By the end of this chapter, you will be competent to...

- investigate the ancient and modern views about the solar system and compare them.
- observe the night sky and identify the zodiac and some constellations.
- understand the existence of stars and galaxies.
- explain the origin and expansion of the universe.
A star speckled night sky filled the minds of men with awe, not only in the past but also at present. From the ancient time, man has observed stars and planets appearing in the night sky and he has come up with various theories about them. Accordingly, astronomy can be considered as the oldest science in the world.

It was the Greeks who introduced Astronomy as a science of studying the sun, the moon and the stars. There is evidence to prove that they used the knowledge from predecessors in Egypt and the Middle eastern countries for this purpose.

In the distant past, celestial bodies were venerated as Gods. The first philosopher to attack the myths regarding these objects was a Greek scientist Thales (640 B.C). According to his theory the earth is flat. It floats on the ocean like a ship. The sun, the moon and the stars are balls of fire revolving around this flat earth.

The idea of a flat earth was rejected by the great philosopher and mathematician Pythagorus (580–500 B.C) who declared that the earth is a sphere. His name became immortalised with the famous pythagorus theorem.

Another Greek philosopher Aristotle (384–322 B.C) also supported the idea of a spherical earth and explained it more clearly. He stated that the edge of the shadow of the earth falling on the moon during an eclipse being a part of a sphere is an evidence of the spherical nature of the earth.

He further stated that if a person were to travel a certain distance from a point in any direction the change of the ascending angle of a star is the same, as evidence for the spherical shape of the earth.

The view of Aristotle was that the sun, the moon and the planets revolve round the earth. This incorrect idea of a geo - centric (earth - centered) model prevailed for about 2000 years.

The first astronomer who put forward the heliocentered idea (sun - centred) was the Greek (national) Aristorcus of Samos (310-250 B.C) who stated that the earth revolves round the sun.

He also stated that the stars appear to rise and set each day because of the rotation of the earth. However, the heliocentred idea was not accepted due to lack of evidence.

Do you know?
One of the craters on the moon is named after Aristarcus.
Although Aristotle presented this idea of a geo-centric model, it was further established on a mathematical basis by Claudius Ptolemaeus (100-178 A.D) who also named as Ptolemy. Ptolemy was also responsible for building up maps of the earth and the celestial bodies.

**Do you know?**

A map of Sri Lanka was made for the first time by Ptolemy.

Ptolemy was successful in compiling a book called *Almagest* which was a collection of all knowledge available at that time. He indicated the presence of 48 constellations in that book out of which 47 are still known by their original names.

His view was that the earth is at the centre of the universe and that the sun, the moon and the planets known at that time revolved round the earth in crystal spheres.

The views of Aristotle and Ptolemy were accepted by the powerful religious authorities at that time. Presenting any views against them was an act that could be punished by law.

**Observing stars is one of the world famous hobby. If you too select it as a hobby you can get a great satisfaction throughout your life where ever you be in the world.**

The helio-centric model, that is, the universe and the other planets revolve around the sun was strongly advocated by Polish Astronomer Nicolaus Copernicus (1473- 1543 A.D). This was a radical and a courageous effort. This became a radical effort because at that time it was believed that the earth we live in, moves through space was an extremely novel idea. It became a courageous effort since at that time speaking against the geo-centred idea that was accepted by the religious authorities was an anti-religious crime that could be punished by law.

Copernicus argued that the sun is at the centre of the universe and that planets revolve around it in mega circular orbits. He also stated that the further away a planet is from the sun, the longer time it takes to revolve around the sun. As evidence for his theory he showed that the closest planet to the sun being Mercury takes about 2 months, while the Saturn takes about 30 years to revolve around the sun, which is the planet farthest from the sun known at that time.

This novel idea of Copernicus led to an intellectual revolution at that time. That is why Copernicus is known as “the great man who rotates the earth”. However, his ideas which contradicted the religious teaching, and therefore the book which contained his ideas was published after his death. (A crater in the moon is named after Copernicus too)
After Copernicus, great astronomers such as Tycho Brahe, Johannes Kelper and Gallelio Galili continued to follow him and to improve the field of astronomy as a science.

