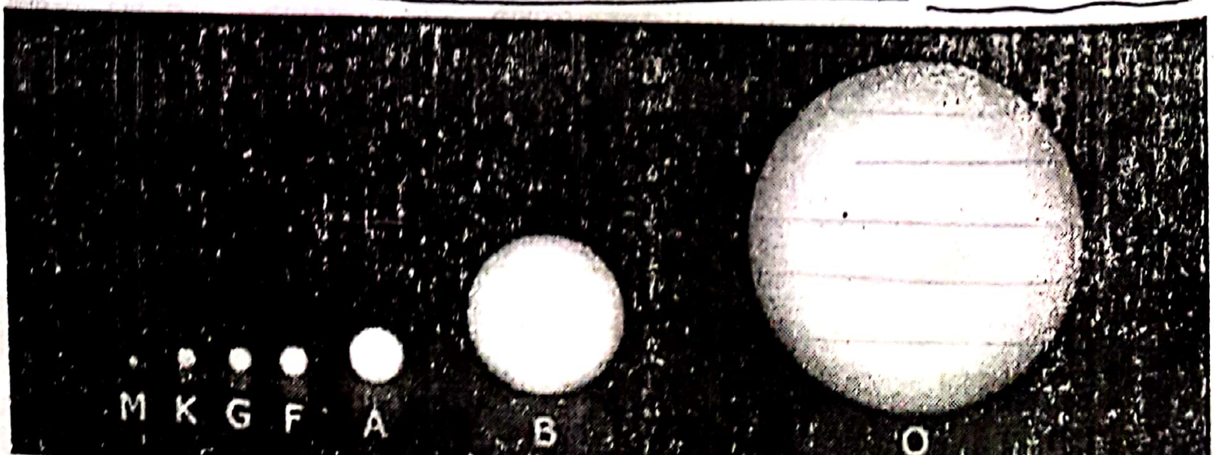

Figure 3.12(b)

Aquarius, Aries, Leo, ...
On

the spectral types of more than two hundred thousand stars. The classification sequence is O, B, A, F, G, K, M, R, N, S, and is known as the Morgan-Keenan spectral classification of stars [See Figure 3.12(a) and 3.12(b). This can be remembered through the mnemonic "Oh Be A Fine Girl Kiss Me Right Now Srimati". Each spectral type is divided into ten subdivisions ranging from 0 to 9. In the case of G type star the range is from G0 (hotter) to G9 (cooler) star. The sun belongs to G5 type. The O, B and A type stars are called hot stars and they have temperatures greater than 7600 K. Stars of types F0 are called cool stars. A Be star means a B type star with H_α emission line.

According to Stefan-Boltzmann's law the total amount of radiant energy E emitted per second per unit area of the surface of a black body is directly proportional to the fourth power of its absolute temperature (T).

$E = \sigma T^4$ were σ is the Stefan's constant. The luminosity L of a star is the total amount of energy emitted which is equal to the radiancy times the surface area of the star.

$$\boxed{L = 4\pi r^2 \times \sigma T^4}$$

where r is the radius. Knowing the values of σ, L and T, r can be calculated. The relation between colour and brightness of stars belonging to the same group was studied by Ejnar Hertzsprung. Henry Russell plotted a graph showing the variation of distance of the stars with their luminosity. This graph is called Hertzsprung – Russell diagram or H-R diagram as shown in figure 3.13. From the diagram it can be seen that most stars are crowded along a diagonal line called the Main Sequence. The hot OB stars occupy the top left hand corner and cooler stars lie at the lower end of the main sequence strip. The stars in the main sequence generate energy by fusion of hydrogen into helium in their cores. Using H-R diagram the evolution of stars can be understood. When a stars starts shining, it

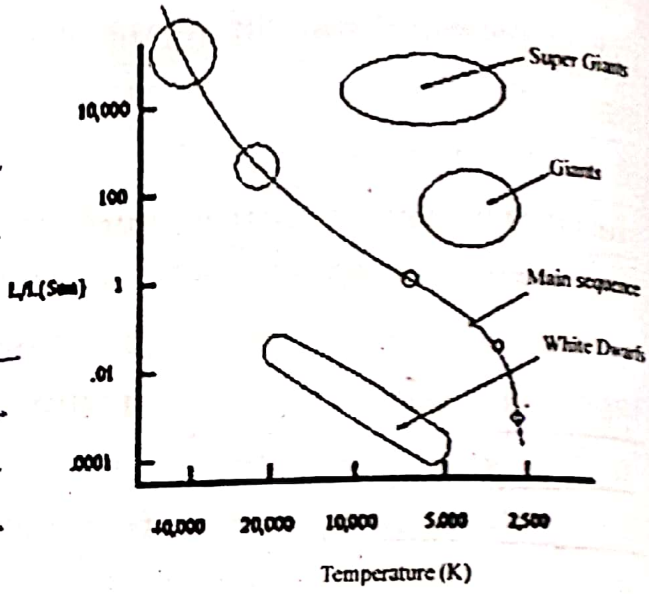

Figure 3.13

is quite cool at the surface and is located in the lower right position of the H-R diagram. Due to contraction the temperature and luminosity rises rapidly and the star moves upto the left in the H-R diagram. During this stage nearly 50% of the energy of condensation and much gas is dissipated into space and is called T.Tauri stage.

