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Geography Preview

GEOGRAPHY

PRELIMS & MAINS

For Civil Services Exams

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CHAPTER 1 UNIVERSE

THE UNIVERSE

The term 'Universe' is made up of two words – 'Uni' and 'Verse'. Uni is a Latin word which means Single (One). The word 'Verse' is derived from another Latin word, which is 'Versus'. The word 'Versus' means turned or combined. Thus, the word Universe literally means everything combined into one or even 'whole'

In simple language, the Universe includes everything. It includes everything from tiny sub atomic particles to larger bodies such as planets, stars and galaxies. It also includes space which is vacuum in nature.

The primary constituent of Universe is the galaxies. Though the estimates vary, as per few estimates, the universe has more than 2 trillion galaxies! These galaxies are made up of stars, planets, dust clouds, interstellar medium (matter that exists in the space between the star systems) and dark matter. Some galaxies are smaller than others, having few million stars, while other larger galaxies have even trillions of stars.

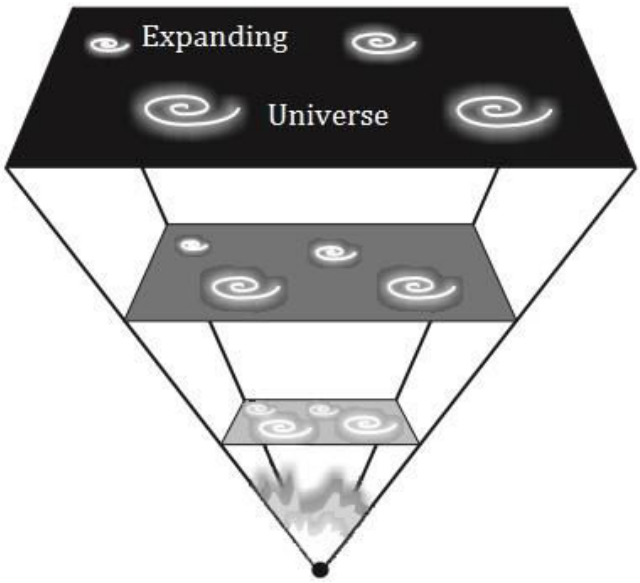
ORIGIN OF UNIVERSE

Since ancient times, humans have been curious about the origin of the universe. However, the origin of the universe has remained a mystery for a very long time. With the help of many theories, astronomers have tried to trace back the events which led to the formation of our universe. A vast majority of these theories were not able to answer counter questions. Hence many of these theories were abandoned but few lead to the development of other advanced theories. With growth in human knowledge, some widely accepted theories were developed which were further validated through experiments and observations. Some widely accepted theories which explain the formation of the Universe are as follows:

Big Bang Theory

At present the most acceptable hypothesis or theory explaining the origin of the universe is the 'Big Bang Theory'. This hypothesis was first proposed in the 1920s. However, the term Big Bang was coined for the first time in 1949.

This theory states that the universe originated from a single point that was in the form of a compact ball. This single compact ball is called 'single primordial atom'. At that time, unimaginably large mass was concentrated in the single compact ball, having very high density and very high temperature. This highly concentrated mass exploded almost 13.8 billion years ago, which led to the birth of the Universe.



The Big Bang

After explosion, the huge mass having extremely high temperature scattered in the space. Gradually, the scattered mass began to cool and formed the tiny subatomic particles (protons, electron, neutrons and others). These subatomic particles merged to form atoms and molecules. Scientists believe that first atoms were formed almost 4,00,000 years after the big bang. One of the earliest formed atoms was Hydrogen. When hydrogen atoms fuse together to form Helium, huge energy is released which leads to the formation of stars and galaxies.

The first stars and galaxies are believed to have formed around 250 million years and 1 billion years respectively after the big bang. New stars and galaxies are forming even today. This causes the continuous expansion of the universe. Our planet earth is much younger and was formed 4.5 billion years ago.

The Big Bang Hypothesis is also called the *Expanding universe hypothesis* because as per this hypothesis the Universe started from a single point and is in continued state of expansion.

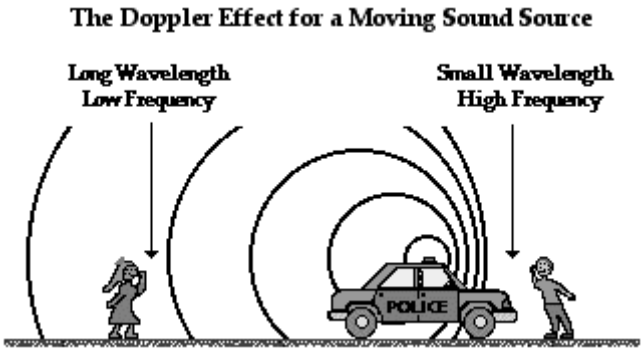
The argument for expansion of the universe is supported by the phenomenon of Red shift. Before understanding Red Shift, let us first understand Doppler Effect because Red Shift is one of the applications of Doppler effect.

Doppler Effect

The Doppler effect is the effect produced by a moving source of waves, in which there is an apparent upward shift in frequency for observers who are approaching the source, and an apparent downward shift in frequency for observers who are receding

from the source. Thus, the Doppler effect is observed whenever the wave source is moving relative to the observer.
It is important to note that the effect does not result from a change in the source's actual frequency. The effect is only observed when the observer's distance from the source is either decreasing or increasing.

The Doppler effect can be observed for all types of waves, including water, sound, and light. Let's understand the application of Doppler effect in case of Sound waves! Can you recall a time when an emergency vehicle approached you on the highway? As the vehicle approached with its siren, the pitch (measure of the sound's frequency) of the siren sound was high; however, as soon as the car passed, the pitch of the siren sound reduces. This is the Doppler effect - Apparent change in frequency of a sound wave which is caused due to movement of a source.

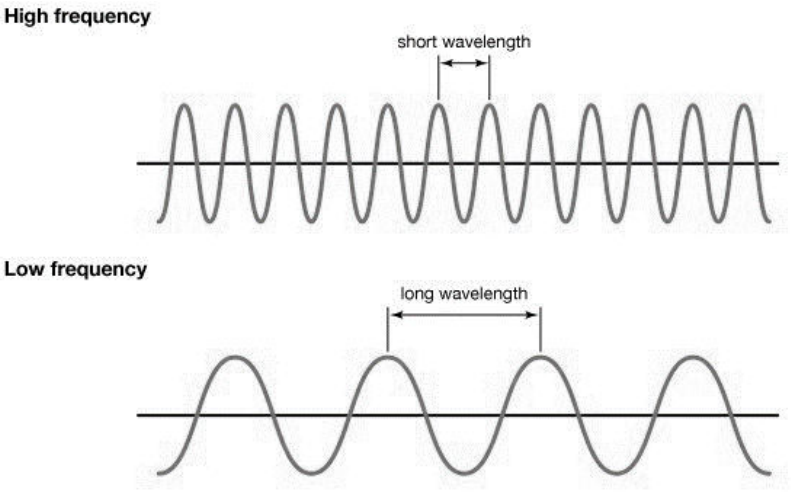


The Doppler Effect in Astronomy
Astronomers study the shift in frequency of electromagnetic waves such as light waves to derive information about the celestial bodies such as stars and galaxies, which are producing these electromagnetic waves. Observations of electromagnetic waves emitted by stars in distant galaxies have contributed to the notion that the universe is expanding.

If the star is moving towards the Earth, the frequency of the light waves coming from star increases (called blue shift). On the other hand, if the star is moving away from the earth, the frequency of the light waves coming from the star decreases (called red shift). Let us under the phenomenon of red shift (and also blue shift) in detail.

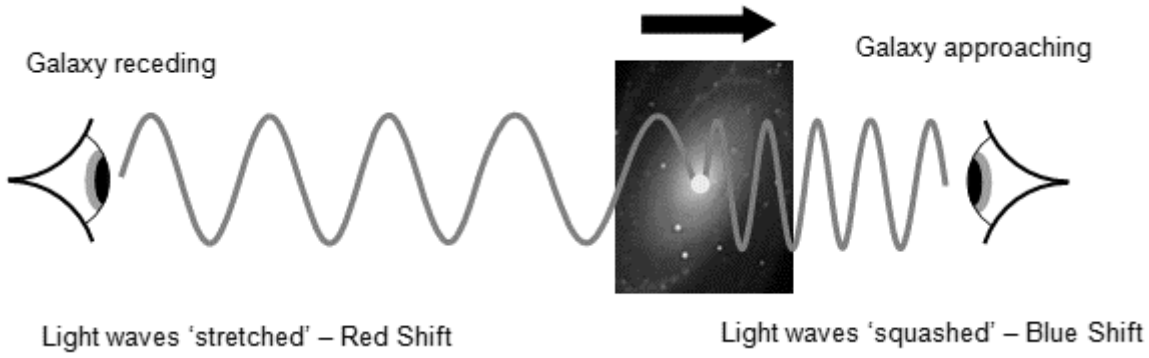
Red Shift
In the spectrum of visible light, red has the lowest frequency and longest wavelength, while violet has highest frequency and shortest wavelength. The arrangement of various colours in the visible light from highest frequency to lowest frequency is in the order of 'VIBGYOR' (Violet, Indigo, Blue, Green, Yellow, Orange and Red).

It is to be noted that frequency of waves and wavelength have inverse relation with each other. The Higher the frequency, the shorter the wavelength; The lower the frequency, the longer the wavelength.



It is observed that light coming from distant stars and galaxies shift towards red-end of the light spectrum and this shift of light is called red shift. Why is red shift taking place?

As the distance of the emitting object increases from the earth, the frequency of light waves reduces and the wavelength increases. So, if light emerging from distant objects is shifting towards red end of the spectrum, it means that the objects are moving away from us.



