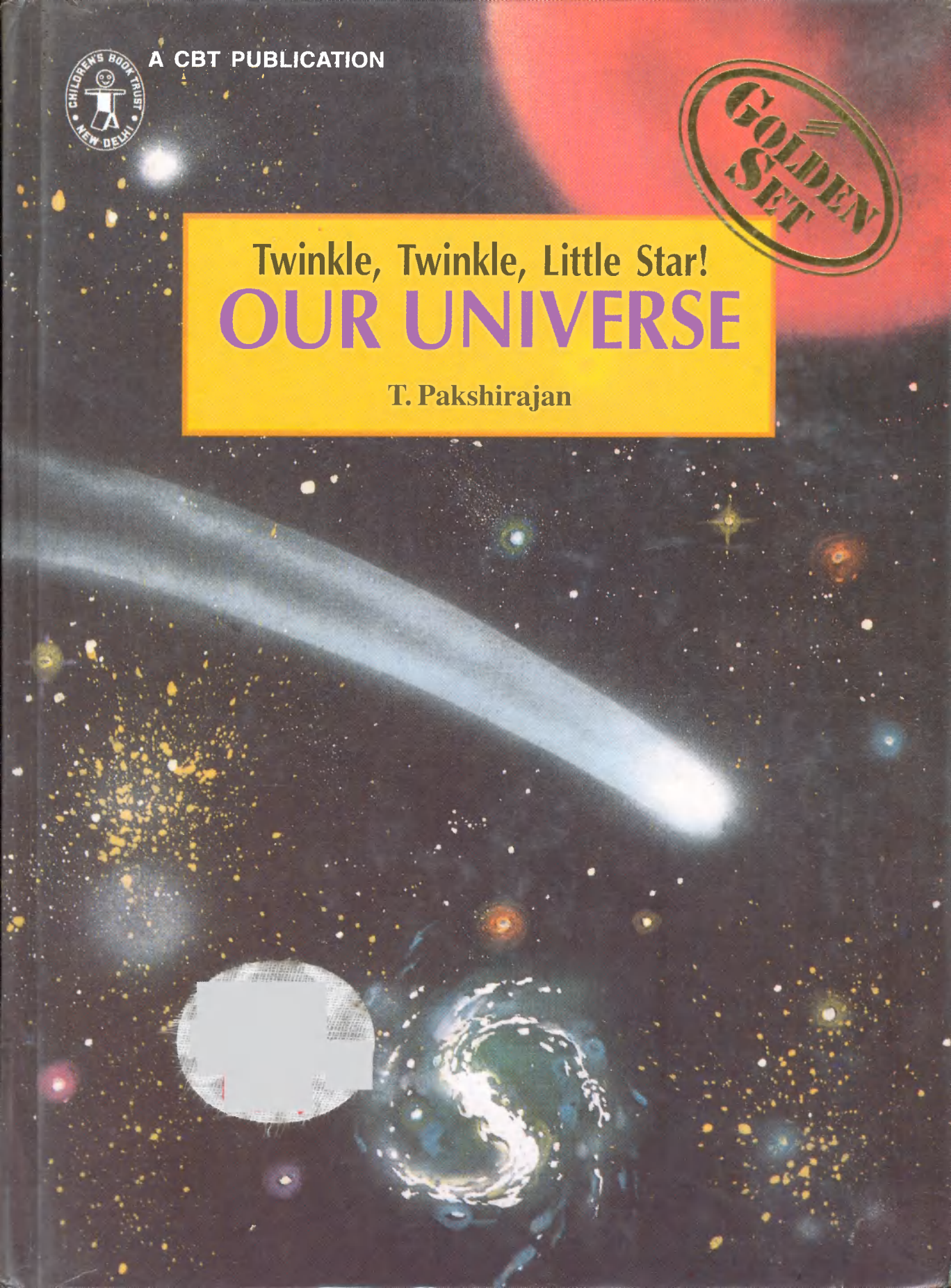
A CBT PUBLICATION

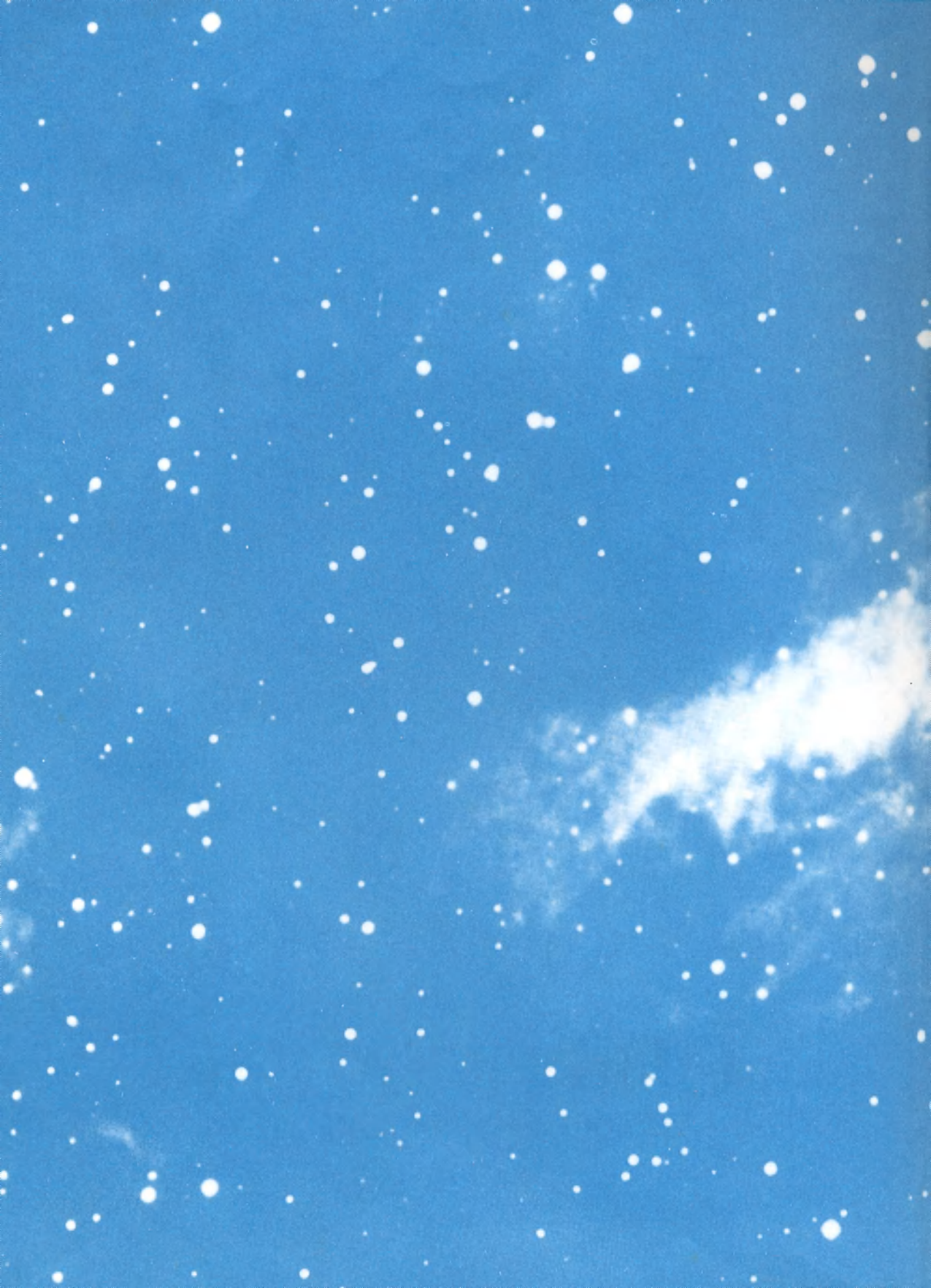
GOLDEN SET

Twinkle, Twinkle, Little Star!

OUR UNIVERSE

T. Pakshirajan

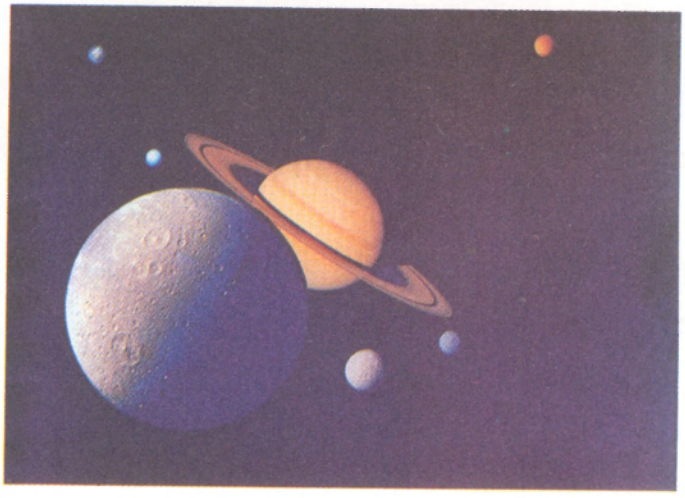




Twinkle, Twinkle, Little Star!

OUR UNIVERSE

By
T. Pakshirajan
Illustrated by Subir Roy



Children's Book Trust, New Delhi

Twinkle, Twinkle, Little Star! Our Universe won a prize in the category Non-fiction/Information in the Competition for Writers of Children's Books organized by Children's Book Trust.

The other titles by the author published by CBT are *Call of the Ocean, K. Kamaraj* in 'Remembering Our Leaders' series and a short story, 'The Great War', in *Kaleidoscope.*

Photographs: Courtesy USIS, New Delhi.

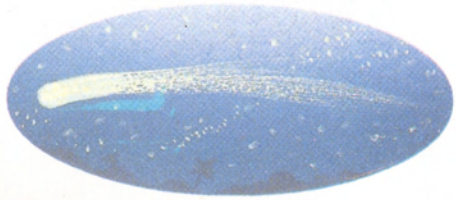
EDITED BY GEETA MENON AND SUDHA SANJEEV

Text typeset in 12/15 pt. Palm Springs

Reprinted 2002, 2004, 2005, 2006.

ISBN 81-7011-892-1

Published by Children's Book Trust, Nehru House, 4 Bahadur Shah Zafar Marg, New Delhi-110002 and printed at its Indraprastha Press. Ph: 23316970-74 Fax: 23721090 e-mail: cbtnd@vsnl.com Website: www.childrensbooktrust.com

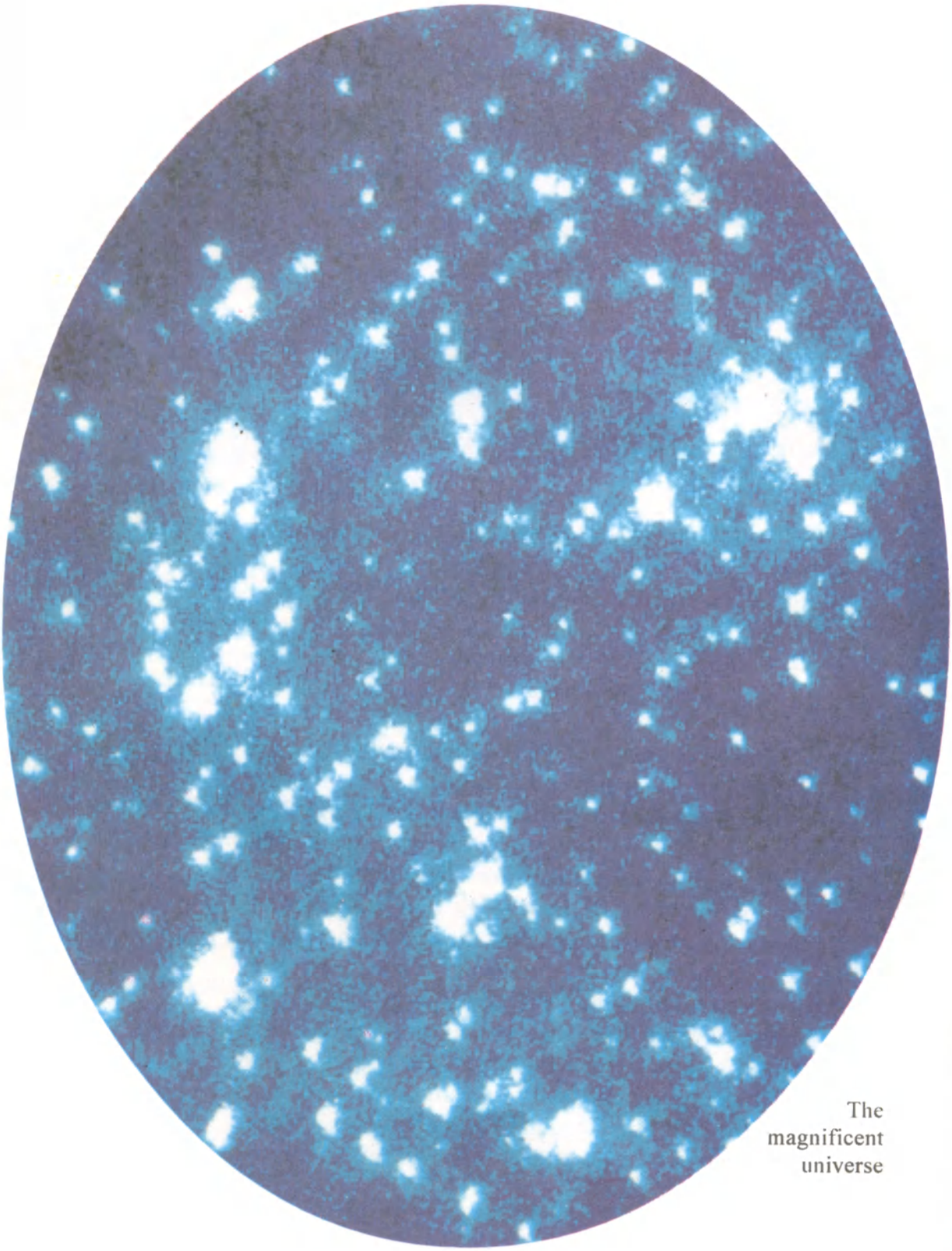


TWINKLE, TWINKLE

Twinkle, twinkle, little star!
How I wonder what you are
Up above the world so high
Like a diamond in the sky!

A familiar nursery rhyme! Perhaps the first rhyme to be taught to every child, this small poem is a beautiful expression of the excitement of a little child who looks at the night sky studded with numerous stars. This wonder seldom diminishes when the child grows up into an adult. Instead, he may well develop a strong desire to know what these stars are made of, how remote they are, who placed them at such a distance and how they keep on shining for so long.

In the sky we have the beautiful Moon gliding among the stars like a silver boat. We have, too, the Sun which gives us the life-giving light and heat during the daytime. There are other heavenly bodies like the planets, planetoids, meteors and comets.



The magnificent universe

Apart from these, there are myriad other objects, invisible to the naked eye, whirling round in the vast, black emptiness which we call 'outer space'. This space, and all the things in it, make the magnificent universe.

A study of the celestial bodies and the universe is called 'astronomy'. One who is engaged in studying the various aspects of the orbs like the Sun, Moon, stars and universe, and in unravelling the secrets hidden in space is an 'astronomer'.

Astronomy is a wonderful science. The Indian scientist, C.V. Raman (1888-1970), who won the Nobel Prize for Physics in 1930, said at a meeting of the Indian Academy of Sciences, "Let me say here and now, my belief (is) that there is no science so grand, so elevating, so intensely interesting as astronomy... I think, a man who does not look at the sky even through that modest equipment—a pair of binoculars—cannot be called an educated person because he has missed the most wonderful thing, and that is the universe in which he lives."

It is but natural for anyone to gaze at the mysterious night-lights called stars, which blink from above like glow-worms, and to wonder at the secrets they seem to hold. The stars are neither 'twinkling', nor are they 'little'; they shine steadily and they are massive in size.

A star is a huge ball of extremely hot and bright gases.

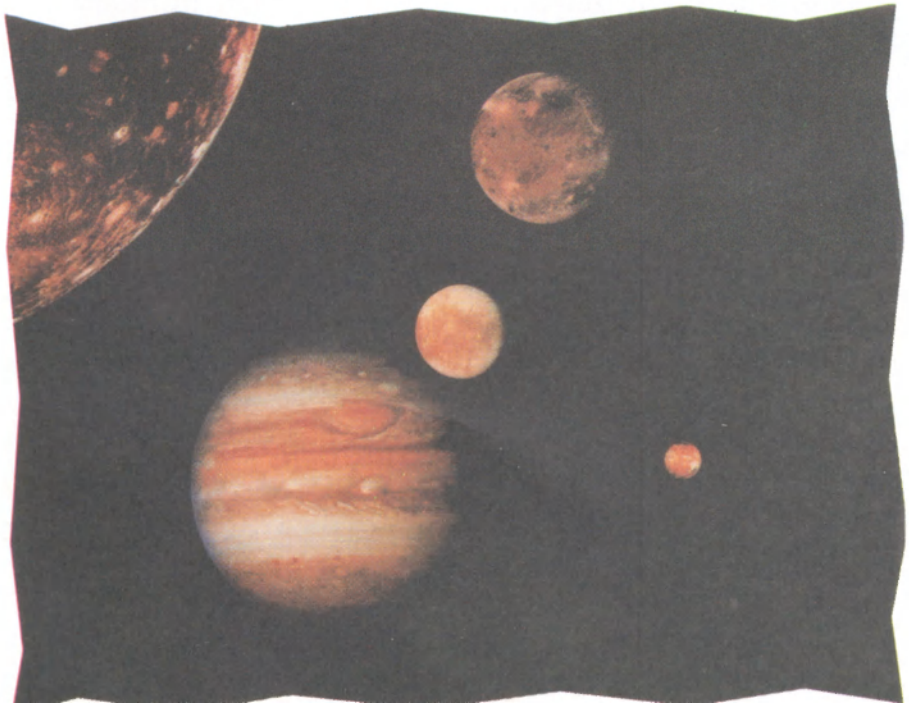
What is a star? A star is a huge ball of extremely hot and bright gases. A major portion of the gases is hydrogen; another is helium, a newly discovered, light, colourless gas, that does not burn. Hydrogen is the most important fuel burnt to produce energy, very similar to the production of atomic energy. The energy is radiated in the form of light and heat. No doubt, the stars contain other chemical elements like nitrogen, oxygen, iron, nickel and zinc.

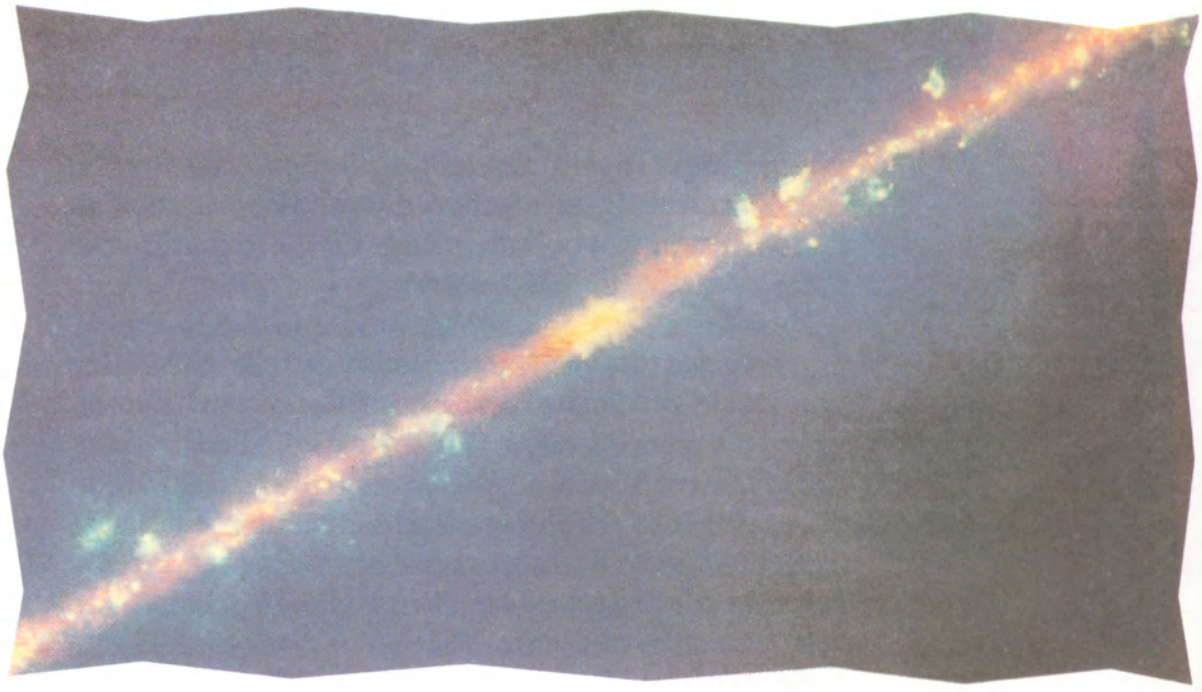
There are an endless number of stars on the firmament. Since all of them are millions and millions of kilometres away, they all look alike; their light has to travel long distances and to pass through many layers of our atmosphere. The light gets refracted through the atmospheric layers. Therefore, the stars seem to wink. We do not feel the heat of the stars, except that of the Sun's, but we see their brightness.

Stars 'wink' when their light gets refracted through the Earth's atmosphere.

When you look at the sky at night, some of the stars are seen scattered all over, like glittering diamonds sprinkled over a black floor. Some are seen in small groups of two, three or four. Some bigger star clusters are visible too. Some of them make formations of garlands, loops and festoons. Some are in long rows.

There are a variety of colours among the stars like red, yellow, blue, white, green and purple—this makes their display more colourful and beautiful. Thus the world of stars is full of wonders and many incredible things. Let us journey through this wonderland.





THE GREAT MYSTERY

The night is calm, clear and cool. There is no Moon. A wonderful zone of cloudy light spans the vast canopy of the heavens. It looks as if someone has spilt milk all over. Faint and indistinct, this hazy streak of light which is in the shape of a flattened disc, is called the Milky Way. It is aglow with light which is the combined lustre of countless stars encircled by dark clouds of dust and gas. A renowned American astronomer, Harlow Shapley (1885-1972), explained that the Milky Way is largely an optical phenomenon.

A group of stars and planets that extend over many millions of miles is a galaxy.

A huge group of stars and planets that extend over many millions of miles is a galaxy. From the earliest times, it has been a subject of fascination for man. There are millions of such galaxies in the universe. Our Sun lies in one part of a very huge galaxy which consists of about 1,00,000 million stars, that is, 1,00,000,000,000. (This can be written in a simpler way as 10^{11}.) In astronomy we come across

Distances in the universe cannot be measured by units applicable on the Earth.

such huge numbers, and hence the term 'astronomical figure'. Suppose you take one second to count a star, you can count all the stars in our galaxy 'easily' in 2,500 years!

How big is our galaxy? Distances in the universe are so great that it is impossible to use the units applicable on Earth to measure them. A different unit was then devised. This unit is called a light year. The width of a galaxy is expressed in light years. What is a light year? The distance that a ray of light travels in one year is known as a light year. Light is the fastest of all things known to man.

A Danish astronomer, Olaus Roemer (1644-1710), first calculated the speed of light in 1676 as 1,86,000 miles (2,97,600 kilometres) per second. Later, even though German-born American physicist, Professor Albert Michelson (1852-1931), made a more accurate calculation of the speed of light as 1,86,284 miles per second, for all practical purposes the speed is taken to be 1,86,000 miles per second. The distance covered by light at this speed in a year is about 6×10^{12} miles or 9.6×10^{12} (96,000,000,000,000) kilometres. This distance is one light year. The maximum width of our galaxy is 1,20,000 light years. Can you try to imagine such a huge formation?

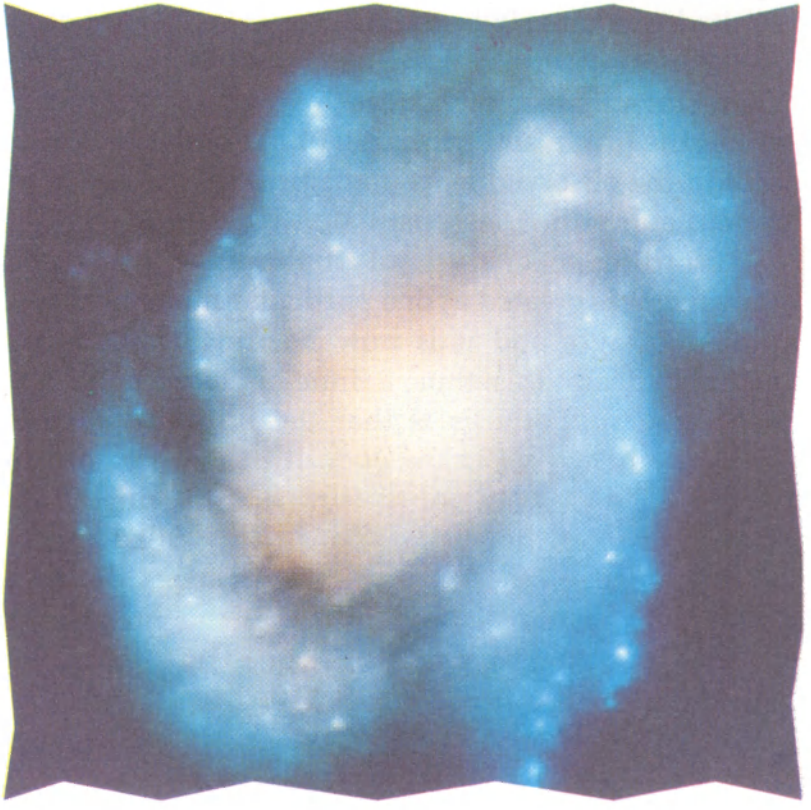
Galaxies have a tendency to cluster together in groups of tens to many thousands owing to their mutual attracting influence. These groups are scattered all over the universe. The most distant galaxy clusters so far observed are billions of light years from our Milky Way. Millions more will be still farther away, beyond our imagination.

Our own galaxy, the Milky Way, belongs to the cluster known as the Local Group which consists of twenty galaxies. The biggest and the most prominent member of this group is the Andromeda galaxy

which is 50 per cent larger than ours and lies 22,00,000 light years away from the Earth. The Large and Small Magellanic Clouds, as two other galaxies in our group are named by the famous navigator Ferdinand Magellan who first described them, are nearer to the Earth, at a distance of 1,80,000 light years. There are other 'super clusters' of galaxies, which are collections of 40 to 50 galaxies.

This galaxy of ours, the Milky Way, is a giant spiral rotating round its central area. Most of the galaxies are spiral-shaped like ours. But there are some which are spherical, elliptical or irregular.

The universe or cosmos is very old and very vast, probably beyond the comprehension of man. Our galaxy is said to be 1,400 crore years old, and the age of the universe, which must be still older, is estimated to be around 2,000 crore years.



The Milky Way is a giant spiral rotating round its central area.

When did the universe actually come into existence? How vast is it? When and how were the Sun, Moon, stars and the planets formed? Why are there so many objects of different shapes and sizes in space? Why are all of them in motion? How long will they be there? All these and more questions arise in our minds. They seem to be riddles which can never be answered satisfactorily by men of science.