formation of stars –

Stars are born when a diffuse, cold, gas cloud collapse under shock wave generated by a supernova explosion. Heat is generated, the cloud shrinks and rotates fast and faster so that the angular momentum is conserved. Some of the material of the original cloud forms a disk rotating around a central body due to the rotating force. When the core temperature reaches 10^7 K proton-proton chain reaction starts. A single star with a planetary system or a double star or a multiple star may be formed, depending on the type, size and dynamic of the original gas cloud. Due to fusion of hydrogen energy is released. When hydrogen is exhausted energy production decreases, the core contracts and the temperature rises. In the case of sun the temperature rises from 15 to

100million kelvin. The energy released will not be radiated away because it is so fast. Hence the star expands and the surface of the sun will reach half way between Mercury and Venus. Due to the expansion surface temperature decreases to 3000K, luminosity increases and the star become a red giant. So its position changes to right up in the H-R diagram. After 5 million years Sun will become red giant. Then temperature on earth will rise, water will be vaporized, all life will be finished.

In the case of stars in the middle part of the Main Sequence, when the star expands, the surface layer cools off. By capturing free electrons, neutral hydrogen and helium atoms are formed. Energy is radiated away. The surface cools and shrinks. Once shrinks it gets warmed and get closer to the photons from interior. Now the surface layer is ionized, free electrons are released and layer expands. This process is repeated, the oscillating period can be between 1 to 100 days in the case of Cepheids. The RR Lyrae stars have period less than one day.

When the core collapses, the temperature rises to 10^8 K and the helium fuses to produce beryllium. But three ^4He atoms they combine to form ^{12}C nucleus with the release of energy. If the mass of sun is less than 2 solar mass, the helium burn to produce helium flash. In the case of Sun the fusion of helium to produce carbon will last about a billion years. During that time the following nuclear reaction will take place.

$^{13}C + {}^4He \rightarrow {}^{16}O + \text{neutron}$

$^{17}O + {}^4He \rightarrow {}^{20}Ne + \text{neutron}$

$^{21}Ne + {}^4He \rightarrow {}^{24}Mg + \text{neutron}$

The neutrons produced are absorbed by other elements to produce heavier elements

$^{56}Fe + n \rightarrow {}^{52}Fe$

$^{57}Fe + n \rightarrow {}^{58}Fe$

$^{58}Fe + n \rightarrow {}^{59}Fe$

$^{59}Fe + n \rightarrow {}^{59}Co + \beta^-$

$^{59}Co + n \rightarrow {}^{60}Co$

$^{60}Co \rightarrow {}^{60}Ni + \beta^-$

In this way bismuth – 209 will be formed. This process takes place slowly. So it is called s-process. Since the next element after bismuth is polonium which is unstable and decays to lead, there will not be any process after bismuth. When the whole helium is converted to carbon, the star stops producing energy. Its core once again collapses and greater amount of energy is released. Now the star expands to a red super giant. The luminosity increases up to 10,000 times. In the case of Sun, it will expand beyond Mars and it will engulf the earth. In our galaxy there are a number of red super giants.

Red super giants expand and mass are ejected out, about half of its mass. Only carbon core, very hot is left. Since there is no reaction it shrinks and becomes a white dwarf, as in the case of Sun. According to Chandrasekhar, if the mass of the star is less than 1.4 solar mass, the collapse will be stopped by the carbon core. This is called Chandrasekhar limit. The white dwarf about 10 billion in our galaxy, radiate away energy, they get cooled and become brown dwarf and then dark dwarf. Stars having mass greater than 3 times solar mass, will become blue giants, because nuclear reaction will be faster and the surface temperature will become 25,0000 K and it will shine with a blue colour. Example is the Rigel star