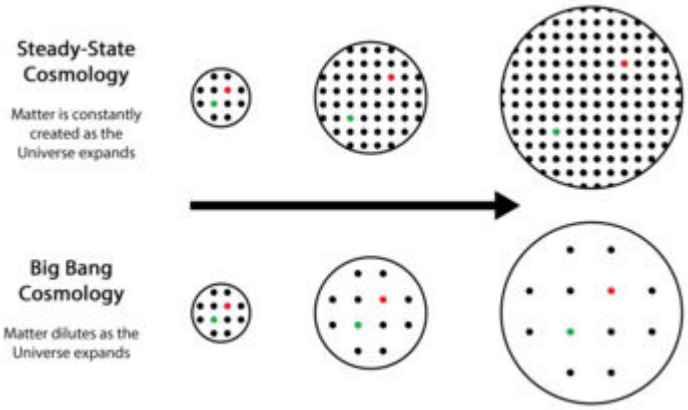
Thus, red shift of the light emerging from various galaxies proves that stars and galaxies are moving away from us and from each other. In other words, we can conclude that the universe is expanding.

Steady State Theory

The Steady State theory adheres to the perfect cosmological principle, which states that the observable universe is essentially the same at all times and in all places. As per

this theory, the density of matter in the expanding universe remains constant due to the constant creation of matter.

This theory upheld the idea of expansion of the universe but explained the expansion of universe in another way than the big bang theory. The theory stated that as the Universe expands, the matter is constantly created. However, the big bang theory states that the concentration of matter dilutes with the expansion of the Universe.



Initially this theory was very popular, but in the 1960s, observations taken from radio telescopes indicated that the universe is changing over time. These developments led to increase in the acceptability of the Big bang theory and decline in the popularity of the Steady state theory. Also, the observational evidence points to a finite age of the universe, which is not predicted by the steady-state model.

Oscillating Universe Theory

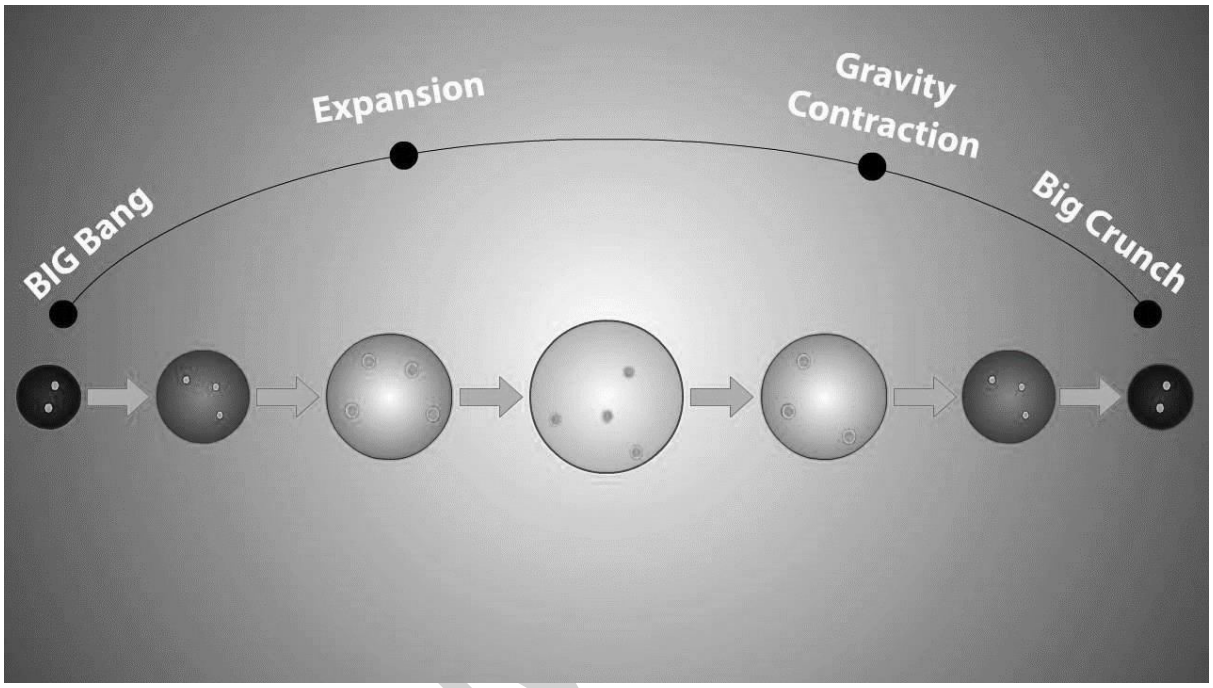
This theory is also called Pulsating theory or Cyclic model of Universe. This theory is an extension of the big bang theory. This theory affirms that at present, the universe is in the state of expansion because of the force generated due to big bang explosion.

The force generated due to big bang is repulsive in nature because it is increasing the distance among objects in the Universe. However, the theory predicts that gradually the magnitude of repulsive force generated due to big bang will be lesser than the gravitational pull of the matter in the Universe. This stage will come after 27.2 billion years (The age of the Universe is already 13.8 billion years!). When this stage will come, the universe will begin to contract and the matter would start moving towards the Centre of the universe. This stage of matter moving towards the Centre of the Universe is called 'big crunch'.

Again, the entire mass of the universe would convert into a compact ball of mass. After the universe has undergone complete expansion, which is 27.2 billion years away, the universe will take 41 billion more years to completely contract. In other words, the universe follows an eternal series of oscillations, each beginning with a Big Bang and ending with a Big Crunch.

Thus, according to this theory, the complete cycle of expansion and contraction of universe takes around 82 billion years (41 billion years for expansion and 41 billion years for contraction).

Once the universe has completely contracted into mass of compact ball, there will be another big bang and the process of expansion will start again. In this way, the process of contraction and expansion is expected to continue forever.



COMPOSITION OF UNIVERSE

In the previous section, we understood about the origin of the Universe. In this section, we will learn about the composition of the Universe. In other words, in this section we will understand what the Universe is made up of. The Universe is composed of Matter, Anti-Matter, Dark matter and Dark Energy. Let us understand them in details.

Matter: Matter is any substance that has mass and takes space in proportion to its volume. Matter can be as small as tiny subatomic particles such as electrons, protons and neutrons and as large as celestial bodies like planets and stars.

However, in the following topics on Antimatter, Dark Matter and Dark Energy, we will notice that they also have mass and they also occupy space. Then, how do we differentiate between the Matter and the rest of the components of the Universe. We can differentiate Matter from Dark Matter and Dark Energy on the basis that the Matter is part of observable universe. In other words, the matter can be studied through available scientific instruments which makes use of electromagnetic waves to study

celestial bodies. On the other hand, Dark Matter and Dark Energy cannot be studied through existing scientific instruments.

The difference between Matter and Antimatter is explained below under the topic of Antimatter.

Antimatter: Antimatter has subatomic particles with opposite electrical charge to that of matter. Theoretically, for every particle of matter, there is an antiparticle (or antimatter). For example, an antiparticle of an electron is antielectron (also called positron). A positron has all the properties of an electron but with positive charge. Antiprotons are antiparticles of protons with negative charge.

Because the sub-atomic particles of Antimatter have opposite charges, it has strong force of attraction towards matter. Thus, Antimatter collides with Matter. This collision results in annihilation of Antimatter and an equal amount of matter and generates a flash of light and energy. It is to be noted that after the big bang, there was large amount of antimatter. However, this antimatter collided and annihilated an equal amount of matter. Only, the remaining amount of matter is left in the Universe. Thus, at present, the Universe does not have anti-matter.

Antimatter is produced naturally in certain types of radioactive decay and is produced artificially in huge particle accelerators such as the 'Large Hadron Collider' operated by European Organization for Nuclear Research at the France-Switzerland border. However, this antimatter gets destroyed as soon as it comes into contact with matter. Thus, antimatter can survive only if it remains in vacuum. It is to be noted that vacuum does have any state of matter, namely solids, liquids and gases. Thus, there is nothing in a vacuum to which anti-matter can collide with.

Dark Matter: Our universe is made up of matter, antimatter as well as mysterious substances and energy. Scientists call these mysterious substances as 'Dark matter' and this mysterious energy as 'Dark energy'. Scientists have reached to a conclusion that our universe is made up of almost 68% dark energy, 27% Dark matter and there is only 5% normal matter which we can detect with the available instruments.

Scientists are not able to detect dark matter with the available instruments because it is completely invisible to light and other electromagnetic radiations. However, scientists are confident of its existence because of its gravitational effect on celestial bodies. Scientists have developed few hypotheses regarding the nature of dark matter. However, till date, they do not understand the actual nature of dark matter.

Dark Energy: Dark energy is even more mysterious than dark matter. In the universe, the space present between matter was thought to be empty. However, now it is believed that there is some mysterious energy present there. This mysterious energy is known as dark energy. Scientists believe that it constitutes 68% of the whole

universe. The very existence of dark energy is confirmed with the expansion of the universe. It is observed that when the universe expands, the empty space develops certain type of repulsive force. This repulsive force is probably due to the presence of dark energy. It is assumed that the dark energy fills the empty space in the universe like a fluid.

Celestial Bodies

Celestial bodies refers to natural bodies which exist in space. It is to be noted that only natural bodies in space are regarded as celestial bodies. Man-made satellites and space stations are not part of celestial bodies.

We can also say that a natural object which is located outside of Earth's atmosphere is a celestial body. A celestial body is also called Astronomical body. Let us understand how a celestial body can also be called an astronomical body!

The word 'astronomical' is derived from the word 'Astronomy'. Astronomy is the study of space and objects in space. Thus, objects in space are also regarded as astronomical objects.