Most of the scientists were engaged in studying things as they were, and only a few attempted to investigate how they came to be. Perhaps cosmogony or the theory of the creation of the universe is a field very puzzling to the scientists.

Man appeared on the Earth billions of years after the cosmos was created.

Another reason why so many riddles remain unsolved is that life appeared on the Earth billions of years after the creation of the wonderful cosmic system, and man came much later still. So with his limited wisdom, skills and instruments, it is not easy for man to ascertain what happened in the remote past. Our scientists can, at best, offer only hypotheses about the origin and evolution of the universe which will fit the observed facts in the present times. There are so many theories postulated by them.

According to one school of thought, the whole universe was created at one particular moment many millennia ago, and it is now heading towards its eventual death. It is, thus, a finite or closed universe.

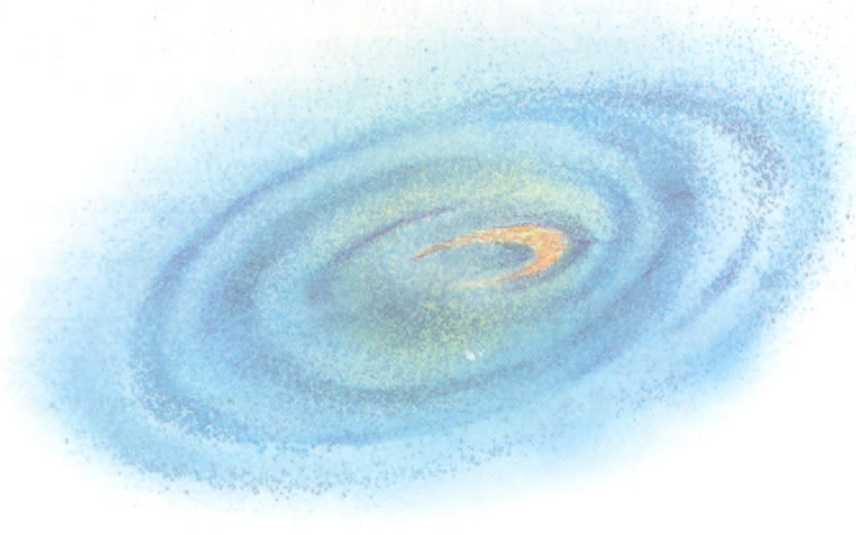
Another hypothesis is that the universe always existed and will exist for ever. It has no beginning or end. The galaxies are rotating and moving away into space and the vacant plot is duly filled up by fresh galaxies. The old stars and galaxies die and new ones are formed. In this way the process of expansion of the cosmic system goes on and on. So the universe is infinite or open.

You can never measure or visualize the universe—your effort will be similar to an ant trying to measure how big an elephant is. Albert Einstein (1879-1955) made a qualified statement that the universe is 'finite yet unbounded'. According to him, a ray of light will require 1000 million years 'to go once round the world'.

Similarly, various theories are in current about the coming into existence of the Sun and the planets. The famous 18th century Scottish astronomer, James Ferguson, tried to explain it this way: In the beginning, God brought all the particles of matter into being in those parts of open space where the Sun and the planets were to be formed. Then he endowed each particle with a power of attraction. By exerting this power, these neighbouring and initially detached particles, in time came together in their respective parts of space. In the course of time, they slowly formed into the different bodies of the family of the Sun called the solar system.

Another scientist's theory is that there was a huge, ball-like mass, the Cosmic egg, whirling round in space. At one stage, it exploded with a big bang and the pieces, blown far and wide, became planets and stars in billions of years.

Man visualizing the universe is like the ant measuring an elephant.

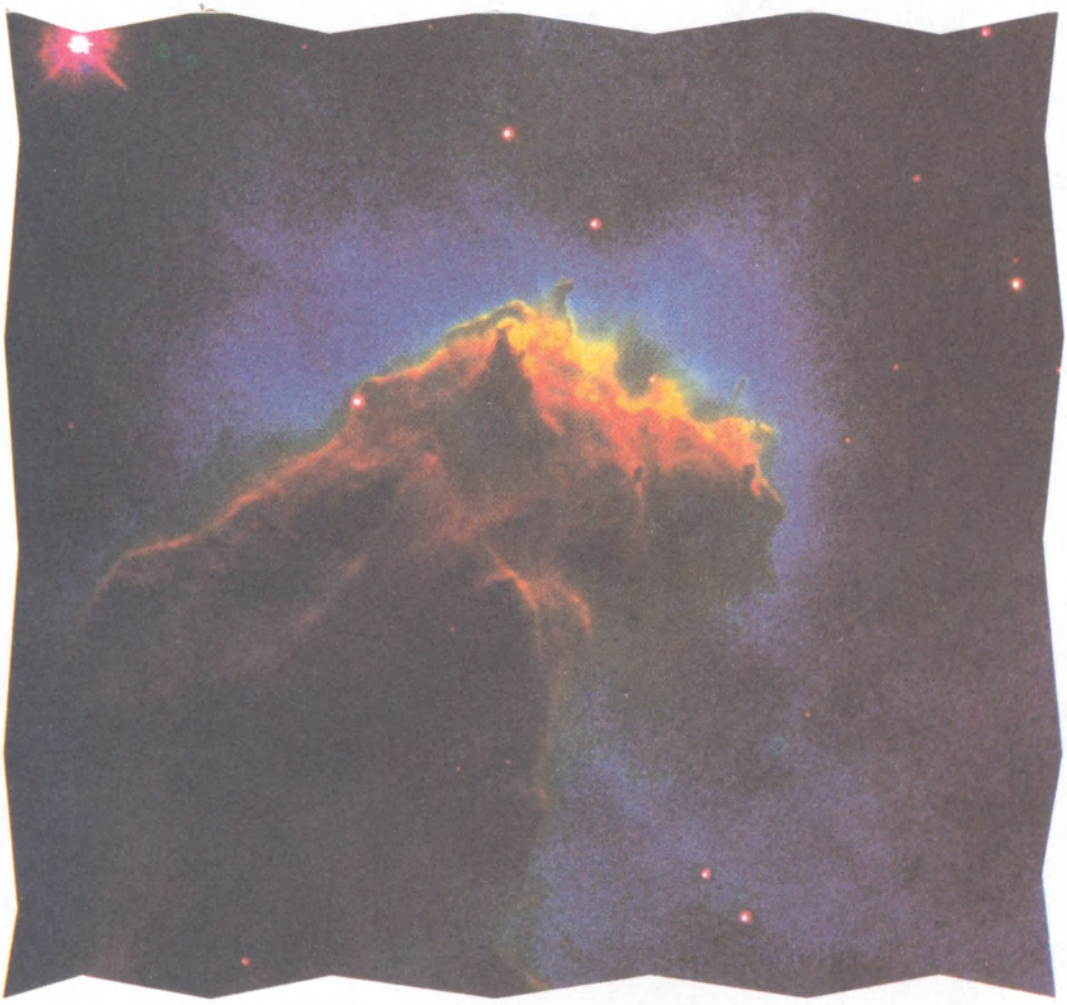


Yet another hypothesis is that there existed a vast nebula or cloud of dust and gas. It rotated rapidly in space as a big wheel upon an axle. After a period of time, it started contracting and becoming denser and hotter. During this process it spun faster and faster. As a result of this, parts of this nebula started flying off. These fragments gradually turned into the various celestial objects, still in motion. The rest of the gas cloud shrank still further to become the hot Sun at the centre.

One other scientific theory too is worth mentioning. Many aeons ago, a huge mass was in motion in space. It consisted of tiny solid bodies known as planetesimals. The Sun was at the centre. It is likely that a very big star passed close by. The strong force of attraction of the star pulled on the Sun raising tides of violence in the Sun. Fragments of the Sun were torn off it, and thrown on all sides. While orbiting, those pieces went on collecting planetesimals on their way just like a wet ball of mud would pick up grains of sand and dust particles in its path. These parts became bigger planets in the solar system as time passed on.

There are many more theories. All of them are but wise guesses, none of which is acceptable as conclusive. Each one was proved to have some inherent contradictions by the subsequent theorists. So the origin of the solar system and the universe remains an unsolved problem of astronomy. But these hypotheses have considerably helped in widening our knowledge of the cosmic system, of which we are a part.

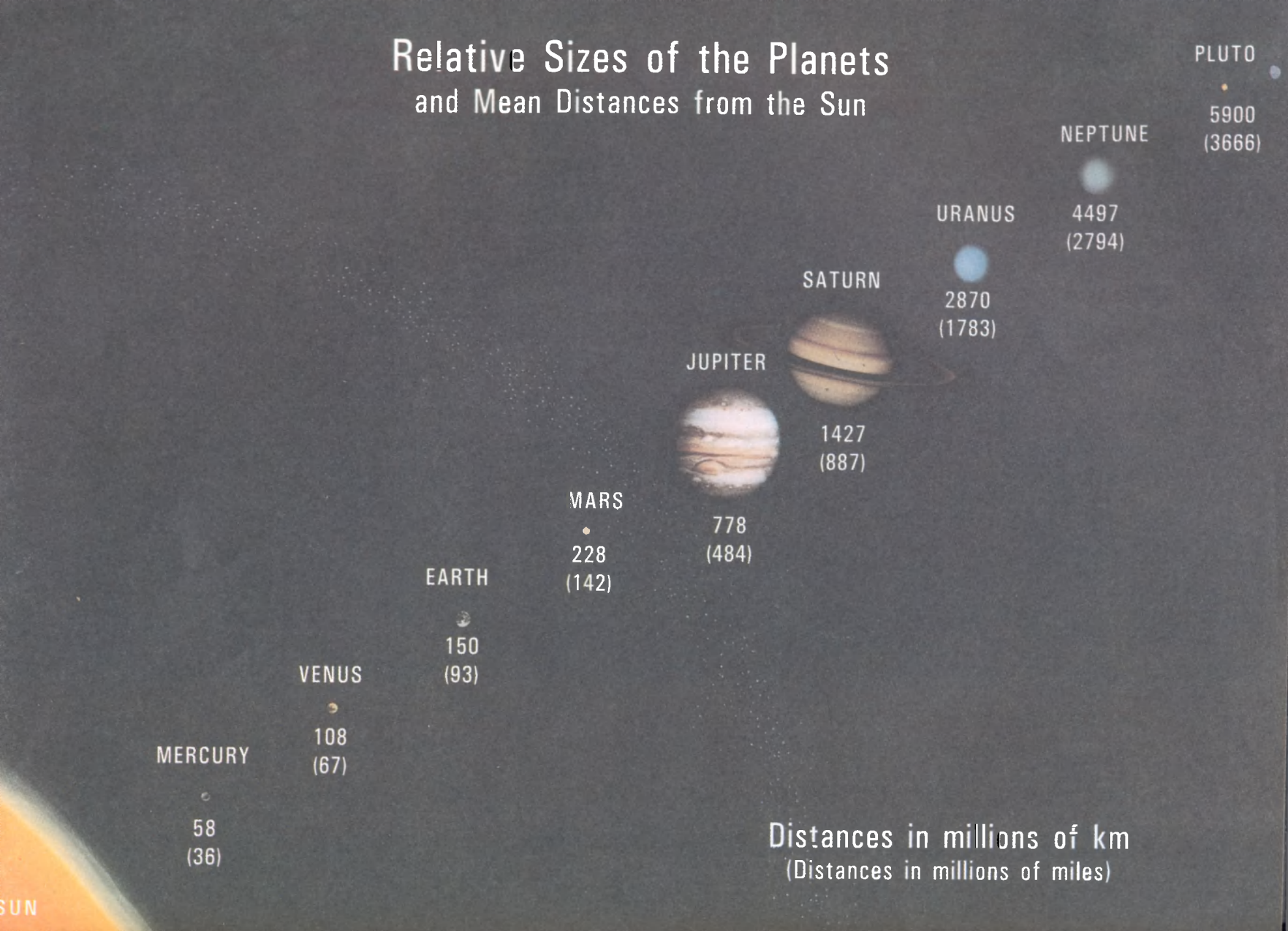
It is true that we have more information and data than our ancestors. But, in astronomy, we cannot be certain of our ground. A theory which appears to be true today may be proved incorrect tomorrow.



Star-birth clouds

One scientist admitted in all modesty that, "It has not been given to man to solve that great mystery, that is, the origin of the wonderful scheme of worlds of which our Earth is a member." But this has not deterred great astronomers and other men of science of the world from striving hard to solve as many mysteries as possible and making steady progress in understanding this complex cosmic system. There have been, no doubt, some remarkable achievements. We shall consider some of their discoveries.

Relative Sizes of the Planets
and Mean Distances from the Sun



Distances in millions of km
(Distances in millions of miles)

THE BIG FAMILY

Let us start with the most familiar and well-known star that shines all alone and makes our day, while all other stars can be seen only in the night. Don't you believe that there can be a day star? It is there—it is our Sun. This knowledge and acceptance that the Sun has been a star was, indeed, one of the most important turning points. The Sun was once counted as a planet. It was then discovered to be but one of the innumerable stars in our galaxy.

Many stars are a million times bigger and more luminous than our Sun.

- The Sun is only an average star—there are thousands of stars which are a million times bigger and more luminous than our Sun. But the Sun is our nearest star. In its tremendous brilliance, stars which are much brighter but farther away are not visible during the day.

The star of the day is not alone. It has a very large family—a family of children, grandchildren and great grandchildren. It is surrounded by countless heavenly bodies.

The Sun is in the centre of a system in which nine planets are revolving round it at different distances, at different speeds and in different periods of time. 'Planet', a Greek word, means 'wanderer', to differentiate it from the stars once thought to be 'fixed' to the sky.

Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto are the nine planets in the order of their distances from the Sun. Mercury is the nearest, at a distance of 5.8 crore kilometres and Pluto, the planet discovered last, is 590 crore kilometres away from the Sun.

The elliptical 'path' by which a planet goes around the Sun is an 'orbit'. All these planets rotate on their axes while travelling round the Sun. The axis is a

kind of imaginary axle that runs through the middle of the planet and on which it spins.

Most of the planets have their attendant or secondary planets called satellites running around the mother-planets all the time and going along with them around the Sun. Inside the wide gap between the orbits of Mars and Jupiter there are innumerable objects going round the Sun too. They are known as asteroids. Comets, the huge stars with giant-size tails, and much smaller meteors join the above planetary bodies in travelling round the Sun. All these different bodies, with the Sun in the middle of the formation, make up the solar system.

Sole, the name of the Roman sun god, is the official name of the Sun. 'Solar' means 'of the Sun'. From this are derived words like solar energy, solar eclipse, solar flares and so on.

The solar system is at 35,000 light years from the galactic centre, and is near the edge of a spiral arm. One estimate puts the age of the solar system at 4.6×10^9 years. The Sun too spins like all the planets on its axis and, with its big family, goes round the centre of the galaxy once in 2,00,000,000 years. This period is sometimes referred to as a cosmic year. All these discoveries were made in the last five centuries or so.

In ancient times people had many a wrong notion. They believed that the Earth they lived on was the hub of the universe, and that it was flat, stationary and immovable. The Sun, the Moon and the five planets (Uranus, Neptune and Pluto were not discovered yet) went round the Earth. The stars glittering above were all 'fixed' to the sky.

It was the great Greek mathematician, Pythagoras, who, in the sixth century B.C., first asserted that the Earth was spherical; but he too strongly believed

that it lay still in the centre of the universe. His view was supported by Aristotle (384-322 B.C.), the Greek philosopher and scientist. Aristotle was born in Stagira. He was the most noteworthy pupil of Plato (427-347 B.C.) and the teacher of Alexander the Great (356-323 B.C.). Aristotle had to his credit nearly 400 works on multifarious subjects like biology, physics, politics, logic, philosophy and astronomy. He stated that the Earth was made up of four elements, namely, water, fire, land, and air.

Around the third century B.C., the Greek astronomer, Aristarchus, observed that the globular Earth rotated in a day on its axis and revolved around the Sun. But he could not cite concrete evidences. All the astronomical works of Aristarchus were lost except a short treatise, 'On the magnitude and distance of the Sun and the Moon'.

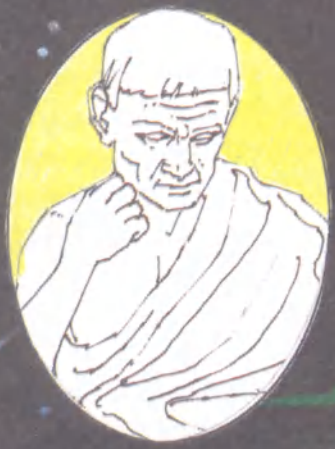
Early Indian astronomers made startling revelations about the Earth, its rotations and revolution round the Sun.

In our country also great astronomers like Aryabhata (born 476 A.D.), Varahamihira (499-587 A.D.) and Bhaskara (born 1114 A.D.) lived in the early period. Even without the aid of proper instruments they made many startling observations about the shape of the Earth, its axial rotation, its revolution round the Sun and the physical aspects of planets.

Claudius Ptolemaeus, generally known as Ptolemy, who lived during the second century A.D., worked in Alexandria and proved to be an extremely skilful astronomer of his day. He wrote his book *Almagest*, summarizing his conclusions and the astronomical knowledge of his time. This work is valuable as it helps us to know about ancient astronomy and geography.

Ptolemy prepared a useful star catalogue. Unfortunately, he made an erroneous theory that the Earth lay motionless in the centre of the universe and all the bodies like the Sun, Moon, planets and

Aristotle 384-322 B.C.



Ptolemy 100?-165? A.D.
Propounded the geocentric theory.

Aryabhata b. 476 A.D.
The earth is round and rotates on its own axis.

Copernicus 1473-1543
Founder of modern astronomy.
Propounded heliocentric theory.

Newton 1642-1727
Discovered the laws of universal gravitation and motion.

Galileo 1564-1642
Founder of modern experimental science
Invented the telescope. Discovered laws of falling bodies and the pendulum.

the spheres of 'fixed' stars were moving round the Earth in a circular path.

This was called the 'Ptolemaic System', though he had not invented it. Strangely enough this geocentric theory ('geo' is from the Greek word for Earth, and is used in combinations like geography, geophysics, geopolitics and so on), which was totally incorrect, remained unchallenged for nearly fourteen centuries, and therefore Ptolemy was hailed as the 'Prince of Astronomers'.

All such wrong notions were shattered and a revolution was effected in human thought by one of the greatest men of science called Micholay Kopernik (1473-1543), more popularly known as Nicholas Copernicus. Born in Poland, Copernicus served during the day as a Bishop, and devoted his nights to the study of his favourite subject, astronomy. He worked untiringly for thirty years and came out with valuable observations even though he did not possess advanced instruments like the telescope, spectroscope, camera or computer now available to modern astronomers.

Copernicus formulated the heliocentric theory.

From his discoveries Copernicus formulated his heliocentric theory ('Helios' is the name of the Greek sun god). According to this, the Sun was at the centre of a celestial system and the Earth was only a planet in this system, revolving round the Sun like the other planets known in those days. This solar system was only a fractional part of an inconceivably vast formation of the universe.

Even so, Copernicus was afraid to announce his conclusions because anyone trying to question the Ptolemaic theory and to push the God-created Earth to the position of a humble planet like the others, and that too, not a big one, was very much against the Christian faith. He would be charged with heresy

Ptolemy's geocentric system

and condemned by his church. So Copernicus did not allow his valuable book to be published till his last days. On May 23, 1543, an advance copy of his magnum opus of nearly 400 pages, *Concerning the Revolutions of the Celestial Bodies*, was delivered to him at his deathbed.

It was the beginning of the modern science of astronomy. The book, as he wished, carried a foreword that the theory of a central Sun was only the opinion of an individual and not to be taken literally as scientific truth. Just as he feared, his theory was condemned vehemently both by scientists and theologians; his book was banned and the followers of the Copernican theory were persecuted in subsequent years.

Eventually truth triumphed and today the Copernican theory has steadily been accepted universally as basic scientific theory. Discovery after discovery has been made to strengthen the Copernican system, as also the Indian concept.

Like Ptolemy, Copernicus thought that planetary orbits were perfectly circular. This error was later corrected by another genius, a German astronomer and mathematician, Johann Kepler (1571-1630) who discovered that planets have an elliptical path.

Tycho Brahe (1546-1601) was a famous Danish astronomer of the sixteenth century. During his student days the tip of his nose was sliced off in a duel, and he had a nose made out of gold, silver and wax. Brahe established an observatory on his own island and worked for nearly twenty years, making his own instruments. He drew up a very accurate catalogue of the stars. Though Brahe did not accept the Copernican system, he made his own findings which in their own way shattered old beliefs.

These also formed the basis for his assistant, Johann Kepler, to make his own observations and enunciate the principles now known as Kepler's Laws of Planetary Motion, after testing various laws for nearly nineteen years.

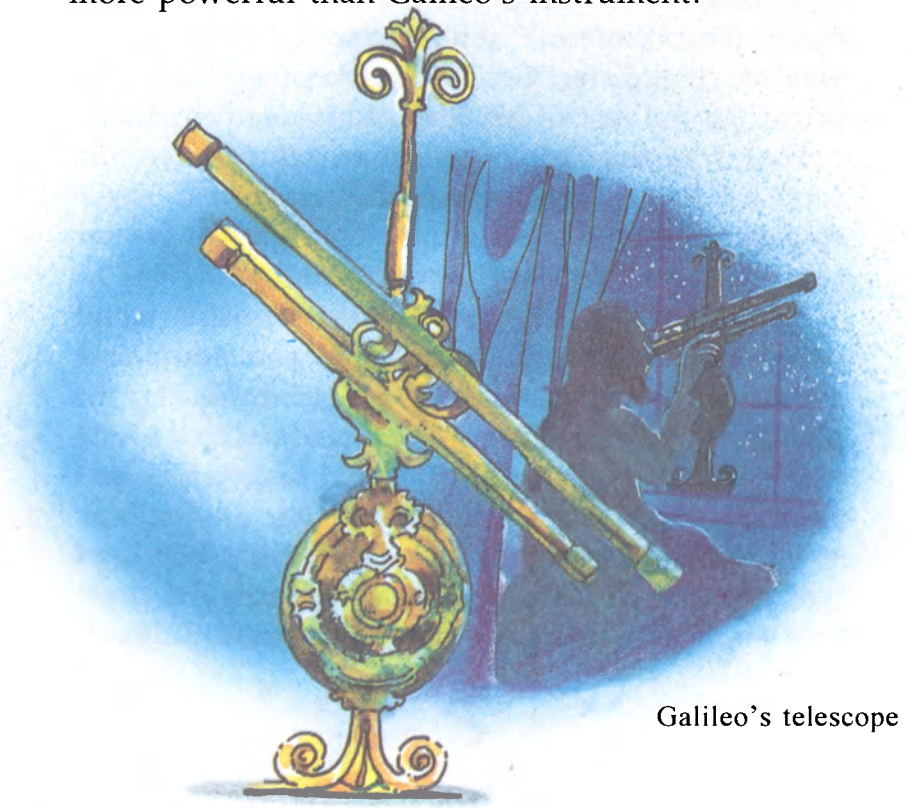
According to them, the planets move round the Sun in elliptical paths, with the Sun placed not exactly in the centre but at one of the points termed as the 'foci' of the ellipses; secondly, a planet moves faster when it comes closer to the Sun; and thirdly, there is a relationship between a planet's distance from the Sun and its period of revolution. These have simplified the understanding of the Copernican theory of the Sun being the ruling orb of the solar system.

You may have heard of one of the wonders of the world, the Leaning Tower in the Italian city of Pisa. In that city was born Galileo Galilei (1564-1642), who earned a unique place of honour among the world-famous astronomers, and whose contributions to the development of astronomy have few parallels.

Galileo conducted research on objects falling from a height and proved that objects of two different weights would fall to the ground at the same time. This paved the way for Isaac Newton's (1642-1727) discovery on gravity. But this went against the popular belief of Galileo's time and disproved Aristotle's claim that heavier objects would fall at a greater speed than lighter bodies.

In 1608, a Dutch optician, Jan Lippersheim, better known as Hans Lippershey (1570-1619), made a crude telescope which he called *kijker* meaning 'looker'. His efforts to get a patent for his invention failed. Next year when Galileo went to Venice he heard of this discovery and made his own telescope with lenses. It was just a small, imperfect 'optical tube', which he turned towards the sky. He thus became the virtual inventor of the telescope and founder of telescopic astronomy. We have, today, telescopes which are a thousand times bigger and more powerful than Galileo's instrument.

It was just a small, imperfect 'optical tube', which Galileo turned towards the heavens.



Galileo's telescope

The newly discovered little instrument in the hands of the most passionate observer, Galileo, turned out to be the golden key for further opening up the doors of the heavens for future generations anxious to peep into that magic world and admire the cosmic beauty. Galileo made careful and systematic observations which convinced him of the superiority of the heliocentric system of Copernicus over the Ptolemaic system. He even wrote a witty book entitled, *Dialogue on Two World Systems*, ridiculing the thought of Ptolemy. All these naturally weakened the authority of Ptolemy and Aristotle.

Galileo incurred the wrath of the orthodox Roman Catholic Church for supporting the Copernican theory. The church insisted that the Earth was stationary at the centre of the universe. Galileo was accused of heresy and brought to trial in Rome. The inquisition forced Galileo to recant his views and make a public statement that he was wrong. But following his recantation, he murmured, *"Eppur si muove* (still it moves)" referring to the Earth which was moving. Later, Galileo was kept under house arrest for the rest of his life till his death in 1642.

Galileo was accused of heresy and brought to trial in Rome.

That was the fate of the man who had made some of the most spectacular discoveries. These discoveries served as stepping-stones for still greater achievements by future astronomers.

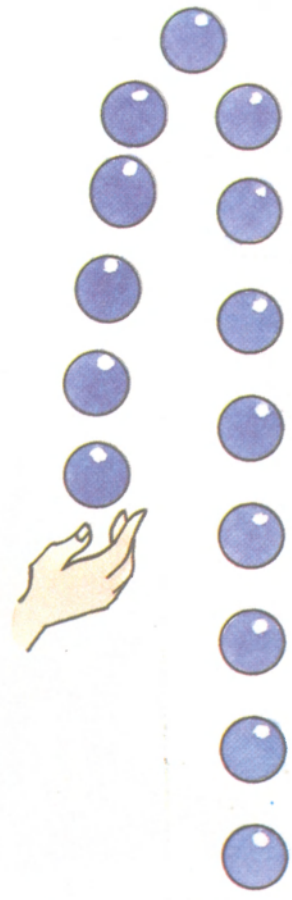
It was Galileo who, with his little magic wand called the telescope, first discovered the mountains, plains and craters on the Moon, the sunspots, the phases of Venus and Mars, the four satellites of the planet Jupiter, namely Io, Europa, Ganymede and Castillo which are named after him as Galilean satellites, the stellar nature of the Milky Way and the exquisite system of rings of Saturn. All these only confirmed that Copernicus was right. Galileo's

multiple findings were valuable additions to man's knowledge of the universe. As one of Galileo's admirers, Castelli, rightly put it, "Galileo's eyes may be truly said to have seen more than the eyes of all that are gone and to have opened the eyes of all that are to come."