In the case of a star having mass greater than three solar masses, on completion of the triple alpha process, the core contracts and the temperature rises sufficiently so that fusion of ^{12}C takes place and new elements ^{16}O, ^{20}Ne and ^{24}Mg are formed as per the reaction given below

$$^{12}C + {}^{12}C \rightarrow {}^{16}O + 2\,{}^{4}He$$

$$^{12}C + {}^{12}C \rightarrow {}^{20}Ne + {}^{4}He$$

$$^{12}C + {}^{12}C \rightarrow {}^{24}Mg + \gamma$$

The temperature of the carbon core can become 10^9K, if the mass of the star is greater than 8 times solar masses. Under this temperature fusion of oxygen takes place

$$^{16}O + {}^{16}O \rightarrow {}^{24}Mg + {}^{22}He$$

$$^{16}O + {}^{16}O \rightarrow {}^{28}Si + {}^{4}He$$

$$^{16}O + {}^{16}O \rightarrow {}^{32}S + \gamma$$

If the core temperature is still higher alpha particles and neutrons are produced during the nuclear reaction, which convert ^{40}Ca to iron. When the core temperature reaches 4×10^9 K, the process stops. In a Star having a mass 25 times Sun, first the hydrogen will fuse, then carbon will fuse for 600 years, oxygen for 6 months and silicon for one day. Ultimately the massive star will have a layered structure with iron core surrounded by other lighter elements. Since the iron core does not fuse, but due to the production of energy, the star blows up and 90% of the mass flies away in space. This is called Supernova explosion.

NEUTRON STARS AND BLACK HOLES

A neutron star is a dim star of high density, rather highest density in the sense that a pinhead of its matter would have a mass of a million tonne, at the end of its life cycle and composed of neutron only. When a star several times heavier than the Sun dies, its core collapse to become a neutron star, with a mass between 1.4 to 3 times the Sun's mass. The collapse is so violent that the electrons and protons within atoms are forced together to form neutrons. The gravity on the neutron star is so intense that, if you were to land on a neutron star, then the force would flatten your body, spreading it thinner and thinner over a wide area until it could be flattened no more. Stars whose cores' mass is in between 1.1 and 3 solar masses, the implosion will force the electron to combine with protons and form neutrons and the star will become a neutron star, 5 to 15 km in radius having a density of 10^{14}gm/cm^3, same as that of nuclear matter.

Due to implosion the radius decreases. To conserve angular momentum of the star its angular velocity increases. The fastest rate of rotation of the known neutron star is 642 turns/sec.

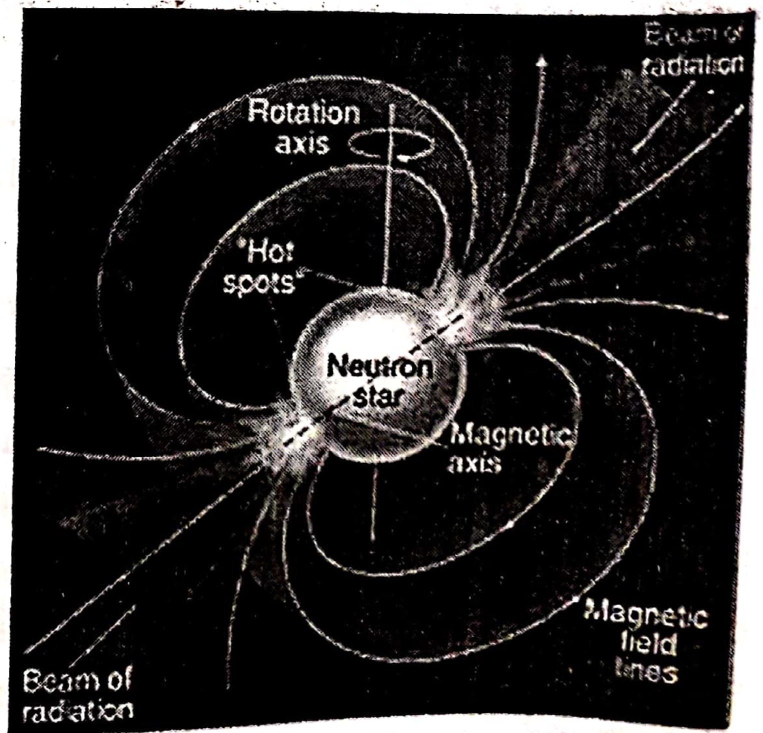

Figure 3.14(a)