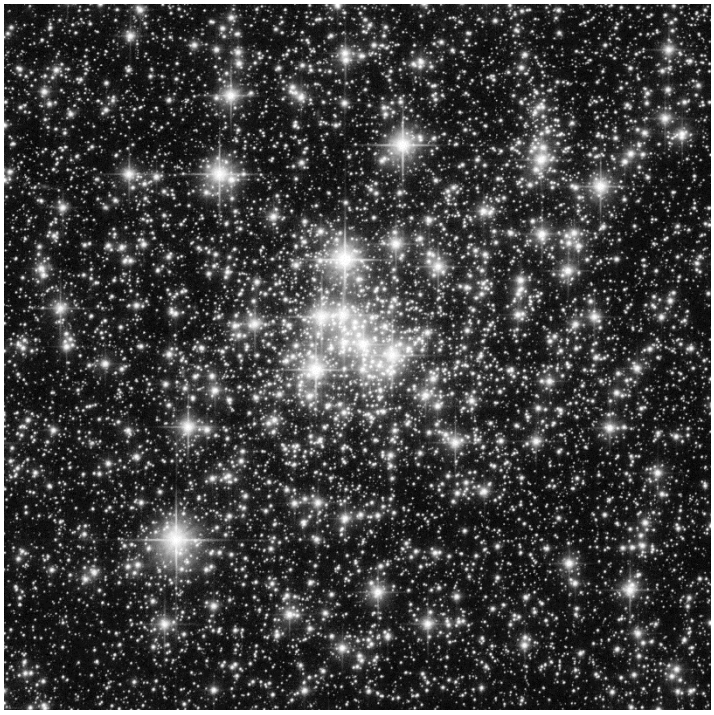
In common parlance, the terms 'object' and 'body' are often used interchangeably. However, in the field of astronomy, there is a difference between the two.

An astronomical body is a single, tightly bound, and hence a contiguous entity; while an astronomical object is a complex, less cohesively bound structure, which may consist of multiple bodies.

Examples of astronomical bodies are a planet, a moon, a star, a comet, and an asteroid. On the other hand, examples of astronomical objects are a planetary system, a star cluster, and a galaxy.

Together astronomical bodies and objects are called components of the Universe. The details about them are as follows:

1. Star: It generates energy in the form of heat and light on account of nuclear fusion. Nuclear fusion is the process in which lighter elements, such as hydrogen, merge to form heavier elements, such as helium. This merger of lighter elements into heavier elements releases energy in the form of heat and light. Bodies such as planets and satellites receive light and heat from the Star.

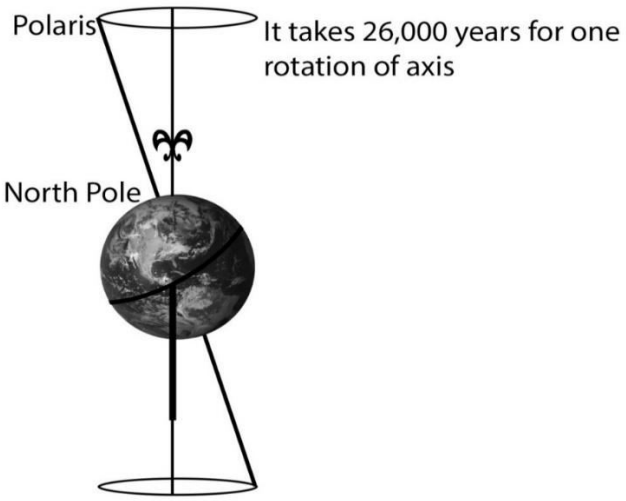


Stars

Sun is the nearest star to earth. Our Solar system receives light and heat from the Sun. After the Sun, **Proxima Centauri** is the next nearest star to the earth. It is located at the distance of 4.2 light years from the earth. (Light Year is the distance travelled by light in vacuum in 1 year. Speed of light is 3×10^5 km/s. Thus, light travels the distance of 3×10^5 km/s × Number of Seconds (Distance = Speed × Time) in the year!

Another star of great interest is **Polaris**. It is commonly known as the North Star or the Pole Star. Its position appears fixed in the sky while all other stars appear to be moving. This is because it lies directly over the Earth's North Pole.

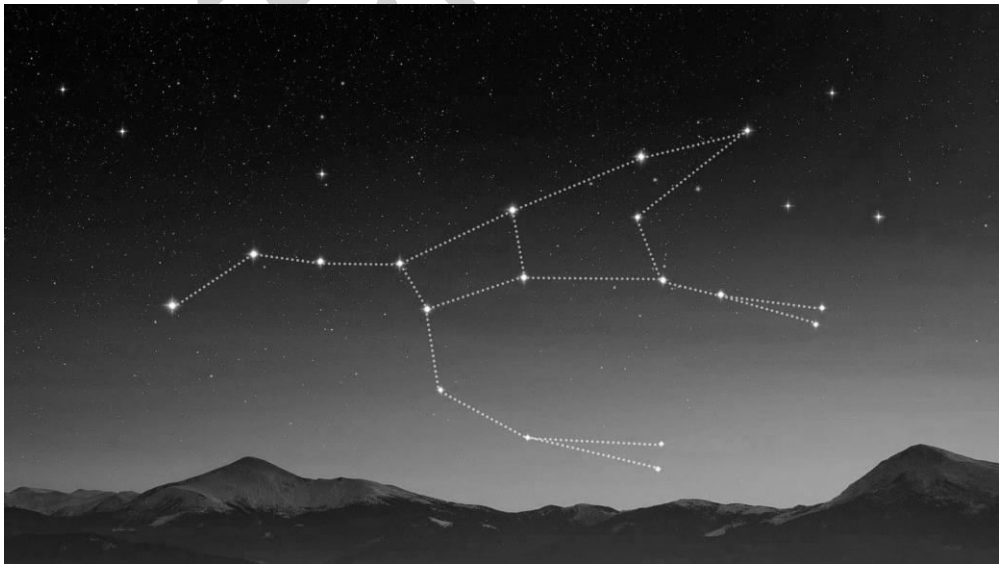
This position however, is not permanent. The orientation of earth's axis too undergoes a change with time. Earth's axis takes 26,000 years to complete one cycle. So, after some hundreds of years from now, Polaris may no longer appear to be the 'static' Pole star as the earth's axis may point towards a new star. The rotation of axis is called Axial Precession. Axial precession is on account of gravitational pull of other bodies.



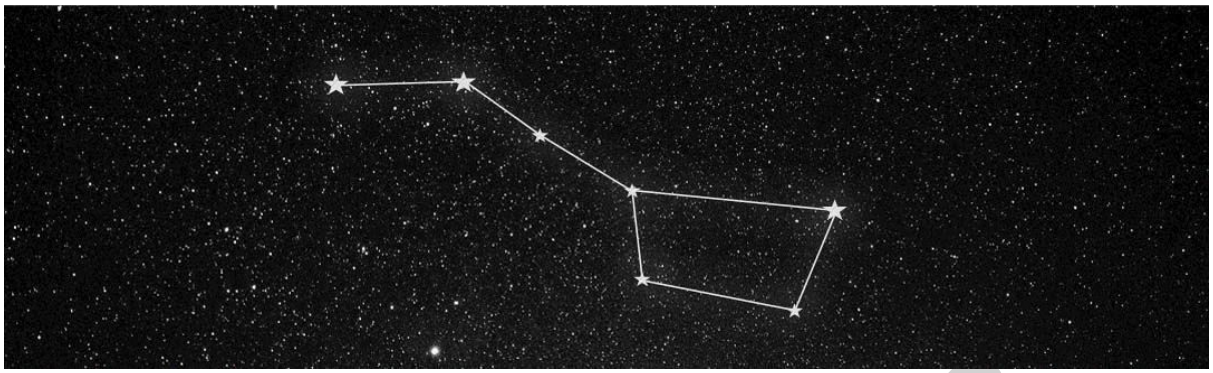
During the course of the night, Polaris does not rise or set, but remains at the same spot above the northern horizon year-round while the entire northern sky moves around it. Thus, Polaris marks the north direction in the sky and helps the travelers in determining the direction of travel.

However, the utility of Polaris is reduced because it is a star of only medium brightness. There are quite a few stars brighter than Polaris in the sky.

2. Constellation: A Cluster of visible stars that forms a definite pattern which is recognizable from the earth is called constellation. **Saptarishi** or the **Big Dipper** is one of the most popular patterns of stars visible in the sky, consisting of the seven brightest stars of the large constellation **Ursa Major (or Great Bear)**. The constellation's most recognizable stars (group of seven stars) are commonly known as "the Big Dipper". The Big Dipper as a whole have mythological significance in numerous world cultures including India.



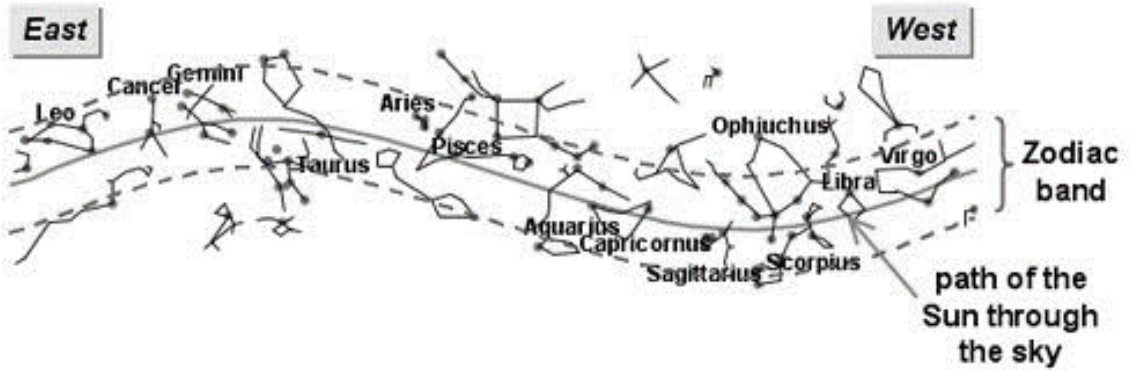
Ursa Major



Big Dipper

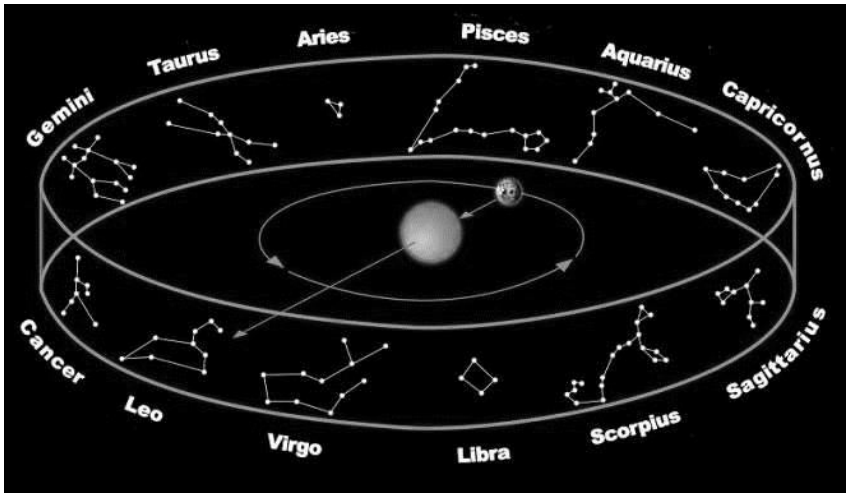
Star signs

In Astrology, the zodiac is the region of the sky where the Sun, Moon, and planets are located. On either side of the ecliptic, the zodiac extends approximately 8 to 9 degrees. The zodiac is narrow because the majority of planets' orbits are only slightly inclined to that of the Earth.



