Chapter One

The Universe and the Solar System

Chapter Concepts

- The Universe
- The Solar System

The Universe

The universe is incomprehensively large in size and dimension. It contains everything that exists, from the tiniest subatomic particles to galactic super-clusters (the largest structure known). Nobody knows how big the universe is, but astronomers estimate that it contains about 100 billion galaxies, each comprising an average of 100 billion of stars.

Expanding Universe

The evolutionary theory of the universe conforms to the principle that the distribution of galaxies is uniform in all directions throughout the space. Under this concept, to an observer from any galaxy, the average composition of the universe would appear the same.

Galaxies

A galaxy is a huge mass of stars, nebulae, and inter-stellar material. The smallest galaxies contain about 100,000 stars, while the largest contains up to 3000 billion stars.

Galaxies are the major building blocks of the universe. A galaxy is a giant family of billions of stars, and is held together by its own gravitational field. The universe is organised into galaxies of stars together with gas and dust.

From the billions of galaxies, two basic types have been identified:

(i) Regular galaxies, and (ii) Irregular galaxies. The regular galaxies **(Fig. 1.1)** may be disc-shaped, elliptical and they generally have new stars. The stars of the irregular galaxies are very old **(Fig. 1.2)**.

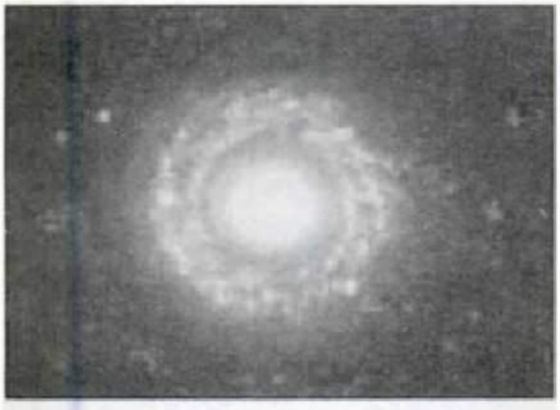

Fig. 1.1(A) – Disc - Shaped

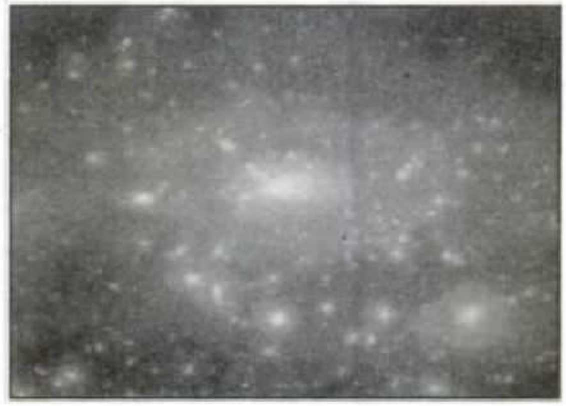

Fig. 1.1(C) – Elliptical Galaxy

Fig. 1.1(B) – Disc - Shaped Andromeda

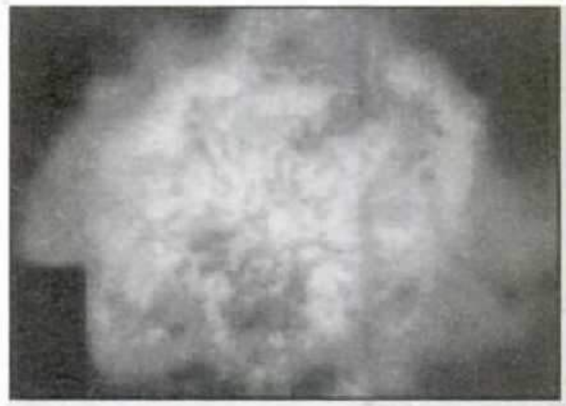

Fig. 1.1(D) – Elliptical

***Fig. 1.1 (A,B,C,D)** – Regular galaxies*

(i) Regular Galaxies

The regular galaxies may be of either spiral or elliptical in shape.

(a) Spiral Galaxies

The Milky Way and the Great Galaxy in Andromeda are examples of large spiral galaxies—disc-shaped with greater concentration of stars near their centres **(Fig. 1.2)**. The spiral galaxies have curved spiral arms. About 25% of all galaxies have curved spiral arms. Spiral galaxies are well supplied with the interstellar gas in which new bright, young stars form. As the rotating spiral pattern sweeps around the galaxy, it encompasses gas and dust, triggering the formation of bright young stars in its arms.

(b) Elliptical Galaxies

The most abundant are probably the elliptical galaxies. These are generally smaller than the spiral galaxies. They are generally symmetrical or spheroidal shape with no obvious structure. Most of their member stars are very old and no new star forming in them. Some of them are so small that the term *'dwarf'* has been applied. The largest known elliptical galaxy is 200,000 light years in diameter. The biggest and the brightest galaxies in the universe are elliptical with masses of 10^{13} times that of our Sun. About two-thirds of all the galaxies are elliptical.

(ii) Irregular Galaxies

The irregular galaxies comprise about one-tenth of all galaxies and come in many subclasses. The stars of the irregular galaxies are generally very old. Some of them have a mixture of the old and new stars. The *Milky Way* and other spiral galaxies consist of populations of old stars in the centre, and the youngest stars located in the arms.

Fig. 1.2 (A)

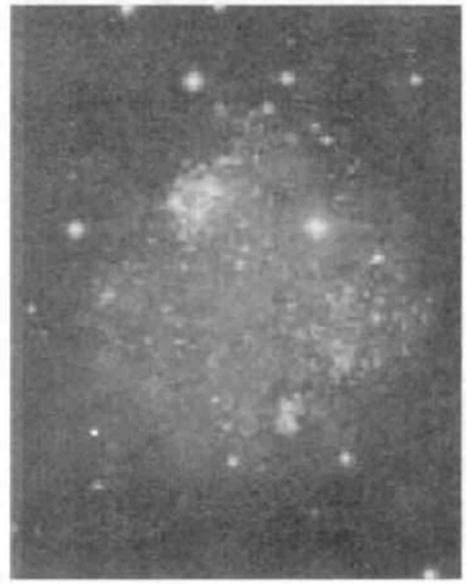

Fig. 1.2 (B)