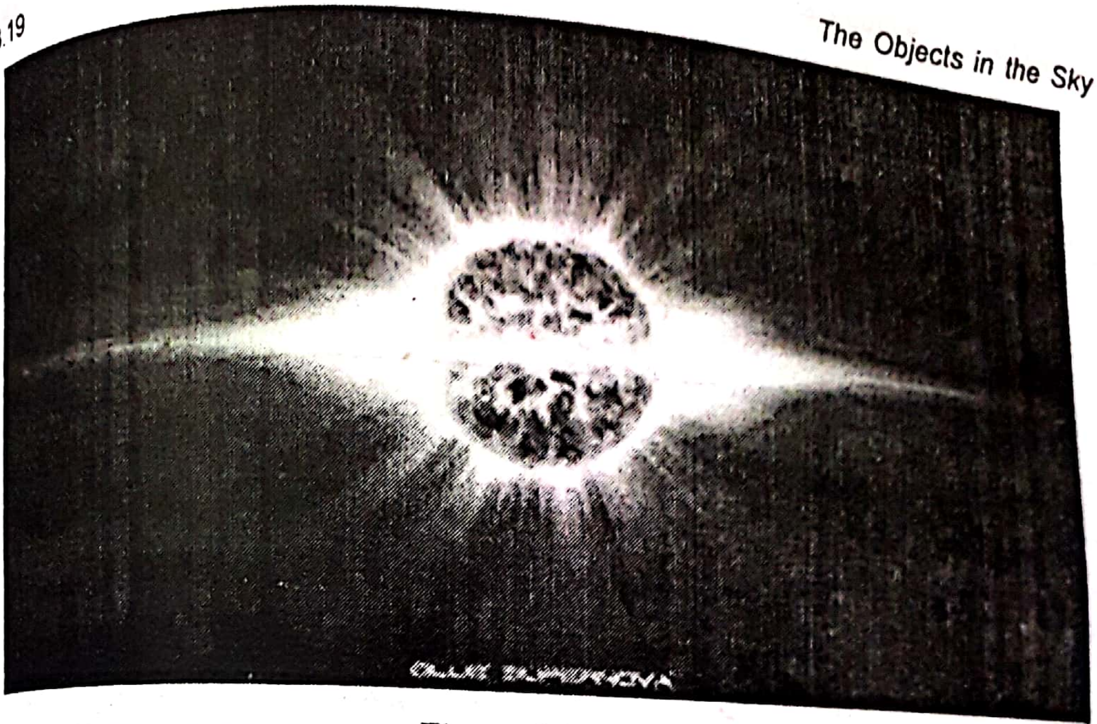

Figure 3.14(b)

Due to the interaction between the magnetic field of the neutron star and the ejected matter, the speed of rotation is different for different neutron stars [See figure 3.14(a)].

The neutrons at the surface of the neutron star decay into protons and electrons. The charged particles spiral in opposite directions outward along the magnetic axis due to the magnetic field of the neutron star. When they accelerate radiations called synchroton radiations are emitted [See figure 3.14(b). The power radiated is inversely proportional to the fourth power of mass. Since the energy of the electron has wide range of values, the electromagnetic radiation of different wavelengths are emitted, which escapes along its magnetic axis. Since the axis of rotation and the magnetic axis do not coincide, we can see the light only if we are along the line of sight. So each time the neutron star makes one rotation, we can see the light like a beam from a light house. So the neutron stars are also called pulsars. The first pulsar was observed by Jocelyn Bell in 1967. After that more that 300 pulsars have been discovered. The amplitude of the pulse may vary but period remains constant. More than 80% of pulsar are less than 20 million years old. If the mass of the core is greater than 3 solar mass, due to implosion the matter collapse into a single point called singularity. The gravitational field near the singularity is so strong that even light will not escape. So this object is called a black hole. The light can escape only beyond a certain distance from the singularity and this distance is called scwarzchild radius. The surface of the sphere with scwarzchild radius is called event horizon. For a non rotating black hole, if r is the scwarzchild radius, M is its mass and G is the universal gravitational constant then $\boxed{r=2GM/c^2}$ where c is the speed of light. If the planet Saturn becomes a black hole then its scwarzchild radius would be about one meter only and its density would be 0.16×10^{24} gm/cm^3 which is much greater than that of nuclear matter. The density of a black hole is the mass of the singularity divided by the volume of the sphere with radius equal to the scwarzchild radius. The mass of the black hole [See Figure 3.15] is concentrated at the center and the remaining part of the spherical region is empty. With increase in mass the density increases. Black hole cannot be identified easily because even