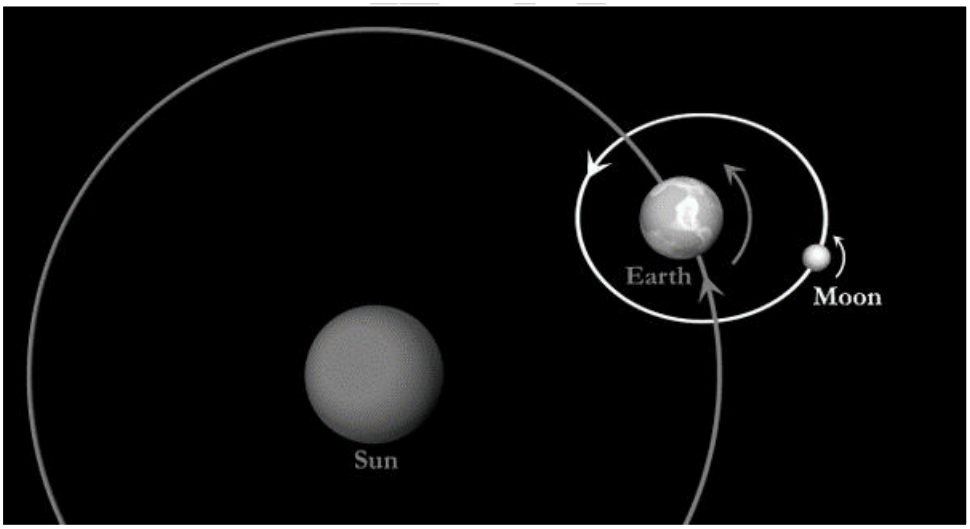
There are 13 constellations on the ecliptic. These constellations are also known as Zodiacal Constellations. These constellations are more commonly known as the astrological "star signs" (or "sun signs"). How is the Star sign of a person is determined? As the Earth moves around the Sun in its orbit, each of the Zodiacal constellations is hidden "behind" the Sun at some point during the year. The Zodiacal constellation which is hidden at the time of birth of a person is the Star sign of the person.

For instance, in the diagram below, Leo is hidden behind the Sun, and thus, is the Star sign of the person.

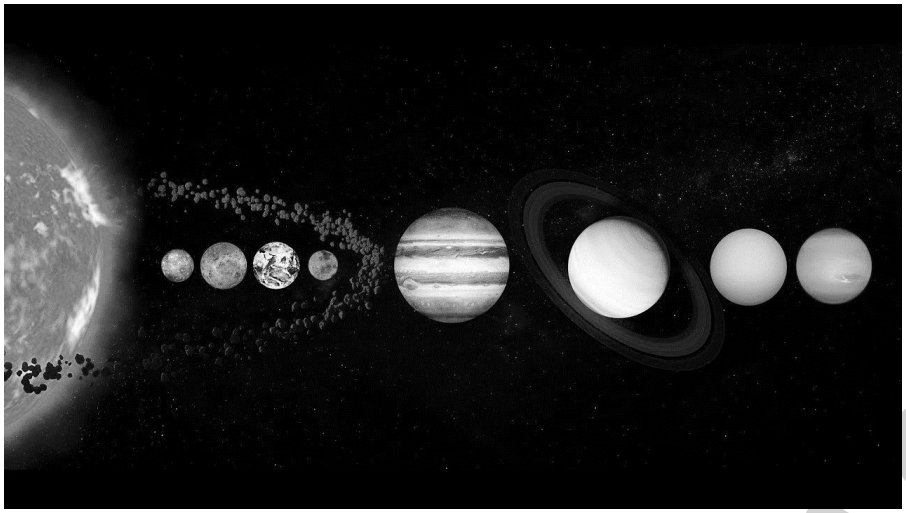


3. Planet: A planet is an astronomical body which revolves around a star in an orbit. A planet must have enough gravitational force to clear all smaller objects in its vicinity and to give it a spherical shape. When the size of a planet is large enough, it develops strong gravitational pull which helps it to hold an atmosphere around it.

4. Satellites: Satellites are objects that revolve around planets. These may be of natural origin or sent by humans. The moon is a natural satellite as it revolves around the Earth and is bound by the Earth's gravitational pull. Humans have also placed artificial or man-made satellites around the earth and other planets for observation and for communication purposes.

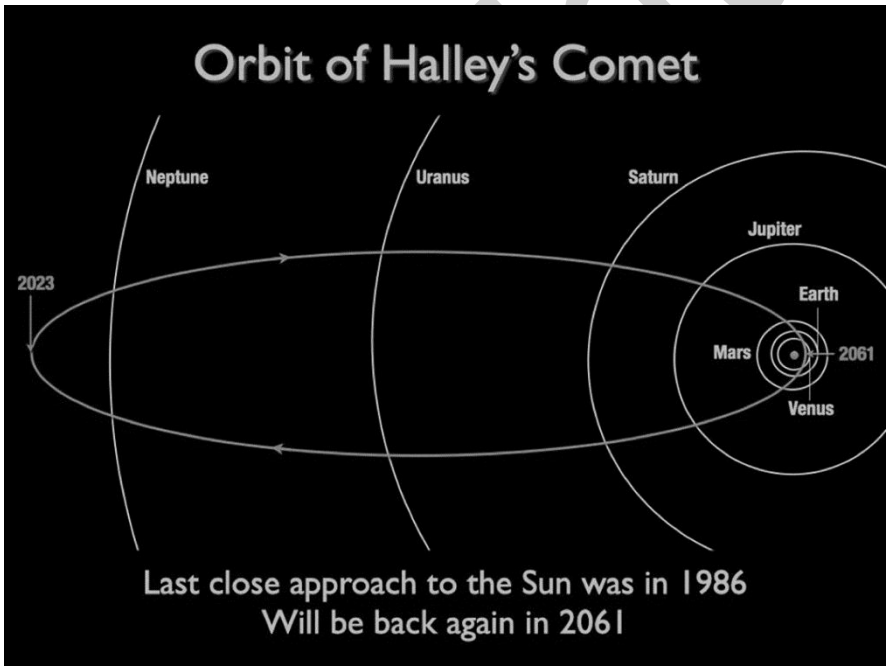


5. Asteroids: Small rocky bodies revolving around the sun in an orbit are known as asteroids. These are the remains of matter or space debris, which could not become part of any planet. In our solar system, asteroids are mainly found, in the **asteroid belt**, between Mars and Jupiter. A vast majority of asteroids are very small and have irregular shape, but few larger ones are nearly spherical. These larger asteroids are known as **planetoids**.



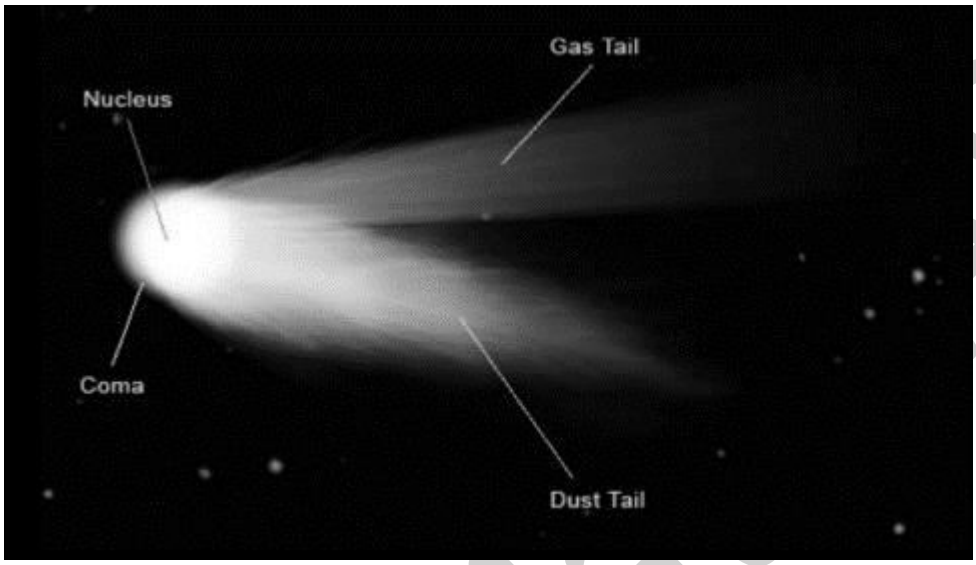
6. Comets: These are loose collections of ice, dust and small rocky particles, found in the outer fringes of the solar system. Comets are of irregular sizes and they orbit around the Sun.

Halley's Comet is a popular comet. It is known for its extremely elliptical path, but it has a definite periodicity i.e. it is visible from earth after regular and predictable intervals. It is visible from the earth after a period of 76 years.