Fig. 1.2 (C)

Fig. 1.2 (D)

***Fig. 1.2** – Irregular galaxies*

Our Galaxy *(Milky Way)*

Our galaxy has the shape of a flat disc with a central bulge. Its diameter is about a hundred thousand light years. In the nucleus the thickness reaches ten thousand light years, whereas in the disc it is five hundred to two thousand light years thick. It consists of stars, gas and dust; superimposed on the general distribution of the star in the pair of spiral arms. We do not know exactly how far the Sun is from the centre, but it is conventionally taken to be 33,000 light years away. Thus our solar system is relatively far from the galactic centre. Our galaxy is vast, about 100,000 light years across (a light year is about 9460 billion kilometers or 9.4607×10^{12} km in comparison the solar system seems small of about 12 light years across (about 13 billion kilometers). The entire galaxy is rotating in the space, although the inner stars travel faster than those further out. The Sun which is about one-third out from the centre, completes one lap of galaxy in about every 220 million years (**Fig.1.3**).

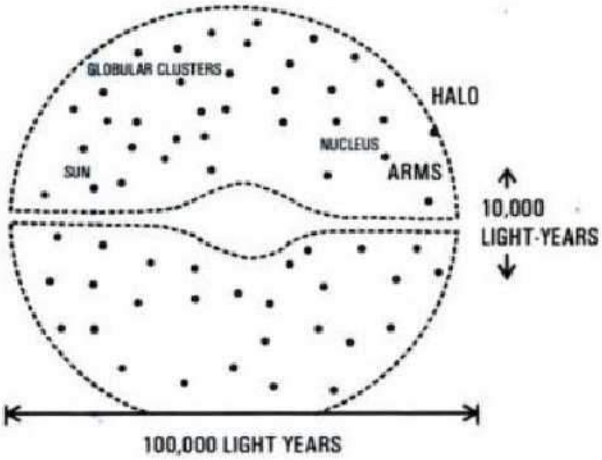

***Fig. 1.3** – Our galaxy – The Milky Way*

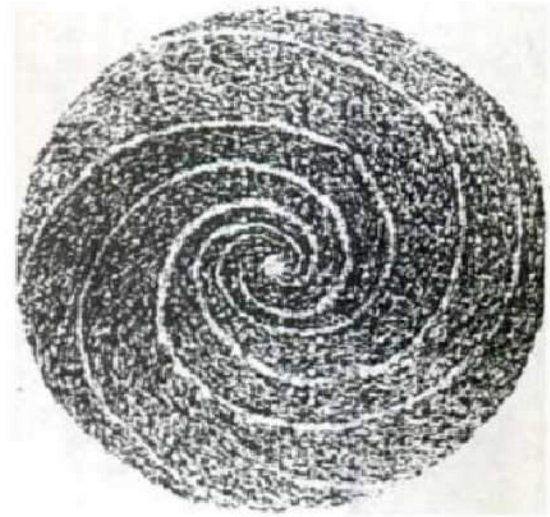

***Fig. 1.4** – Nebulae*

Nebulae

A nebula is a cloud of dust and gas inside a galaxy (**Fig.1.4**). Nebulae become visible if the gas glows or if the cloud reflects straight or obscures light from distant objects. The processes of evolution of stars and star-systems from a nebula have been shown in **Fig. 1.5**.

Dwarfs

White dwarfs are extremely small stars with densities greater than that of any known terrestrial material. It is believed that white dwarfs were once normal sized stars whose internal heat energy was able to keep these gaseous masses from shrinking under their own gravitational force. Eventually, however, these stars depleted their nuclear fuel and collapsed to planetary size. Although some white dwarfs are not larger than the Earth, they are nearly as massive as the Sun. Thus, their densities may be a million times that of

***Fig. 1.5** – A size comparison of planets in our Solar System. The size of each planet and the Sun is approximately to scale.*

water. A spoonful of such matter would weigh several tons. Great densities are only possible when electrons are displaced from their regular shells and pushed closer to the nucleus, allowing atoms to take up less space. The matter in this state is called '***degenerate matter***'.

Once a star has contracted into a white dwarf, it is without a source of energy and can only become cooler and dimmer. Although none has been sighted, the terminal stage of white dwarf must be small, cold, non-luminous body called a '***black dwarf***'.

Black Holes (Neutron Stars)

The smaller white dwarfs are the most massive, and the larger one are the least massive. The reason for this is that a more massive star, because of its greater gravitational force, is able to squeeze itself into a smaller, more densely packed object than a less massive star. Thus, the smaller white dwarfs were produced from the collapse of larger and more massive stars. If the earth were to collapse to the density of a white dwarf (neutron star), it would have a diameter equivalent to the length of a football field.

The Solar System

The family of the 'Sun' is known as the solar system. Eight major planets, one dwarf planet (Pluto), satellites and countless minor planets (asteroids), meteors, and comets orbit the Sun to form the solar system. The Sun, our motherly and nearest star, creates energy from nuclear reactions deep within the interior, providing all the light and heat that make life possible on the Earth. The size, comparison and relative distance of planets in our solar system has been shown in **Fig.1.5**.

Origin of Solar System

The solar system was probably formed by the gravitational collapse of a huge cloud of gas and dust. The reason for differences in planetary composition appears to be related to distance from the Sun. Bodies close to the Sun (the terrestrial planets) were formed from rocks and metals that crystallized at high temperature, while the outer planets were formed from elements that form solids (condense) at low temperatures.

Most scientists believe that the universe began about 15 billion years ago in what has become known as the ***Big Bang***. This gigantic explosion caused matter to expand to form billions of swirling galaxies and over the time, the stars and their planets. It is generally believed that our solar system was spawned in a cold, diffuse cloud of gas and dust, deep within the spiral arm of the Milky Way Galaxy. The huge cloud was made up largely of two lightest elements, hydrogen and helium along with traces of other elements including oxygen, silicon, and iron. The cloud rotated slowly about a central concentration of mass and contained a system complicated eddies. Under the force of gravity, the giant cloud began to collapse and assume the shape of a rotating disc, with an increasingly hot and dense mass at the centre.