Tycho Brahe (1546-1602 A.D) was also a pioneer in constructing instruments for studying about stars. He was able to record the movement of nearly 700 stars and the solar system correctly. He rendered a valuable service at that time by correcting some of the existing data on astronomy.

Brahe did not accept the helio-centric model of Copernicus. He stated that the five planets then discovered revolved around the sun and that the sun and these planets revolved around the earth once a year. (The ‘Tycho’ crater on the moon is named after this astronomer)

Although Brahe’s ideas on the movement of planets were incorrect, the information he gathered formed the ground work for later astronomers. Johannes Kelper made use of his observations and measurements to establish the ideas of Copernicus in later years.

Johannes Kelper (1571-1630 A.D), a German astronomer was able to formulate three laws of planetary motion.

The ideas of Kelper’s laws of planetary motion can be summerised as follows:

• Every planet moves in an elliptical orbit which keeps the sun at one focus.
• The planets which revolve around the sun in their orbits move faster when it is closer to the sun, and move slowly when it is far away from the sun.
• The length of the year of the planets which are close to the sun is shorter than that which are far of the planets away from the sun.

Let us conduct the Activity 2.1.1 to identify the nature of an elliptical orbit.

**Activity - 2.1.1**

Fix a white sheet of paper on a wooden board by means of drawing pins. Place 2 pins apart from each other on the paper. Take a piece of thread, tie the two ends to form a loop, and pass it around the two pins. Now use the pencil and draw an ellipse with the thread tightly sketched. The points where the pins were fixed will be the two centres of the ellipse.
Gallelio Galili (1571 - 1630 A.D) an Italian scientist, is considered as the father of modern astronomy. When he came to know that a telescope has been made by Hanz Liperzi a Holland national, he also made a telescope and observed the following.

- sunspots.
- mountains and craters on the moon
- phases of the planet venus.
- location of the four largest moons of the planet Jupiter.

The four largest moons of the planet Jupiter are named as Gallilean moons. Gallelio observed with the telescope that these moons revolve around the planet. Similarly our moon too revolves around the earth, and as Copernicus predicted, all planets revolve around the sun. Therefore, Galileo is respected for establishing the helio-centred view of the earth. This was an important milestone of astronomy.

Do you know?

Galileo had to face many difficulties because his ideas conflicted with the existing religious convictions. He was advised many times not to support the helio-centric views of Copernicus. Later, he was brought before a religious authority and was found guilty. He was subjected to house arrest and later became blind, before his death. In 1992, the Pope removed this penalty.

Assignment - 1

Prepare a booklet including the information about great astronomers and their discoveries.
One of the items in the educational trip organised for the students of grade 9 in Saman Vidyalaya was a visit to the planetarium.

All students entered the hall of the planetarium and took their seats. They were observing the roof of the planetarium. It was a white hemisphere.

The hall became gradually dark accompanied by lovely music. The ‘Planetarium sky’ got lit up by stars one by one, till the white area was completely filled with stars.

The lecturer of the planetarium started his lecture. “We welcome all of you to our planetarium today. First of all, let us identify the 4 directions of our planetarium sky.” Having said this, he directed the special torch he held in his hand up to the planetarium sky. A small arrow appeared in the sky. He directed the torch to the letters N, S, E, W and drew the attention of the audience to them.

Students observed that all the stars appearing were moving from the east to the west direction. The lecturer explained that the stars in the night sky showed as if they appeared to move from the east to the west because the earth is rotating from the west to the east. This is similar to what we observe when we are travelling in a vehicle, the trees and houses on either sides of the road appear to move backwards.

**Do you know?**

In a planetarium, it is possible to view the sky on any day, at any time and at any place. This is done by an instrument called the Universal Projector.

This instrument is mounted on a stage at the centre of the planetarium. From here it is possible to observe the eclipses of the sun and the moon, meteorite rains, comets as well as the view of the solar system to a person observing it from outside, and the view observed if one were to travel in a space craft in a journey through the solar system.