As a comet approaches the inner solar system, solar radiation causes the volatile materials such as frozen gases within the comet to vaporize. These vaporized materials carry away dust with them. This dust left by comet reflects sunlight. When we see this reflection of sunlight from earth, it appears as if the comet has a shining tail behind it. Under the influence of solar winds (charged particles emanating from the Sun), the tail of the comet always points away from the sun.

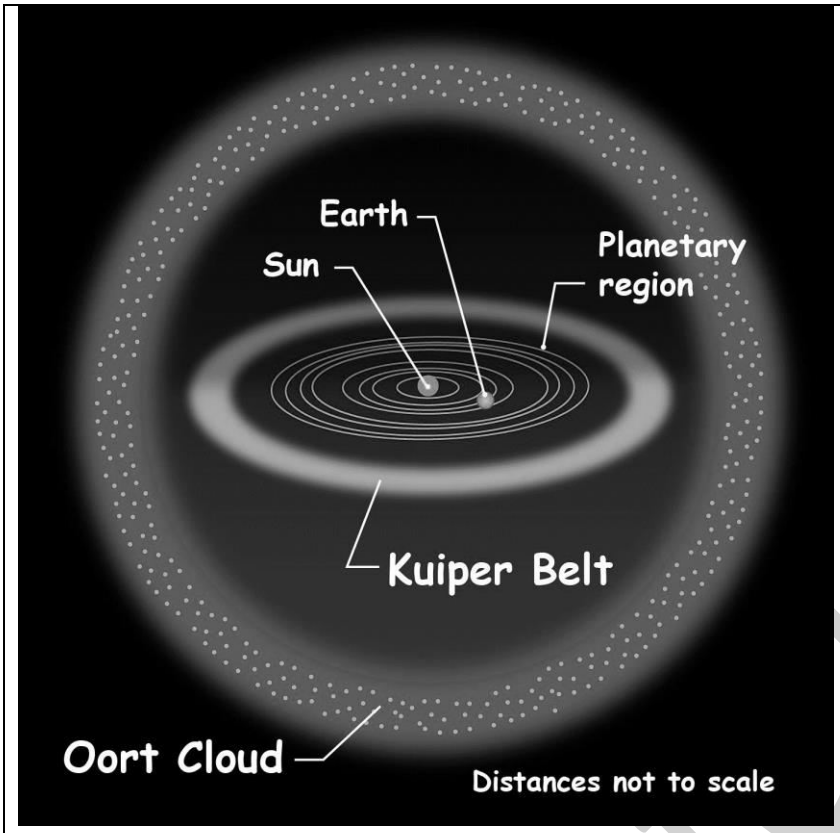
Also, as a comet approaches the inner solar system, it heats up and its frozen gases produce an envelope known as the coma around its nucleus. The envelope includes carbon-based molecules that are in turn excited by ultraviolet light from the sun. This results in the formation of a simple but fragile molecule known as dicarbon (C_2 in chemical notation). It is basically made up of two carbon atoms bonded together. These dicarbon molecules emit green colour light. Thus, the head of comet appear greenish in colour.



Kuiper Belt and Oort Cloud

Beyond the orbit of Neptune, Kuiper Belt is a donut-shaped area of icy bodies. These icy bodies are known as Kuiper Belt objects (KBOs) or trans-Neptunian objects (TNOs). There are millions of such icy bodies in the Kuiper belt. This belt also contains Pluto, which was once considered a planet.

The Kuiper Belt, like the asteroid belt, is a region of remnants from the early solar system. However, it is a thick disc (like a doughnut) rather than a thin asteroid belt.
The Oort Cloud is even beyond the Kuiper Belt. The Oort Cloud is like a large spherical shell that surrounds the Sun, planets, and Kuiper Belt Objects. Both the Oort Cloud and the Kuiper Belt are home to comets.



7. Meteors or Shooting stars: A meteor or a shooting star is a flash of light that appears when a small chunk of interplanetary debris burns up as it enters into our atmosphere. The debris produces flash of light (and heat as well) because when it enters from space (vacuum) into earth's atmosphere, then it experiences friction due to presence of gases in the earth's atmosphere. It is to be noted that "**Meteor**" refers to the flash of light caused by the debris, not the debris itself.

Image of a Meteor

The debris is called **meteoroid**. Most meteoroids are only few millimeters in size. Most meteoroids are so small that they destroy completely upon entering the earth's atmosphere and never reach the surface.

If any part of a meteoroid survives the fall through the atmosphere and lands on the surface of Earth, it is called a **meteorite**. Although the vast majority of meteorites are very small, their size can range from about a fraction of a gram to 100 kilograms or even more.

8. Galaxy: A galaxy is the congregation of millions of stars held together by their own gravitational force. In between these stars, galaxies also have interstellar matter such as dust and gas clouds, and even dark matter. It is estimated that the universe has more than two trillion galaxies of different shapes and sizes. Our galaxy is called Milky Way. Milky way is a spiral shaped medium sized galaxy. It has around 200 billion stars. Galaxies can be classified on various criteria:

Classification on basis of Size
Stars are the primary constituents of the galaxies. Thus, the size of the galaxies can be identified on the basis of the number of Stars in these galaxies. On the criteria of number of stars, Galaxies can be classified into three categories:

a. **Small Galaxies –** These galaxies have Millions of Stars in them.
b. **Medium Galaxies –** These galaxies have Billions of Stars in them. Our galaxy, Milky way, is a medium sized galaxy because it has approximately 200 billion stars in it.
c. **Large Galaxies –** These galaxies have Trillions of Stars in them.

Classification on basis of shape and age
The more scientific approach is to classify galaxies on the basis of their shape. Based on their shape, galaxies are divided into three categories

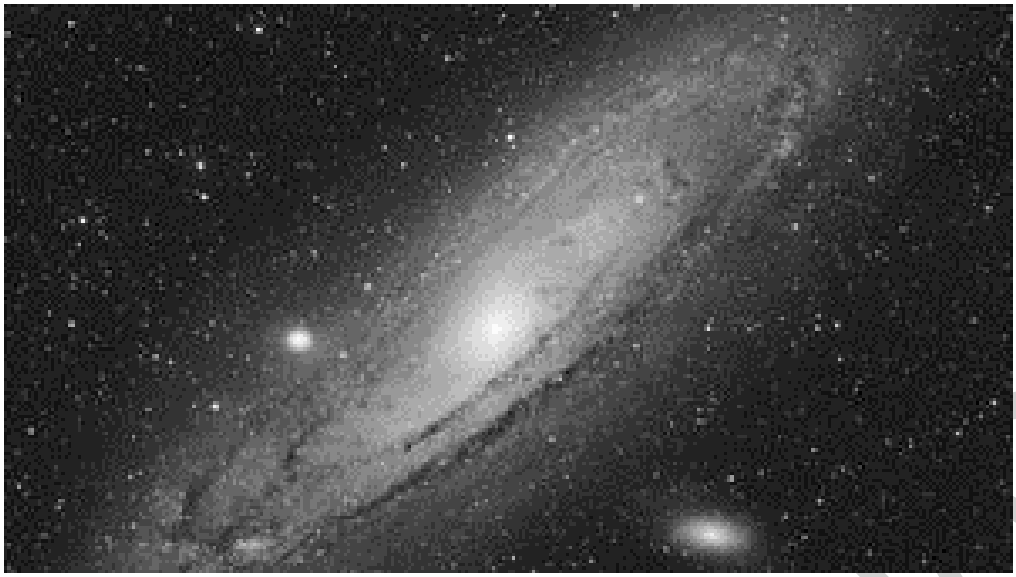
a. Elliptical galaxies: Elliptical galaxies are roundish (Bulge in Centre) in shape, unlike spiral galaxies which appear like a flat oval disc. Thus, these galaxies are far thicker than the spiral galaxies.

Two third of all galaxies (around 66%) in the universe are elliptical galaxies. These galaxies are the oldest galaxies in the Universe. This has three major implications:

1. The mass in these galaxies is evenly distributed. All the adjustments in the mass distribution have already taken place in these galaxies.

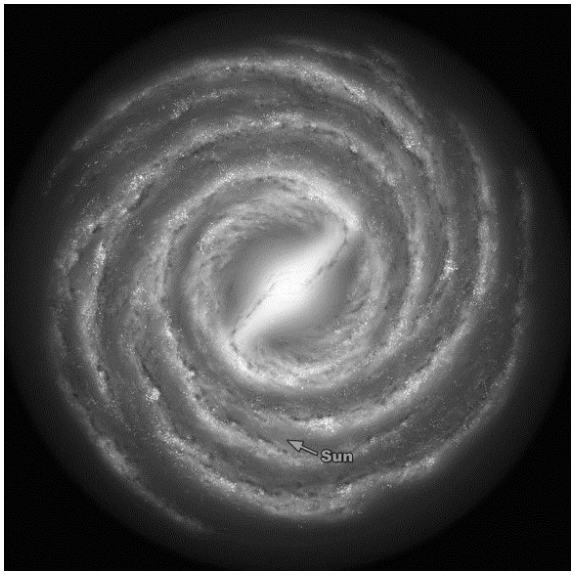
2. These galaxies are generally red in colour. The red colour indicates that the light is coming from old stars.