Sun

Diameter: 1,392,000 km (864,948 miles)
Mass: 1990 million, million, million, million tons
The Sun was formed when a swirling cloud of dust and gas contracted, pulling the matter into its centre. When the temperature at the centre rose to 1,000,000°C, nuclear fusion – the fusing of hydrogen into helium, creating energy–occurred, releasing a constant stream of heat and light.

Photosphere

The photosphere is the bright outer layer of the Sun that emits most of the radiation, particularly visible light. It consists of a zone of burning gases 300 km thick. The photosphere is an extremely uneven surface. The effective temperature on the outer side of the photosphere is 6000°K (11,000°F).

Chromosphere

Just above the photosphere is the chromosphere. It is relatively a thin layer of burning gases.

Sunspot

A dark patch on the surface of the Sun is known as sunspot. Sunspots appear as dark areas because they are about 1500° cooler than the surrounding chromospheres. The individual sunspot has a lifetime ranging from a few days to a few months. Each spot has a black centre or umbra, and a lighter region or penumbra, surrounding it. The number of visible sunspots fluctuates in an eleven year cycle. It has been suggested that the Sun is 1% cooler when it has no spot, and that this variation in solar radiation might affect the climates of the Earth.

Planet

A celestial body moving in an elliptical orbit round a star, the Earth is known as planet. Planets are generally divided into :
(i)the Inner Planets (Mercury, Venus, Earth and Mars), and (ii) the Outer Planets (Jupiter, Saturn, Uranus, Neptune, and Pluto-dwarf planet).

Inner Planets

Mercury (*God of Commerce and Skill*)
Diameter: 4,878 km (3,031 miles)
Mass: 330 million, million, million tons
Temperature: -173° to 427°C
Distance from the Sun: 58 million km (36 million miles)
Length of day: 58.65 earth days
Length of year: 87.97 earth days
Surface gravity: 1kg = 0.38 kg

Mercury is similar to the Moon with a surface dominated by craters and a younger area of dark plains presumably made from floods of lava. Most of the Mercury's surface is nearly saturated with craters whose range of sizes is similar to that of Moon's craters.

Venus (The Veiled Planet, Goddess of Beauty)

Diameter: 12,102 km (7,520 miles)
Mass: 4,870 million, million, million tons
Temperature: 457°C (extremes not available)
Distance from the Sun: 108 million km (67 million miles)
Length of day: 243.01 earth days
Length of year: 224.7 earth days
Surface gravity: 1kg = 0.88 kg
Venus is often considered to be the Earth's twin, but the two planets are not identical. Venus has high plateaus, folded mountain belts, numerous volcanoes, and relatively smooth volcanic plains. The surface of Venus is totally obscured by a thick atmosphere composed mostly of carbon dioxide, with clouds of sulfuric acid. It contains volcanic plains, mountain belts, volcanoes and two high '*continents*' that rise several kilometers above vast rolling low lands which shows that Venus has a surface similar, in some ways, to the surface of the Earth with its continents and ocean basins.

Earth

Diameter: 12,756 km (7,926 miles)
Mass: 5,976 million, million, million tons
Temperature: -80° to 58°C
Distance from the Sun: 150 million km (93 million miles)
Length of day: 23.92 hours
Length of year: 365.25 earth days
Surface gravity: 1 kg = 1 kg

The Earth is shaped like a ball, but it is not perfectly round. The force of the Earth's rotation makes the world bulge very slightly at the equator and go a little flat at the North and the South poles. So the Earth is actually a flattened sphere, or a *'geoid'*.

The Earth is unique among the terrestrial planets (Mercury, Venus, Earth, and Mars) because of its size and distance from the Sun. The Earth is unique in the solar system in that it supports life: its size, gravitational pull and distance from the Sun have all created the optimum conditions for the evolution of life. It is large enough to develop and retain an atmosphere and a hydrosphere. Temperature ranges on the Earth are such that water can exist on its surface as liquid, solid, and gas. Water, more than anything else, makes the planet Earth unique. The Earth is a delicate ball wrapped in filmy white clouds. The blue water and swirling patterns of clouds that dominate the scene underline the importance of water in the Earth's system.

The Earth's Atmosphere

During the early stages of the Earth's formation, ash, lava, carbon and water vapour were discharged onto the surface of the planet by constant volcanic eruptions. The water formed the oceans, while carbon dioxide entered the atmosphere or was dissolved in the oceans. Clouds, formed of water droplets, reflected some of the Sun's radiation back into space. The Earth's temperature stabilised and early life forms began to merge, converting carbon dioxide into life-giving oxygen.

The Earth's oceans and seas cover more than 367 million sq km, i.e. twice the surface of Mars and nine times the surface of the Moon.

The Pacific Ocean contains the deepest places on the Earth's surface–the ocean trenches. The very deepest is the Challenger Deep in the Mariana Trench which plunges 11022 m into the Earth's crust. If Mount Everest, the highest point on land at 8,848m was dropped into the trench, its peak would not even reach the surface of the Pacific.

Mars (Red Planet, God of War)

Diameter: 6,786 km (4,217 miles)
Mass: 642 million, million, million tons
Temperature: -137° to 37°C
Distance from the Sun: 228 million km (142 million miles)
Length of day: 24.623 hours
Length of year: 188 earth years
Surface gravity: 1 kg = 0.38 kg

Mars is smaller than the Earth and Venus, but has many fascinating geological features, indicating that its surface has been dynamic. Almost every geologic feature is gigantic. Three huge volcanoes, one more than 28 km high exists at Mars. An enormous canyon extends across the entire hemisphere, a distance roughly equal to that from New York to San Francisco. Mars is a planet of fascinating geologic features. Almost everything is gigantic including the landscape and eroding deep channels. Wind action is also an important process: volcanoes, canyons, and landslides. There is evidence not only of stream action, but of catastrophic flooding in which sheets of water, possibly 300 m deep, surged over the landscape, eroding deep channels. Wind action is also an important process on Mars. In addition polar regions are covered with alternating layers of ice and wind blown sediment.

Outer Planets

Outer Planets are Jupiter, Saturn, Uranus, Neptune and the dwarf planet – Pluto. Planetary bodies in the outer solar system were formed mostly of the lighter elements: hydrogen, helium, and oxygen. Hence, the satellites of the giant planets are composed mostly of ice, not of rock, like the inner planets.