When you throw up a ball or stone, it goes up to a point and then comes down and falls to the ground. Your science teacher may have taught you that this is due to the gravitational attraction of the Earth, by which it draws all unsupported bodies towards it. The existence of this invisible power was discovered by Isaac Newton, the great British scientist. Newton was a versatile genius and made his mark in many a field of science like astronomy, dynamics, light, sound and colour. He even constructed the first reflecting telescope.

Newton had long been engaged in studying the laws of planetary motion and realized that the same force of gravity was acting in the relationship between the Sun and the planets. He found out that the universal law of gravitation operated at all distances and on all particles of matter—from the tiniest sand grains to the mightiest orbs in space. Then he formulated his famous laws in his book known by its shortened title *Principia*. Its publication, in 1687, was financed by his friend Edmund Halley (1656-1742), whose name is associated with a comet. It may be mentioned here that Kepler's three laws formed an indispensable part of Newton's theory. Galileo's contribution to Newton's success was no less.

According to Newton's laws, any body that is at rest continues to remain in that state till some other force disturbs it; likewise when an object is in motion in a straight line, it moves on and on unless and until another outside force crosses its path and



When you throw a ball, it goes up to a point and then comes down.

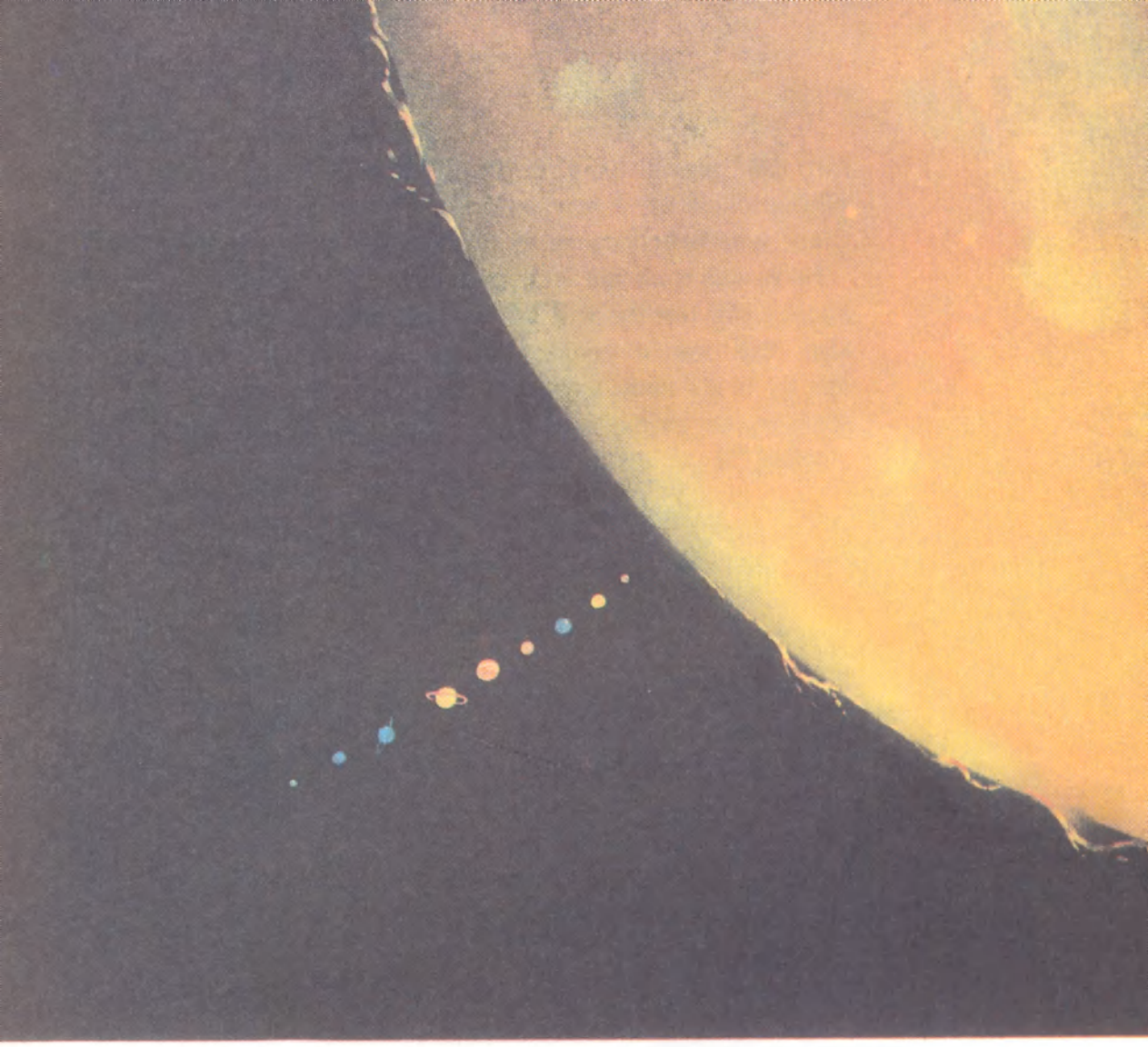
changes its course. Secondly, change of motion is proportional to the applied force and takes place in the direction in which the force acts. Thirdly, to every action there is always an equal and opposite reaction.

With these laws everyone suddenly felt that most of the riddles related to the solar system were solved and the law of the universe became a little clearer. A force of attraction exists between all objects. If the mass (amount of matter) of one of the two attracting bodies is doubled, its gravitational attraction will also be doubled; but if their distance apart is doubled, the force will only be one-fourth measure. That is, the bigger and heavier object draws easily the smaller and lighter body towards itself.

The entire mass of the Sun is more than 99 per cent of the total mass of the whole solar system. To put it in another way, the total mass of the planetary system including all the known major planets, satellites, asteroids and meteors is no more than 0.134 per cent of the total mass of the Sun. Therefore, like a mighty ruler, the Sun has been keeping all the planetary matter, from their birth, as prisoners under its tremendous gravitational influence for billions of years. Owing to the mutual play of the same force, the planets hanging in space without any solid support, keep to their tracks without impeding or colliding with each other for ages. Thus many of the mysteries were explained and the whole gamut of astronomical thinking underwent a revolution of immense consequence. As one said,

Nature and Nature's laws lay hid in the night
God uttered, 'Let Newton be!' and all was light.

Most important of all, Newton's discovery, once and for all, put to rest the controversy over the Copernican theory. It was finally established that the Sun was at the centre, exercising unquestionable



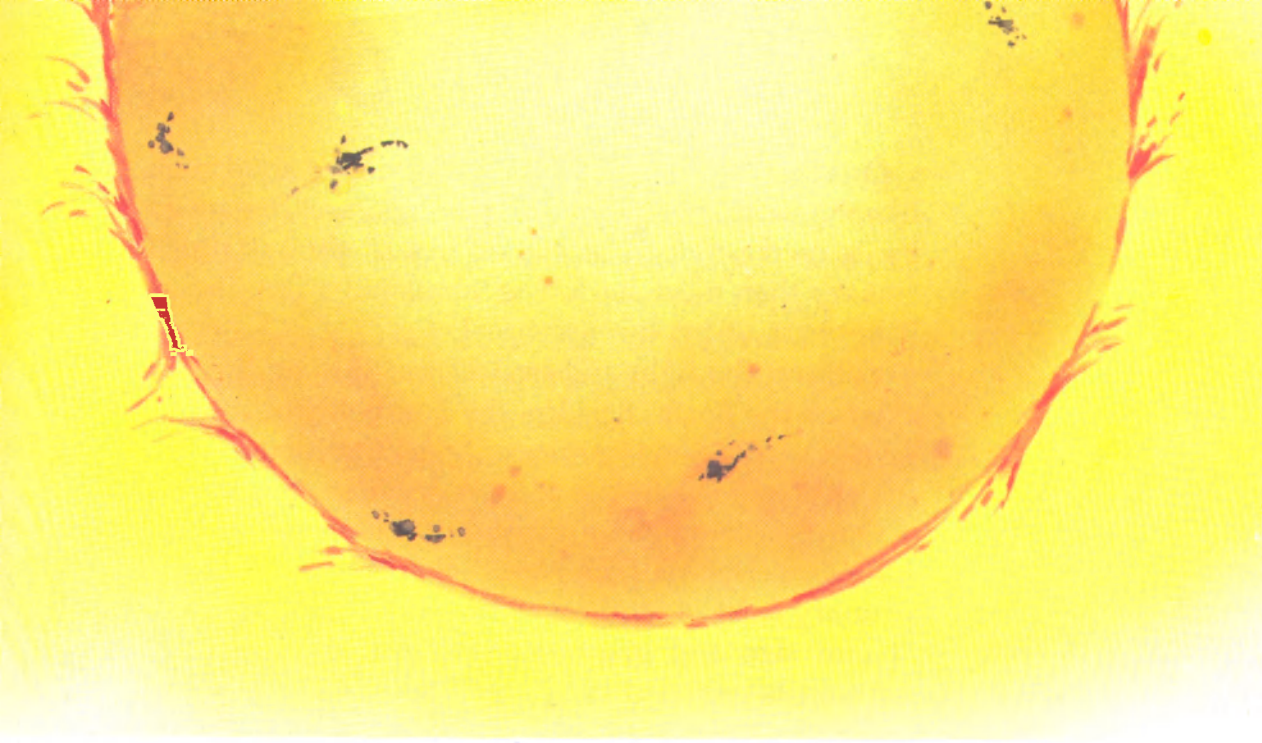
The planets as compared to the Sun

authority over all the planets including our beloved Earth which obediently goes around the Sun.

This was really the greatest discovery made by man. Newton became a celebrity. But in all humility, he simply said that he stood on the shoulders of his predecessors like Kepler and Galileo, and that made him look taller. He politely declined to be drawn

into the limelight saying that he was just like a child who picked up a few pebbles from the beach and there was much more to understand of Nature.

So it was that our Sun, an average star, could head such a big family and keep it together for millions and millions of years. Just as the day star has a family of its own, scientists believe that many other stars in our galaxy and other galaxies may also have similar 'solar' systems.



HEAD OF THE FAMILY

Our Rig Veda salutes the Sun as 'the soul of all that moves and all that does not move'.

Now to meet the head of our solar family, the Sun or *Surya*. In many of the ancient civilizations of the world, the Sun has been worshipped. Men were always fascinated by celestial bodies like the Sun and the Moon. In fact Sun worship goes back to the dawn of civilization. Even the New Stone Age man adored the Sun, for light was godly and darkness, evil. Our Rig Veda, the oldest of the four Vedas, salutes the Sun as 'the soul of all that moves and all that does not move'. The idol of the sun god can be seen even today in the Hindu temples among the idols of the nine planets, *navagraha*, which are believed to influence the life of an individual.

Copernicus, the propounder of the heliocentric theory, said, "In the centre of everything is the Sun. Nor could anyone have placed the luminary at any other better point in this beautiful temple than that from which it can illuminate everything uniformly."

Our Sun is a typical yellow star, not of solid rock like the Earth, but a globe of glowing gases, balanced by its own gravity. It is a giant in size, though much smaller than most stars. The Sun is not a flat disc as it appears to be, but spherical.

Without the light and heat of the Sun, no life can exist on the Earth. Besides, the Sun holds us always near it by the same immense force of attraction with which it guides all the planets in their courses.

Our Sun is indeed a giant, but a benevolent one. John Frederick William Herschel (1792-1871), whose primary field of study was the stellar system, said, "Giant size and giant strength are ugly qualities without beneficence. But the Sun is the almoner of the Almighty, the delegated dispenser to us of light and warmth as well as the centre of attraction, and as such the immediate source of all our comforts, and indeed of the very possibility of our existence on the Earth."

Do you know how far, how big and how hot the Sun is? When Galileo first spotted the solar spots as early as in 1610, he began a scientific study of the Sun. It was he who gave us the first proof of the Sun's rotation and its near-spherical shape. Subsequently, many astronomers have made useful discoveries about various features of the Sun.

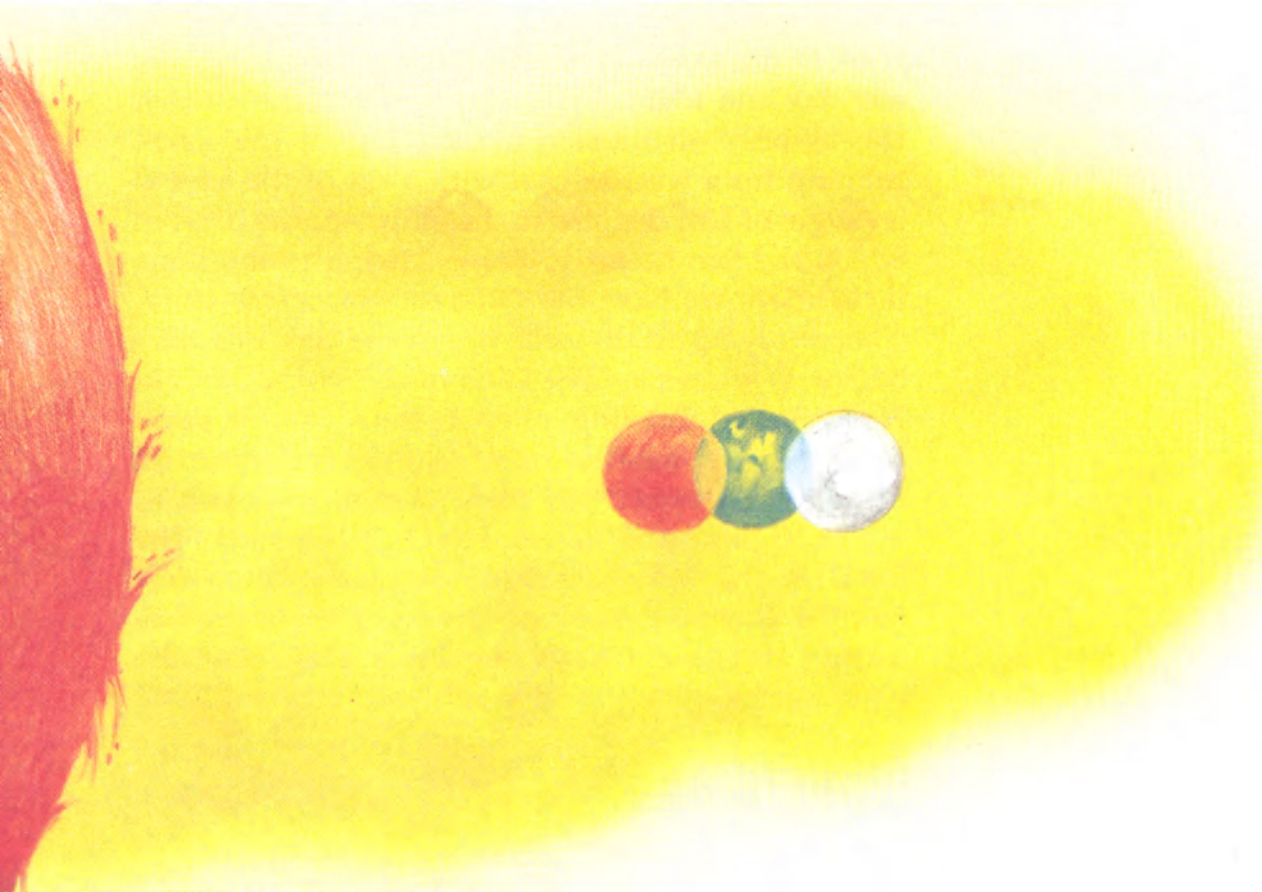
The Sun is our nearest star. It is 1,49,600,000 or 15 crore kilometres away from us. The distance between the Earth and the Sun is one Astronomical Unit or AU. This is only the mean distance between the two. Since the Earth travels round the Sun in an elliptical orbit, there will be a slight variation in the distance between the two orbs whenever the Earth is nearest to the Sun, called 'perihelion', or farthest from the Sun, called 'aphelion'. The distance between the Sun and the Earth at 'perihelion' is

1,46,240,000 kilometres while at 'aphelion' 1,51,360,000 kilometres. So we take the mean distance. This applies to all planetary positions with respect to the Sun.

The mean distance between our Earth and the Sun is constant and the Earth's orbit, stable. In other words, Nature has placed our planet at the right distance from the hot Sun. If we move a little nearer to the Sun, say by 10 per cent of the present distance, we will be burnt to death; moving a little farther, by 10 per cent, means that we will be frozen. We cannot choose either. How nice it is to feel that we are comfortably placed in relation to the Sun!

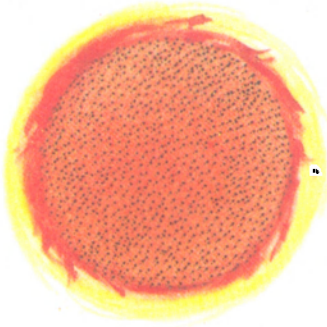
A little nearer to the Sun, and we will be burnt; a little farther, we will be frozen.

The diameter of the Sun is 1,400,000 kilometres. This is roughly 110 times the Earth's diameter.



The Sun's circumference is roughly calculated as 4,160,000 kilometres. The mass of the Sun is three and a half times the Earth's—that is to say, 2.2×10^{27} tons. The Sun is so huge a 'container' that you can easily pack 13 lakh Earths into it and still some room will remain!

There is no comparison at all between the Sun's and the Earth's surface gravity, which is 28 times greater on the Sun. In other words, a person who can lift 50 kilograms on Earth would be crushed by its weight on the Sun as it would weigh 1,400 kilograms there. It is no wonder that, possessed with such a mighty force, the Sun has easily, for millions of years, kept under its perpetual control, all the major and minor planetary bodies, even the remotest planet, Pluto, lying at a distance of 590 crore kilometres. These captives of the Sun can neither escape nor waver from their marked paths.



The Sun is so huge a 'container' that you can easily pack 13 lakh Earths into it.

You are taught in your childhood that the Sun rises in the east and sets in the west, thus causing our day and night. You may have later learnt that this is only an illusion arising out of the Earth rotating from west to east with a tilt of the axis at an angle of 23½ degrees to the ellipse or the orbit in which the Sun seems to move. Owing to the same inclination, we have the different seasons.

Japan, lying in the east where the day officially begins, is known as 'The Land of the Rising Sun'. In Norway, an amazing phenomenon can be seen. During certain months in the year the Sun shines all through the night. This phenomenon is known as 'Solar Nights', and the country is nicknamed 'The Land of the Midnight Sun'. Similarly, for a few months in winter, the Sun does not show its face during daytime. These are 'Dark Days' for the Norwegians.

The Sun is our perennial supplier of unrationed light and warmth free of cost. The Sun's light takes 8½ minutes to reach the Earth. This light, looking pure white, is a mixture of seven basic colours, namely, violet, indigo, blue, green, yellow, orange and red (VIBGYOR). Once again, it was Newton who discovered this fact.

The Sun's light looks pure white, but is a mixture of seven basic colours.

When a ray of sunlight is passed through a glass prism, it splits into a band of colours with red at one end and violet at the other, called a spectrum. The rainbow which you see in the sky is Nature's marvellous spectrum. The spectroscope, an advanced instrument, used for the study of the stars and planets is based on this principle. Joseph Von Fraunhofer (1787-1826), a Bavarian, became a great maker of lenses and prisms by sheer hard work and talent. Later he went on to head an optical establishment in Munich. During his experiments with the prism, he found some dark lines in the solar spectrum. Unfortunately, before he could make a deeper study of these lines, he died at the young age of 39. The dark lines investigated by him are since known as Fraunhofer lines.

Another German scientist, Gustav Robert Kirchhoff (1824-1887), initiated, in 1859, spectroscopic astronomy in a laboratory at Heidelberg. He conducted the study of the Fraunhofer lines with the help of a spectroscope and found that each of them indicated the presence of a different chemical element in the Sun. As per his findings, sodium, magnesium, iron, calcium, nickel, copper, and zinc exist in the Sun.

Another important discovery which was made with the spectroscope nine years hence, is worth a mention here. Norman Lockyer (1836-1920), of England, examined the chromosphere which is the

proper solar atmosphere and detected an unusual line in the solar spectrum. It could not be ascribed to any element familiar on the Earth. It seemed to indicate the existence of a special element in the Sun. That new substance was named 'helium', after the Greek word Helios for the Sun. Helium is now known to exist on our Earth too but in a very negligible quantity.

The spectroheliograph, a very special instrument, was designed independently by Professor George Ellery Hale (1868-1938), an American astronomer, and M. Henri Alexandre Deslandres (1853-1948), an astrophysicist. This is an invaluable accessory of the telescope and spectroscope and enables one to investigate the chromosphere thoroughly. With this attachment, Hale made useful discoveries.

How does the Sun radiate so much energy? Ancient people thought that it was 'burning itself' to give light to mankind. Had it been true, the Sun would have burnt out long ago and turned into ashes. It is not 'burning' in the normal sense. The Sun, as mentioned earlier, does not consist of any solid or liquid material but only of very hot gases. The volume of the gases is said to be 5408×10^4 cubic kilometres of which 70 per cent is hydrogen, the lightest and the most plentiful of all gases in the universe, while 26.5 per cent is helium and the other elements are 3.5 per cent.

Our Sun is a nuclear reactor in which 700 million tons of hydrogen are converted into helium every second.

Our Sun is a nuclear reactor in which 700 million tons of hydrogen are converted into helium every second. This nuclear fusion takes place in the hot central core, the radius of which is 4,00,000 kilometres. The energy thus generated is transported to the surface. From here it is radiated by the Sun into space, mainly as light and heat. This radiating surface is called the photosphere. In this process,

Flame-coloured projections, or solar prominences, rise to thousands of kilometres.

the quantity of gases lost is at the staggering rate of over four million tons per second. But there need be no fear that the fuel would soon be exhausted. No, according to a modern theory, the Sun, which is said to be 5,500 million years old, has enough stock of gases to last for another 5,500 million years, possibly longer.

Nuclear fusion provides the Sun with an inexhaustible reservoir of energy. Would you like to know how much energy is radiated every second? It is in order of 4×10^{26} joules—that is, you add 26 zeroes to the number 4 to get the figure. Joule is a unit of energy named in honour of the British scientist, James Prescott Joule (1818-1889), who propounded Joule's law. Of this enormous output, the Earth receives only 126×10^{12} horse power per second which is 2,000 billionth of the energy poured out by the Sun—it is equivalent to a pin-head! All the planets together receive only 200 millionth of the total energy of the Sun. The rest of the energy is lost in space. According to one estimate, the Sun, so far, must have radiated a total amount of energy in the order of 5.5×10^{43} joules. The waves of sunlight spread out in all directions at a tremendous speed of 2,99,800 kilometres a second.

All the planets together receive only 200 millionth of the Sun's total energy.

Today, the indiscriminate consumption of conventional energy sources like wood, coal and petroleum has resulted in the rapid dwindling of their stock and has alerted people to non-conventional energy sources like the Sun and the wind. Every country, including India, has launched massive projects to tap solar energy for industrial development and domestic purposes.

If the Sun is such an enormous furnace, you can imagine how hot its surface would be. The temperature of the Sun's photosphere is 6,000 degrees

Celsius. (The surface temperature of our Earth is just 60 degrees Celsius.) Beneath it, at the centre of the Sun it is 21,000,000 degrees Celsius and the pressure unimaginable. The Sun's light is so bright that scientists advise us never to look directly at the Sun even when it is low down and appears to be harmless. Through the telescope the Sun appears to be granular in texture.

The Sun, too, has two kinds of motion.

One, it rotates like a giant, flaming top at a speed of 280 kilometres per second. As it is composed of dense gases, the period of one rotation cannot be uniform all over. Near the equator it spins once in 25 days; but near the poles it takes 34 to 38 days.

The Sun spins like a giant flaming top at 280 kms per second.

Two, as stated elsewhere, our Sun, carrying with it its entire family of planets and other attendants, is moving at a speed of 19 kilometres per second. It travels among the billions of stars of the galaxy, heading towards that part of the northern heavens occupied by the constellation of stars known as Hercules, noted by Sir William Herschel and many others. Another version is that the Solar family is proceeding towards the red star, Vega, in the constellation of stars named Lyra.

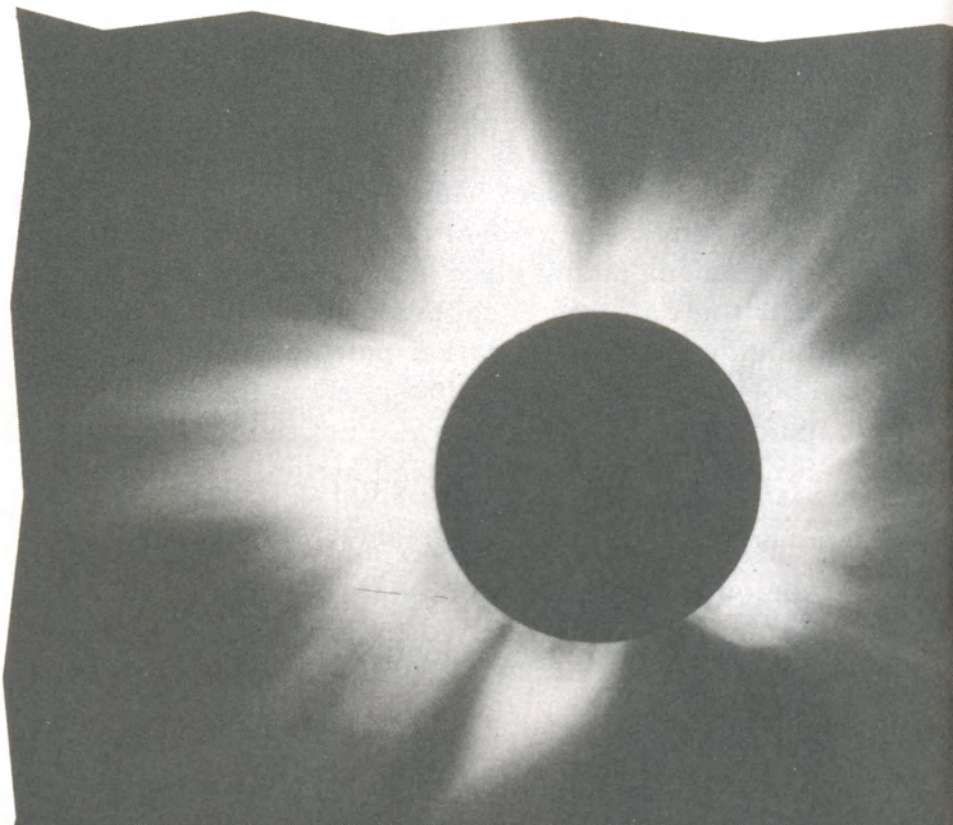
Astronomers observed some interesting phenomena taking place in our Sun. You may think that the day star is spotless. But Galileo's optical tube detected many darker patches known as solar spots on the brilliant photosphere of the Sun. These patches or sunspots were also noticed by Christoph Scheiner in Germany as well as Johannes Fabricus (1587-1615) in Holland.