3. Elliptical galaxies have negligible dust clouds and no new bright stars are born here.



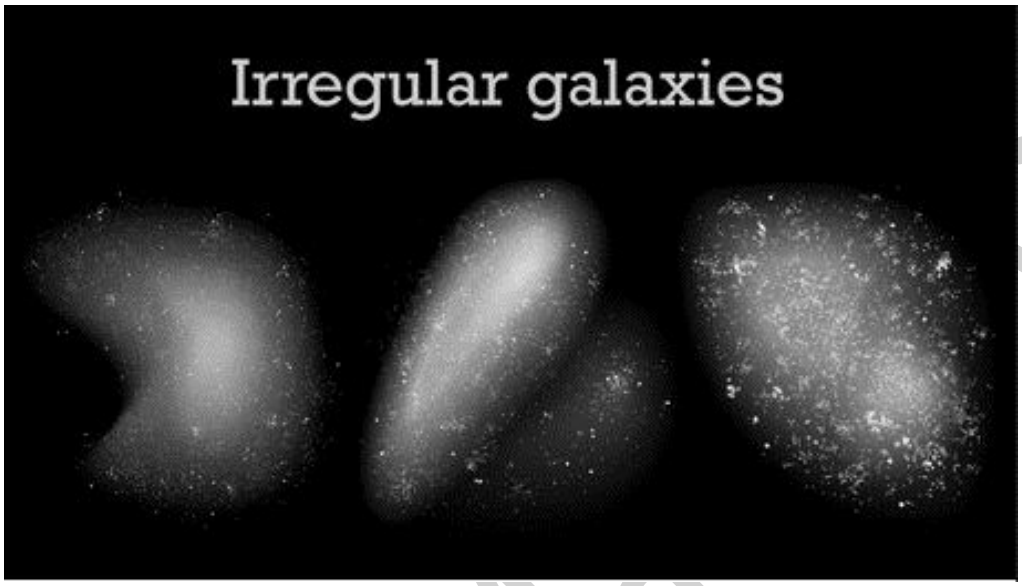
b. Spiral Galaxies: Spiral galaxies have shape of a flat oval disc at the Centre and curved spiral arms at the sides. The degree of Ovality may vary from being circular to elongated. One-fourth of all galaxies (around 25%) in the universe are spiral shaped. Spiral galaxies are younger than elliptical galaxies with abundant interstellar dust and gas clouds. In these clouds, new bright and young stars are born. Major mass of spiral galaxies is in the form of dust clouds and is concentrated at Centre. Our galaxy, Milky way is also spiral shaped.

The Milky Way is a flattened disc with spiral arms. This galaxy rotates in a clockwise direction. Its disc contains dust and gas clouds and stars, rotating from the Centre point. Our solar system belongs to one of the arms in the Milky way galaxy. Andromeda Galaxy is the nearest galaxy to our galaxy. It is also a spiral galaxy.



Milky Way galaxy along with marking of our Solar System

c. Irregular galaxies: The galaxies that are neither elliptical nor spiral shaped are called irregular galaxies. These galaxies are unlike spiral galaxies because they don't have distinct rotating arms. They are also unlike elliptical galaxies because they don't have a definite centre bulge. These galaxies do not form any symmetry because they are under the influence of gravitational forces of other galaxies. The irregular galaxies are full of gas and dust clouds, where new stars form. Around one-tenth (10%) of total galaxies in the Universe are of irregular shape.



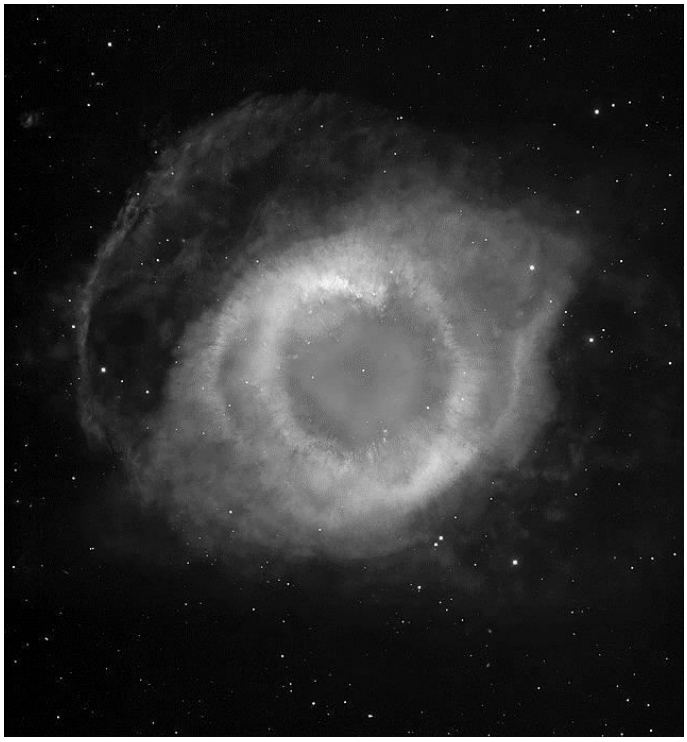
THE LIFE CYCLE OF A STAR

A star is a luminous body of gas. It produces light (along with heat) upon fusion of lighter elements into heavier elements. The fusion of lighter elements into heavier elements is called nuclear fusion. A star evolves through many stages from a cloud of gas and dust to a dark, dense matter. Various stages in the life cycle of a star are as follows:

Nebula

A nebula is a huge cloud of gas (particularly hydrogen) and dust in space. The gases and dust are present in a nebula in a diffused form. When these gases and dust particles get attracted towards each other due to their own gravitational pull, they start getting concentrated at the Centre of the nebula. With further contraction at the Centre, an inward explosion takes place. This explosion causes the birth of a protostar. Therefore, nebulae are also called the nurseries where stars are born.

The outer parts of nebula also get concentrated into lumps of matter. These lumps of matter gradually develop into planets, satellites and other celestial bodies present in the star system such as our solar system. The closest nebula to us is Helix Nebula.



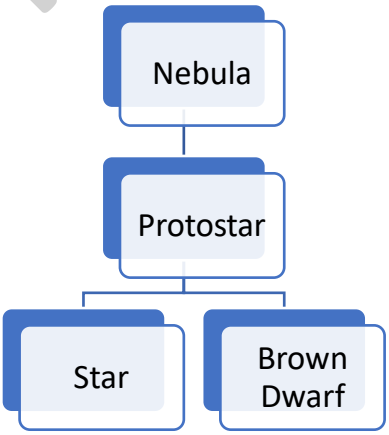
Helix Nebula

On the basis of their appearance, nebulae (plural of nebula) can be broadly divided into two categories:

a. Dark Nebulae: These are irregular shaped black patches of matter in the sky.They appear black because of absence of luminous particles. In other words, the matter in such nebulae is not concentrated enough to initiate nuclear fusion reaction.

b. Bright Nebulae: These nebulae appear bright. Their bright appearance may be on account of two reasons: They may be reflecting the light coming from nearby stars.

It may also happen that their brightness is on account of the nuclear fusion reaction which has initiated in them.



Protostar

The Protostar which emerged from a nebula may become a star or a brown dwarf. If nuclear fusion continues at substantial level, then protostar becomes bright enough to be called a Star. However, if nuclear fusion does not attain substantial level, then the Protostar becomes a brown dwarf.

Brown Dwarfs

The term 'Brown Dwarfs' is made up of two words – Brown and Dwarfs. The word 'Brown' is used to depict the appearance of such protostars. These protostars are brownish in colour because their surface temperature is low and thus, they are faint in appearance. This is due to the fact that their mass is less than the critical mass. Thus, they contain less fuel for nuclear fusion and thus, they do not shine bright like a normal star.

These protostars are regarded dwarfs because their size is approximately one tenth of that of the Sun.

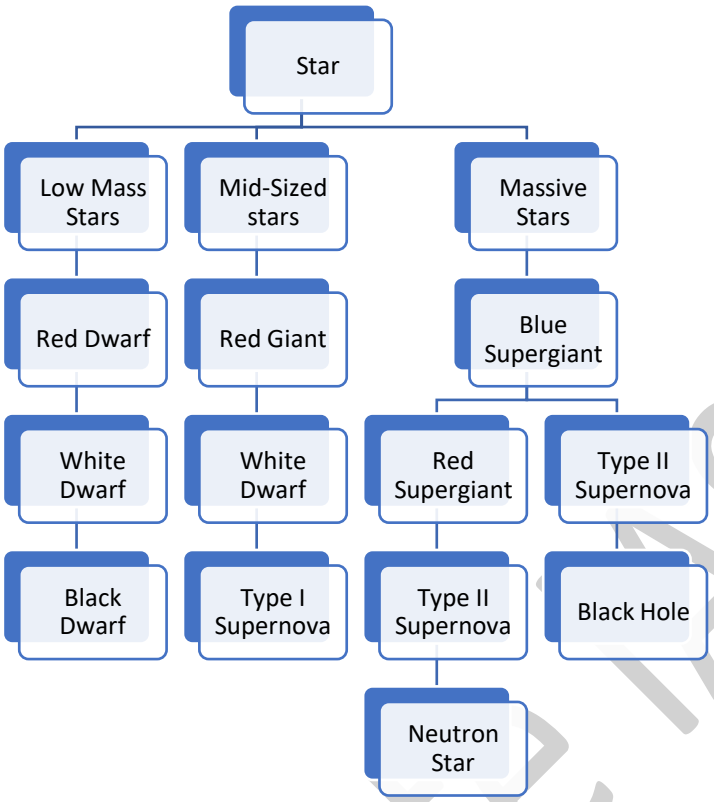
Colour of Light

To understand the life cycle of stars, we need to first understand the reason behind the different colours of light emitted by different Stars. The colour of light emitted by a star depends upon its surface temperature. The surface temperatures of a star can range from 2000°C to even above 30,000°C. A star with surface temperature near 30,000°C appears blue and near 2000°C appears red. High temperature of the star generate light waves of high frequency, which are on the violet end of the spectrum of light. On the other hand, low surface temperature of the star generate light waves of low frequency, which are on the red end of the spectrum of light.

The Sun's surface temperature is about 6,000°C. As a result, it appears yellow to us. If the Sun's surface temperature was low, it would give more light on the red end of the spectrum, and if the Sun's surface temperature was higher, it would give more light on the blue end of the spectrum.

Classification of Stars on basis of Mass

The mass of a Star has crucial role in determining its life cycle. On the basis of mass, the stars can be categorised into three types: Low Mass Stars, Mid-Sized stars and Massive Stars. Low Mass Stars have mass even less than that of Sun, Mid-Sized Stars have mass similar to that of Sun, and Massive Stars have far more mass than that of Sun.