Jupiter (Giant Planet, Ruler of Gods)

Diameter: 142.984 km (88,846 miles)
Mass:1,900,000 million, million, million tons
Temperature: -153°C (extremes not available)
Distance from the Sun: 778 million km (483 million miles)
Length of day: 9.84 hours
Length of year: 11.86 earth years
Surface gravity: 1 kg = 2.53 kg

It is composed mostly of gas and liquid swirling in complex patterns. Jupiter has no solid surface and hence no record of a geologic history. Its moons are, however, solid planetary bodies that contain geologic wonders. Jupiter's four large moons (Io, Europa, Ganymede, and Callisto), called the Galilean satellites because they were discovered by Galileo in 1610, have composition dramatically different from those of the rocky inner planets. Three of these moons have surfaces composed mostly of water ice. Each of the Jupiter's moons shows a diverse landscape resulting from impact, volcanism, and surface fracture. Jupiter has a volume of 1300 times greater than that of the Earth.

Saturn (Ringed Planet, God of Agriculture)

Diameter: 120,660 km (74,974 miles)
Mass: 570, million, million, million tons
Temperature: -185°C (extremes not available)
Distance from the Sun: 1,427 million km (887 million miles)
Length of day: 10.23 hours
Length of year: 29.46 earth years
Surface gravity: 1 kg = 1.07 kg

Saturn is similar to Jupiter in many ways. It is a gigantic ball of gas, mostly of hydrogen, and helium, and is the centre of a miniature planetary system with an elaborate family of satellites. Its atmosphere is marked by dark bands alternating with higher lighter zones. Saturn's rings for long have been considered as its most dramatic feature. The rings are probably made up of billions of particles of ice and ice-covered rocks, ranging from a few micrometers to a metre or more in diameter. Each particle moves in its independent orbit around Saturn, producing an extra-ordinarily complex ring structure.

Uranus (The Green Planet, God of Heavens)

Diameter: 51,118 km (31,763 miles)
Mass: 86,800 million, million, million tons
Temperature: -214°C (extremes not available)
Distance from the Sun: 2,870 million km (1,783 million miles)
Length of day: 17.9 hours
Length of year: 84.01 earth years
Surface gravity: 1 kg = 0.92 kg

Like Jupiter and Saturn, it has no solid surface, but is enveloped by a thick atmosphere of hydrogen and helium. In contrast to all other planets in the solar system, it is tipped and spun on its sides, that is its axis of rotation lies nearly the plane of its orbit. Thus, it rolls, like a ball, as it moves on its orbital path around the Sun, whereas other planets spin like tops. Uranus has five major moons. Each moon occupies a nearly circular orbit, lying in the plane of Uranus' equator.

Neptune (A Twin, God of Sea)

Diameter: 49,528 km (30,775 miles)
Mass: 102,000 million, million, million tons
Temperature: -225° C (extremes not available)
Distance from the Sun: 4,497 million km (2,794 million miles)
Length of day: 19.2 hours
Length of year: 164.79 earth years
Surface gravity: 1 kg = 1.18 kg

Uranus and Neptune are called the twins of the outer solar system. Surrounded by thick atmosphere of hydrogen, helium and methane. It has about a dozen moons, out of which Triton is the largest.

Pluto (A Dwarf Planet-God of Death)

Diameter: 2300 km (1428 miles)
Mass: 13 million, million, million tons
Temperature: -236°C (extremes not available)
Distance from the Sun: 5,900 million km (3,666 million miles)
Length of day: 6.39 hours
Length of year: 248.54 earth years
Surface gravity: 1 kg = 0.30 kg

Asteroids

Millions of objects, remnants of planetary formation, circle the Sun in a zone lying between Mars and Jupiter. They are known as asteroids. Fragments of asteroids break off to form meteoroids, which can reach the Earth's surface. Comets, composed of ice and dust, originated outside our solar system. Their elliptical orbit brings them close to the Sun and into the inner Solar System.

Table 1.1: *Facts about the Planets*

Planet	*Mean distance from Sun (Million of km)*	*Period of Revolution*	*Inclination to Ecliptic*	*Orbital Velocity (Km/s)*
Mercury	58	88 days	7°00′	47.9
Venus	108	225 days	3°24′	35.0
Earth	150	365.25 days	23°50′	29.8
Mars	228	687 days	1°51′	24.1
Jupiter	778	12 years	1°19′	13.1
Saturn	1427	29.5 years	2°30′	9.6
Uranus	2869	84 years	0°46′	6.8
Neptune	4498	165 years	1°46′	5.4
Pluto	5900	248 years	17°12′	4.7

Source: Tarbuck and Lutgens (1976, p.408).

Table 1.2: *Planets and their Satellites*

Planet	*No. of Known planets*	*Main Satellites*
Mercury	-	-
Venus	-	-
Earth	1	Moon
Mars	2	Deimos, Phobos
Jupiter	65	Ganymede, Callistro, Io, Europa
Saturn	31	Titan, Teythes, Mimas, Rhea, Enceladus, Dione
Uranus	27	Miranda, Titania, Oberon, Ariel, Umbriel
Neptune	13	Triton, Nereid
Pluto	1	Charon

Comets

Comets are among the most spectacular and unpredictable bodies in the solar system. They have been compared with large, dirty snowballs, since they are made of frozen gases (water, ammonia, methane and carbon dioxide) which hold together small pieces of rocky and metallic minerals **(Fig. 1.6)**. Many comets travel along very elongated orbits that carry them beyond the Pluto. On their return, the comets are visible only after they have moved within the orbit of Saturn. One of the larger comets is the Halley's Comet. The orbit of Halley's Comet brings it close to the Earth every 76 years. It last visited in 1986.

Meteoroids

Meteor is a body of matter travelling at a great speed through space which becomes luminous when enters into the atmosphere (ionosphere) at about 200 km above the Earth's surface, because it is heated by friction. Generally, this latter process dissipates the material into meteoric dust. A meteor is popularly termed a *'shooting star' or 'falling star'*.