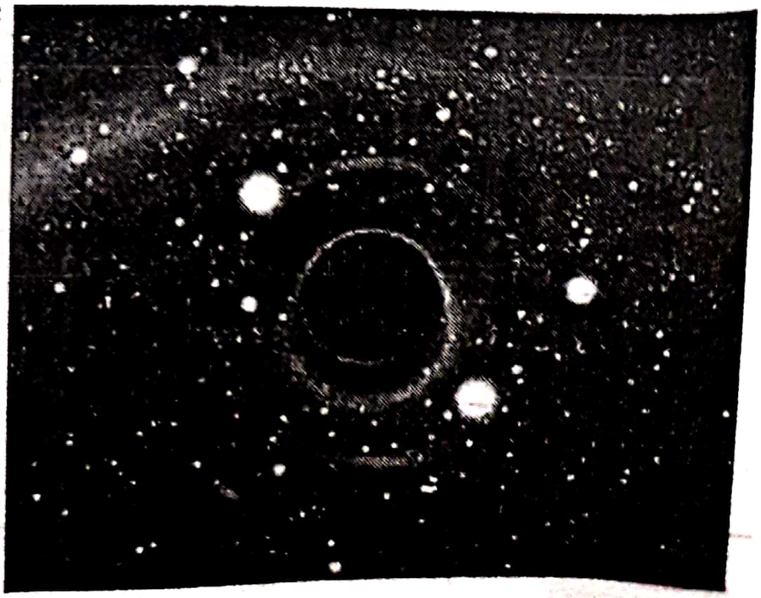

Figure 3.15

light cannot escape from it. Suppose some mass falls into it then it can emit some radiation detecting which the black hole can be identified. Also the presence of black hole can be felt if it has a companion star, through the gravitational perturbatiuon of the companion star. Only three object in the sky are identified as black holes. The black holes need not exist for ever because according to Stephen Hawking it can evaporate due to the presence of virtual particle-anti particle in the event horizon of the black body. The scwarzchild radius of Sun is 3 km only. This means if the radius of Sun is brought below 3km, it would become a black hole. The time required for a black hole to evaporate depends upon its mass. For a massive black hole the time required is longer than the current accepted age of the universe. Suppose a black hole was formed during the time of big bang and it is to evaporate now its mass should be about 10^{15} grams.

SUPERNOVA

Sun supports life on Earth. Stars support life in the Universe and they control the activities of the Universe. Supernova is an explosion producing brilliant light visible for weeks in the sky. There are two categories; type I and type II. The type I occurs in binary stars where one is red giant and the other is a white dwarf. Type II occurs when a red giant or red super giant explodes. In type I supernova the hydrogen Balmer lines are absent but in type II they are present. Type I Supernova is a nuclear explosion on the surface of white dwarf caused by the accretion of hydrogen [Figure 3.16]. The type II supernova is the explosion of a star after its main sequence life is over. Its core collapses, a large amount of gravitational energy is converted into heat. This generates powerful

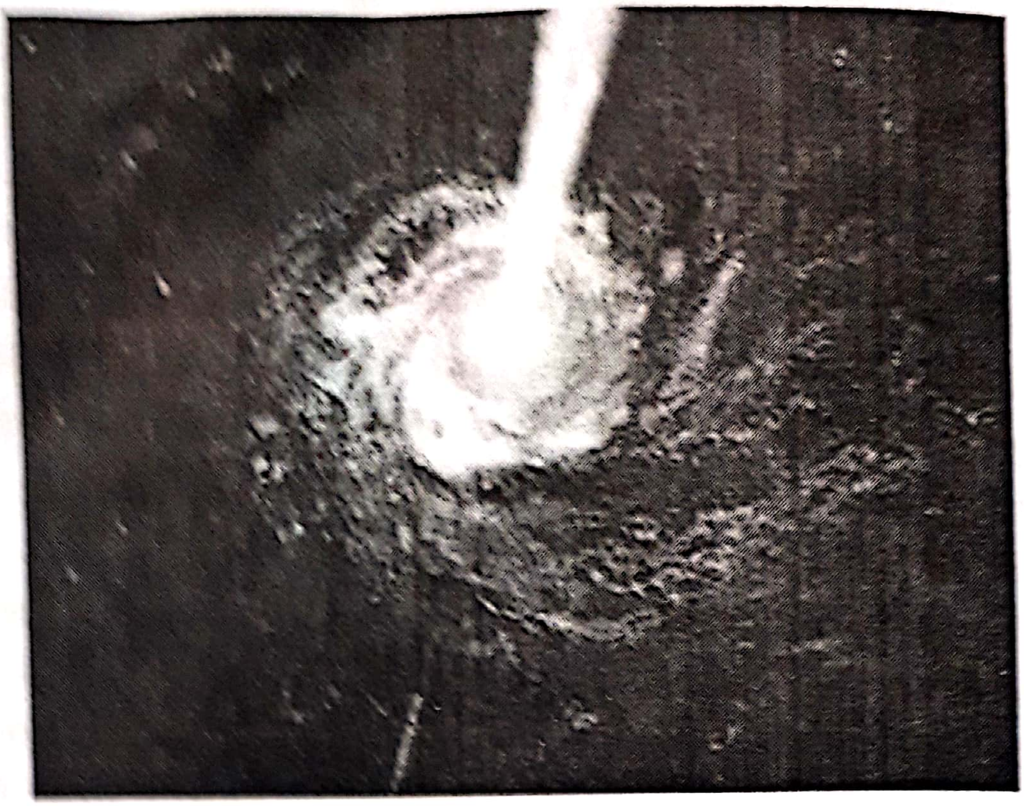

Figure 3.16

blast or shock waves which ejects the star's envelope into the interstellar space. The explosion produces very bright object consisting of plasma, which remains visible for weeks or months. After Supernova the star can become a neutron star or a pulsar or a black hole. During the explosion nuclei of heavier elements are broken and neutrons are freed. But the freed neutrons are quickly captured by lead and bismuth nuclei to form different heavier elements upto thorium, uranium and beyond. Since the process is rapid it is called r-process. The unstable elements like polonium, radium, radon, actinium, do not get time to decay. During Supernova explosion other unstable elements like technetium, promethium and transuranic elements are also produced.