Red Dwarf

Red Dwarfs are Low Mass Stars. These stars have fraction of the mass as that of our Sun (minimum 8% mass of the Sun). They appear red because their surface temperature is about 3,500°C. Thus, Red dwarfs have lower surface temperature. The surface temperature of red dwarfs does not exceed because they have less fuel on account of their small mass. Consequently, the light emitted by these stars is towards the red end of the spectrum. Proxima Centauri and Barnard's Star are examples of red dwarfs.

Because these stars burn fuel very slowly, they have estimated lifetimes of 100 billion years or more. Thus, Red dwarfs have a longer lifespan than other stars. However, eventually they also exhaust their fuel reserves. When this happens, the red dwarfs transform into white dwarfs. White dwarfs eventually lose all of their heat and transform into black dwarfs.

White Dwarf

Eventually, star loses some of its outer layers on account of gravitational pull exhibited by nearby bodies. Moreover, the remaining star contracts further under its own gravitational pull, resulting into a white dwarf. A White dwarf is a very small and hot star. The surface temperature of a white dwarf is 8000°C or more. Some white dwarfs have a mass similar to that of the Sun, with only 1% of its diameter. Because they are so small in size, they cannot be seen with the naked eye.

However, the White Dwarf is regarded as dead star because there is no nuclear fusion in it. There is no nuclear fusion because the star has already exhausted its fuel supply. On account of reduction in nuclear fusion, it emits around 1% light as that of the Sun. White dwarfs cool down and fade over several billion years. They eventually loose all of their heat and ultimately become black dwarfs.

Red Giant and Red Supergiant

Towards the end of its life, a mid-sized star turns into a red giant. Red giants have a diameter between 10 to 100 times of that of the Sun. Because they are so large in size, they appear very bright. They have a lower surface temperature of about 2000-3000°C. This is because they have already fused Hydrogen into Helium at the core.

After the fuel exhausts at the core, the fusion of hydrogen begins in a shell surrounding the core. Red giants become larger in size because when their outer layer burns, the heat energy released from the outer core pushes against the core of the star and thus, the volume of the star expands. The outer layers of the star escape the star, leaving behind only core.

When all the hydrogen of the star converts into Helium, the star begins to contract under its gravitational pull; resulting further in the fusion of helium into heavier elements. Very large red giants are called Super Giants. Super giants can have 1000 times diameter as that of the Sun and their luminosity can be 10,00,000 times greater than that of the Sun.

Blue Supergiant

Massive stars have a lot of hydrogen fuel in their core. Not only they have a lot of hydrogen fuel in their core, but they also burn the fuel at very rapid pace. Consequently, their surface temperature is very high, giving them bluish appearance. Because these stars burn at rapid pace, they have a short life than that of our Sun.

Supernova

In this stage, a star has an explosive death. The star becomes 100 million times as bright as the Sun but for a short time. Supernova are further divided into two types on the basis of the reason behind their occurrence:

Type I Supernova stage can occur when gas from a nearby star falls on to a white dwarf, causing it to explode.

Type II Supernova stage can also occur in stars that are ten times or more in size as that of the Sun. These stars experience quick internal nuclear reactions at the end of their lives, leading to an explosion.

Supernova explosion leave behind neutron stars and black holes. Supernovae (plural of Supernova) are thought to be main source of elements heavier than hydrogen and helium because high temperatures at them facilitate fusion into heavier elements.

Neutron Stars

Neutron stars are called so because they are composed mainly of neutrons. These stars emerge from supernova explosion, forcing the protons and electrons to combine to produce neutrons.

Neutron stars are very dense. A typical neutron star has three times the mass as that of the Sun but a diameter of only 20 km. If the mass is even greater, its gravity is so strong that it shrinks further to become a black hole.

Most neutron stars are observed as pulsars. Pulsars are rotating neutron stars observed to have pulses of radiation at very regular intervals that typically range from milliseconds to seconds. Pulsars have very strong magnetic fields which funnel jets of particles out along the two magnetic poles. These accelerated particles produce very powerful beams of light.

Black Holes

Massive stars at the end of their life cycle result into black holes. The gravitational pull of a black hole is so high that nothing can escape from it, not even light. The density of matter in a black hole cannot be measured. Black holes distort the space around them, and often suck mass in their neighbourhood.

Cepheids

Cepheids are reasonably abundant and very bright. Astronomers can identify them not only in our Galaxy, but in other nearby galaxies as well. If one requires the distance to a given galaxy one first locates the Cepheid variables in this galaxy. From these observations one determines the period of each of these stars. The brightness at the distance of one light-year will be larger than the observed brightness due to the fact that brightness drops with the distance. From these numbers one can extract the distance to the stars. This method works up to 13 million light-years when Earth-bound telescopes are used; for larger distances these stars become too dim to be observed. Recently, space-based telescopes such as the Hubble Telescope, have used these stars to much farther distances. Looking at a galaxy in the Virgo cluster called M100, astronomers used the Cepheid variables observed there to determine its distance - 56 million light-years.

Practice Questions

1. A meteorite is:
(a) A comet with a bright gaseous tail.
(b) A piece of matter that burns and gets converted into ash as it enters the Earth's atmosphere from outer space.
(c) A piece of matter that does not burn completely and reaches the surface of the Earth.
(d) None of the above.

2. What is the difference between asteroids and comets?
1. Asteroids are found between Mars and Jupiter, whereas comets are in the outer fringes of the solar system.
2. Asteroids are gaseous in nature, whereas comets are not.
3. Comets have a tail, while asteroids do not.
Which of the statements given above is/are correct?
(a) 1 and 2 only
(b) 1 and 3 only
(c) 3 only
(d) 1, 2, and 3

3. Which of the following statements about our universe is/are correct?
1. Our universe is in the state of expansion.
2. Light waves are used to study the distant galaxies present in the universe.
3. Sound waves are used to measure the distance among various celestial bodies.
Select the correct answer using the codes given below:
(a) 2 and 3 only
(b) 1 and 2 only
(c) 1 only
(d) 1, 2, and 3

4. Consider the following statements:
1. Comets have highly elliptical orbits that bring them close to the Sun, often beyond the orbit of Pluto.
2. Solar wind is responsible for the formation of tails in comets.
Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

5. Consider the following statements about our universe:
1. Our universe was formed 9 billion years ago.

2. Light waves help in determining the distance among celestial bodies.
3. Our solar system is in a continuous state of expansion.
Which of the statements given above is/are correct?
(a) 2 and 3 only
(b) 1 and 2 only
(c) 2 only
(d) 1, 2, and 3

6. Consider the following events after the formation of the Big Bang:
1. Among all the elements, Hydrogen was the first element which was formed after the big bang.
2. The first stars are believed to have formed not earlier than 12 billion years ago.
3. The planet earth is less than 5 billion years old.
Which of the above statements is/are correct?
(a) 1 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

7. Consider the following statements about Red shift:
1. The distant celestial bodies emit more of the orange light than the blue light in the visible light spectrum.
2. If an object is emitting more of red light as compared to other colours in the visible light spectrum then what it used to emit 10 years ago, then it can be concluded that the object is coming near to the earth.
Which of the Statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

8. Which of the following conclusions can be drawn from the Oscillating Universe Hypothesis?
1. The Universe does not have a definite beginning.
2. The Universe does not have a definite end.
Select the correct answer using the code given below:
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

9. Consider the following statements about the Composition of the Universe:
1. Dark matter and Dark energy constitute more than 90% of the Universe.

2. Dark matter is more than 5 times in mass as compared to the visible matter.
3. The continued expansion of the Universe is the evidence for existence of Dark energy.
Which of the Statements given above is/are correct?
(a) 2 only
(b) 1 and 2 only
(c) 2 and 3 only
(d) 1, 2 and 3

10. Consider the following statements about galaxies:
1. It is estimated that there are less than 1 million galaxies in the Universe.
2. Elliptical galaxies are older than the circular galaxies.
3. Milky way is an example of elliptical galaxy.
Which of the Statements given above is/are correct?
(a) 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1 and 2 only

11. Consider the following Statements about the types of Galaxies:
1. Elliptical galaxies do not experience the birth of new stars.
2. The number of elliptical galaxies is more than the combined number of spiral and irregular galaxies.
3. Elliptical galaxies are like a flat circular disc, elongated in a particular axis.
How many of the above statements are correct?
(a) Only one
(b) Only two
(c) All three
(d) None

12. Consider the following statements about Polaris:
1. Polaris is also known as North Star because it lies directly over the Earth's North Pole.
2. Earth's axis takes 26,000 years to complete one cycle. The position of Polaris changes with the orientation of the Earth's axis.
3. If you want to travel towards the south direction, you will walk in the opposite direction of the Polaris.
How many of the above statements are correct?
(a) Only one
(b) Only two
(c) All three
(d) None

13. Consider the following statements about Big Dipper:
1. The Big Dipper or Saptarishi consist of seven bright stars.
2. The Big Dipper is part of a large constellation Ursa Major.
Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

14. The gravitational force of a planet plays which of the following roles?
1. It clears the objects in the vicinity of the planet as gravitational force attracts the nearby objects which ultimately merge into the planet.
2. It enables the planet to obtain spherical shape from irregular shape.
Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

15. Consider the following statements about Meteor, Meteoroid and Meteorite:
1. When debris from the space enter into earth's atmosphere, we see a flash of light called Meteoroid.
2. The debris which generates spark of light when it enters the earth's atmosphere from space is called Meteor.
3. If the debris, from space, survives through the earth's atmosphere and lands on the surface of earth, it is called meteorite.
How many of the above statements are incorrect?
(a) Only one
(b) Only two
(c) All three
(d) None

16. The surface temperature of the Sun is about 6,000 °C. The light from the Sun appears yellowish to us. In context of this statement, consider the following statements:
1. If the surface temperature of the Sun increases to 30,000 °C, it will start appearing reddish to us.
2. If the surface temperature of the Sun reduces to 2,000 °C, it will start appearing bluish to us.
Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2