Meteorite

Any particle of solid matter that has fallen to the Earth, the Moon, or another planet from the space. It is composed of various proportions

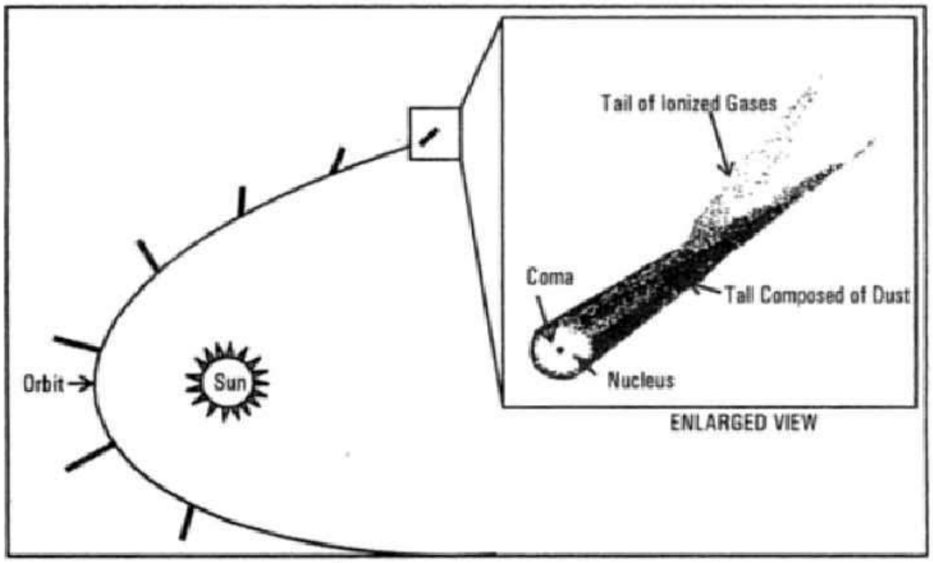

Fig. 1.6: Orientation of a comet's tail as it orbits the Sun

of a nickel-iron alloy (typically about 10% nickel and about 90% iron) and silicate minerals.

Largest Meteor Crater: A meteor crater in Arizona (USA) is 4,200 ft (1,300 m) deep is the largest meteor crater in the world. It was formed over 10,000 years ago.

Seasons

The axial tilt of the Earth of 23.5 degrees as it moves around the Sun causes seasonal changes **(Fig 1.7)**. When in June the Northern Hemisphere tilts towards the Sun, it gets maximum heat while the Southern Hemisphere gets little heat. It is thus summer in the Northern Hemisphere and winter in the Southern Hemisphere. Six months later, in December, the situation is reversed as the Earth travels halfway around the Sun and its Northern Hemisphere is tilted away from the Sun.

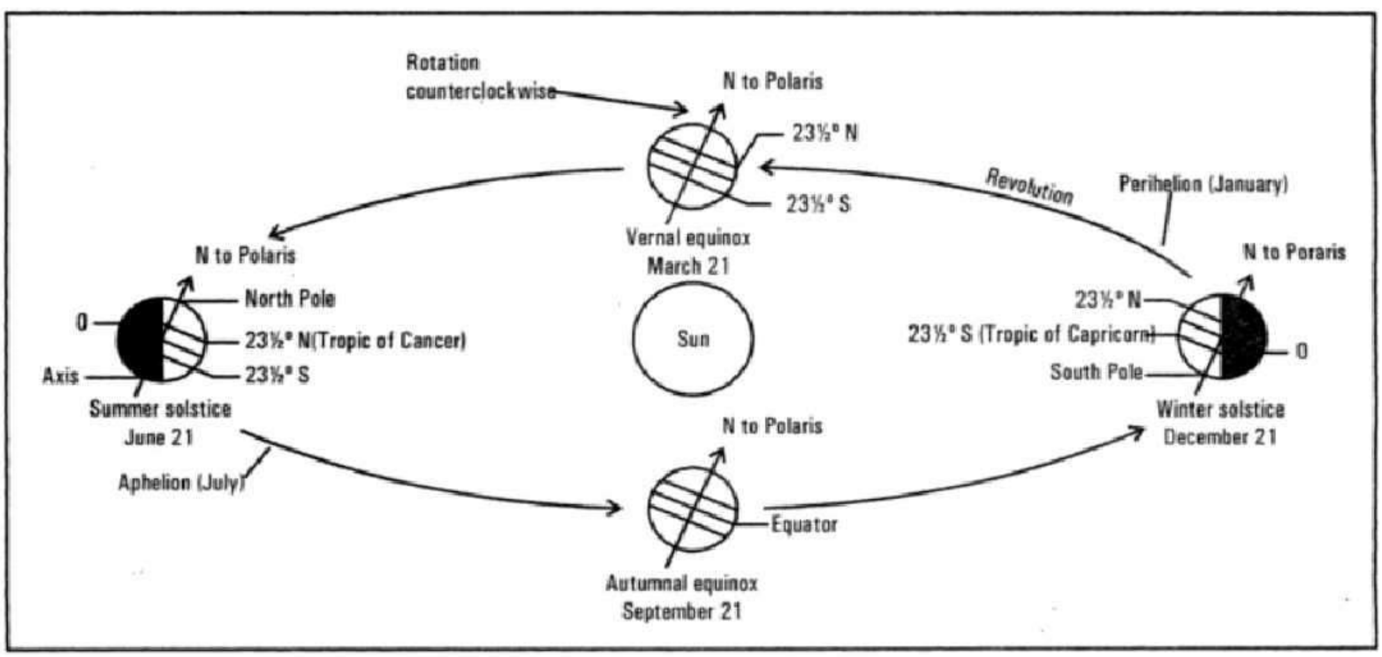

Fig. 1.7 – Earth–Sun relationship

***Table 1.3**: Five Reasons for Seasons*

Factor	Description
Revolution	Orbit around the Sun; requires 365.25 days to complete at 107,280 kmph (66,660 mph).
Rotation	Earth turning on its axis; takes approximately 24 hours to complete at 1,675 kmph at the equator (1,041 mph)
Tilt	Axis of the Earth is aligned at 23.5° angle from a perpendicular to the plane of the ecliptic (the plane of the Earth's orbit).
Axis	Remains in a fixed alignment of axial parallelism, with Polaris directly overhead at the North Pole throughout the year.
Sphericity	Appears as an oblate spheroid to the Sun's parallel rays; the geoid.