The sunspots are darker and cooler than their surrounding areas and they are of irregular shapes. Though these are referred to as spots, some of the large ones are nearly 1,45,000 kilometres long and

96,000 kilometres wide. Groups of sunspots measure 3,20,000 kilometres in length.

The surface temperature of the Sun is, as we know, 6,000 degrees Celsius whereas around the sunspots it would only be 4,000 degrees Celsius. They often appear in groups. Very small ones vanish in a few hours, while larger spots or spot groups last for a few months. Sometimes active sunspots may produce outbursts on the chromosphere known as 'solar flares', which may cause serious disruptions in the radio reception on the Earth. These flares develop in a few minutes and remain for hours. They mostly consist of ultraviolet radiation.

The world of science owes a lot to Samuel Heinrich Schwabe (1789-1875) for a major discovery. Working in a medical shop in Germany, Schwabe closely studied, as a pastime, the solar spots through a small telescope, for not less than 17 years and, in 1874,

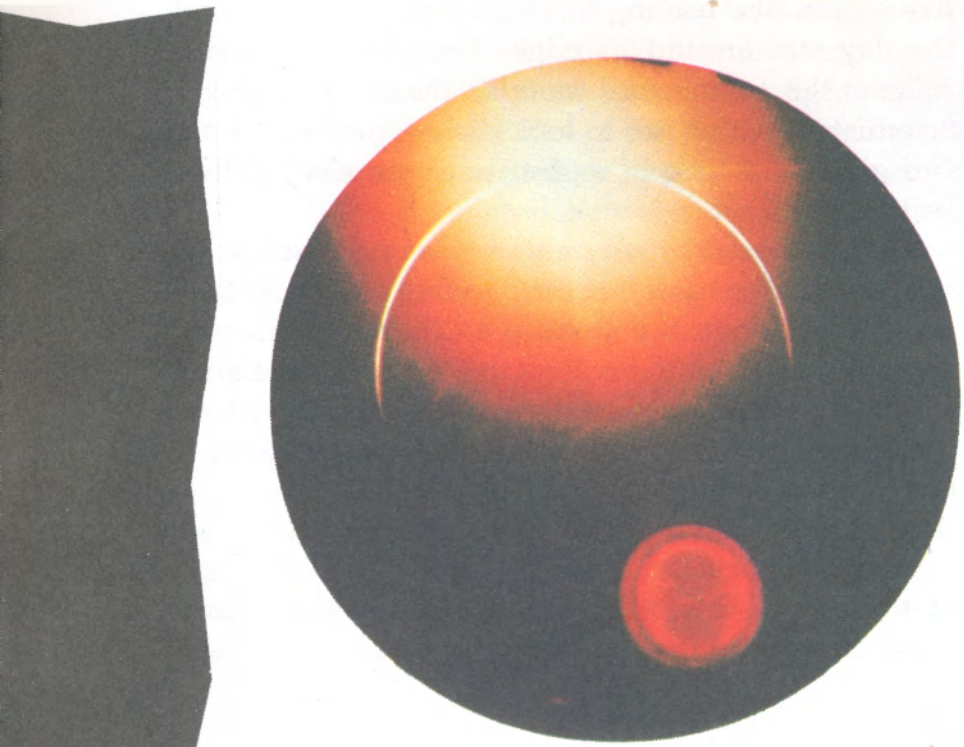


Solar eclipse

came to the conclusion that the appearance and disappearance of these spots followed a cycle of 10 years. This period was later accurately calculated to be 11.11 years by Swiss astronomer, Rudolph Wolf (1816-1893) of Zurich. This duration is known as the 'sunspot cycle'.

George Hale made some valuable additions. First, the spots 'are caused by vortices (whirling storms) in the solar atmosphere'. Secondly, the visible spot is always associated with an 'invisible spot', which is not cool and dark enough to be seen from Earth.

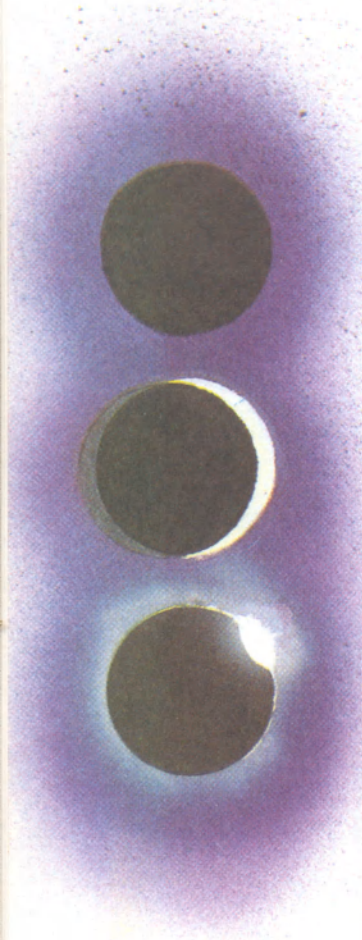
Another phenomenon is the solar eclipse. A solar eclipse cannot be seen throughout the world at the same time but only at a few places. The Moon circles round the Earth once in 29½ days. At times it passes directly between the Earth and the Sun, and hides the Sun partially or completely. Thus occurs the solar eclipse. But the Moon is 400 times smaller than the



The Sun's corona

Sun; how then, you may wonder, can such a little planet hide a giant star? This is possible because the Moon is 400 times nearer to the Earth than the Sun.

There are three kinds of solar eclipses, namely, partial, total and annular eclipses. If the Sun is hidden completely by the disc of the Moon, it is called a total eclipse. This is a very rare occurrence. It is said that at any one place on the Earth a total solar eclipse will be visible once in 360 years. A total solar eclipse is the most suitable occasion for astronomers to carry out their various investigations of the Sun, but it lasts for only a few minutes, never more than eight minutes. So scientists rush with all their equipment to far-off places where total eclipses would be visible.



Solar eclipses: total, partial and annular

Sometimes the Moon is far away from the Earth and cannot hide the Sun completely, only partly. This is known as a partial eclipse. At some other time, it may so happen that the Moon covers the whole Sun like a dark disc leaving a beautiful bright outline of the day star around its edge. This is an 'annular' eclipse, the Latin word *annulus* meaning 'a ring'. Scientists warn us not to look directly or even with sun glasses at an eclipse, lest our eyes shall suffer serious damage.

Solar eclipses happen only on new moon days. In a year you may have from two to five solar eclipses. Another noteworthy feature is that it does not happen every month because the orbits of the Earth and the Moon are not on the same plane. The latter sometimes passes above and sometimes below the orbit of the Earth.

Total eclipses may be coupled with another wonderful spectacle. When the Sun's disc is totally blotted out by the Moon, red flames and the silvery 'corona' are observed and photographed. They are

seen above the chromosphere of the Sun, providing an unusual picture of the solar disc. 'Corona' is a luminous, high-temperature, rarified gas envelope, very close to the Sun. These flame-coloured projections are called 'solar prominences', which rise to great heights—hundreds and thousands of kilometres. The great eclipse prominence of 1919 rose up to 7,52,000 kilometres. The record was broken the following year when the prominences rose up to a height of 9,30,000 kilometres.

The great eclipse prominence of 1919 rose up to 7,52,000 kilometres.

The prominences vary widely in shape, size and motion. Sometimes these last for months. These can be active or quiescent. Active prominences seem to have some association with the sunspot groups. These prominences remain a puzzle to the scientists. These may probably be due to some magnetic forces operating upon the Sun. Briger Vassenius of Sweden was the first to describe, in 1733, this spectacular display of the Sun. John Evershed (1864-1956), who happened to direct the observatory at Kodaikanal in Tamil Nadu, recorded 60,000 prominences.

Our Sun offers still more spectacular sights near the North and South Poles of the Earth. Solar flares send out electrified particles which cross the distance of 150 million kilometres between the Sun and the Earth and enter the upper part of the atmosphere. As a result of this, a brilliant display of coloured lights, mainly red and green, in streamers and bands, is seen in the sky. They are some 80 to 160 kilometres above the Earth. We call these lights seen in the northern hemisphere 'Aurora Borealis' or the Northern Lights, and the lights in the southern hemisphere 'Aurora Australis' or the Southern Lights. Sometimes both are called the 'Aurora Polaris'. They are most commonly seen during the maximum of the sunspot cycle.

What are these lights? What causes them? Scientists are searching for the answers. The Sun poses many such riddles.

Perhaps, by now, you may have guessed that our Sun must be a turbulent star. Indeed it is so. In recent years with the availability of radar and short wave radio receivers another amazing side of the Sun has been discovered. It seems to be a powerful 'broadcasting station' not broadcasting musical programmes, but sending out noisy radio signals of very high frequency which were discovered in 1942 on British radar sets. These are often noticed as accompanying outbursts of sunspots and great solar flares. It happens, this jumble of solar noises sometimes jams our radio broadcasts. Similar electromagnetic radiation waves are emitted by other celestial objects also. They range from 0.04 inch to 100 feet. Through measuring and analyzing them, scientists collect valuable data about stars. This study is called 'Radio Astronomy'.

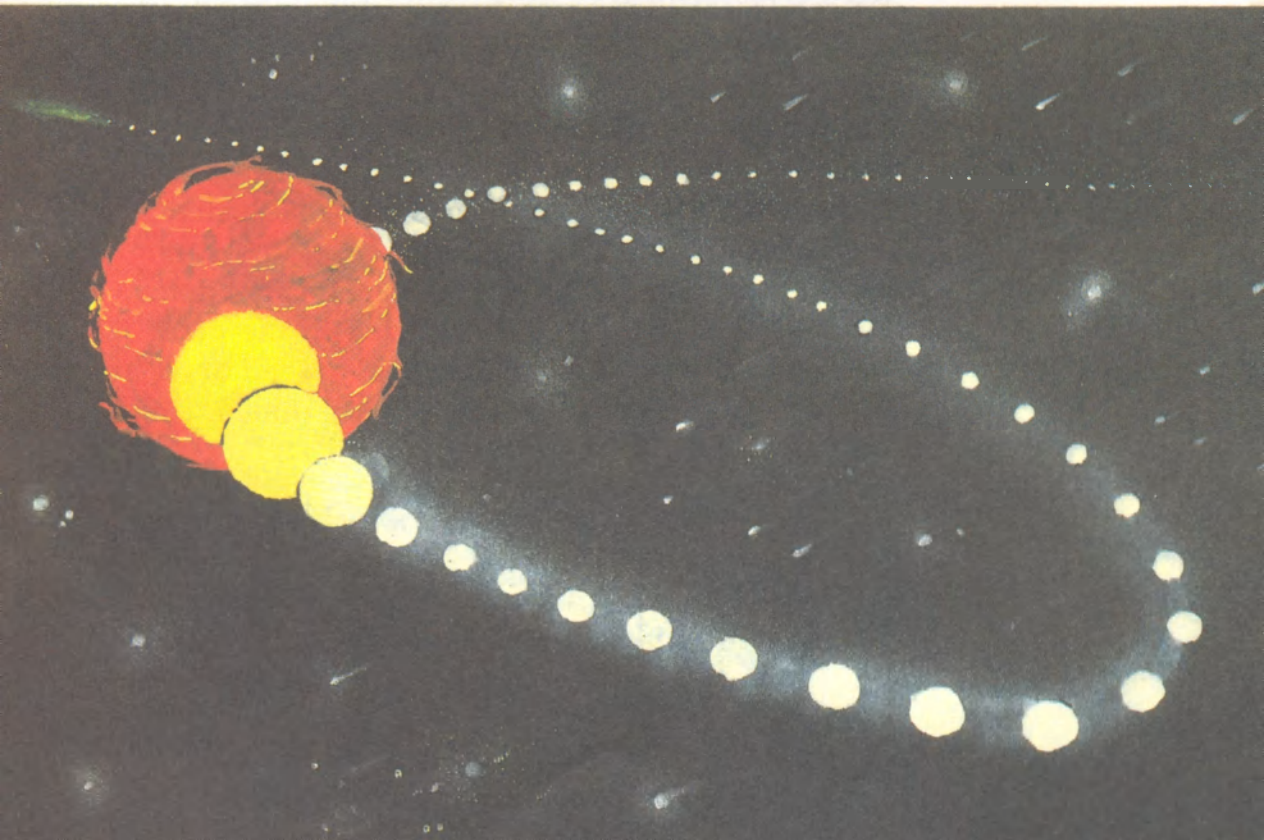
In the case of a few stars in the stellar system, the luminosity seems to increase and decrease at regular intervals. The period may vary from star to star. Such stars are known as 'variable stars'. We shall later meet them in their world. In the early part of this century, an astrophysicist in the U.S.A., Dr. Charles Greeley Abbot (1872-1973), after a careful research, made a revelation that the Sun may, in reality, be a variable star, probably with a very small range of variation in an eleven-year period. This finding is yet to be confirmed.

The head of the solar family has immense powers and innumerable surprises. Will it finally stop shining one day? Will such a giant too meet with its death? Will the great dispenser of light and heat become dark and cold? Unfortunately, yes. Our Sun,

too, will die like all other stars—but not in hundreds or thousands of years—only after billions of years.

How then will its end come? Our Milky Way is more than 10,000 million years old and our Sun which came later and which is a relative newcomer to the galaxy, is only half that—5,000 million years old. Like all stars, the Sun is supposed to have been shaped out of a cloud of dust and gas. Slowly, as the cloud started condensing, it gained its shape, temperature and luminosity under its own gravitational power.

The Sun is now a yellow star in the second stage of its career. The Sun will slowly swell—growing bigger and bigger and, at the same time, gradually becoming hotter and hotter. It will turn into a red giant, approximately after 10^9 years, radiating



Our Sun, too, will die like all other stars.

enormous heat beyond bearable limits. 'Mercury will be baked; Venus will be fried.' Our dear Earth will become terribly hot; its rivers, lakes and oceans will reach boiling point and soon evaporate; all plants and animals will be scorched to death; and our world that was once bubbling with life will have the pathetic look of a barren desert. In this condition billions of years will pass. The Sun, once replete with hot gases, will be slowly depleted of its stock, that is, all nuclear energy sources will be used up.

'Mercury will be baked; Venus will be fried.' The Earth will become terribly hot.

In the final stage of evolution, the Sun will start shrinking, with colour changing from red to white. Its brightness will fade; it will lose all its splendour; its internal temperature will decrease; and our great Sun will collapse into a tiny star, much smaller than the Earth. At this stage it will be incredibly dense and heavy. It will be one of the types of stars known as 'white dwarf'.

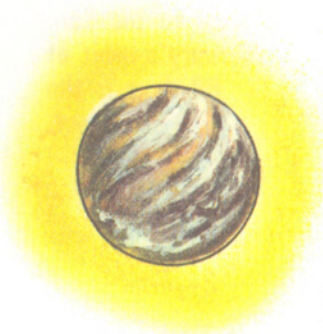
After 5,000 million years, having used up the last of its fuel, it will turn as black and heatless as the empty space surrounding it. It will be dead and silent, and go into obscurity. That will be the end of the orb once called the Sun, which ruled as an unquestioned monarch over the vast solar system. The longevity of the Sun is estimated to be 10^{10} years. All stars have very similar evolution and extinction.

As the life of the Earth is linked with the great master, it too will become a lifeless, black ball of ice and rock sans light, to remain in that domain of dreadful silence called space.

THE DWARFS

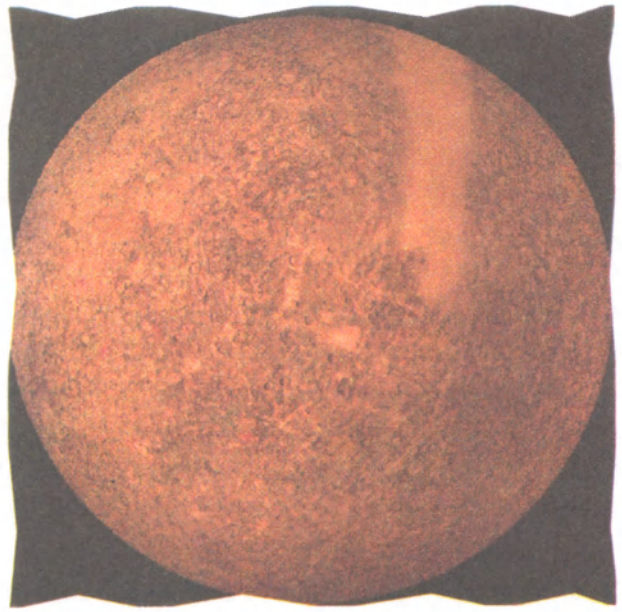
Stars and planets are basically different. A star is a huge gas balloon and is luminous. A planet, on the other hand, is relatively small, running round a star like the Sun. It has no light of its own but receives light from the Sun and reflects a fraction of it. This reflective power is called albedo. The albedo varies from planet to planet. For instance, Mercury (and Moon) has very poor albedo—of 7 per cent—that is, it reflects only 7 per cent of sunlight. Venus has the highest albedo of 70 per cent followed by Neptune with 55 per cent. Uranus comes next with 45 per cent and Saturn with 42 per cent. Our Earth, covered with oceans all around has an albedo of 40 per cent.

The nine planets are classified into two groups: the giants and the dwarfs.



The nine planets are classified into two groups: Mercury, Venus, Earth, Mars and Pluto are dense and small terrestrial planets. The other four are giant or Jovian planets. While Earth, Mercury, Venus and Mars are nearer to the Sun and also called inner or interior planets, the other five, being far away from the Sun, are designated outer planets. The inner planets are dwarfs in size in comparison with the Jovian planets.

All planets, except Mercury and Venus, have smaller companions orbiting them. These secondary planets are known as satellites. They spin on their axes, revolve round their mother planets and travel along with their 'mothers' round the Sun—all simultaneously.



Closest to the Sun, Mercury's orbit of 88 days is the shortest.

Mercury

Mercury, a dwarf planet with a diameter of 4,880 kilometres, was considered the smallest planet till Pluto was discovered. Its orbit lies closest to the Sun, at a distance of 58×10^6 kilometres.

Mercury is the name of the messenger of the Roman gods and he is thought to be shuttling all the time between Heaven and the Earth. Aptly the planet appears, disappears and reappears and seems to be rightly named. Sometimes Mercury can be seen twinkling as a star in the sunset twilight or sometimes before dawn.

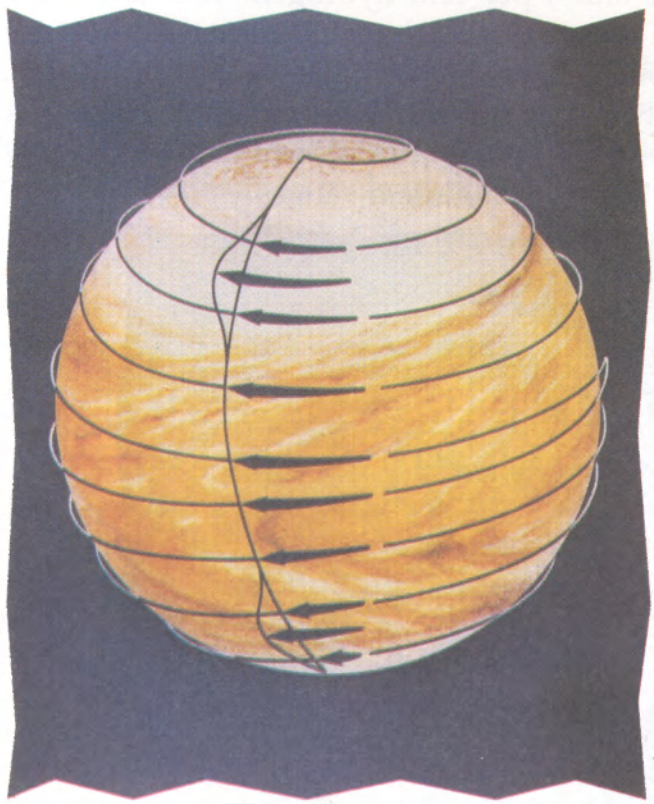
Mercury takes 58 days to spin once on its axis. Closest to the Sun, its orbit is the shortest, one circuit of which is completed in 88 days. The planet looks like a bare ball of rock with no proper atmosphere or water but pockmarked with craters, like the surface of the Moon.

Venus

The next planet closest to the Sun is Venus, the brightest of all planets. Venus is the name of the Roman goddess of love and beauty. Worthy of its name, the planet looks extraordinarily bright and beautiful, and is hailed by people as the Morning and Evening Star. It shines 15 times brighter than even Sirius, the brightest of all stars known to us. Astronomers say that the planet Venus will look like a crescent moon from far away. When Galileo first observed Venus, he noticed its phases—a phase being the gradual increase and decrease of the area of brightness visible from the Earth.

Brightest of all stars, Venus is hailed by the people as the Morning and Evening Star.

The orbit of Venus lies at a mean distance of 108×10^6 kilometres from the Sun. It requires 7½ months (224 days 16 hours 49 minutes) for Venus to make one round of the Sun, at a speed of 35 kilometres per second.



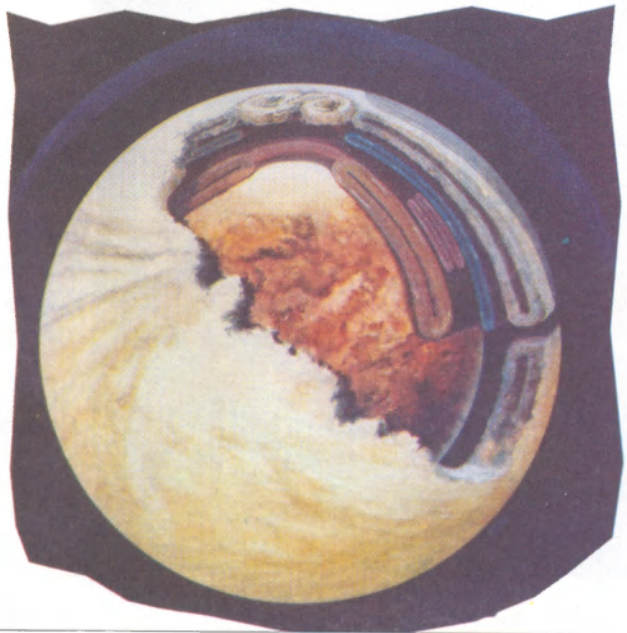
Venus's atmosphere

Venus rotates on its axis more slowly than any other planet—once every 243 Earth days. Two peculiarities of Venus deserve mention here. One, unlike most planets (except Uranus and, possibly, Pluto), Venus rotates on its axis in a retrograde direction, from east to west. Two, it is the only planet that does not rotate in the same direction that it travels round the Sun.

In mass, radius and density this planet is regarded as 'Earth's twin sister'. Its diameter is 12,320 kilometres whereas the diameter of the Earth is 12,756 kilometres. The density of Venus and the Earth is respectively 4.86 and 5.52 of water. Venus has 88 per cent of the Earth's gravitational force, and has seasons similar to the Earth.

The surface of Venus is totally obscured by swirling clouds of sulphuric acid.

But in many other respects Venus is quite different from Earth. Its surface is totally obscured by dense swirling clouds of sulphuric acid. The atmosphere is composed of 96 per cent suffocating carbon dioxide and 4 per cent hydrogen. The heat has no way of escape and the surface is sizzling hot, with a temperature as high as 500 degrees Celsius. So virtually no life can exist on the planet. The surface displays giant craters (evidence of volcanic activity), rift valleys and mountain ranges.



Cross-section of Venus

The Earth from the Moon

Earth

Third in the queue from the Sun, the Earth is at a distance of 15 million kilometres. 'Terra', the name of the Roman goddess, refers to the Earth. One theory of the geologists about the birth of the Earth is this: Long, long ago, a big, whirling mass of gas was blown away from the Sun owing to its rapid rotation. That mass slowly cooled in the course of millions of years to become the orb of the Earth. It looks like a huge, bluish ball of solid rock from space. Our Earth is said to be $5{,}500 \times 10^6$ years old.

The surface temperature is 60 degrees Celsius. If one goes deeper and deeper, it gets hotter. At the centre of the Earth the temperature is estimated to be 5,500 degrees Celsius and it is believed that there is a huge ball of molten iron of diameter

6,500 kilometres. It indicates that though the surface has cooled a bit, the interior remains very hot. Our world is always 'shivering' and every two or three minutes an earthquake is happening somewhere.

The Earth rotates rapidly on its axis, once in 24 hours—precisely 23 hours 56 minutes 22.7 seconds. This is one day for us. Secondly, our planet goes on its elliptical path around the Sun at a speed of 29.2 kilometres per second, taking 365 days, 6 hours, 9 minutes, 10 seconds, the true length of a year, for one revolution.

The Earth rotates on its axis once in, precisely, 23 hours, 56 minutes, and 22.7 seconds.

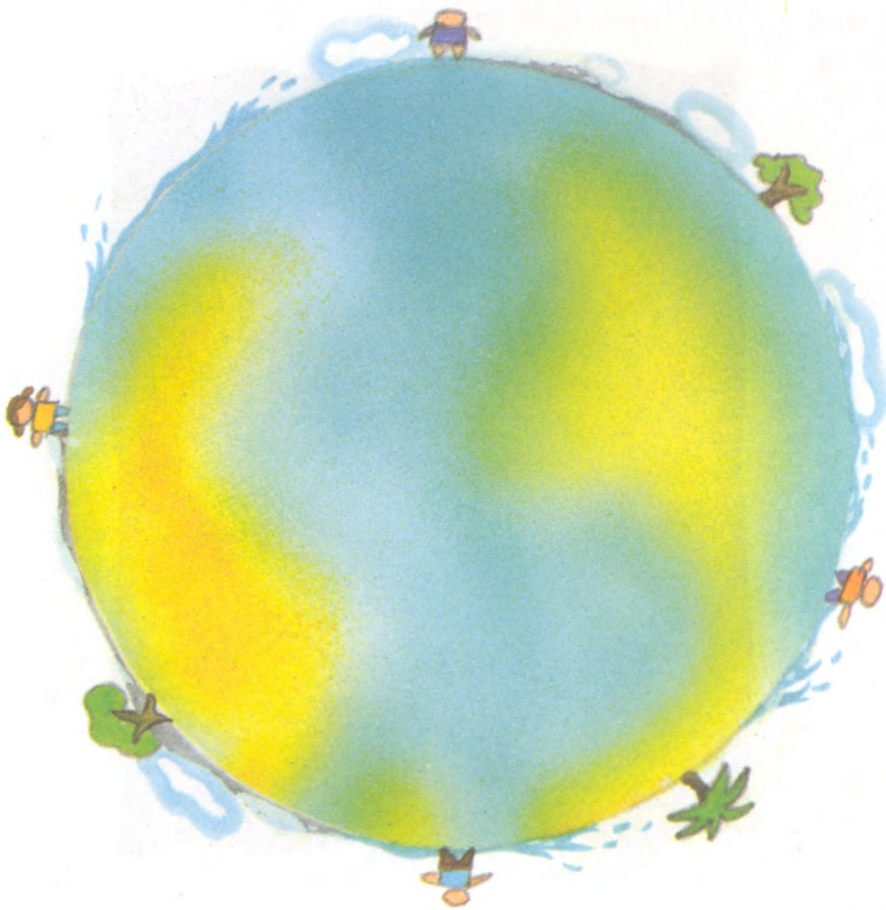
Perhaps you have learnt in your geography class that three-fourth of the Earth's surface is covered by oceans; it is rightly called a 'watery planet'. It is water that makes this planet habitable. But for this, our planet would also be desolate like its sister planets. Water is precious. It is the elixir of life. For the present we know that the Earth alone is inhabited in the entire solar system.