In the spiral galaxies there are two or three supernova explosions per century. In our galaxy during the past 1000 years four supernova explosions have been observed even though more have taken place and those were not visible.

The brightest supernova explosion occurred and was seen from Earth in 1054, in Crab nebula which is 6,500 light years away. This means the explosion took place in the year 5450 B.C. and we have seen it in 1054. During Supernova explosion the new elements and isotopes formed are scattered into interstellar cloud of gases and dust. They mix with hydrogen and helium atoms. New stars formed from this mixture will have heavy elements like thorium and Uranium. Again the stars with heavier elements undergo explosion, this process continues and new stars with heavy elements are born. The shock waves created by the explosion can trigger the formation of new star.

The variation of the abundance of the different elements in the solar system with the atomic number is as shown in figure 3.17. Hydrogen and Helium are most

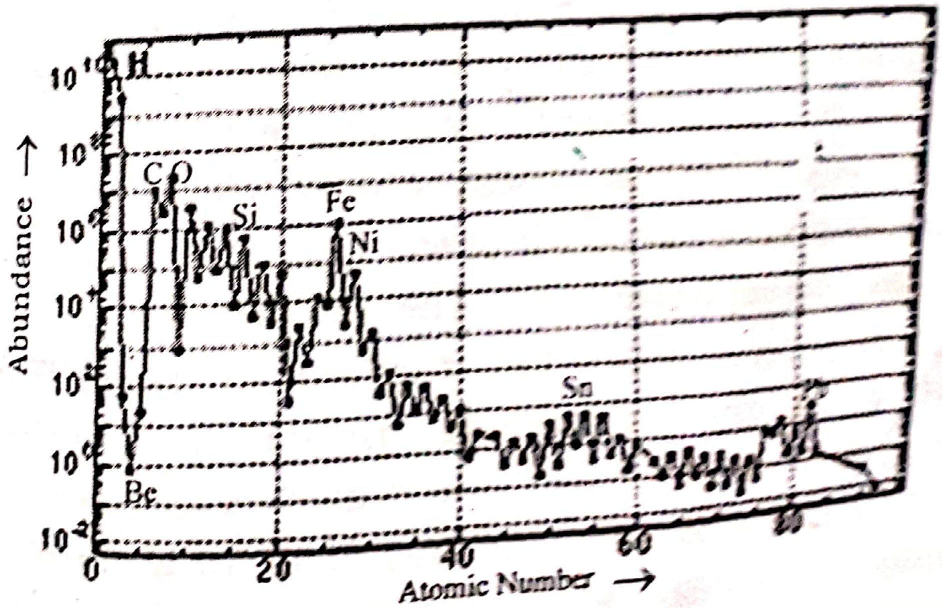

Figure 3.17

abundant, about 98% of the total. The elements with even number of protons and are more abundant than those with odd numbers because their nucleus of iron is tightly bound to each other. The nucleus of iron is very strongly bound so it is abundant. The abundance of nuclei with their number of protons or neutrons or both equal to 2, 8, 20, 28, 50, 82, 126 are well bound and their abundance is greater. These numbers are called magic numbers and they refer to the shell model for the structure of nucleus.

GALAXIES

The star cities where star live together are called galaxies. A collection of huge matters floating in space, a gravitationally bound system consisting of planets, stars, interstellar gas and dust and the dark matter is called a galaxy. Most galaxies contains a large number of multiple star systems, clusters of stars and different types of nebulae. There are 10^7 to 10^{12} stars orbiting around the centre of gravity of the galaxy. The diameter of the galaxies varies from several thousand to several hundred thousand light years. The space between the galaxies is called intergalactic space : Galaxies, these enormous collections of star started off as huge clouds of gas soon after the birth of the Universe. Gravity pulled the gas into separate stars. The galaxies are so vast that it takes several years for starlight to travel from one side to the other. The stars are arranged within in a galaxy in a particular way and it gives a distinctive shape to the galaxy. The sun, our star, lives in a spiral shaped galaxy called Milky Way. Till the present century it was believed that the Milky Way galaxy was the only galaxy in the Universe. But you know, at present we have 100,000 million galaxies and are categorized into three.

(i) Elliptical galaxies

(ii) Spiral galaxies

(iii) Irregular galaxies

This system of galaxy classification was made by Edwin Hubble and hence it is called Hubble sequence as shown in Figure 3.18.