(d) Neither 1 nor 2

17. Consider the following statements about Red Dwarfs and Brown Dwarfs:
1. Red dwarfs are larger in size than the brown dwarfs.
2. The Surface temperature of the red dwarfs is less than that of the Sun.
3. Because the fuel contained in the red dwarfs is less than that of the Sun, their life span is also less than the life span of the Sun.
How many of the above statements are correct?
(a) Only one
(b) Only two
(c) All three
(d) None

18. Consider the following statements about Red Giants:
1. A star turns into a red giant stage in the beginning of its life.
2. The nuclear fusion reaction takes place mostly in the core of a red giant.
3. Red Giants are usually twice the size of the Sun.
How many of the above statements are correct?
(a) Only one
(b) Only two
(c) All three
(d) None

19. Consider the following statements:
1. The stage of white dwarf in the life cycle of a star comes next to supernova explosion.
2. White dwarfs usually have a mass similar to that of the Sun.
3. White dwarfs have only 1/100th of the diameter as that of the Sun.
Which of the Statements given above is/are correct?
(a) 1 only
(b) 1 and 2 only
(c) 2 and 3 only
(d) 1, 2 and 3

20. A Supernova explosion can lead to which of the following type of stars:
1. Neutron Stars
2. Black Holes
3. Red Dwarfs
Select the correct answer using the code given below:
(a) 1 only
(b) 1 and 2 only
(c) 2 and 3 only
(d) 1, 2 and 3

Perfecting Past Prelims

1. What is the difference between asteroids and comets? (2011)
1. Asteroids are small rocky planetoids, while comets are formed of frozen gases held together by rocky and metallic material.
2. Asteroids are found mostly between the orbits of Jupiter and Mars, while comets are found mostly between Venus and Mercury.
3. Comets show a perceptible glowing tail, while asteroids do not.
Which of the statements given above is/are correct?
(a) 1 and 2 only
(b) 1 and 3 only
(c) 3 only
(d) 1, 2, and 3

2. A person stood alone in a desert on a dark night and wanted to reach his village, which was situated 5 km east of the point where he was standing. He had no instruments to find the direction, but he located the Pole Star. The most convenient way now to reach his village is to walk in the direction (2012)
(a) Facing the Pole Star.
(b) Opposite to the Pole Star.
(c) Keeping the Pole Star to his left.
(d) Keeping the Pole Star to his right.

3. Which of the following is/are cited by scientists as evidence for the continued expansion of the universe? (2012)
1. Detection of microwaves in space
2. Observation of red shift phenomenon in space
3. Movement of asteroids in space
4. Occurrence of supernova explosions in space.
Select the correct answer using the codes given below:
(a) 1 and 2 only
(b) 2 only
(c) 1, 3, and 4
(d) None

4. Consider the following pairs: (2023)

Objects in space	Description
1. Cepheids	Giant clouds of dust and gas in space
2. Nebulae	Stars which brighten and dim periodically

3. Pulsars	Neutron stars that are formed when massive stars run out of fuel and collapse

How many of the above pairs are correctly matched?
(a) Only one
(b) Only two
(c) All three
(d) None

5. Consider the following statements: (2024)
Statement-I: Giant stars live much longer than dwarf stars.
Statement-II: Compared to dwarf stars, giant stars have a greater rate of nuclear reactions.
Which one of the following is correct in respect of the above statements?
(a) Both Statement-I and Statement-II are correct and Statement-II explains Statement-I
(b) Both Statement-I and Statement-II are correct but Statement-II does not explain Statement-I
(c) Statement-I is correct, but Statement-II is incorrect
(d) Statement-I is incorrect, but Statement-II is correct

Answer Key

Practice Questions

1. (c)	2. (b)	3. (b)	4. (c)	5. (c)
6. (c)	7. (a)	8. (c)	9. (d)	10. (a)
11. (b)	12. (b)	13. (c)	14. (c)	15. (b)
16. (d)	17. (b)	18. (d)	19. (c)	20. (b)

Perfecting Past Prelims

1. (b)	2. (c)	3. (a)	4. (a)	5. (d)

Solutions

Practice Questions

1. (c) A meteorite is space debris that strikes the Earth's surface.

Meteoroid is space debris before striking the surface of the Earth. Meteor is the light emitted by space debris when it enters the Earth's atmosphere.

2. (b) Statement 2 is incorrect because comets are gaseous in nature, whereas asteroids are solid space debris.

3. (b) Statement 3 is incorrect. Sound waves cannot travel through vacuum. Therefore, they cannot be used to measure distance among celestial bodies.

5. (c) Statement 1 is incorrect. Our universe is 13.8 billion years old.

Statement 3 is incorrect. The distances within our solar system are fixed. Our solar system is not in a state of expansion.

6. (c) Statement 2 is incorrect. The Big Bang took place almost 13.8 billion years ago. The first stars are believed to have formed around 250 million years after the big bang. Statement 3 is correct. The planet earth is less than 5 billion years old. It was formed 4.5 billion years ago.

7. (a) Statement 1 is correct: The arrangement of various colours in the visible light from highest frequency to lowest frequency is in the order of 'VIBGYOR' (Violet, Indigo, Blue, Green, Yellow, Orange and Red). Also, distant objects emit more light of lower frequency and less light of higher frequency.

Statement 2 is incorrect: If an object is emitting more light towards the red end of the spectrum, it means that the object is moving away from the earth.

8. (c) According to Oscillating Universe Hypothesis, the Universe follows an eternal series of oscillations, each beginning with a Big Bang and ending with a Big Crunch. Thus, there is no definite beginning and definite end of the Universe.

9. (d) Statement 1 is correct: Dark matter and Dark energy constitute 27% and 68% of the Universe respectively.

Statement 2 is correct: Dark matter constitutes 27% of the Universe and visible matter constitutes 5% of the Universe. Thus, Dark matter is more than 5 times in mass as compared to the visible matter.

Statement 3 is also correct: The expansion of Universe is the evidence of the existence of dark energy. It is observed that when the universe expands, the empty space develops certain type of repulsive force. It is assumed that this repulsive force is due to the presence of dark energy.

10. (a) Statement 1 is incorrect: It is estimated that the universe has two trillion galaxies. Statement 3 is incorrect: Milky way is a spiral shaped galaxy.

11. (a) Statement 1 is correct: Elliptical galaxies have negligible dust clouds and thus, no new bright stars are born here.

Statement 2 is correct. Two third of all galaxies (around 66%) in the universe are elliptical shaped. Spiral and irregular galaxies together contribute the remaining one third galaxies.

Statement 3 is incorrect: Elliptical galaxies are roundish in space. They are not like a flat disc.

Thus, only two statements are correct.

12. (b) Statement 1 is correct.

Statement 2 is incorrect: The position of Polaris does not change with the orientation of the Earth's axis. Polaris will not always remain the North Pole Star.

Statement 3 is correct: As Polaris is in the north direction, if we walk in the opposite direction to that of the Polaris, we will walk in the south direction.

Thus, only two statements are correct.

15. (b) Statements 1 and 2 are incorrect. "Meteor" refers to the flash of light caused by the debris, not the debris itself and the debris is called a meteoroid.

Thus, Only two statements are incorrect.

16. (d) Statement 1 is incorrect: If the surface temperature of the Sun increases to 30,000 °C, it will start appearing bluish to us. High temperature of the star generate light waves of high frequency, which are on the violet end of the spectrum of light.

Statement 2 is incorrect: If the surface temperature of the Sun reduces to 2,000 °C, it will start appearing reddish to us. Low surface temperature of the star generate light waves of low frequency, which are on the red end of the spectrum of light.

17. (b) Statement 3 is incorrect. Even though the fuel contained in red dwarfs is less than that of the Sun, the fuel in the red dwarfs burn very slowly. The red dwarfs have estimated lifetimes of 100 billion years. On the other hand, the estimated life span of the Sun is 15 billion years.

Thus, only two statements are correct.

18. (d) Statement 1 is incorrect: Towards the end of its life, a star turns into a red giant.

Statement 2 is incorrect: The nuclear fusion reaction takes place mostly in the surrounding shell of a red giant because the fuel has already been exhausted in the core.

Statement 3 is incorrect: Red giants are 10 to 100 times in size than that of the Sun.

19. (c) Statement 1 is incorrect. In the life cycle of a star, the stage of white dwarf is next to the stage of red giant.

20. (b) Statement 3 is incorrect: A supernova explosion may lead to neutron stars and black holes, but not red dwarfs.

Perfecting Past Prelims

1. (b) Statement 2 is incorrect. Comets are found in the outer fringes of the solar system.

2. (c) The person would walk keeping the Pole Star to his left direction. Pole Star is situated in the north direction. If a person walks by keeping polestar in the left direction, then the person is moving in the east direction.

3. (a) Statement 1 is correct. Microwaves have wavelengths that can be measured in centimetres! The longer microwaves, those closer to a foot in length, are the waves that heat our food in a microwave oven. Microwaves are good for transmitting information from one place to another because microwave energy can penetrate haze, light, rain, snow, clouds, and smoke. There are microwaves-based telescopes to study the universe.

Statement 3 is incorrect. Asteroids are space debris. They have very small size and are attracted by mass of the universe. Their movement does not provide evidence of universe expansion.

Statement 4 is incorrect. Supernova explosions help us in determining the distance of a particular star. However, they do not provide evidence about the continued expansion of the universe.

4.(a) Pair3 is correctly matched. Remaining pairs are not correctly matched.

5. (d) Statement I is incorrect: Giant stars have shorter lifespans compared to dwarf stars because they burn their fuel much more quickly.
Statement II is correct: The more massive a star, the greater the rate at which nuclear reactions can take place in the core. More massive stars have a stronger gravitational

force acting inwards so their core gets hotter. The higher temperatures mean that the nuclear reactions occur at a much greater rate in massive stars.