We live on the other one-fourth land area, enclosed by seas. So we are actually on an island! Don't you feel thrilled to realize that our island is hanging in space without any support whatsoever, rotating on an axis and at the same time making a year-long journey round the Sun? The most exciting aspect of it all is that we never feel the motion. Why is it so? It is simply because we move along with the surface and the atmosphere.

Our Mother Earth, carrying the whole of mankind, all the mountains, rivers, valleys, seas, oceans, plants and animals through the orbit, has been and will be circumnavigating in space for millions and millions of years. In spite of such a motion, the objects on the surface do not fly off, the ocean waters do not flow over, we do not roll off the Earth. How can this phenomenon happen?

The great miracle performer is gravity. According to Newton's Law of Universal Gravitation, the greater the mass, the more powerful is the attraction. Our Earth weighs 6,600 trillion tons ($6,600 \times 10^{18}$), and naturally has enormous gravitational force that not only attracts everything on the surface to its bosom, but also extends up to a great height in space. We stay put on the ground because of this influence; otherwise we would be floating in the air and in that state would have to sit, stand, eat, drink or sleep. As when man goes into outer space, he feels weightless, starts floating and suffocates for breath like a fish out of water.

We stay put on the ground because of the influence of gravity.



Mars

Mars, the last of the dwarfs near the Sun, is named after the Roman god of war, the father of Romulus and Remus, the legendary founders of the historic city of Rome. The Babylonian astronomers named the planet Nergel after their god of death and pestilence which for the Greeks was Ares, the god of battle. The traditional symbol of Mars represents a shield with a spear. The planet was an enigma to ancient astronomers. The very name 'Mars' instills fear in the minds of men, probably because the planet is reddish in colour and has an abnormally rapid rotation.

Red in colour, Mars is named after the Roman god of war.

The orbit of Mars lies at an average distance of 228×10^6 kilometres from the Sun. The planet makes one round of the Sun at a speed of 24 kilometres per second in 687 days, almost twice as long as our Earth. But the axial rotation of Mars is almost the same as that of earth, that is, 24 hours 40 minutes. Thus a day of Mars is the same as the Earth's but its year is twice as long. Mars is also tilted at an angle of 24 degrees from the vertical to the solar orbit. Therefore, it may have seasons similar to ours but they will be twice longer.

A year on Mars is twice as long as that on Earth.

The diameter of the red planet is 6,700 kilometres. It has lofty volcanoes most of which may not be extinct. The largest is Olympus Mons, 25 kilometres high, which is three times the height of Everest, our highest mountain on land.

The study of Mars, started by Galileo, was taken up by many astronomers. The most prominent of them was an Italian, Giovanni Virginio Schiaparelli (1835-1910). After a study of 13 years, he came out with some startling findings that took the world of science by surprise.

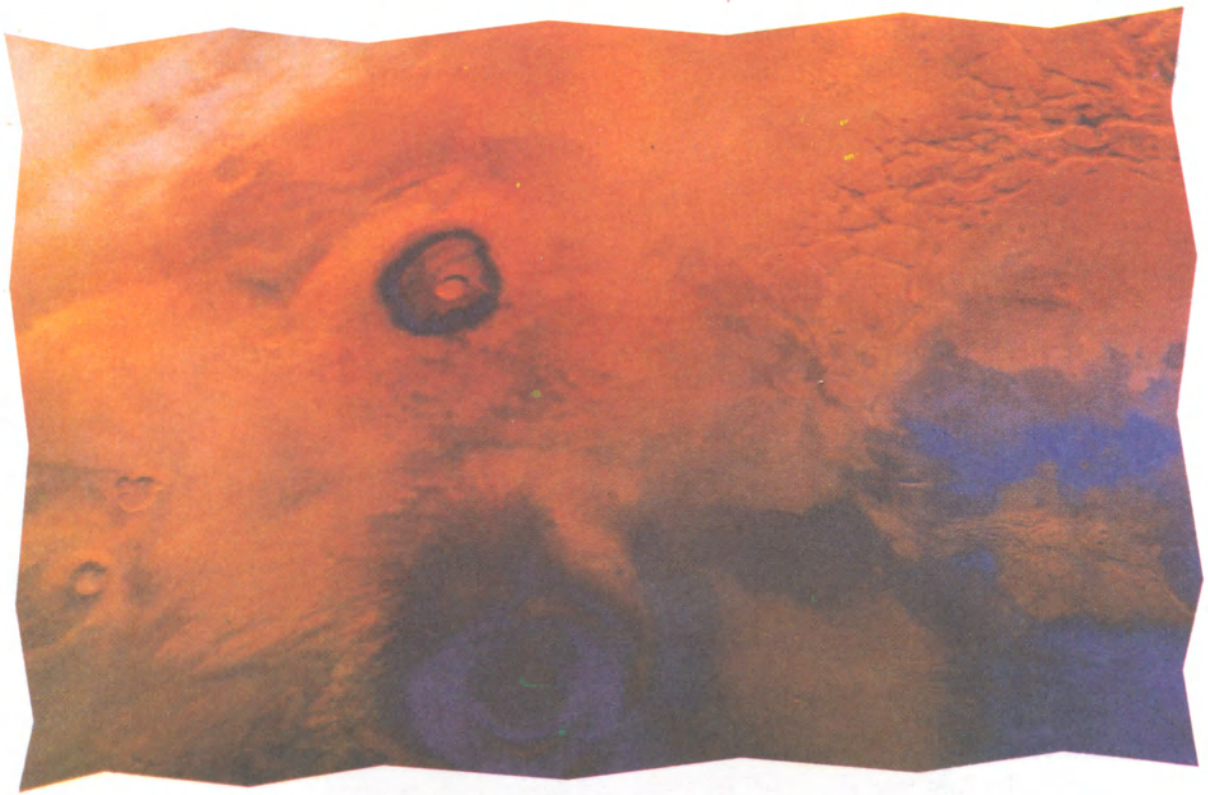
A network of dark, straight, artificial-looking lines were noticed by Schiaparelli who assumed they were waterways constructed by the inhabitants of Mars for taking water from the snow-clad poles to the arid areas for cultivation of crops. He designated the lines by the Italian word 'canali' which actually meant 'channels' but was translated into English as 'canals'. This gave rise to much debate among the scientists, some of whom could not accept the existence of water and life on Mars.

Dr. Percival Lowell (1855-1916), the celebrated American astronomer, championed Schiaparelli's theory. In fact, he erected, in 1894, an observatory at Flagstaff in Arizona with the express purpose of

studying planets in general and Mars in particular. He confirmed that there existed on Mars nearly 500 canals running up to 4,800 kilometres which were an engineering marvel of beings more intelligent, civilized and advanced than earthlings. Lowell even drew up a map of the planet and wrote a book, *Mars and its Canals*. This observation, however, was received with scepticism while Lowell commanded much respect for his other valuable observations.

Recent studies disproved all such claims and so far astronomers have not found any sign of water or life on the red planet. To quote W.H. Pickering, "I doubt very much if what are usually known as canals and oceans contain any water at all."

Olympus Mons, the largest volcano on Mars, is three times the height of the Everest.



Volcanic ridge on Mars

THE GIANTS

We cross over a wide gap of 550 million kilometres from Mars and enter the region of the four giants of the Solar family.

Jupiter

First comes Jupiter alias Jove, named after the king of the Roman gods. Jupiter is treated as the prince of planets.

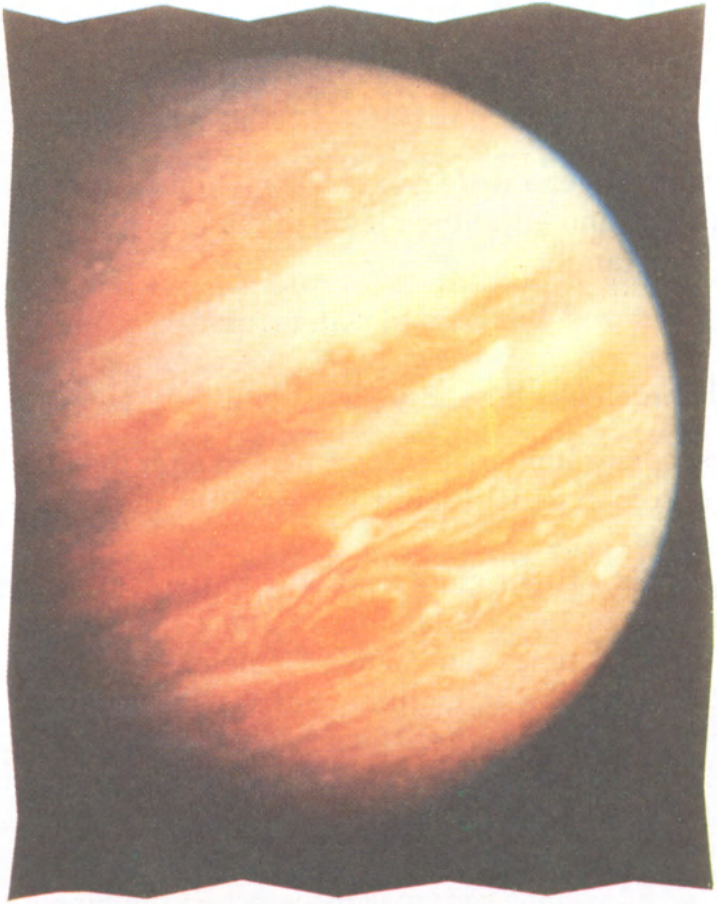
Jupiter is a super giant next only to the Sun, with a diameter of 1,42,800 kilometres along the equator which is 11.2 times the Earth's diameter. It is equal to 13,000 Earths in volume but its mass is not correspondingly greater. The mass of Jupiter is only 318 times that of the Earth. This means that Jupiter is not made of solid matter but only of light gases. Still Jupiter's gravity is 2½ times greater than the Earth's and so men cannot stand erect on the planet.

Jupiter is a super giant, next only to the Sun.

In volume and mass, Jove exceeds the rest of the planets put together. It can easily hold within it all the other eight planets. Such a super giant takes less than 10 hours (9 hours, 50 minutes, 30 seconds) to rotate once on its axis. This is one Jupiter day. The non-spherical shape of the planet is attributed to its fast axial rotation.

Jupiter, the fifth in the line of planets, orbits at a distance of 778.3×10^6 kilometres and makes one revolution round the Sun in 11.8 Earth years which is called one Jupiter year.

Astronomical studies revealed a big red spot running on the planet's surface, called the Great Red Spot, even though its colour sometimes changes to light red or grey. The surface area of the spot is



The 'eye' of Jupiter

greater than that of the Earth and measures 40,000 kilometres in length and 12,800 kilometres in breadth. It is semi-permanent in the sense that it vanishes for a short while but returns soon after. Some call it the 'eye' of Jupiter.

On either side of the equator some rings were noticed and they seemed to change their colour every 12 years.

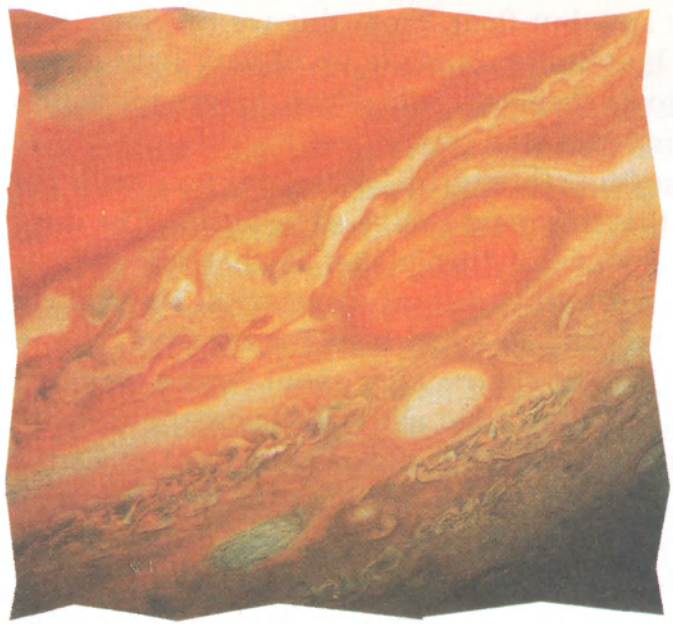
The most interesting fact is that the chemical composition of Jupiter is quite similar to that of the Sun's. Jove is made up of 82 per cent hydrogen and 18 per cent helium. It radiates twice as much energy as it receives from the Sun. This suggests that nature has provided inside Jupiter an internal storehouse of energy.

Jupiter is the second brightest planet, shining twice brighter than Sirius, the Dog star. All these add up to make a theory that Jove is more a star than a planet. In fact, Zollner of Leipzig states 'it is a veritable semi-sun'. The conception of Jupiter as 'half Sun and half world' has been accepted by many scientists.

A Russian astronomer was tempted to hypothesize that Jupiter was once at the centre of the present solar system as a gigantic star from which some parts flew off to become the planets. Later, for reasons not known, Jupiter lost its importance to the Sun and became the planet it is.

Even today, scientists believe that if any sudden dislocation is caused inside Jupiter, the internal temperature may shoot up and cause a great explosion resulting in Jupiter becoming a star again. If and when it happens, we may have a second Sun.

Details of the Red spot on Jupiter



Saturn

The second largest planet in our solar system is Saturn. As we move from one planet to another, we are moving farther away from the Sun. Saturn makes its revolution at a distance of $1,427 \times 10^6$ kilometres. This journey takes 30 Earth years. Saturn was regarded as the outermost planet in the solar system till 1781 when another giant, Uranus, was located.

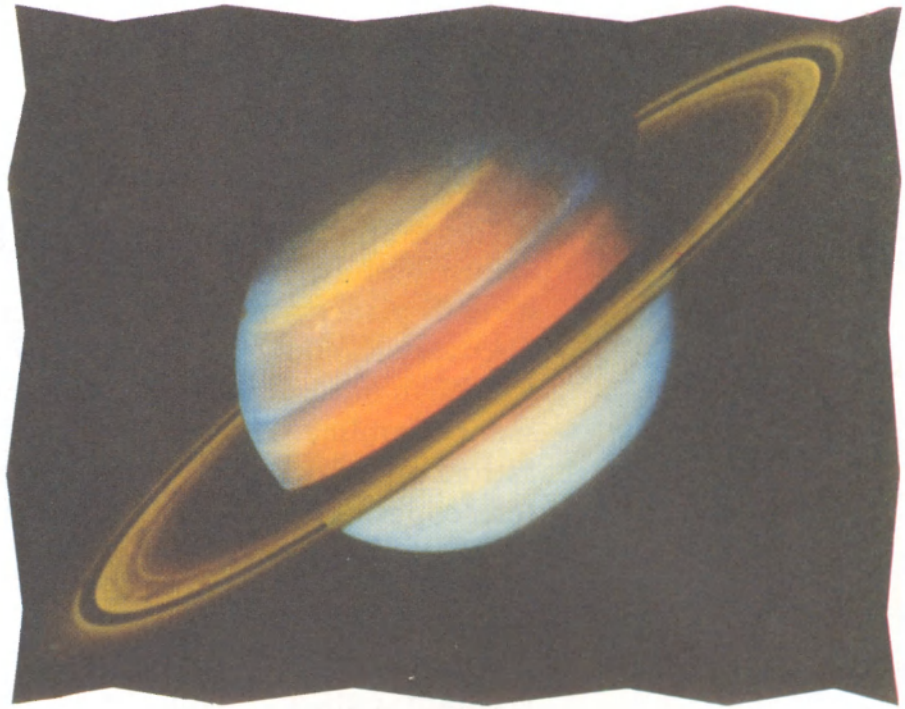
Saturn and Jupiter are relatively similar. Like Jupiter, Saturn does not rotate on its axis as a whole. The period of rotation varies between 10 hours, 14 minutes, 24 seconds, and 10 hours 39 minutes.

Saturn is not as dense or heavy as the Earth.

Saturn has an equatorial diameter of 1,20,800 kilometres and polar diameter of 1,09,000 kilometres suggesting that it is the most oblate, that is, flattened at the poles, planet. While Saturn is much bigger than the Earth, it is not as dense or heavy as the latter. If it can be lifted and thrown into water, it will not sink but float. From this we can infer that Saturn, like Jupiter, is made up of very light gases. Owing to its chemical composition, Saturn too shines like a first-rate star.

If you look through a telescope, you will not believe that this giant can be so beautiful. The most unique feature of this planet is that Nature has decorated it with a colourful system of rings along its equator. This is a real feast for the eyes.

Some kind of abnormality about Saturn was first noticed by Galileo, but since his telescope was not powerful enough, he could not pinpoint what the abnormality was. It was Dutch astronomer, Christian Huygens (1629-1695) who first found out the truth. "The planet is surrounded by a slender, flat ring inclined to be elliptic and nowhere touching the



The rings of Saturn

body of the planet."

A few years later, Giovanni Dominico Cassini (1625-1725), a French-Italian, discovered the double nature of the rings and the gap between them. This gap of 27,000 kilometres is since known as 'Cassini's Division'. Later discoveries revealed that it is really a complete system of not less than six rings which do not touch the planet anywhere. The whole system, like the planet, is inclined at an angle of 27 degrees to the orbital plane.

The outermost ring, which is greyish-white, extends 73,000 kilometres above the planet's clouds. The middle ring is the brightest of all and looks white. The innermost ring is greyish-blue and rather faint and indefinite. This is known as the 'Crepe' or 'Gauze' ring. The rings look very thin and flat. The mystery of these appendages is yet to be solved. These are made up of icy chunks which whirl round the planet like tiny 'satellites', owing to the gravitational force of the mother planet. They are too small to be seen individually. They may be the remnants of an old satellite of Saturn which wandered too close to the mother planet and was split up by the planet's immense gravitational pull.

Uranus

The myth that there was no planet beyond Saturn was exploded in the 18th century when a seventh planet was discovered. The credit for this discovery should go to Friedrich Wilhelm Herschel, a German music teacher settled in England with his sister, Caroline. His primary interest was stellar astronomy and he constructed his own powerful telescopes with which he penetrated the star depths again and again. As his sister put it, "My brother was not contented with knowing what former observers had seen."

On the evening of March 13, 1781, suddenly Herschel sighted a strange object among the stars in the constellation of Gemini. He mistook it for a comet. After continuous observation, realization came to him that he had accidentally discovered a new planet. Though the discovery was by chance, it was rightly hailed as 'the greatest discovery since Newton's day'. It extended the known boundaries of the solar system and also paved the way for the discoveries of two more planets in the succeeding two centuries.

Uranus orbits the Sun in a horizontal position.

Towards the end of his career, Herschel's ambition in life was well-expressed by himself: "A knowledge of the construction of the heavens has always been the ultimate object of my observations." True to his words, he contributed a lot to the study of stars, which, as it remained, was overshadowed by the discovery of a planet. Herschel shot into instant fame all over the world. He had the most fitting epitaph: 'He broke the barriers of the skies.'

The discoverer desired to name his discovery as Georgium Sidus in honour of George III, King of England. But the world of science had some

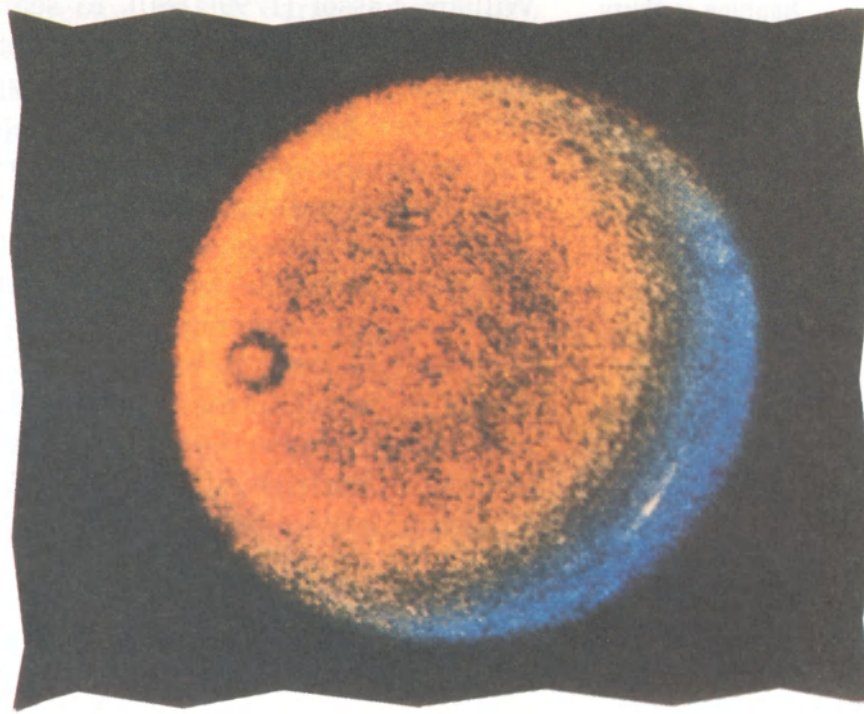
reservations in accepting it. Seventy years later, in 1850, the planet was christened Uranus, the name originally suggested in the year of its discovery by the renowned German astronomer, Johann Ehlert Bode (1747-1826) who was then the Director of the Berlin Observatory. After six years of his discovery of the planet, Herschel discovered two of its satellites too.

Uranus is a giant but much smaller than the previous two. It has a diameter of 50,800 kilometres and rotates at full speed once in 10 hours 49 minutes. It has a mass nearly 15 times the Earth's.

Uranus is nearly 287×10^7 kilometres away from the Sun. This is more than 19AUs. So despite its great dimensions, the study of Uranus presents a handicap to the scientists.

Normally planets orbit round the Sun in a vertical position. Uranus does it in a horizontal fashion. Its axis is tilted at an angle of 98 degrees—it lies on the plane and rolls along the long path. Uranus completes one such pilgrimage in 84 years, within which time the Earth makes 84 rounds of the Sun.

Some dark rings, which are not easily visible, were observed on Uranus. The composition of Uranus is like that of Saturn's—predominantly hydrogen and helium.



Neptune

The last of the four giants is Neptune. Its discovery reads like a thriller. For quite some time astronomers were perplexed to notice some irregularities in the orbital motions of Uranus and guessed that these were caused by the gravitational pull of an unseen body nearabout in that vicinity. Rev. T.J. Hissey, in 1834, suggested that it must be a huge planet.

John Couch Adams (1819-1892), a graduate of Cambridge, worked hard for two years and made his calculations about the probable size of a new planet and the position where it could be found. He sent his papers to James Challis (1803-1882), Director of the Cambridge Observatory who forwarded them to George Biddel Airy (1801-1892), at the Greenwich Observatory. Unfortunately the study was not pursued.

Another astronomer, also British, William Rutter Dawes (1799-1868), happened to read Adams' papers. Impressed by them, he wrote to his friend, William Lassel (1799-1880), to search for the new planet as he possessed an efficient telescope. The letter was accidentally destroyed by the maid. It was all Adams' bad luck.

Neptune is thirty times farther away from the Sun than the Earth.

Meanwhile, some French astronomers were also engaged in finding out the body that caused the deviations of Uranus. Le Verrier (1811-1877) was one of them. Unaware of Adams' calculations, he worked on it and came to conclusions very similar to those of Adams. According to Le Verrier, the new planet would be found in the constellation of stars called Aquarius. He sent his conclusions to his friend, Johann Gottfried Galle (1812-1910), at the Berlin Observatory to make the search. Galle began his hunt.

On September 23, 1846, the hunt was over. Galle located the new planet only 52 degrees away from the position that was predicted by Le Verrier. He announced the discovery. Challis, too, found the planet but failed to recognize it. So Galle got the acclaim; Adams lost the race.

The discovery of this 'new' member was the greatest triumph of Newton's gravitational theory and the methods of orbit computation. At the suggestion of Le Verrier, Dominique Arago, a French physicist, who served as Director of the Paris Observatory, baptized the newly-found captive of the Sun as Neptune, in honour of the Roman sea-god, controlling all the waters of the world.

Neptune is like Uranus in mass, size and composition. It is slightly smaller than Uranus with a diameter of 4,94,000 kilometres. In volume, forty-two Earths are equal to Neptune. The massive planet takes 18 hours, 24 minutes for one axial rotation.

Neptune is positioned quite far away—nearly 4,500 million kilometres from the Sun which is thirty times the distance between the Sun and us. Neptune does one orbit of the Sun in 164.8 years. Scientists are yet to know more about our new find.

We have indeed travelled far—nearly 5,750 million kilometres—and have come to the outer boundary of our solar system as it is known to us at present. Here let us meet our new little friend, Pluto. This is the latest addition to the Solar family, discovered in this century.

Pluto's discovery also makes interesting reading and happens to be yet another affirmation of Newton's theory. Percival Lowell and many other astronomers were studying the erratic orbits of Uranus, for which Neptune was later found to be one responsible factor. They suggested that one more body beyond Neptune must also be the cause of the perturbations in the orbits of Uranus and Neptune. Lowell started his research in 1908. He came to the conclusion that the new planet would be a little one at a distance of 6,800 million kilometres and would orbit the Sun in about 282 years. Lowell did not live long enough to see that his predictions were quite accurate.

Astronomers spread their nets in the outer space for the inhabitant. Clyde William Tombaugh, born 1906, who joined the Lowell Observatory, took part in the search. He adopted the technique of photographing, part by part, the space under study. The planet was finally seen on February 18, 1930, not far from Lowell's location. The official announcement was made on March 13, 1930—Lowell's birth anniversary as well as that of the discovery of Uranus.

The find was named Pluto—the first two letters representing the initials of Percival Lowell. Pluto or Hades is the Greek god of the dead and also the name of the underworld he ruled. The planet, Pluto,

clouded in mystery, deserved the name. According to Greek mythology, the dead were ferried to Hades by the boatman, Charon, across the river, Styx. Interestingly, a satellite of Pluto, discovered in 1978, has been named Charon.