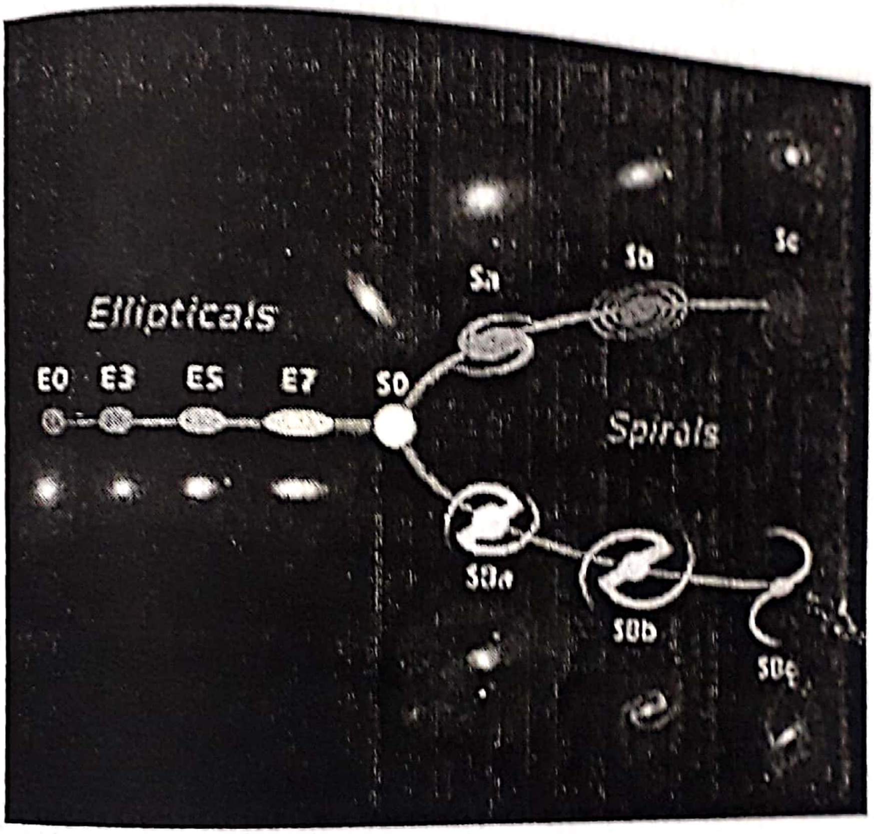

Figure 3.18

Elliptical galaxies are flattened ball-shaped collection of old stars. They are the most common type of galaxy in the Universe. Example is M49 Elliptical galaxy .It has a diameter of 50,000 light years. The Elliptical galaxies contain 10^6 stars to 10^{12} stars. Elliptical galaxies are named from E_0 to E_7. E_0 has the shape of a ball which could be giant globular clusters. E^7 has the shape of a disc.

Spiral galaxies contain young and old stars. They are disc shaped with spiral arms. Their arms are centred about the central bulge and vary from one galaxy to another. The galaxies are named from Sa to Sd, S stands for Spiral. If a number 0 is attached to S, then it means that it has no arm (So). A bright central disc with smooth but tightly wound arms is denoted by Sa. If the galaxy has very loose arms generating most part of the luminosity then it is denoted by Sd. NGC 5194 is an example of spiral galaxy. The spiral galaxy contains 10^{10} to 10^{11} stars. Other examples of spiral galaxies are triangular galaxy, whirlpool galaxy, Andromeda galaxy and sunflower galaxy. Our Milky Way was considered to be a spiral galaxy. For a long time, but recent researches have shown that it is a barred spiral.

Irregular galaxies are those that have not formed into a specific shape. They are the rarest in the Universe. These galaxies do not fall into Hubble classification. They have a chaotic appearance. From their structure a nuclear bulge or a spiral arm could not be traced out. They form about 10% of the galaxies. It is believed that the irregular galaxies were once spiral or elliptical in nature, but then deformed by the action of gravitation. Examples of irregular galaxies are IC 1613, IC 10, Leo A, Messiner 82, NGC 1569 etc. The irregular galaxies and the spiral galaxies contain interstellar gas and are the site of star formation. Gravity waves are produced from spiral galaxy due to gravitational interference among the individual orbits of the stars around the galactic centre. These waves move through the space at a speed of 30 km/s and produce shock waves, which results ultimately in the formation of the new stars. The study of orbital motion of the stars in spiral galaxy led to the existence of dark matter. It was observed that at a distance of 10,000 light years from the centre of the galaxy the orbital velocity was not decreasing. From that it was concluded that there is invisible dark matter increasing in concentration from the centre of the galaxy with distance as shown in figure 3.19. The dark matter is assumed to