To observe these views get into the web www.starrynight.com. You can obtain compact disc containing all these information from the Arthur C. Clerk Centre.
To study about the star patterns, **observing the night sky** is a ‘must’. The instructions you have to follow are given below.

- Select a day close to new moon (Amawaka) day.
- Cover the face of your torch with a red coloured cellophane paper.
- Stand on a stage during observations in order to protect yourself from snakes, poisonous animals and thorny bushes.
- Be prepared for sudden changes of weather.
- Get a photocopy of the star maps provided in this book and use them.
- Keep a note book and a pencil.
- It is better if you use a compass to identify directions. If not, use the direction of the buildings and trees you noted during the day. Once the star patterns are identified they will help you to identify directions.

The imaginary pictures built up by joining the stars observed in the night sky are known as constellations. These pictures may be of natural objects or characters from mythology.

Fig 2.2.2 shows some constellations that can be seen in the sky in the months of February and March around 8 p.m. in the night.
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Orion

In the months of February and March around 8 p.m. in the night this constellation which forms a pattern resembling a hunter will be seen in the sky (Fig 2.2.3). It has seven very bright stars. The two stars on his shoulders and the two stars on his knees appear as four corners of a square. The belt of the hunter is made up of three bright stars. The head is indicated by three stars which are not very bright. The case of the sword hanging from the belt contains three small stars. Now, you can build up an imaginary picture of the hunter.

Since the head of orion is directed to the north direction, this constellation helps to identify the North. The betelgeuse star indicating the right shoulder be named as $\alpha$ (alpha) orionis. This is a giant red star. The star indicating the left leg is $\beta$ (beta) orionis or Rigel is a blue giant star. These two stars are among the brightest twenty stars in the sky.

About Orion...

According to Greek mythology orion is an expert warrior and a hunter. He was the son of god Neptune, who was the God of the oceans. The other Gods who noted his talents were jealous and killed him using a poisonous scorpion. But Goddess Diana placed him among the stars in the sky and made him immortal. At the sametime she placed the scorpion on the opposite side of the sky so that it cannot get closed to orion. Even today, when orion sets in the western sky, scorpion rises up in the eastern sky.

Do you know?

In order to identify the stars in a constellation, Greek alphabetical letters have been used. The Greek alphabet is as follows.

<table>
<thead>
<tr>
<th>Letter</th>
<th>Greek Letter</th>
<th>Greek Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>Alpha</td>
<td>$\beta$</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Beta</td>
<td>$\gamma$</td>
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<td>$\gamma$</td>
<td>Gamma</td>
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<td>$\epsilon$</td>
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<td>Sigma</td>
<td>$\omega$</td>
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<td>$\omega$</td>
<td>Omega</td>
<td></td>
</tr>
</tbody>
</table>

In a constellation, the brightest star is indicated as alpha ($\alpha$), the second brightest as beta ($\beta$) and third brightest as gamma ($\gamma$), etc.

Fig 2.2.3 - Hunter
Once you identify the head of Orion, north of it and slightly to the East, two bright stars close to each other are visible. They are Castor and Pollux. These two stars indicate the heads of the twins in the Gemini constellation (Fig 2.2.4).

Now connect the three stars in the belt of Orion and took along the line towards the east. Now, you will observe the brightest star in the sky. This is Sirius. It belongs to the constellation Canis Major (Fig 2.2.5).

### Taurus Constellation.

Now, look at the north direction the west of the Orion. You will see a group of stars in the shape of a letter ‘V’. The bright red star in the ‘v’ is Alpha Centauri or Aldebaran. This is supposed to depict one eye of an ox which is about to attack Orion (Fig 2.2.6).