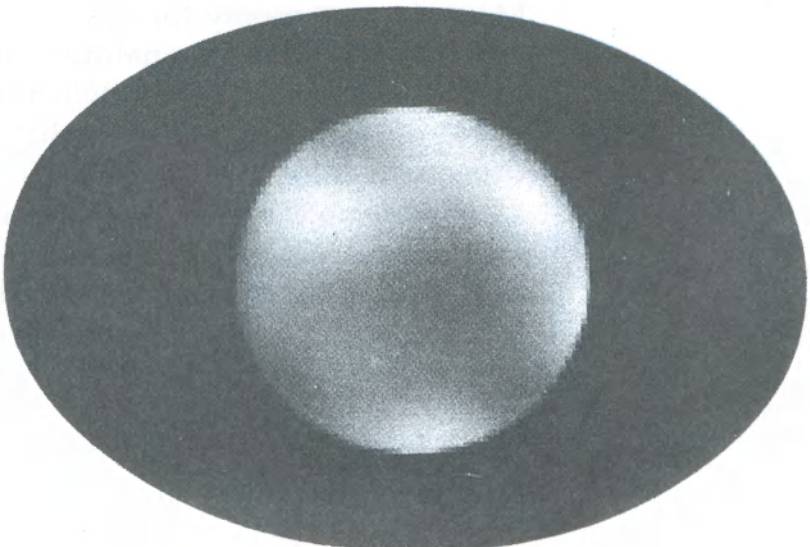
Pluto is too far away to be closely studied by scientists. It requires the largest telescope to have a look at it. The distance between the Sun and Pluto is 5,900 million kilometres.

If you look at our Sun from Pluto, it will look like a twinkling little star. Pluto makes the longest journey around the Sun in 248 years and has an eccentric orbit sometimes crossing into the path of the eighth planet, Neptune. It receives very little sunlight because of the great distance from the Sun; notwithstanding this the mighty ruler's gravitational force holds it in its grip. Pluto can only be a terribly cold, dry planet.

Pluto is the smallest planet of the solar system with a diameter of 2,500 kilometres. You may remember that from Mercury to Mars it is a zone of the dwarfs, and then comes the domain of the four giants. How then can Pluto, the smallest, get into the area immediately after the giants? This is a cosmic riddle posed to the scientists.

The period of axial rotation of Pluto is just 6.3 days. It appears as a yellowish disc with dark markings.

Let us return to our Earth, for we have to meet someone special there—the queen of the night!



Pluto demoted!

On August 24, 2006, the International Astronomical Union (IAU) declared that Pluto ceases to be a planet. As per the new definition, a planet must meet the following three requirements—a planet must orbit the Sun; it must be big enough for gravity to squeeze it into a round ball; and it must dominate the neighbourhood so that it can 'sweep up' asteroids, comets and other debris, clearing a path along its orbit. Pluto has been demoted as it does not fulfil the third condition: its 'moon' is about half the size of Pluto while all the other planets are far larger than their moons. Besides, Pluto's orbit is somewhat untidy.

QUEEN OF THE NIGHT

The sun sinks in the ocean. Night falls. The Moon comes up in the sky and shines from afar like Nature's brightest 'lamp' to dispel darkness! The whole world bathes in cool, tranquil moonlight. Poets the world over have sung in praise of the beautiful 'lamp'. John Milton, the English poet, wrote,

And God made two great lights, great for their use
To man; the greater to have rule by day
The less by night altern...

The Sun is the king of the day, and the Moon, the queen of the night! Romans regarded the Moon as a goddess and named her Luna. From this, we have lunar eclipse, lunar rock, lunar mountains and so on.

The Moon looks bright and effulgent to attract everyone. But how does it shine so bright? Is it naturally beautiful? What kind of a picture of the Moon has astronomy for us?

The Moon is the only natural satellite of Earth. It has a diameter of 3,476 kilometres, one-fourth of the Earth's diameter. Our Earth is 80 times bigger than its satellite. The Moon takes 27 days, 7 hours, 43 minutes to make an orbit round the Earth from a distance of about 3,82,000 kilometres, and in the same period rotates once on its axis. As a result of this, the Moon keeps the same face to the Earth all

'Earthshine'—a faint outline around the dark area of a crescent Moon

the time. We are always looking at the same side of the Moon. The other part of the Moon remains turned away from us. This does not mean that the other side will always be dark.

Satellites, as you know, only reflect sunlight. The Moon is a giant mirror, but not a good one, because it reflects only seven per cent of the light it receives from the Sun though it illuminates our whole world. The Earth is a better mirror, as it lends some of the sunlight to the Moon. When you look at a crescent Moon, you see a thin, faint outline around the dark area. This is known as 'earthshine'. Many centuries ago, Leonardo da Vinci, one of world's geniuses, first explained it correctly as the faint illumination of the Moon by sunlight reflected from the Earth.

The Moon circles the Earth and both move together around the Sun. So the Moon is not always facing the Sun and not receiving direct sunlight all the time. Different parts of the Moon receive sunlight at different periods. When the Moon comes between the Earth and the Sun, it is not visible to us and it is called new Moon. Then the Moon facing the Earth begins to be lighted up. The lighted part appears as a thin, curved slice of a circle, say a semi-circle, which we call a crescent. Slowly the area of bright surface visible from the Earth grows larger and larger till the face of the Moon is fully lighted. That is our full Moon. These changes are the phases of

the Moon and the whole cycle lasts just 29½ days which is one lunar month for us.

These phases delight every child. That excitement is expressed in these lines by Eliza Lee Follen:

Oh, look at the Moon,
She is shining up there,
Oh, mother, she looks
Like a lamp in the air.
Last week she was smaller
And shaped like a bow,
But now she's grown bigger,
And round as an 'O'.

Just as we have solar eclipses, lunar eclipses too occur. At times the Earth comes between the Moon and the Sun, and then the Moon passes into the shadow of the Earth; the direct supply of sunlight is completely cut off, and it is a total lunar eclipse. The Moon loses its shine and from pearly white turns a dull, coppery colour. When the Moon is partially shadowed by the Earth, it is a partial lunar eclipse. Lunar eclipses can happen only on full Moon days and they can be partial or total and never annular.

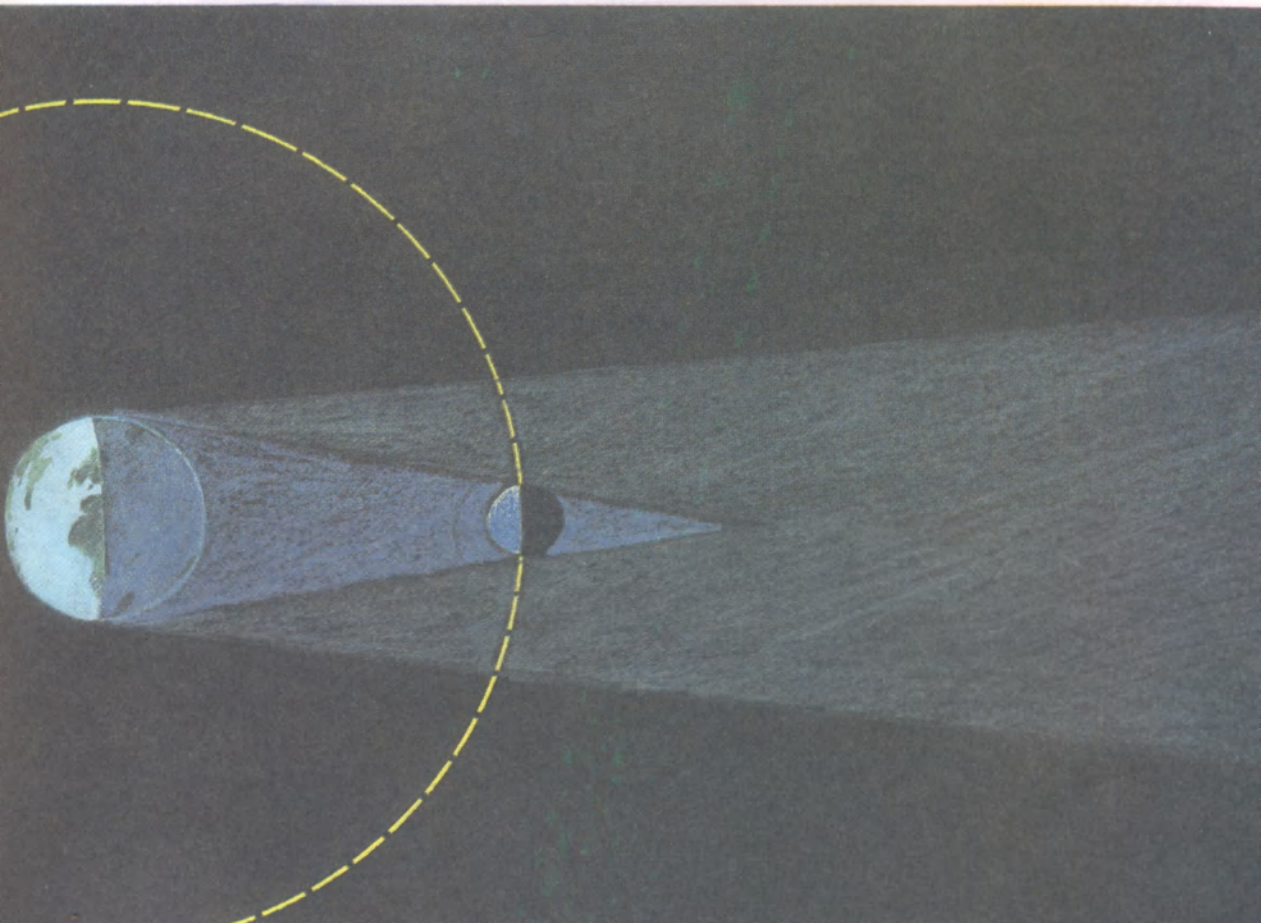
Unlike solar eclipses, lunar eclipses last longer and can be seen from any place where the Moon is above the horizon. Lunar eclipses, though beautiful and interesting to watch, have no serious astronomical significance.

If you can get hold of a telescope and turn it towards the Moon, you too will exclaim, "Wonderful! Wonderful!" as Galileo did some hundreds of years ago. The surface of the satellite is covered with ring-shaped mountains, peaks, rocks, clefts and giant craters. Johann Hieronymus Schroter, an eighteenth century astronomer, was the first to make an intensive study of Moon's surface and is the founder of modern selenography (lunar astronomy).

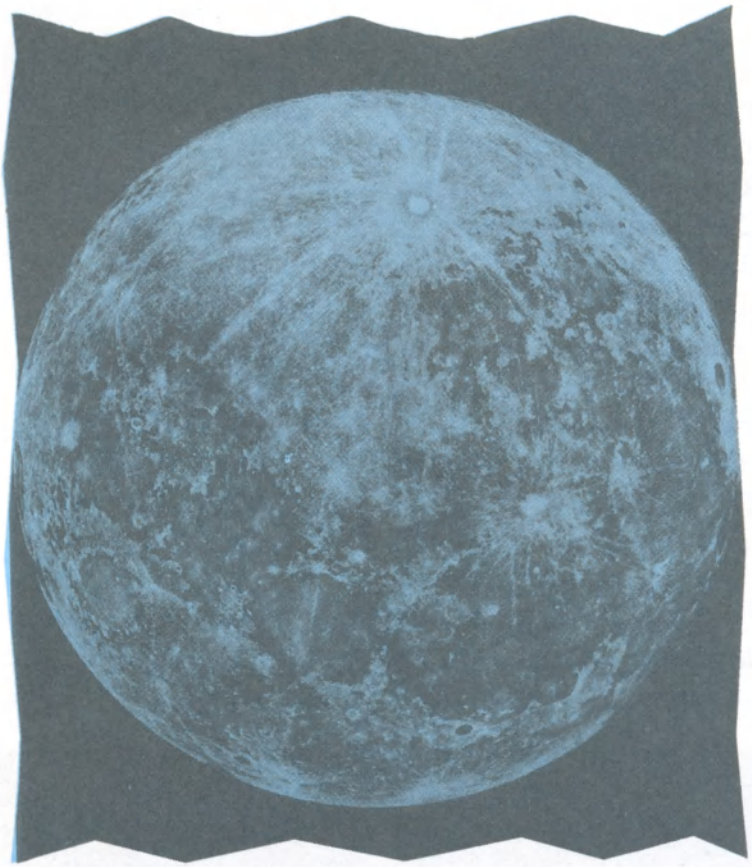
He reported a large number of craters not detected earlier. The 'surface' of the 'Queen' is not smooth and polished as it appears to be, but thickly scarred.

The lunar mountains are named like the mountains on Earth—the Alps, Apennines and Caucasus. Though they are not steep, some of them are 26,000 to 30,000 feet high. The Apennines, though only 16,000 feet high, are the most spectacular of them. The height of Leibnitz, another mountain, is 35,000 feet—taller than the Everest.

On the Moon, the great men of ancient Greece like Hipparchus, Atlas, Plato, Aristotle, Aristarchus and Heredotus, and the modern scientists like Archimedes, Copernicus, Tycho Brahe, Newton, Kepler, Herschel, Bessel and others have been immortalized. These are the names of some of the



The moon's surface is covered with rocks, mountains, peaks, and craters.



The 'surface' of the 'queen' is not smooth and polished but thickly scarred.

30,000 lunar craters on the hemisphere turned towards the Earth. One large crater on the far side of the Moon, never visible from the Earth, is named after the Russian, Tsiolkovsky.

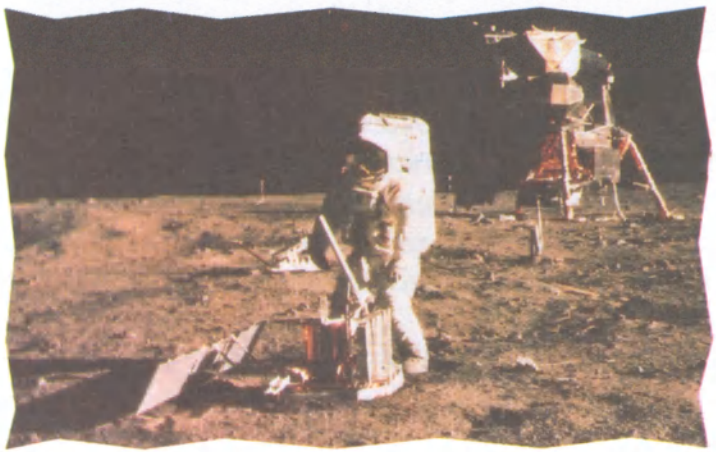
The naming of the craters after prominent personalities was initiated by an Italian Jesuit, Father Riccoli, when he drew a map of the satellite in 1651. He did not forget to allot himself a large crater. That system was later adopted and extended, but most of Riccoli's original names were retained. These craters were probably created by volcanic activity or 'meteoric bombardment'.

Would you like to see seas and oceans without water? They are there on the Moon. In the seventeenth century, astronomers like Galileo noticed a number of dark spots all along the surface of the

Moon and mistook them for seas. In the lunar charts they were marked by the Latin term *Maria* meaning 'seas' (singular 'mare'), which misnomer was perpetuated by later observers. As a result, there are so many seas on the lunar surface, like *Mare Nectaris* (Sea of Nectar), *Mare Orientale* (Eastern Sea), *Mare Nubium* (Sea of Clouds), *Mare Serenitatis* (Sea of Serenity), *Mare Imbrium* (Sea of Showers), *Mare Tranquillitatis* (Sea of Tranquillity), *Mare Crisium* (Sea of Crisis), *Mare Vaporium* (Sea of Vapour), to mention a few. There is an ocean named *Oceanus Porcellarum* (Ocean of Storms); a bay called *Sinus Iridium* (Bay of Rainbows) and a marsh by the name *Palus Putredinis* (Marsh of Decay). There is also a hell, named after the Hungarian astronomer, Father Maxmilian Hell. But all of them are simply flat, dry plains, the result of volcanic activity, with no trace of water.

In reality, the Moon has no air and no atmosphere. Devoid of basic requisites for any life to originate, the Moon is a 'lifeless' planet. Yet it was always the ambition of man to go there and have a closer look at the 'night lamp'. That was fulfilled in 1969 when Neil Armstrong, an American astronaut, landed on the Moon and returned home safely with samples of lunar rock. The Moon is the only heavenly body in the solar system on which man has set foot.

The Moon is a 'lifeless' planet having no air, no atmosphere.



Other Moons

The Moon is the Earth's satellite; the satellites of other planets are also known as moons. So far, sixty of them have been discovered. There may be some more. Earth has only one, the Moon. Venus and Mercury have none. Saturn seems to have a big family of 17 moons with Jupiter and Uranus following respectively with sixteen and fifteen 'children'. Neptune has eight and Mars only two. Even Pluto has one.

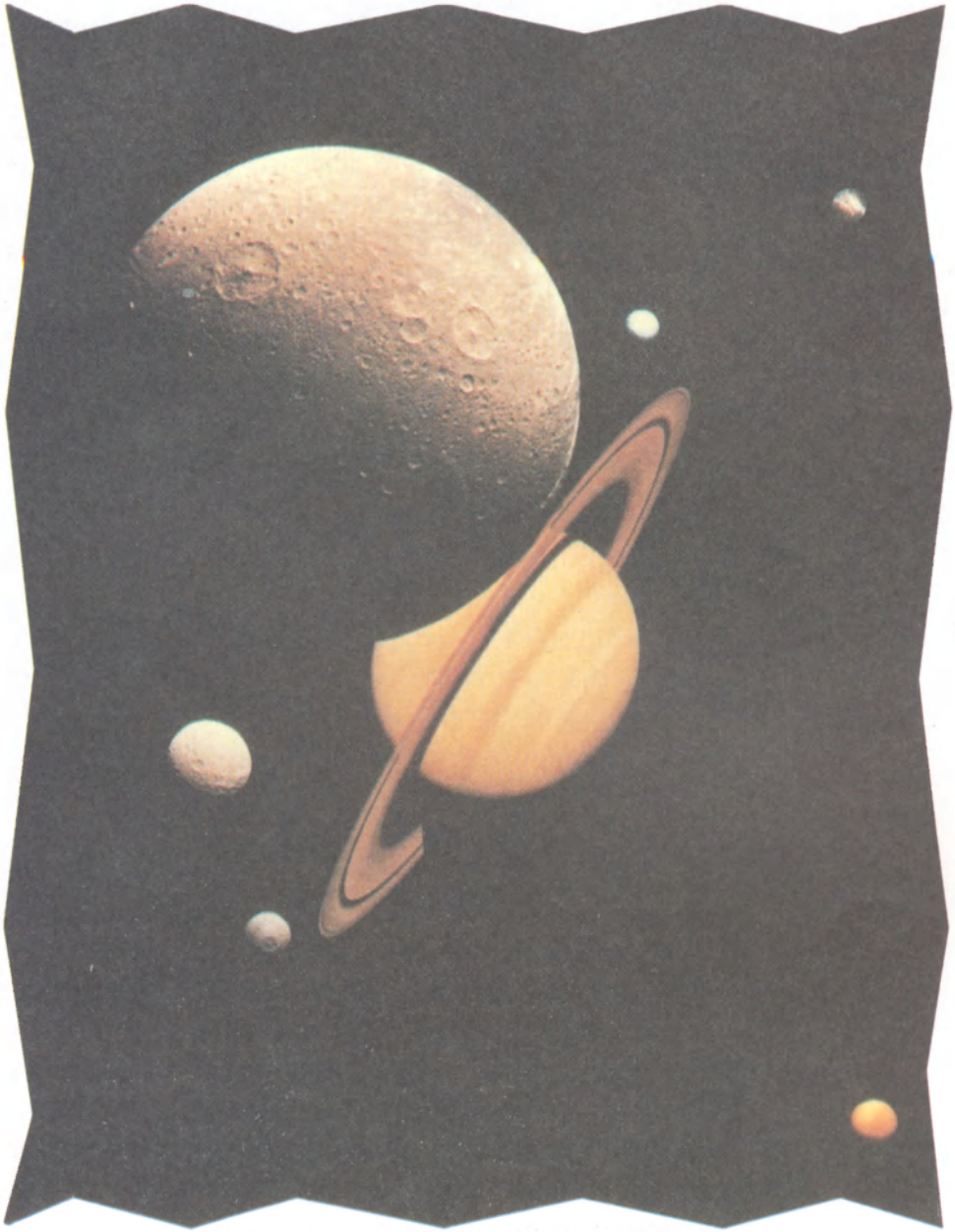
A few of the moons have diameters of planetary dimensions, like the Galilean satellites, namely Io (3,630 kilometres), Europa (3,140 kilometres), Ganymede (5,260 kilometres) and Callisto (4,800 kilometres) of the super giant Jupiter, and Titan (5,150 kilometres) of Saturn.

Some Moons have diameters of planetary dimensions.

Jupiter's four big 'children' take the same time to make one axial rotation and one revolution of the mother planet. They, therefore, keep the same face to their 'mother' just as our Moon shows us the same side.

Some of the moons, for some unknown reason, go round the planets in a retrograde direction, that is, from east to west. The two moons of Mars are Phobos (Fear) and Deimos (Terror), named after the mythical chariot horses of the war god, Mars. One peculiarity is that Phobos, with a radius of 13 kilometres, goes round Mars in just 7 hours 39 minutes whereas Mars takes about 24 hours to rotate once. That is, Phobos makes three revolutions before its 'mother' makes one rotation. So the moon, Phobos, appears to rise in the west and sets in the east. This is a rare phenomenon which takes place only on Mars.

Another queer thing worth mentioning is that the



giants are overcrowded with satellites and so have many lunar and solar eclipses.

Added to these sixty moons are the small bodies comprising the rings of Saturn, Uranus and Jupiter. Our Earth has one Moon and our solar system has hundreds of moons!

Our Earth has one Moon and our solar system has hundreds of moons!

THE WORLD OF URCHINS

We are now in the world of urchins, known in astronomy as asteroids, comets and meteors. All these are close relatives. They are the most queer and the naughtiest members of our solar system.

'Urchins' are the queerest and the naughtiest members of our solar system.

Asteroids

You know that there is an unusually wide gap of 560 million kilometres between the orbits of the dwarf, Mars, and the giant, Jupiter. How could nature leave so much space empty without putting in it a planet? Kepler and Prussian astronomer, physicist and biologist, Johann Daniel Titius (1729-1796) suggested that there must be an unseen planet.

Bode formulated a principle, since then known as Bode's Law, in order to calculate approximately the distances of various planets from the Sun. Accordingly, he strongly felt that such a vast empty space between planetary orbits was unnatural in the set-up of the solar system, and that a planet must have its orbit in between. A search for this planet was justified. He called for a congress of 24 astronomers. A team by the name 'The Celestial Police' was formed under the leadership of the German-Hungarian astronomer, Franz Xaver Von Zach (1764-1832). Each one of them was to search in a particular zone of space.

Unaware of this development, the Italian astronomer, Guiseppe Piazzi (1746-1826) who was deeply engrossed in star-gazing, hit a jackpot. On January 1, 1801, the first day of the nineteenth century, a strange object came into his view. It was too small to be a planet. Piazzi notified Bode about

his finding. The first small 'catch', with a diameter of only 768 kilometres, was named Ceres after the guardian angel of Sicily.

It was only a beginning. Many such were discovered by astronomers. As these were quite small and much different from planets, Herschel, in 1802, preferred to name them 'asteroids'. They can also be called 'planetoids' or 'minor planets'.

The second asteroid, found by Heinrich Wilhelm Mathaus Olbers (1658-1840) on March 28, 1802, was named Pallas. It was smaller than the first, with a diameter of 480 kilometres. After three years was found the third, Juno, extraordinarily small, with a

diameter of only 192 kilometres. Then came the fourth, Vesta, whose diameter was 384 kilometres. Afterwards there was a lull in the hunt and 'The Celestial Police' was disbanded as much breakthrough was not made.

Forty years later, once again, the hunt picked up momentum and planetoids like Astraea and Hebe were discovered. Thereafter, reports of more and more successes poured in from everywhere, sometimes as many as twenty were picked up in a year. Towards the end of the nineteenth century, a German, Max Wolf (1863-1932), introduced photography in the search. Even smaller asteroids like Eros (diameter 48 kilometres), Amor (diameter 3 kilometres), and Hermes (diameter 1.6 kilometres) were detected. When the scientists searched for a major planet, they got minor planets.

Asteroids, made of rocks and stones, have eccentric orbits round the Sun.

There are thousands of planetoids filling the gap between Mars and Jupiter. The space is no more vacant. Asteroids do not differ much from meteors. Asteroids are shaped nearly like spheres and are probably made of rocks and stones. They have eccentric orbits round the Sun. They often bump into each other. Like reckless vehicle drivers, familiar on our roads, trying to overtake from the wrong side and causing many accidents, these celestial urchins collide frequently and break up into pieces. They are then knocked out of their paths and have to make their new orbits. These tiny bits of planetoids become meteors.

Asteroids are allies to comets. Sometimes asteroids threaten to hit our planet. Eros, on one occasion, went past our Earth at a distance of about 24 million kilometres. Likewise, Hermes, the tiny Adonis and Icarus, too, played pranks with us. But scientists assure us that we are safe from these naughty ones.

The tail of a comet pointing away from the Sun

Comets

Comets are the most dreadful members of the solar family. With funny heads, fluffy physiques and long, awe-inspiring tails and dazzling brilliance, they acquire the look of monsters and demons we come across in our ancient lore. But, in reality, they are quite harmless and powerless.

From the beginning of time, without rhyme or reason, comets struck terror in people's hearts as portents of the death of a monarch, great disaster, war, famine and plague. They were once taken as warnings of God.

There are millions of comets orbiting the Sun. Of these, nearly 1,000 bodies have been identified. Only very few are sighted near the Earth.

A comet consists of three parts. There is a small 'nucleus' of ice and dust which may be 16 kilometres wide. It is surrounded by an immense, tenuous, luminous cloud of gas and dust that is called a 'coma'. This may be about 16,000,000 kilometres wide. Third, there is a giant-size tail also of gas and dust, some 1,60,000,000 kilometres long. The tail of the Great Comet that appeared in 1843 was 2,00,000,000 kilometres long.

A comet acquires a tail when it nears the Sun!

Comets are generally named after their discoverers with one exception of Halley's comet. Some prominent ones are Pons, Encke, Biela, Bennet, Seki, Mrkos, Donati, Delawan and Pickering. A few of the comets were discovered by more than one scientist like Arend-Roland and Tago-Sato-Kosaka.

One interesting aspect is that a comet acquires its tail when it nears the Sun. As it approaches the Sun, there is evaporation from its head and minute particles are driven out with a velocity equal to that of light to form the tail. According to Olbers, these tails are temporary phenomena visible while the comets are in the vicinity of the Sun. The tail always points away from the Sun. When the comet is moving outward from the Sun, it actually travels with the tail in front. Perhaps the comet is scared to wag its tail before the great master!