Source: Christopherson, R.W., *1995*, ***Elemental Geosystem- A Foundation in Physical Geography***, Prentice Hall, p. 48.

On June 21, the Sun is directly overhead the Tropic of Cancer (23.5° degrees North) and it is mid-summer in the Northern Hemisphere. Mid-summer in the Southern Hemisphere occurs on 23rd December when the Sun is directly overhead the Tropic of Capricorn (23.5° degrees South).

***Table 1.4:** Annual March of the Seasons*

Approximate Date	*Northern Hemisphere Name*	*Location of the Sub-polar Point*
December 21-22	Winter solstice (December solstice)	23.5° S latitude (Tropic of Capricorn)
March 20-21	Vernal equinox (March equinox)	0° (equator)
June 20-21	Summer solstice (June solstice)	23.5o N latitude (Tropic of Cancer)
September 22-23	Autumnal equinox (September equinox)	0° (equator)

Source: Christopherson, R.W., 1995, ***Elemental Geosystems - A Foundation in Physical Geography***, Prentice Hall, p.51.

The Moon

With the development of space programme, the Moon has become one of the best understood planetary bodies in the solar system. The Moon is the natural satellite of the Earth, with a diameter of 3,470 km. The Moon is pock-marked with billions of craters, which range in size from microscopic pits on the surface of rock specimens to huge circular basins of hundreds of kilometers in diameter.

The Moon rotates more slowly than the Earth and takes a little over 27 days to rotate once. Since it takes about the same time to revolve around the Earth, it always presents the same face or hemisphere to the Earth. The interval between one Full Moon and the next is 29.5 days. The Moon seems to have different shapes at different times of the month because of its changing position in relation to the Earth. The different shapes are known as the phases of the Moon **(Fig. 1.8)**.

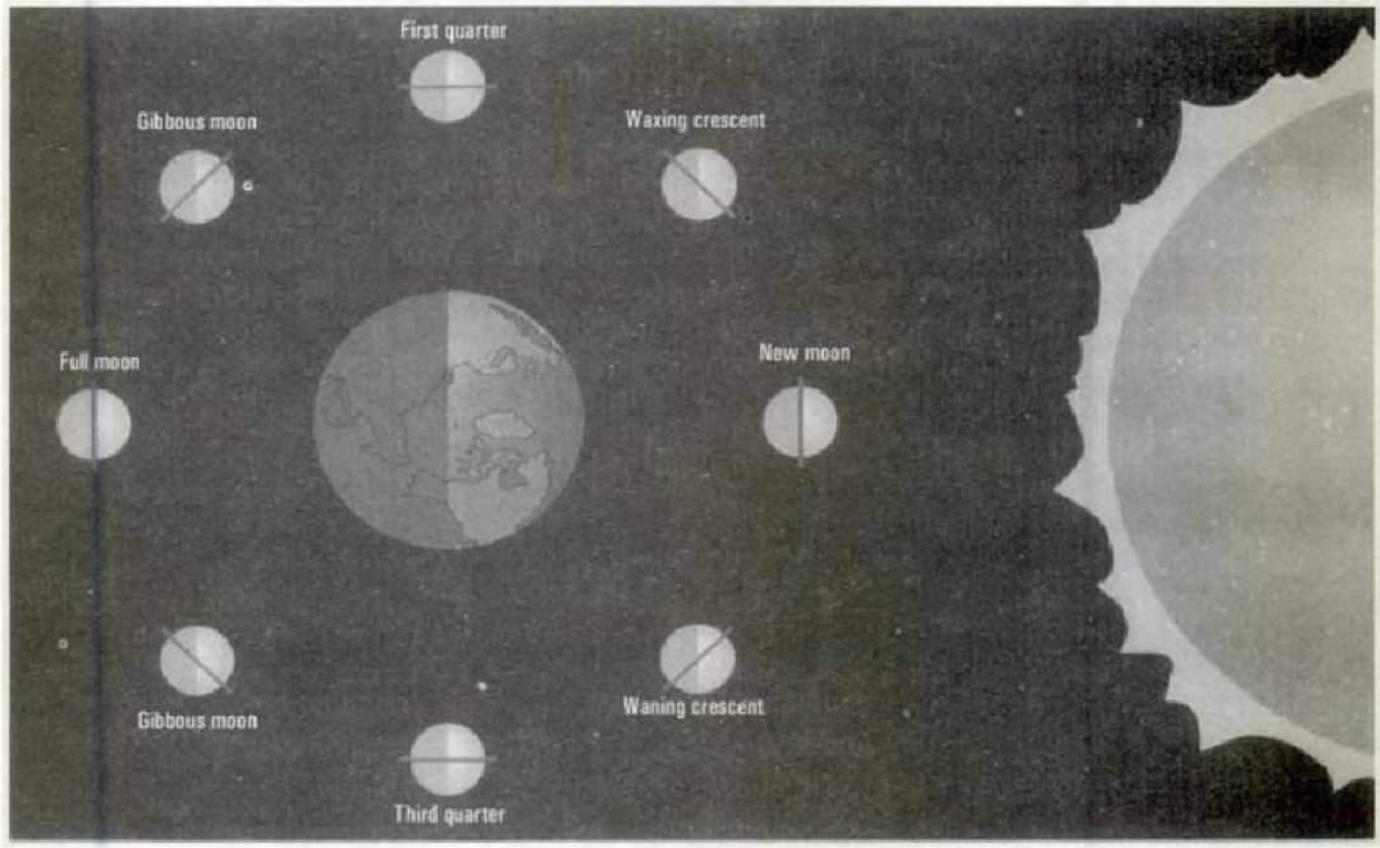

Fig. 1.8 – Phases of the Moon
(After: Conte, Thompson, Moses, *Earth Science,* 1997, Mc Graw Hill Higher Education, p.34)

International Date Line

Any place just west of 180° is twelve hours ahead of Greenwich Mean Time; point just east of it are twelve hours behind. To reconcile these facts, an imaginary line – the International Date Line – has been established. The line follows 180° longitude except where it crosses land so there are some departures from the meridian. As the traveler moves from east to west over the International Date Line he or she 'skips' a day; the date is put forward one day. The traveler moving in an opposite direction keeps gaining time, so that a day must be repeated in order to reconcile the gains; thus, the date is put back one day. The International Date Line and the Standard Time Zone have been shown in **Fig. 1.9**.