The face of the ox is denoted by the five stars in the shape of letter ‘V’. If you examine closer you would be able to find the two stars fairly apart at the end of the horn of the ox. In the Taurus constellation there is a very attractive star group called Pleiades. When observed with the telescope Pleiades constellation appears as to consisting of more than two hundred stars. The maximum number of stars that can be observed by the naked eye is nearly nine. The brightest star of this group is Tori. (Fig 2.2.7)

### Activity - 2.2.1

In the past people have used the Pleiades group of stars to check their eyesight. Observe the Pleiades group of stars on a clear night and how many stars can you identify in the group.
Observe the sky around 8 p.m. in the months of February and March. You can identify the brightest star Sirius. As you go on observing from the top to down you will be able to identify the second brightest star Canopus in the sky. If you examine it carefully you will see that its colour changes constantly. If you can connect the stars Sirius and Canopus by an imaginary line and extend that line downwards you are getting close to the south pole of the sky. By this you can identify the south direction of the sky in the night.

Given below are some constellations you will see in the mid-night sky in the months of February and March. They can be observed in the months of May and June around 8 p.m. in the night.

**Ursa major**

At the above mentioned months and time the Great Bear or Ursa Major composed of seven bright stars is visible high up in the sky to the north direction. The four stars forming a rectangle depicts the body of the bear, while the remaining three will depict the tail. In some countries this constellation is termed as Big dipper or as Saptharishi (Seven rishis).

The two stars on the side of the head in the rectangle of great bear are called ‘indicator stars’. Connect these two stars by an imaginary line and extend this line about five times downwards. It will lead you to the Pole star or Polaris which is a bright star.
The special feature about this star is that its position never changes. Even in Sri Lanka this star is found very low down in the horizon. But as you proceed to the countries in the North direction of the earth, it moves up from the horizon and in the North pole it is right on top of the sky.

The reason for this star to remain stationary is because it is located directly above the North pole on the axis of rotation of the earth. Hence it is useful for navigators and for people travelling in deserts in the night. By this they can identify the North direction as well as the latitude where they are. Pole star is situated in the constellation called little Bear or Ursa Minor. This is at the end of the bear’s tail.

**Leo Constellation**

If you raise your eyes upwards in the sky along the two indicator stars of the Great Bear constellation, you will see a sickle shaped bright constellation. To the east of this Constellation, three bright stars can be seen at the corners of the right angled triangle. This sickle and the triangle together form the Leo constellation.

The brightest star in the Leo constellation is **Regulus**. At this time, a slanted cross on the southern side of the sky will be visible. This constellation is called the **Southern Cross**.

Two bright stars will be seen closer to the southern cross and east of it. Out of these, further away from the Southern cross is the Alpha Centauri. It is the brightest star of the Centaurus constellation surrounding the Southern Cross. If this is examined with the telescope, it is found to be made up of three stars. Out of the three stars the star closer to Earth is Proxima Centauri. It is the closest of the stars that are visible to the Earth.

**Do you know?**

The distance from the earth to the stars and the distance between stars is measured in units called light years. A light year is, the distance that light travels in one year, which has a speed of 300000 kilometres per second.

That is 300000 x 60 x 60 x 24 x 365 kilometres.

Proxima Centauri is at a distance of 4.2 light years and Sirius is at a distance of 8.7 light years from the earth.
Zodiac

The Earth as well as the planets revolve around the sun. In the same plane as the sun and the planets, in the distant space twelve constellation have been identified as the Zodiac. As the earth revolves around the sun, for us who are on the Earth it appears as if the sun is travelling from one constellation to the other.

These constellations are as follows:

Aries  Taurus  Gemini  Cancer  Leo  Virgo  
Libra  Scorpius  Sagittarius  Capricorn  Aquarius  Pisces

Assignment - 1

The 12 signs of the zodiac are indicated in 12 stamps which are in current usage. Collect these stamps, paste them and prepare an exhibit.

Since a sphere has $360^\circ$ and there are twelve constellations, the space in the sky for each constellation will be $30^\circ$. When the sun is between the earth and a particular constellation, it is said that the sun is in that constellation.

Example: In the following situation, it appears as if sun is positioned in Taurus constellation when observing from the earth.

When observing the night sky and, if the whole sky can be observed, we will see six constellations. Every two hours one constellation will rise up the Eastern horizon and another constellation will set in the western horizon. We can make use of the star maps to study constellations. (Fig 2.2.14)
Fig 2.2.14 - Star map
By using the date scale at the top of the map one can find out the constellation where the sun would be situated in a particular day of the year.