Comets are seen with a variety of tails—some with thick, bushy tails and some with thin, long ones. Some comets appear to have more than one tail. Donati has had three beautifully curved tails. When a comet's tail disintegrates by the radiation of the Sun, each piece becomes a tail. The famous Decheseaux's comet of 1744 had seven such tails. In 1944, a comet with six tails and in 1948, one with two tails were sighted. Funnily, tailless comets are also seen. Thus comets may have a demoniacal

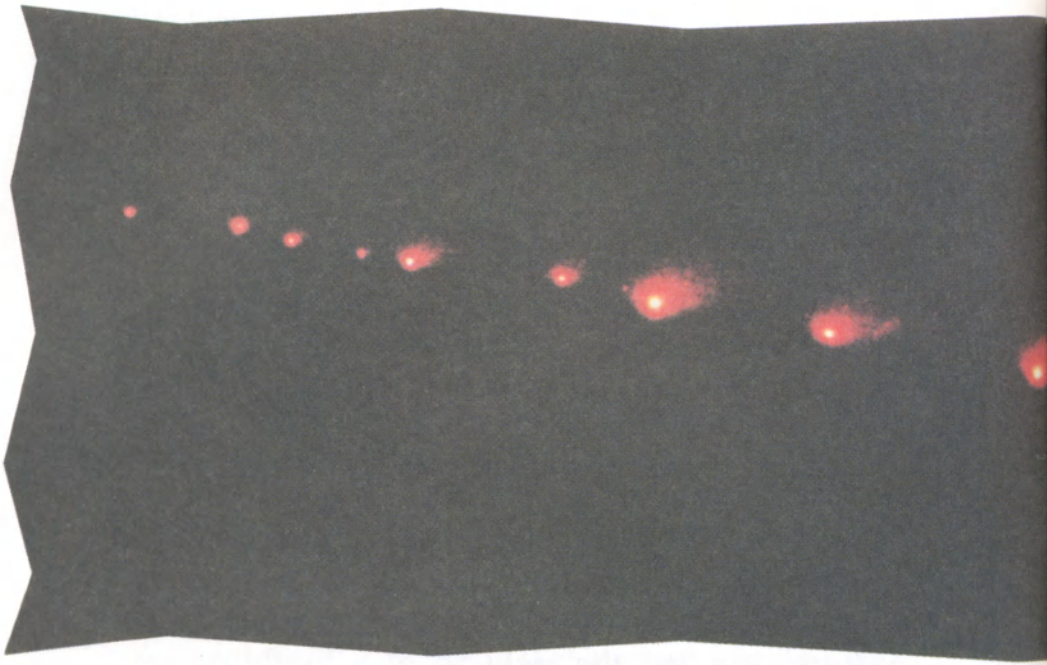
exterior but as Lowell rightly put it, they are but 'empty bags'. In the last two centuries, our Earth passed twice through the tail of a comet unharmed.

Comets, unlike planets, have elongated and eccentric orbits reaching out as far as 10^5 AUs. A few comets have fairly short periods of revolution. For instance, Encke's comet can be seen once in twenty-seven months. Dozens like Halley's have short orbiting periods of less than 150 years. The orbiting period of most comets exceed 10,000 years. The comet of 1914 known as Delawan has an orbit of twenty-five million years.

Halley's comet has become the most famous in recent years. Sir Edmund Halley (1656-1742), a British astronomer, and a very good friend of Newton, studied the sighting of a bright comet which had a record from 240 B.C. It was observed in 1531, 1607 and 1682. People mistook it as being different comets. It was Halley who observed that the same comet was seen in a period of 75-76 years. He was the first to point out that comets did not appear at random but had specific periodical orbits. To honour him, the comet, though not discovered yet studied by him, was named Halley's comet. True to his prediction, Halley's comet visited us on Christmas day of 1758, before which the astronomer passed away, and again in March 1986. It is expected again in 2062 when quite a few of you may have a chance to watch it.

Comets do not appear at random but have specific periodical orbits.

About the origin of comets, scientists have different opinions. Newton's view was that they were natives, born of the solar system and they moved according to the law of gravitation. Laplace says that comets are visitors from inter-stellar space—outside our solar system, and that Halley's is an exception that has been accidentally dragged



in by the Sun. Comets are very rarely seen near the Earth and they go very far away from us, some even beyond the orbit of Pluto. They remain out of our sight for a pretty long time. There is a vast cloud named Oort Cloud, after the Dutch astronomer, Jan Hendrik Oort, born 1900, some 50,000 AUs from the Sun. That is considered to be the place of origin of 10 million or more comets.

Every time a comet passes the Sun, it is exposed to solar radiation and pressure. As a consequence, it diminishes in bulk. The lost particles are driven off into space, even beyond the solar system. Eventually the comet decays to produce a stream of meteoroids around its orbit.

Biela's comet, a fine example, had the most colourful life. Discovered by an Austrian, Wilhelm Von Biela (1782-1856), on February 27, 1826, it was found to circle the Sun in six to seven years. When it was expected in 1832, astronomers created a big

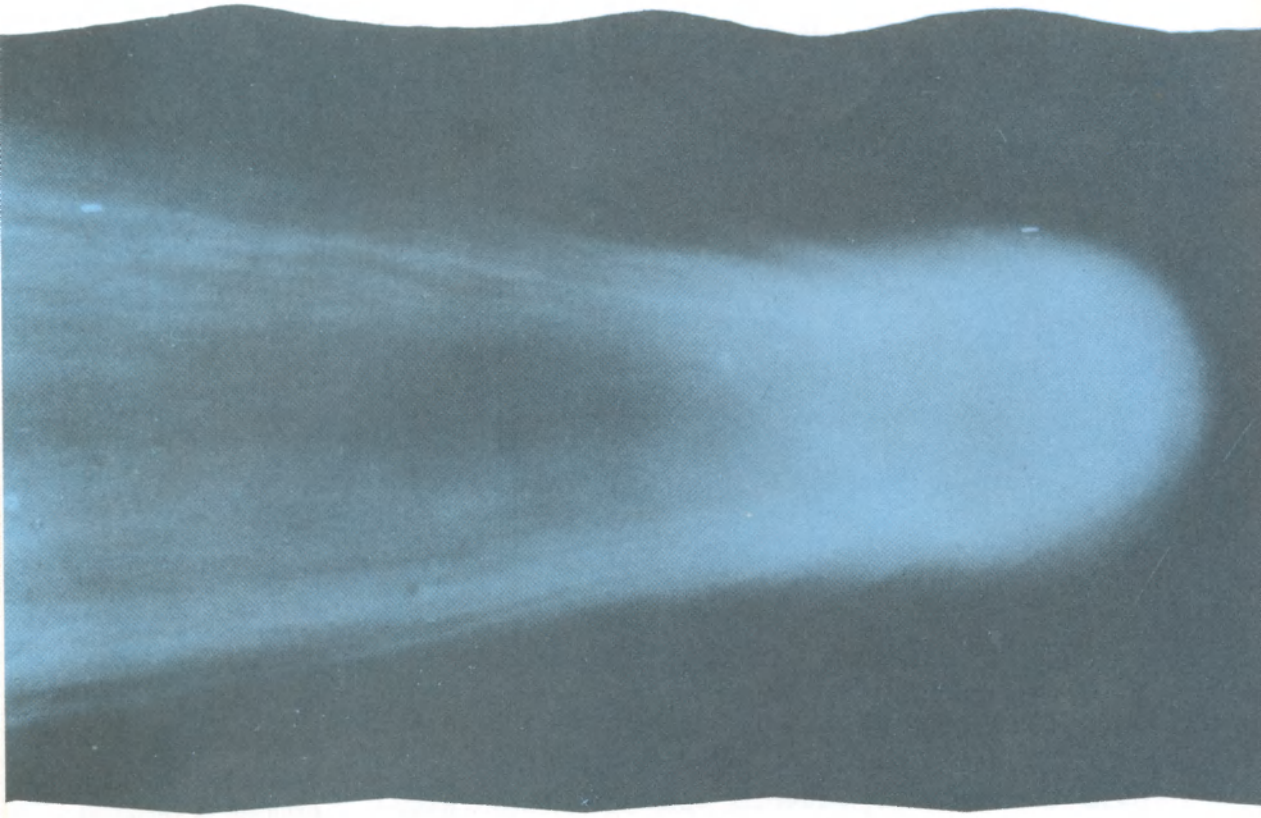
When a comet passes the Sun, it is exposed to radiation and pressure.

scare that it was going to hit the Earth. But it did not come nearer than 80 million kilometres.

On December 29, 1846, Challis, at Cambridge, witnessed an unusually strange phenomenon. To his amazement, Biela's comet virtually split into two separate comets and both travelled side by side, increasing the distance between them as they moved on. Another surprise was that the two were seen swapping their brightness as they went along. In 1852, the pair made another visit.

On November 27, 1872, a colourful display of meteors that was the result of the comet's disintegration was seen. Some 40 to 50 thousand particles travelled the old path of the missing Biela's comet. Denza, an Italian observer, described this aptly as "a real rain of fire"! Scientists realized that Biela's comet had met with its end. It is sometimes referred to as the Double comet or the Lost comet.

One interesting news of recent times was about the comet 'Shoemaker-Levy 9' which was discovered



The Halley's comet

by the American couple, Caroline and Eugene Shoemaker, and David Levy, through tele-photographs on March 24, 1993. This comet looked unusually like a pearl necklace made up of 21 pieces.

It collided with Jupiter on July 17, 1994, precisely as predicted by scientists. The comet started its collision with Jupiter at 1.30 a.m. that day. Thereafter, the fragments of the comet went on bombarding the planet till July 23.

This is hailed as the biggest celestial event of the century. J.J. Agarwal, Joint Director of the Nehru Planetarium, Mumbai, expressed the opinion that the collision of comet Shoemaker-Levy 9 with the planet Jupiter had sparked off a thermo-nuclear reaction which could convert the planet into another Sun after a billion years.

Meteors

Meteors definitely belong to our big family. They are also called 'shooting stars', but have no connection whatsoever with stars. A meteor is a comparatively small body, not much different from an asteroid, travelling round the Sun. It is a lump of rock and metal.

Meteors have a tendency to move in swarms in parallel paths through the blackness of space. For billions of years, ever since the planets were formed, millions of meteors have been zipping like race horses round and round the Sun, far beyond our visibility range.

Some of these meteoroids happen to plunge from outer space straight towards the Earth. As they cross the Earth's atmosphere they glow red-hot. A modest estimate is that every day as many as 200 million meteoric bodies enter the Earth's atmosphere. They travel at a tremendous speed of 72 kilometres per second, and rub hard against the air. The air surrounding our Earth is, of course, soft like the petal of a flower or the feather of a bird, but its resistance to swift motion is very strong. This friction makes the meteor hotter and converts it from

red-hot to white-hot. Its temperature may be 7,000 degrees Celsius. Bits of the meteor burn up leaving a trail of glowing gases. Such burning rock resembles a bright streak or flash of light and is called a 'shooting star', or 'falling star'.

While most of the smaller meteors are completely burned up in mid-air, occasionally some big ones manage to hit the ground with the force of a missile. Such an impact of the meteoric bombardment creates huge craters as on planets like Mercury and Venus, and on the Moon. Such chunks of metal and rock are termed as 'meteorites'. You can see a big crater caused by a 'fallen meteor' in Arizona. It is about 4,150 feet across and 570 feet deep. Another notable crater is in Wolf Creek in Australia. There are a number of stories about such incidents. Twice, in 1908 and 1947, Siberia in Russia was hit by meteorites which caused extensive damage. On both occasions, no human life was lost since the meteorites had dropped on forest areas. Had they fallen on a crowded city, they could have caused heavy casualties.

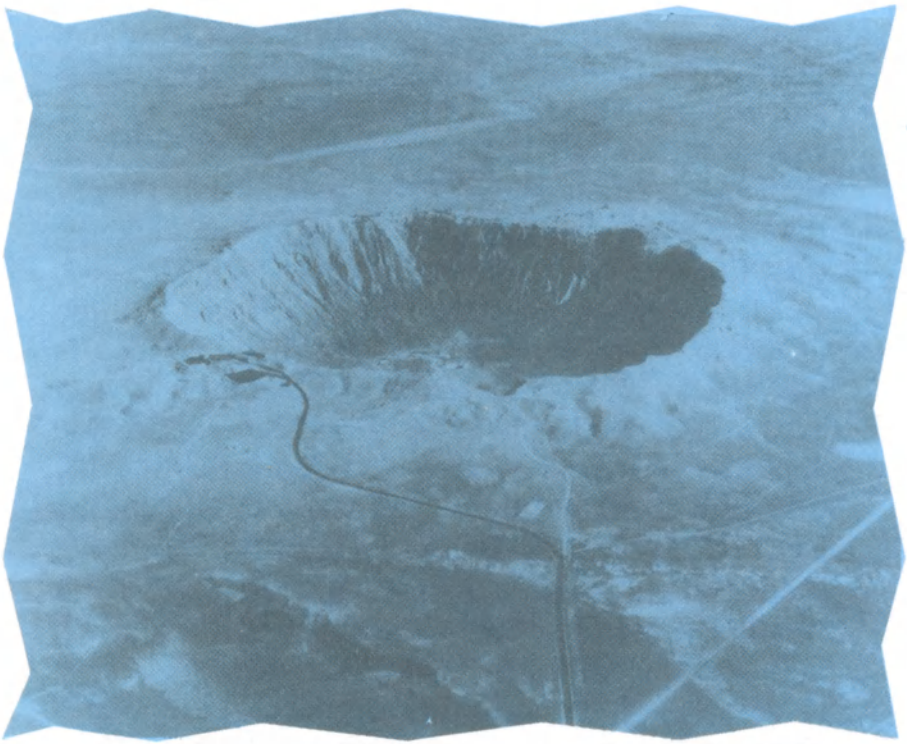
Canadian born U.S. astronomer, Simon Newcomb (1835-1909) has made an interesting observation. Not less than 1,46,000 million meteoric bodies fall each year upon the Earth. If one in a thousand strikes a human being, the entire global population will be decimated in a single year. Luckily, such accidents have not happened. Nature has provided our planet

with many safeguards against the onslaught of these little monsters. First, we are surrounded by oceans on all sides into which most of the meteorites plunge. Second, our armour of atmosphere sees to it that most of the falling stars are burnt up. Yet there is one hazard. The fine dust of vapourized meteors sinks very slowly and ultimately settles down on the Earth. You may be shocked to be told that every time creatures breathe, mild doses of this meteoric dust finds its way into their bodies.

Scientists have collected some specimens of these meteoric stones. The biggest, that weighs 60 tons, is still left at Hoba West in Africa. Admiral Robert Edwin Peary (1856-1920), the American Arctic explorer and the first man to explore North Pole, brought one found in Greenland, that weighs 36½ tons, to the planetarium at New York. Likewise, many other museums have specimens though smaller. Most of them are rocks. In some, nickel, magnesium, cobalt, iron, sulphur and a few other elements with silica and metal pieces were found Very rarely were diamonds seen inside them.

Another rare phenomenon is the remarkable shower of shooting stars which look like the celestial bodies celebrating some cosmic festival with a colourful display of fireworks. One such magnificent display was recorded by Roman historians in 467 B.C. Another was witnessed in 1799 in the U.S.A. by Humboldt, who was not taken seriously. In 1833,

astronomers turned their attention to watch a shower on the night of November 12-13 in the U.S.A. lasting throughout the night, and thereafter began their study. Olbers predicted another shower in 33 years. It came true on the night of November 13-14, 1866. John Couch Adams, the co-discoverer of Neptune, established that the period of meteoric shower is 33½ years. The origin, nature and composition of meteors are shrouded in mystery.



Crater created by a meteor

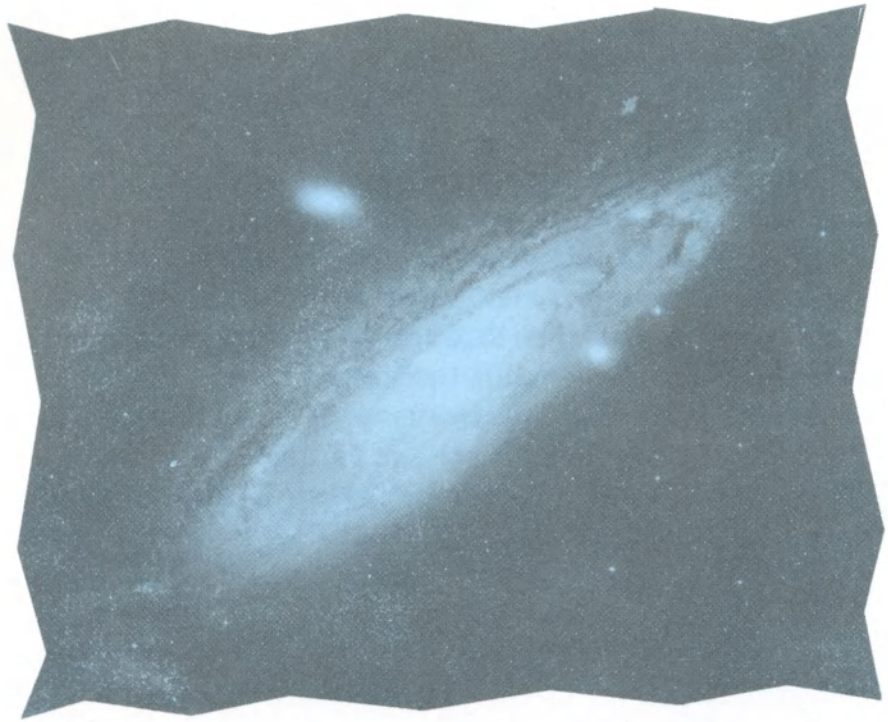
THE FAIRYLAND

We are on the final leg of our odyssey. We shall move out of the solar system and gently step into the most fascinating fairyland of the stars. It is not confined to our galaxy as such but extends to millions of galaxies throughout space—a unique world of curios which is too vast to be seen fully in several lifetimes. The heavens are dazzling with millions and millions of stars of various sizes, shapes and colours and varying magnitude. At one place they are gathered together, elsewhere they are scattered lavishly, and, in some places, they lie in geometrical patterns! In that wonderland we shall see some mysterious happenings too!

Stars are massive balls of glowing gases, rotating on their axes.

Our Sun is a star, and conversely, all stars are suns shining in the night. Therefore, these stars do not run round our Sun in the solar system as planets and planetoids do. In early times, people believed that the stars were lamps fixed to an invisible crystal sphere surrounding our Earth. But stellar-astronomy ('stella', in Latin, means 'star') established that stars are massive balls of glowing gases predominantly hydrogen and helium like our Sun. They do not stay still but rotate on their axes. They move about in the outer space. Halley noted the shifting of positions of stars. A star-gazer has put it beautifully and imaginatively, "...the great universe of stars encompassing us on every hand remains to ordinary perceptions unchanged; in reality, not for a moment does it rest, even when unseen by human eyes."

Very huge clouds of gas, dust and meteoric matter, namely, cosmic clouds or inter-stellar clouds, are moving about space. They are known as 'nebulae' (nebula means 'mist'). Nebulae are of different shapes and are in the order of millions in the



Great nebula

universe. Gaseous nebulae are the birthplace of stars while some, like Crab Nebula, are their burial ground. Our Sun and the solar system were, according to one hypothesis, born out of a nebula.

Inside a cool nebula, gas particles of hydrogen and helium gather together owing to gravitational pull and get pressed down to form a big ball of gas. As the temperature rises because of internal nuclear reactions, the gases begin to glow. A new star is born! The star begins to shine more and more brightly.

The life and end of the stars mostly depend on their masses and composition. The large, bright and hot stars will burn up their nuclear fuel speedily to end within 10^{10} years. On the other hand, stars that are smaller, faint and cool, live for about 10^{13} years.

Our day star, Sun, is the nearest to us. Others are very remote and their motions are not noticeable. Alpha Centauri and Proxima Centauri are considered

to be the nearest of the night stars and they are 4.3 light years away from Earth. Sirius, the brightest, is at a distance of 8.7 light years. The distances of Rss-128 and Procyon are 10.9 and 11.9 light years respectively. Stars such as Algol lie at 116 light years.

Do you know what all this means? For example, the light of Algol we see today has taken 116 years to reach us from its abode. Its light is so many years old. Polaris, which is at present our North Pole Star, and Deneb are respectively 650 and 600 light years away: that is to say, their lights started their journey from their homes some six centuries earlier. Many stars are millions of light years away. This will give you an idea as to how far away these stars are placed. Naturally, their light gets distorted by the layers of our atmosphere, and they seem to sparkle. If we could see them in their homeland, we would find them shining steadily.

The light from the stars we see today began its journey long ago.

The Sun is a middleweight star. Generally stars are much bigger in size and luminosity. For instance, Betelgeuse is $44x10^7$ kilometres wide—that is, more than a million times bigger than the Sun. If this star was in the place of our present Sun, then the Earth's orbit would, necessarily, be within the circumference of, or inside the star and not outside. Auriga is 2,500 times bigger than our Sun. The radii of Antares, Alpha Hercules and Mira Ceti are respectively 560, 480 and 420 times that of the Sun. At the same time there are stars called white dwarfs with a diameter of only 27,200 kilometres and which are 100 times heavier than super giants.

Hipparchus started classifying stars according to their apparent magnitude. As per this norm, the brightest stars were of the first magnitude and those faintly visible to the naked eye were of the sixth magnitude. Today stars are graded into at least 20

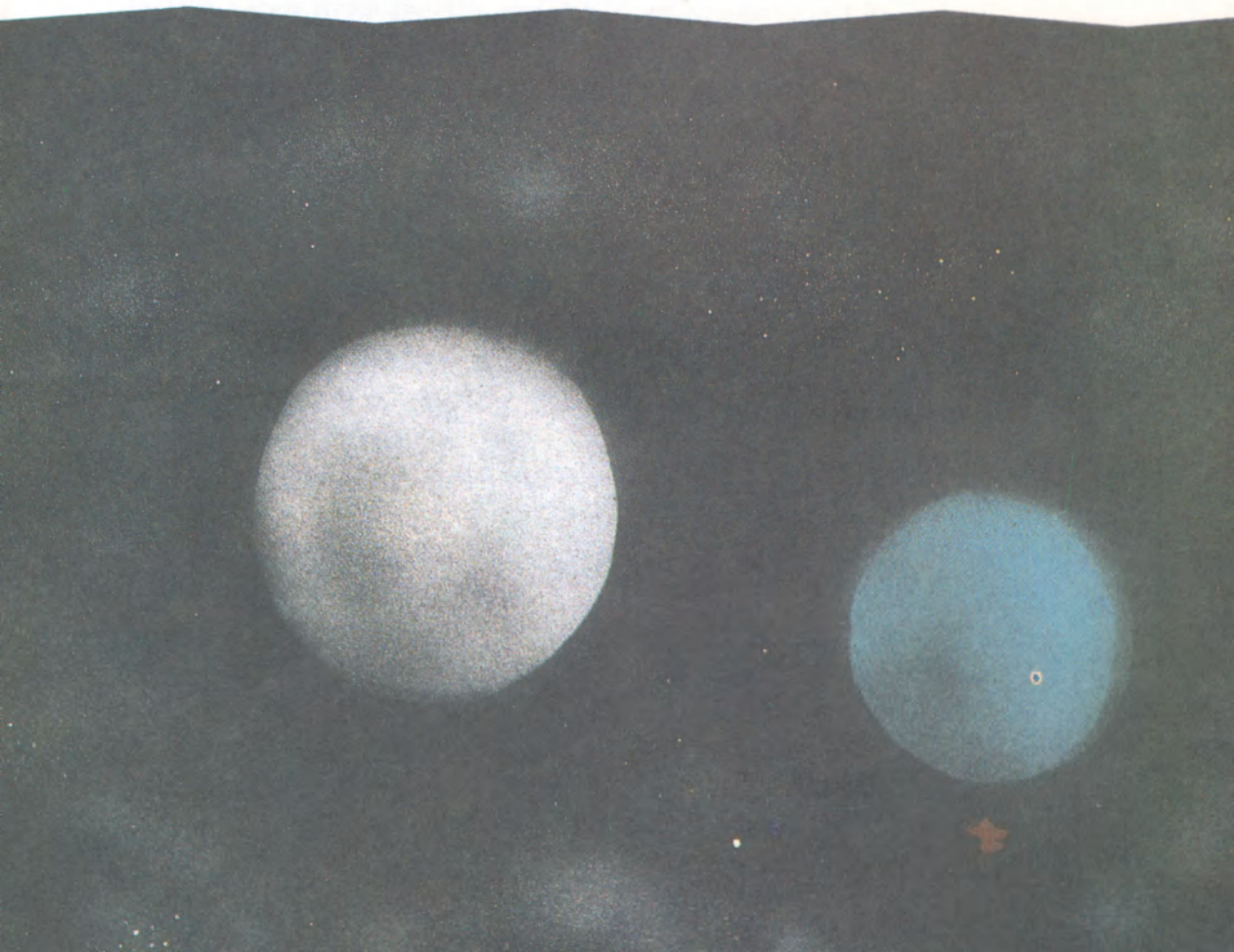
classes magnitude. A star of the first magnitude is the brightest, the second is less bright and so on. A great many stars are much superior to our Sun in brightness. Even twenty Suns are not equal to Sirius; Regulus is 70 times brighter than the Sun, and Vega, 50 times. The stars Rigel and Deneb have respectively 50,000 and 10,000 times more luminosity; they are very far away.

Actually there are coloured suns. The colour of a night star shows how hot it is. The brilliant blue stars are the youngest and hottest with a surface temperature of 2,27,750 degrees Celsius and they are massive. These are known as helium stars. Next come the white stars, younger and slightly less hot.

The blue, white, or red colour of stars shows how hot they are.

Stars which are yellowish-white in colour, known as hydrogen stars, have a temperature of 10,000 degrees Celsius. The coolest of all and much older stars are the red giants. Their surface temperature is only 1,650 degrees Celsius. In reality, the red giants are, as one remarked, 'effete suns hastening rapidly down the road to final extinction'.

You would think that the stellar domain is all peaceful and silent. If so, you are wrong—it is as noisy, if not noisier than our world. Richard A. Proctor says, "More wonderful yet, perhaps, is the thought that where all seems peace and repose, there is in reality a clangour and a tumult compared with which all the forms of uproar known on our Earth



(the roar of the hurricane, the crash of the thunderbolt, the bellowing of the volcano and the hideous groaning of the earthquake) sink into utter insignificance."

If only we could listen to and understand the language of the stars! The great distance and the absence of a proper medium to convey the sounds are big handicaps. In recent years, we have devised instruments to receive the radio waves emitted by our remote neighbours and thereby to identify some more cosmic members.

Constellations are groups of stars occupying different areas of the sky.

In ancient times, people saw various groups of stars occupying different areas of the sky and called them constellations (gathering of stars). They named them after mythological characters, living creatures or inanimate objects. Ptolemy listed 48 of them. Some of them occupy the northern hemisphere of the sky and some the southern hemisphere. *Draco* (Dragon), *Ursa Major* (Big Bear), *Ursa Minor* (Little Bear), *Cygnus* (Swan), *Auriga* (Charioteer), *Cepheus* (name of a king), *Cassiopeia* (a queen), and *Perseus* (a story-book hero who saved a princess from a monster) are a few of the constellations in the northern sky. Like them, in the southern part, we have the Plough, the Crux (Cross), *Triangulum Australe* (Southern Triangle), *Musca* (Fly), *Pavo* (Peacock), *Grus* (Crane), *Orion* (Deer-head), *Vela* (sail of a ship) and *Carina* (ship's keel). To the 48 constellations that Ptolemy listed, 40 were added later.