Coordinated Universal Time

Greenwich Mean Time was replaced by a universal time system in 1928, and this system was expanded in 1964 when ***Coordinated Universal Time (UTC)*** was instituted. Today, UTC is the reference for official time in all countries. Although the Prime Meridian still runs through Greenwich, UTC is based on an average time calculations collected in Paris broadcast worldwide.

Each time zone theoretically covers 7.5° on either side of a controlling meridian and represents one hour **(Fig. 1.9)**. However, as you can see **(Fig. 1.9)** time zone boundaries are adjusted to keep certain areas together in the same time zone – see China, for example.

Daylight Saving Time

In many countries, time is set ahead one hour in the spring and set back in the autumn – a practice known as *Daylight Saving Time*. The idea of extended daytime in the evening was first proposed by Benjamin Franklin, although not until World War I, did Great Britain, Australia, Germany, Canada and the United States adopt the practice.

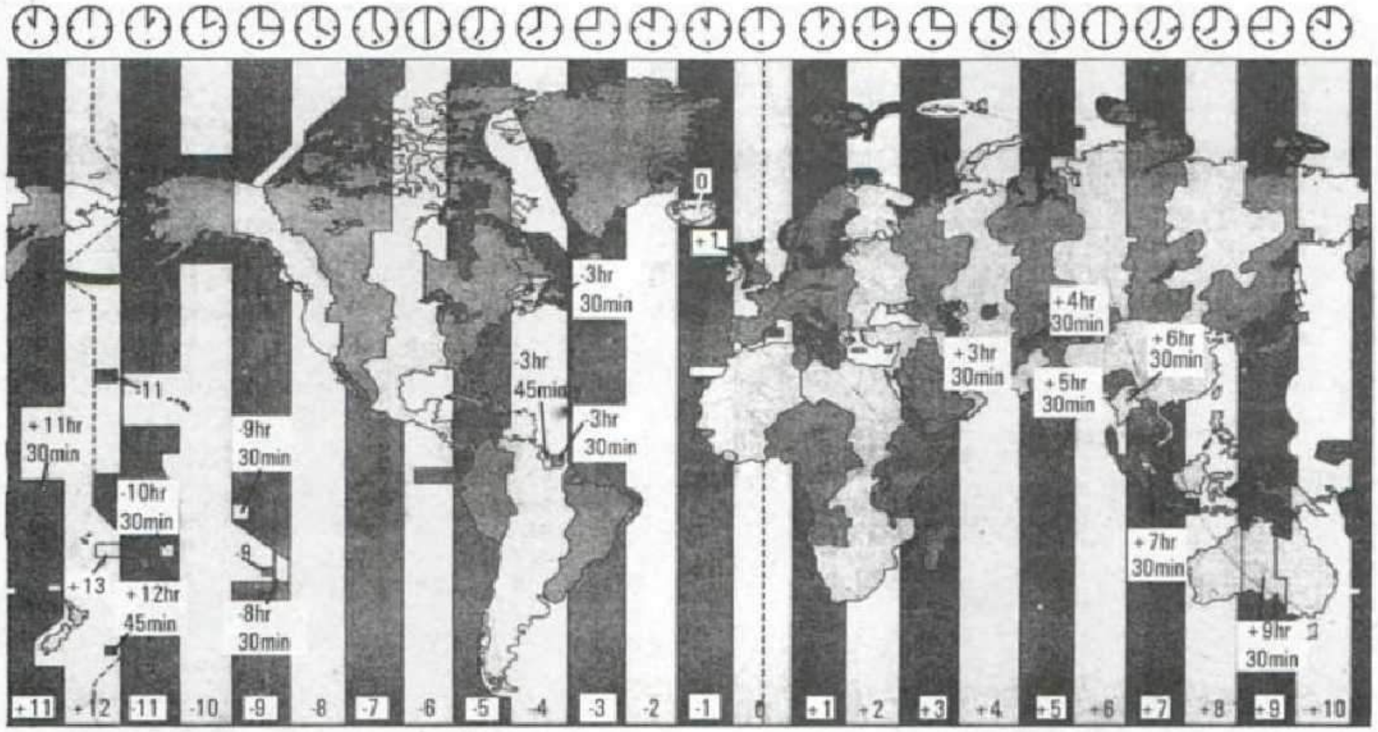

Fig. 1.9 – Standard time zones of the world
(After: *Earth Science* – Mc Graw Hill Higher Education, 1997, p.35)

Clocks in the United States were left advanced an hour from 1942 to 1945 during World War II, producing an added benefit of energy savings (one less hour of artificial light needed), and again during 1974-1975.

Daylight saving time was increased in length in the United States and Canada in 1986. Time is set ahead on the first Sunday in April and set back on the last Sunday in October – only Hawaii, Arizona, portions of Indiana and Saskatchewan exempt themselves. In Europe the last Sunday in March and September generally are used to begin and end Daylight Saving Time.

Great Circles and Small Circles

Great circles and small circles are important concepts that help summarise latitude and longitude. A *great circle* is any circle of Earth's circumference whose centre coincides with the centre of the Earth. An infinite number of great circles can be drawn on the Earth. Every meridian in one-half of a great circle that passes through the poles. On flat maps, airlines and shipping routes appear to arch their way across oceans and landmasses. These are great circle routes, the shortest distance between two points on the Earth. Only one parallel is a great circle – the equatorial parallel. All other parallels diminish in length toward the poles and, along with any other non-great circle that one might draw, constitute small circles – circles whose centres do not coincide with the Earth's centre **(Fig. 1.10)**.

The Northern and Southern Hemispheres

The equator is an imaginary line drawn around the middle of the Earth, where its circumference is the greatest. If we cut the Earth along the equator, the Earth separates into two hemispheres, the northern and the southern hemispheres. Most of the Earth's land is in the Northern Hemisphere. Europe, and North America are the only continents which lie entirely in the Northern Hemisphere. Australia and Antarctica are the only continents that lie in the Southern Hemisphere **(Fig. 1.11)**.