**Example**: Let us find the constellation where the sun is located on 20th of August.

The dates of 15th and 25th of August are marked at the top of the scale. 20th of August is between these two days. When you go vertically down between two days, you will come across Leo constellation. Therefore, the sun will be in the Leo constellation on this day.

This map can also be used to identify the constellation in the night sky. This map has been prepared to tally with 8 p.m. according to Sri lankan time. By using this, we can find the constellation that are visible in the middle of the sky at 8 p.m. in the night.

**Example**: Let us find the constellation in the middle of the sky on the 13th of February at 8 p.m.

The dates of 11th and 15th of February are marked at the bottom of the scale. If we run our fingers vertically up along the line between these 2 days you will meet Taurus constellation. That is the constellation at the top of the sky on the 13th of February.

Once the constellation at the top of the sky is identified the other constellations on its east and west can be found out from the map.

You can make a large photocopy of this map and can use it to observe the night sky. Hold the map over your head in order to tally the four directions of your map with the 4 directions of the earth.

**Uses of constellations.**

1. Constellations can be used to find the directions in the night.

   **Example**: The constellation Ursa Major indicates the North direction while the Southern cross indicates the South direction.

2. The position of a particular planet can be stated with respect to the constellation.

   **Example**: By saying that “planet Mars is in the scorpius constellation” means, that the planet can be seen in the area of the sky, which belongs to the scorpius constellation.
3. Constellations help us to identify the direction in which you should observe to see the meteorite rains.

**Example:** Every year the meteorite shower ‘Leonids’ can be seen in the background of Leo constellation on the 15\(^{th}\) November.

4. The appearance of a comet can be predicted.

**Example:** In 1986 Halleys comet was seen in the area between scorpius and Sagittarius constellations.

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**Do you know?**

The “Lagna” or ‘Rasi’ of a person is, the constellation that arises on the Eastern horizon at the time of his/her birth.

You will note that, three dotted lines going across the middle of the map. Observe the middle one. That line indicates the apparent path of the sun across the sky throughout the year. It is known as the ecliptic. Moon and all the planets are seen in an area spreading 8\(^{o}\) North and 8\(^{o}\) South of the ecliptic.

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**Do you know?**

The ecliptic is a wavy line because the axis of the earth is inclined at an angle of 23.5\(^{o}\) to the orbital plane.
2.3 Existence of stars and Galaxies

We live on the earth which is one of the planets belonging to the solar system. The solar system belongs to the Galaxy known as the Milky way.

It has been estimated that the milky way Galaxy contains about hundred billion stars similar to our sun. The milky way Galaxy takes a spiral shape. The centre looks thicker in a side view. (Fig 2.3.1). Our sun is situated at a distance of about 30,000 light years from the centre of the Galaxy.

The milky way galaxy keeps rotating like a lit up top.

Do you know?

Great bear constellation belongs to M 81 galaxy. Its circumference is about 100,000 light years. It is also a spiral galaxy like Milkyway.

Since galaxies are found far away from the Earth, they cannot be seen with the naked eye. But there are two galaxies that can be seen with the naked eye, they are Andromeda galaxy and Magalenic cloud.

It has been found that in addition to spiral galaxies there are also elliptical and irregular galaxies (Fig 2.3.2).
Birth and death of a star

Just like human beings, a star too has to face stages of birth, middle age and death. However, the life span of a star is millions and billions of years.

A star begins its life by the condensation of a molecular cloud due to a gravitational collapse. A molecular cloud is a large cloud containing dust, and gases such as hydrogen and helium. Such a cloud is many light years in length and width. Due to gravitational force, this cloud of dust and gases shrinks gradually and subject to rotate at high speed generating a great deal of heat and pressure. When the temperature reaches about 150,000 K the centre of the dark cloud appears to shine. Such place is called a Protostar.