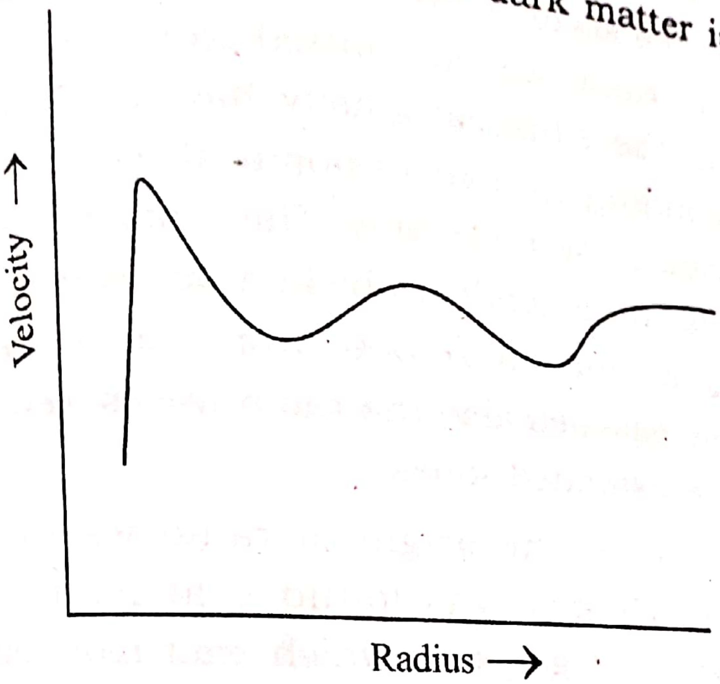

Figure 3.19

be made of neutrinos of mass 1.8×10^{-5} u. Our galaxy is a spiral galaxy 50,000 ly in radius and 1000 ly thick at the centre. The speed of the galaxy increases radically outward. At the centre it is 150 km/S. But at a point half way from the centre where the Sun is present the rotational velocity is 225 km/s. The variation in the rotational velocity shows the existence of dark matter, whose distribution is different at different points as shown in figure 3.20.

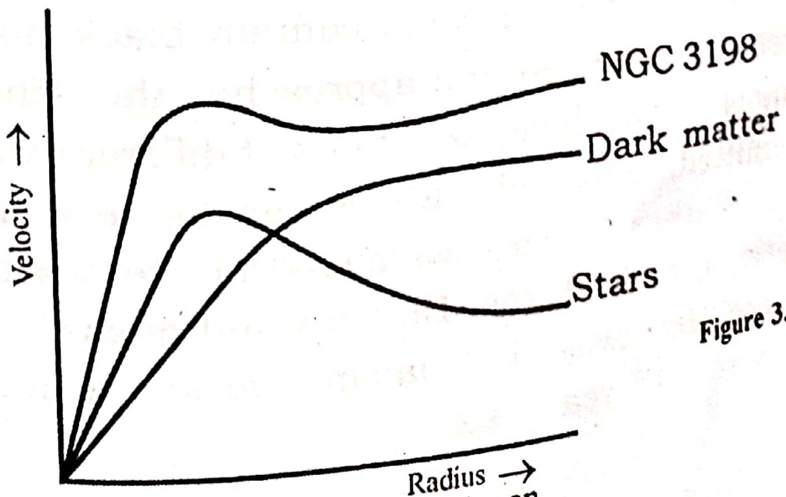

Figure 3.20

Radio telescopes are used to study the instant stars. The radio waves emitted from the galaxies were received and studied by the radio engineer Karl Jansky and Grote Rober. Powerful radio waves emitted from the Cygnus constellation in the elliptical galaxy had a red shift of 0.057, corresponding to a recessional speed of 16,600 km/s and a distance of 9.22×10^{8}ly. The radio waves were emitted from the two extended lobes on opposite sides of the galaxy at a distance of 16,000 from the centre. For other 75% of the galaxies also the radio waves were seen to emit from the extended lobes.

After world war II, the origin of radio waves were located exactly. Then it was found that many radio sources were so active galaxies, which emit more energy than our galaxy. Seyfert galaxies emit infrared waves. They belong to spiral galaxies. The most active Seyferts are quasars, emitting more powerful infrared waves. The quasars have power in the range from 10^{38} to 10^{41} W. About 1% of quasars are radio sources. For example BL Lacertae objects are similar to quasars, but they emit radio waves. From these observation it was concluded that BL Lac objects are the cores of distant elliptical galaxies and quasars are the cores of Spiral galaxies. It is believed that such cores contain black holes. When matter is accelerated and approaches the Schwarzschild radius of a black hole, radiations of different wavelengths are emitted. Only radio waves can be seen from Earth because other shorter wavelengths are scattered. The radiations received from BL Lacs and quasars show that they are 10^{10} away. This means we are seeing them as they were 10^{10} years ago.

Galaxies can be grouped into different clusters consisting of 10-1000 galaxies, as regular and irregular clusters. In regular clusters the elliptical galaxies dominate whereas in irregular galaxies the spiral galaxies predominate. When galaxies collide, then gases and new stars are formed. The elliptical galaxies formed stars very early and now they are deprived of gas .But spiral and irregular galaxies suffered fewer collisions. So there is sufficient gas and stars form now also. The Universe has a lacy appearance because galactic clusters grouped into super clusters and they were arranged in long, intersecting filaments.