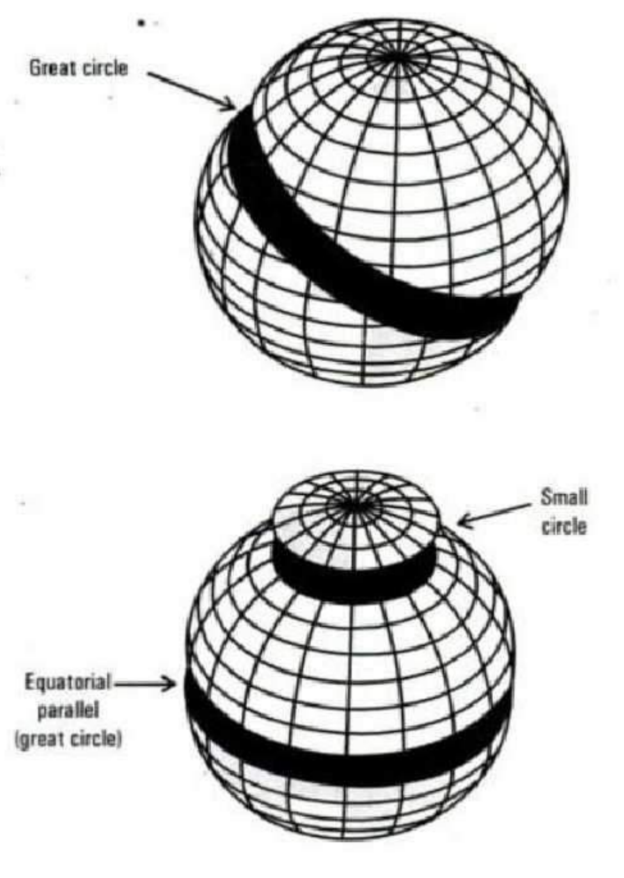

Fig. 1.10 – Great circles and small circles on Earth

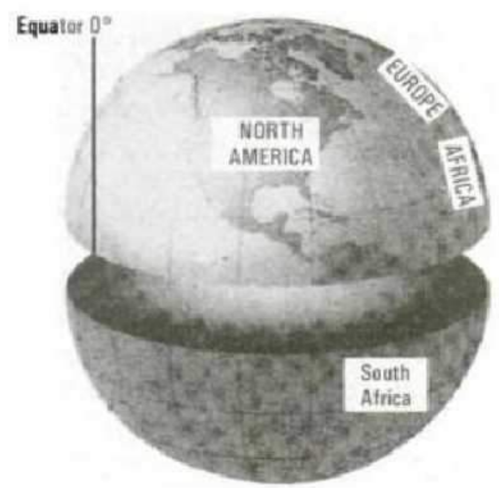

Fig. 1.11 – The southern hemisphere contains three of the Earth's four great oceans — the Pacific, Indian and Arctic oceans

The Eastern and Western Hemispheres

The Earth can also be divided along two other imaginary lines – the Prime Meridian (0°) and 180° – which run opposite each other between the North and South poles. This creates the Eastern and the Western Hemispheres. The continents in the Eastern Hemispheres are traditionally called the *Old World*, while those in the Western Hemisphere – the Americas – were named the New World by the Europeans who explored them in the 15^{th} century **(Fig. 1.12)**.

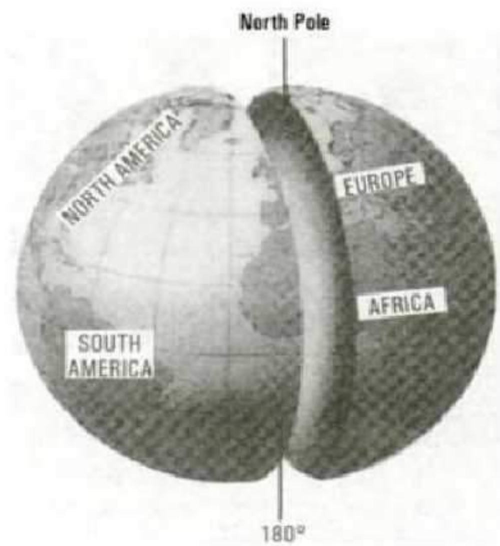

Fig. 1.12 – The Eastern and Western hemispheres

The Land Hemisphere

The land hemisphere is dominated by the continents of Asia, Africa and Europe. The area of the land hemisphere is however, taken up by the waters of the Pacific, Atlantic and Indian oceans.

The Water Hemisphere

The Pacific Ocean is so enormous, it stretches across a whole hemisphere, reaching halfway around the globe at its widest point. It is bigger than all the land put together and contains almost half of all the water on the Earth. The southern hemisphere containing less land is also known as water hemisphere.

The Global Positioning System (GPS)

The Global Positioning System (GPS) comprises 24 orbiting satellites that transmit navigational signals for earth-bound use. Originally devised in the 1970s by the Department of Defence for military purposes, the GPS in its present form is now commercially available worldwide. A hand-held receiver about the size of a pocket radio accesses three satellites at the same time and calculates and displays your latitude and longitude, accurate within 40 to 100 m (precision down to millimeters) is possible for military applications.

GPS is useful for such diverse applications like ocean-navigation, land surveying, commercial fishing, tracking and the monitoring of highway taxes, mining and resource-mapping, farming, environmental planning and as of 1994, airlines began using GPS to improve routes and increase fuel efficiency. GPS is also available for the back-packer and sportspersons. The importance of GPS to geography is obvious because this precise technology reduces the need to maintain ground control points of location, mapping, and spatial analysis.

REFERENCES

Bondi, H., 1960, ***The Universe at Large***, New York, Doubleday.

D.K. ***Concise Atlas of the World,*** 2001, London, Dorling Kindersley Ltd.

Christopherson, R.W. 1995, ***Elemental Geosystems: A Foundation in Physical Geography***, Englewood Cliff.

Hamblin, W.K. and E.H. Christiansen, ***Earth's Dynamic Systems***, Seventh Edition, Printice Hall, Englewood Cliffs, NJ.

Lyttleton, R., 1956, ***The Modern Universe***, New York, Harper and Row.

Reader's Digest, Great World Atlas, London.

Struve, O., 1962, ***The Universe***, Cambridge, Mass. M.I.T. Press.

Strahler, A., et. al. 1997, ***Physical Geography***, New York, John Wiley & Sons Inc.