As the protostar shrinks further, its temperature and pressure rises up more and more, and speed of rotation increases. The two areas known as the core and the disk can be identified. Astronomers are of the opinion that real stars are formed from the inner core, while planets are formed from the outer disc. The planets revolve round the respective star.

Around a temperature of about 15000,000 K ‘nuclear fusion’ starts, where small atoms collect together to form large atoms. Here there is, formation of helium atoms combining hydrogen atoms.

During the action of nuclear fusion it generates an enormous amount of energy, as well as pressure. The large amount of energy causes the star to shine brilliantly. This is the way of formation of a ‘real star’. Our sun is such a star. Vega Sirius, is another star at this stage.

A place where a star is born is called a Nebula. There is a Nebula that can be observed with the naked eye in the sword of the famous orion or hunter constellation. It is called the great orion Nebula.
Orion Nebula is at a distance of about 1600 light years from the earth. Its circumference is about 30 light years.

**Activity - 2.3.1**

Observe the Orion constellation and identify the giant Orion Nebula inside it.

The ‘Hubble’ telescope positioned in the space was recently directed towards the Orion Nebula. About 150 protostars have been identified there. This establishes the fact that Orion Nebula is a place where stars are born.

Once a star is born it gradually reaches the young stage. During this time the conversion of Hydrogen gas to Helium takes place at a maximum rate. The energy released makes the star shine at maximum. Stars with higher mass, are relatively brighter.

Our sun is considered as a star in the middle age. Its age is estimated round 4500 million years. It may go on exist for about 4500 million years more.

As the sun gets older it gradually turns into a red giant. The red Antares star in the scorpius constellation is such a star (Fig 2.3.4).

The sun which becomes a red giant will be 250 times as it is at present. Then the sun will expand up to the orbit of Mars.

It will then explode and release the outer crust to the space. Such a crust will form a planetary nebula. The small star at the middle of the planetary nebula is called the white dwarf. An example of such a star that can be observed at present is the Cat’s eye nebula (Fig 2.3.5).

After about 3000 million years this white dwarf star will cool down and enter its last journey as a Black star, making a black hole. The life history of the other stars are considered to be similar to that of the sun.

**The origin and expansion of the universe.**

If the universe is a large ocean, galaxies can be considered as islands floating on it. Since the distance between galaxies are large most of the universe is an empty space.

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*For free distribution*
How did the universe begin? As answers to this question many theories have been put forward. The one which is accepted today is the Big-Bang Theory.

According to this theory a very small source had undergone a huge explosion resulting the origin of the Universe (Fig 2.3.6).

This had happened 15 billion years ago. From the time of starting, the universe has been expanding.

Telescopic observations show that, galaxies are moving away from each other at high speeds. This is an important evidence of the Big Bang Theory.

Time and space did not exist before the Big Bang. Scientists believe that the enormous amount of energy from this explosion resulted the creation of matter, gravity and magnetism.

It has been found recently that the radiation emitted at the beginning of the earth is still echoing. This is called background radiation. The Big Bang theory is not only a theory of the origin of the universe. Astronomers are still conducting research on it. You too may have an opportunity to being such an astronomer in the future.

**Do you know?**

The Japanese, Kaoru Ikeya who started observing the sky at a very early stage, discovered a comet using a telescope constructed by himself. He is the youngest person who discovered a comet. It has been named as Ikeya Seki.
Exercises

1. Fill the following puzzle using the names of constellations.

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2. Name the two important models for the movement of planets and the sun presented so far.

3. Which model is more accepted?

4. State the astronomers who contributed for the following instances which were important or the progress of astronomy.
   i) Declaring for the first time that the earth is a sphere.
   ii) Presenting evidence for the first time for the spherical nature of the earth.
   iii) Declaring that the earth travels around the sun
   iv) Preparing a list of the names of the constellation currently used.
   v) Presenting a Helio-centric model in a more acceptable way.
   vi) Constructing accurate instrument for studying the movements of the stars.
   vii) Showing that planets move around the sun, not in spherical orbits but in elliptical orbits.
   viii) Establishing the Helio-centric model by using telesophic observations.