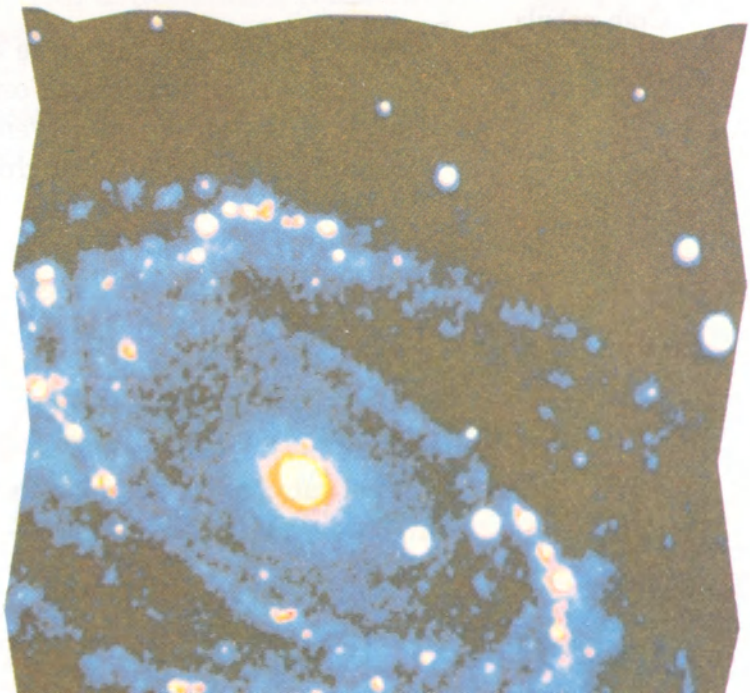
In the stellar world even the death of a star is an extraordinary event known as 'nova'. The term 'nova', which means 'a new star', is used here in a loose sense. A star nearing its final days experiences a tremendous internal explosion. It flares up and becomes 10-15 times more brilliant than its normal magnitude within a day. After such a period, it

returns to normalcy. Those who saw a sudden brightening of an old faint star mistook it for a new star and referred to it as a 'nova'. It can best be called a 'spasmodic' or a 'capricious' star. Records show that in some rare cases, stars have had several explosions that are called 'recurrent novae'. This sudden outburst does not destroy the star but affects its outer part.

Novae are very rare occurrences. They are named after the constellations in which they were sighted along with the year of their notice. In the past, novae were observed in several constellations; for instance, Nova Cygni (1876), Nova Aurigae (1892), Nova Persei (1901), Nova Geminorum (1903), Nova Geminorum (1912), Nova Aquilae (1918), Nova Cygni (1920), Nova Pictoris (1925), Nova Hercules (1934), Nova Pappis (1942), and Nova Cygni (1975).

'Supernova', as the name indicates, refers to a super-giant star! When it begins to die, it also explodes. But then, this explosion is several thousand times more powerful than in an ordinary nova and destroys the star. Most of the star's parts are blown off at high velocity into space in the form of gigantic clouds of glowing gas. Sometimes new stars and planets are likely to form out of this cloud. A supernova at death may be a million times brighter than before.

The spiral galaxy



Crab nebula

The Chinese and Japanese astrologers recorded a supernova they witnessed on July 10, 1054. It was five times brighter than 'Venus in the morning or evening', and visible even during the daytime; and it faded after a year or so. The Chinese called it 'Guest Star'. The same was seen in many other parts of the world. The wreckage of this supernova took the shape of a nebula, nicknamed by Lord Rosse as Crab Nebula which is 6,000 light years away from us. Tycho Brahe had the opportunity of seeing one supernova in Cassiopeia in 1572.

The supernova seen by both Galileo and Kepler in 1604 was the brightest as well as the last in our

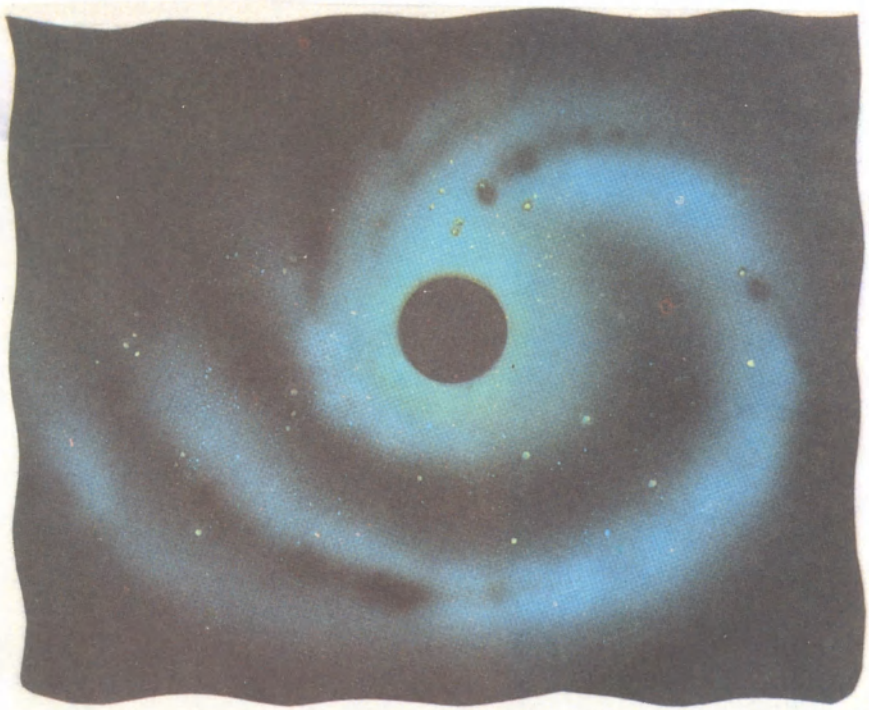
galaxy. In recent times, on February 24, 1987, scientists witnessed a similar supernova. It was the blue giant star Sanduleak suffering an explosion in the nearby Large Megallinic Cloud. It was named SN 1987. This was at a distance of 170,000 light years. It signified that what people saw in 1987 was an unusual phenomenon which happened 1,70,000 light years earlier in that remote star world. It seems difficult to comprehend but this way Sanduleak died a super star's death. Till now only six supernovae have been recorded. If a star's core happens to survive such outbursts, it probably ends up as a 'neutron star', 'black hole' or a 'pulsar'.

What is a black hole? Dr. Subramanian Chandrasekhar (1910-1995), an Indian-born in Lahore, was a world-renowned astrophysicist who had settled in the U.S.A. He won the Nobel Prize in 1983 for Physics. Chandrasekhar made an extensive study of the evolution of stars and white dwarfs. He deduced that if the mass of a star on its deathbed reaches the limit of 1.44 times the Sun's mass, it will collapse under its own gravitational force and become a 'black hole'. This astronomical calculation has come to be known as 'Chandrasekhar's Limit'.

An enormous star, that has neared its end by using up its fuel, shrinks and becomes small and dense.

What does it mean? An enormous star, that has neared its end by using up its fuel, shrinks and becomes small and dense. It is squeezed together so tightly that nothing is left of it, but its gravity. The pull of gravity will be so strong that not even light can escape from it. So it will be dark and cool, and not visible from outside. For all purposes the star, that once was, has vanished. So it is named a 'black hole'. This will be of immense mass—10^6 to 10^9 times the solar mass. Such ghosts of stars are believed to exist in space.

Suppose the mass of a star on exhaustion of its



A dying star collapses under its own gravitational force and becomes a 'black hole'.

fuel is between 1.4 and 2 times the mass of the Sun, it probably becomes a neutron star. Soviet physicist, Lev Davidovich Landau (1908-1968), who worked in a variety of fields and won the Nobel Prize for Physics in 1962, predicted the presence of neutron stars in space in 1932. His assumption was that a neutron star would be quite small, but unusually heavy. Why? You know that the solar mass is 2.2×10^{27} tons. Suppose twice this huge mass is squeezed tight into a small star, will it not become much denser and heavier than even water? It cannot contract any further. This is called a neutron star.

A pulsar is also the remnant of a star that has gone through a supernova explosion. Accidental discoveries are quite common in astronomy. The presence of pulsars too was discovered by chance by a research student at Cambridge, Jocelyn Bell, in 1967. One day she was surprised to pick up suddenly on her radio receiver, powerful radio waves. She found out that they were coming from a celestial body at an extremely regular interval

of 1.33 (1.33728 to be very precise) seconds and the pulses were very weak lasting 0.3 seconds. The world of science believed her as some more were reported by scientists. By 1975, nearly 150 were located.

The new discoveries were stars having a peculiar habit of pulsating or changing in brightness. They emitted rapid, intense pulses of radiation with infallible regularity. They were named pulsating radio sources or, in short, pulsars, because they gave out energy not steadily but like the beating of the heart, 'Pulsars pulse'. It is estimated that 10^7 pulsars may be present in our galaxy. With their strong beaming effect—radiating 5,000 times more energy than the Sun—they are not easily observable.

Binaries are twin stars mutually bound by gravitational attraction.

There is no end to the surprising items which the stellar kingdom could display to a visitor. Many stars are found changing their light output according to some time-table. Fabricius was the first to notice this kind. The electric bulbs in our houses shine bright or dim depending on the fluctuations in the voltage of the power supply. Similarly, with the expansion and contraction of the surface layers, the stars show a rise and fall in their luminosity. All such stars are known as variables or pulsating stars. The pulsars mentioned above are of the same species.

In 1784, British astronomer, John Goodricke (1764-1786), detected the Delta Cephei in Cepheus constellation to be brightening and fading within a period of 5.3 days. Since then stars with fluctuating periods ranging from three to fifty days were called 'Cepheid variables'. In 1912, Henrietta Leavitt made a point. Near about nineteen thousand variables have been located. As a rule, Cepheids are giants which have matchless luminosity. More important Cepheids lie in far-out galaxies and so by measuring

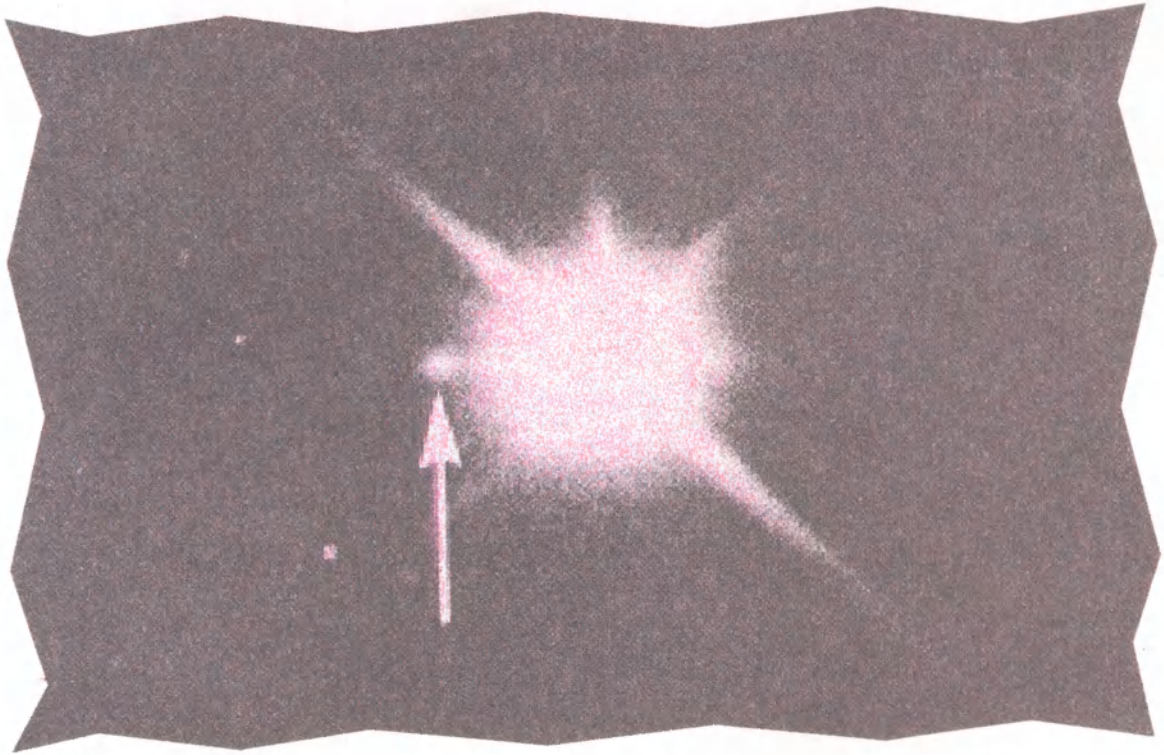
their positions we can locate distant galaxies and the extent of the universe.

When you look at the stars, some of them appear to be single and lonely; but on close observation they appear to be twin stars. They are designated as 'binaries'. William Herschel was the pioneer in the discovery of binaries by cataloguing 700 of them. The pairs are placed sufficiently close to each other in space to be bound in a mutual bond of gravitational attraction. They circle a common centre of gravity. Both the members were born out of inter-stellar gas in the same region of the space and at the same time. But strangely enough the twins are unequal in mass, size and luminosity. For instance, an orange giant will be twinned with a medium-sized blue one; a yellow star such as our Sun will be matched with a white dwarf; a brighter one may have a fainter companion. Sirius is a good example. It is 10,000 times brighter than its companion which is, by the way, a white dwarf and officially known as Sirius 'B'.

There are varieties of binaries. Some are called visual or telescopic binaries. These are placed quite far from each other, the distance between them ranging from 100 to 10,000 AUs, and can be identified only by visual telescope. Several thousands of them have been discovered.

Pickering found a class of binaries in which one of the twins is far brighter than the other, such as the Sirius twins. Their speed of motion can be measured through a spectroscope. These are spectroscopic binaries. Nearly 520 of them have been located.

The third pair make a distinct system. Goodricke is accredited with their discovery. These are eclipsing binaries. As the name indicates, two stars



Sirius

periodically eclipse one another. That is, one of them first eclipses a part or even the entire disc of the other star lying beyond it. After half a revolution, it is the turn of the other star previously obscured to eclipse its mate. This game has been going on uninterrupted for billions of years. These are often mistaken for variables. How marvellous, if it would have been possible to watch this at close quarters!

Apart from these, if you observe very carefully, you may see triples and quadruples too. Some three or four stars will be in bondage of mutual gravity. Significant numbers of such systems exist even among stars seen with naked eyes. A wonder is that some groups of triple or quadruple stars are attended by a distant star which may itself be a close double. That makes a rare system of quintuple or sextuple stars, all of them running round a common centre of gravity. This is known as a

Star clusters are big groups in which hundreds of stars, having common origin and motion, are held together by gravity.

multiple system. What a variety of games these stars play! Is it not exciting to watch them?

Another collective system of stars is known as 'star clusters'. These are big groups in which hundreds of stars are held together by gravitational attraction, with a common origin and motion. The width of some clusters may be more than 30 light years. Their location will be from 500 to 20,000 light years away. Thus the whole world of colourful suns provides a feast to your eyes and puzzle for your mind.

Let us see one last thing in outer space. There are some strange and puzzling objects discovered first in 1963. They look very much like stars but they are not. Scientists have named them 'quasars', an abbreviation of 'quasi-stellar radio sources'. These quasars do have a star-like appearance and generate intense energy in a small volume in its core. The energy output makes a quasar shine much brighter than several hundred giant galaxies. So they are erroneously identified as stars in our galaxy.

In fact, these strangers are the remotest objects ever discovered by astronomers. They lie on the outer fringes of the universe as it is now known to man. The distance is said to be approximately 8 billion light years. When you see a quasar, remember that you are looking at the light that left its home 8 billion years before, that is, before the dawn of civilization on Earth, to travel through space to reach us today. Another startling thing is that these quaint celestial bodies are racing away from us almost at the speed of light, into space. So far 3,500 have been located as powerful sources of x-ray, infra-red and radio waves. These too pose many riddles to wits.

FAREWELL

If you move into the inner depths of space, you may see still more wondrous objects and exclaim like the angel in the German poem of Richter's:

End is there none to the universe of God;
Lo! also there is no beginning!

You may not be inclined to leave the star world of exquisite beauty and brilliance. Alas! we do not belong to that part of the cosmos. So our space tour has to be concluded and we have to return to our earthly moorings. Let us, therefore, bid farewell to the stars!

Now that you have visited the land of stars, when you look at the stars next time, you may no more merely repeat, but put meaning into the rhyme, 'Twinkle, twinkle, little star', and add:

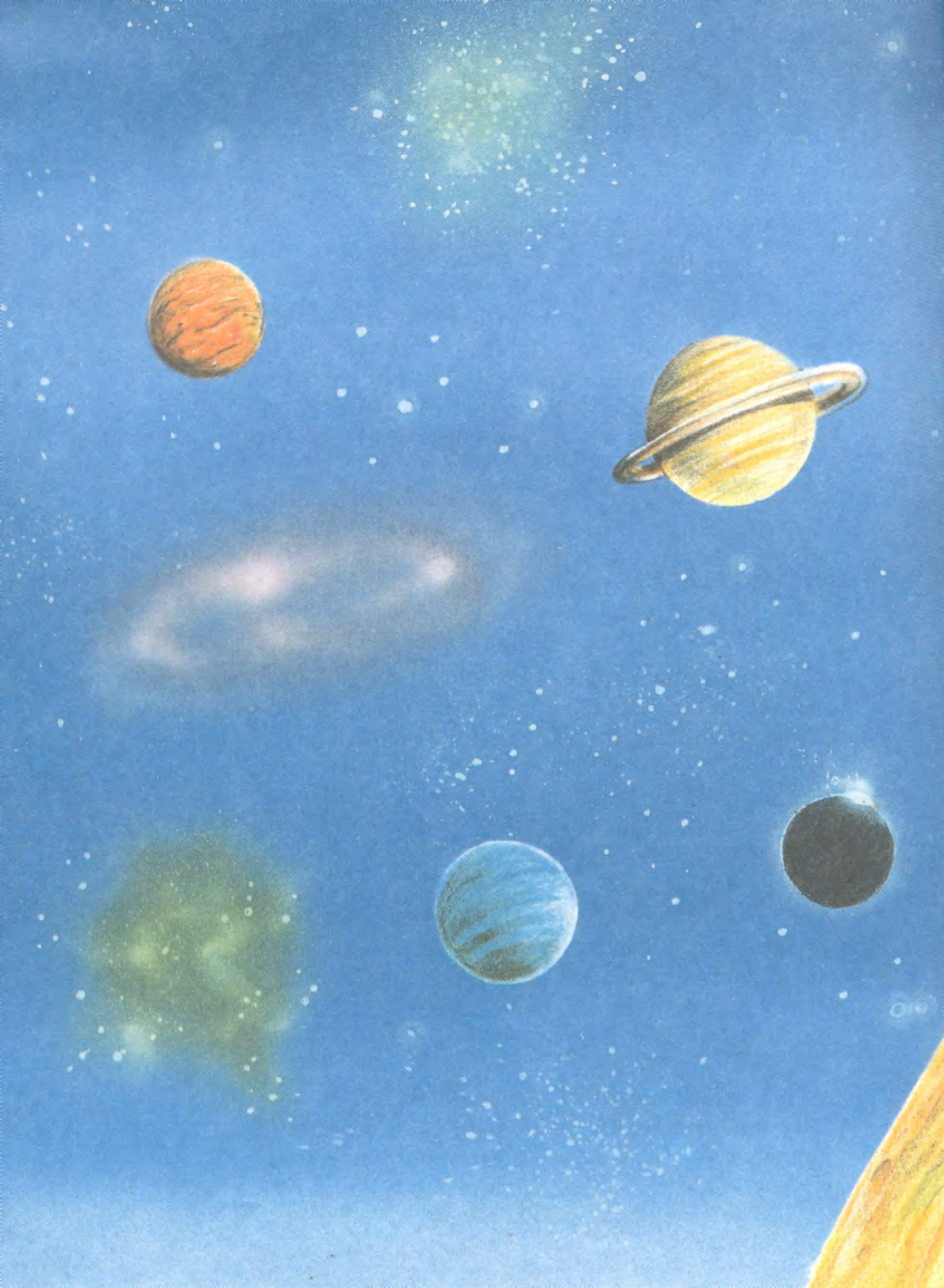
Shine, shine, giant star
We now know what you are!

what we know is but little; what we do not know is immense.

It is true that we have learnt much about the true nature and greatness of our stars. They still hold many a mystery for us. Laplace remarked on his deathbed, "What we know is but little; what we do not know is immense." How true are the words!

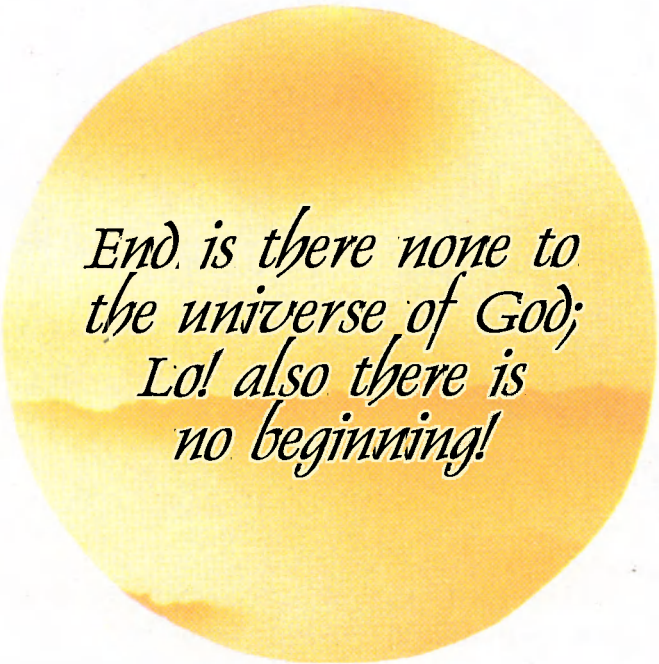
Astronomers fully realize that as newer discoveries are made, the cosmic mystery but becomes deeper and deeper, and their amazement grows greater and greater. Perhaps Proctor is right when he says, "What we know of this universe is what our senses enable us to know, and is very far indeed from affording a true measure of the real universe, either in extent or in the complexity of its structure or in the splendour of its various parts."

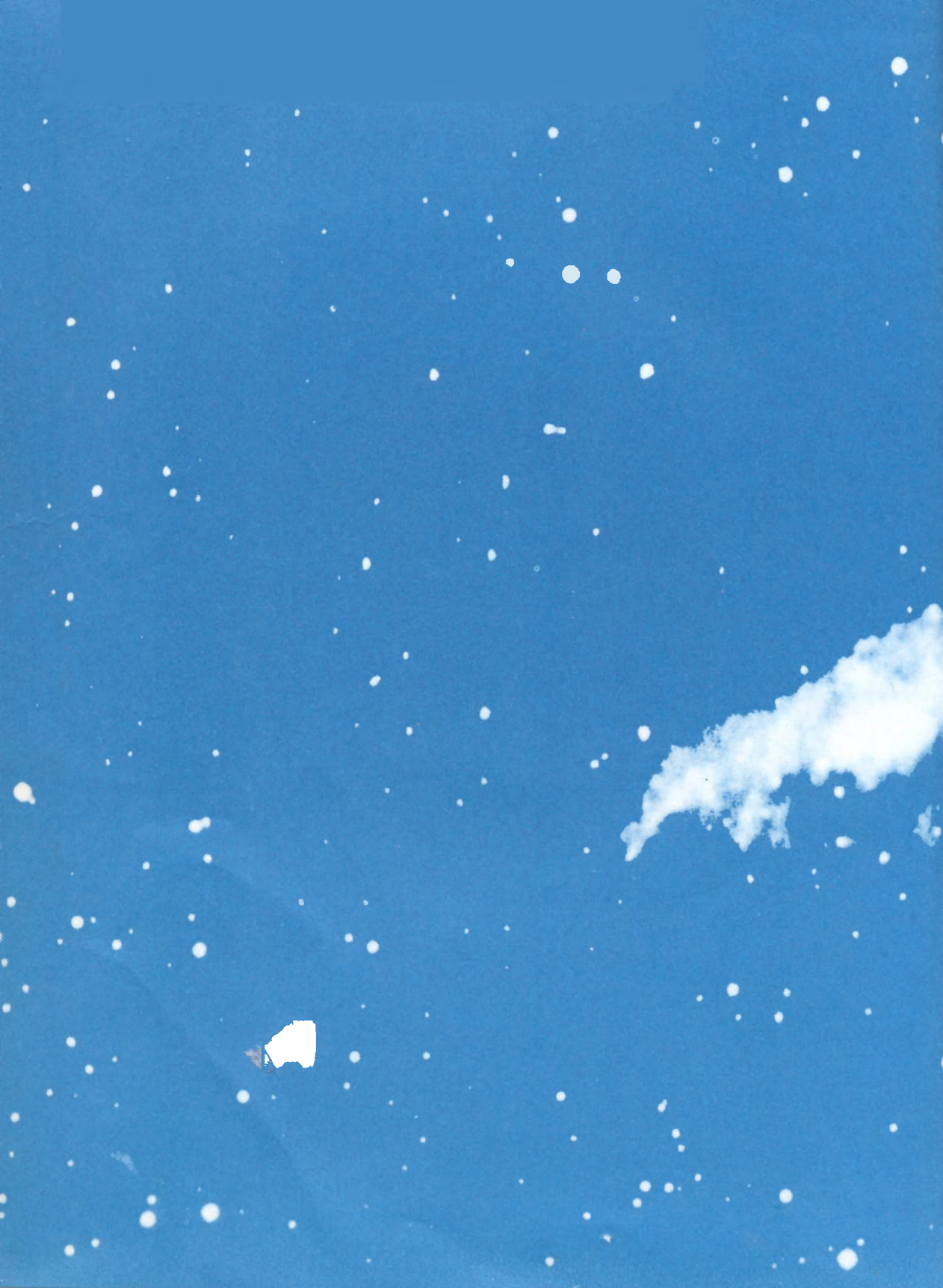
Yet, man's quest to know more and more about this universe which he lives in is unquenchable. Some of you may take up astronomy as a career



and unravel a few more mysteries and add a new dimension to human knowledge of the universe. In the words of Arthur Stanley Eddington (1882-1944), the English astronomer, physicist and mathematician, "Each phase of the scientific advance has contributed something that is preserved in the succeeding phase. That, indeed, is our ground for hope that the coming generation will find something worth preserving—something that is not wholly illusory—in the scientific thought of the universe as it stands today..."

The universe awaits you with its challenges!


End is there none to
the universe of God;
Lo! also there is
no beginning!



The Sun and the planets in the solar system such as Mercury, Venus, Earth and others are part of a galaxy. There are innumerable galaxies in the universe. The heavenly bodies move, spin on account of the gravity which each body exerts. It is mind-boggling to speculate on the size or number of the stars, planets, and the distances at which they are placed. The science of cosmology has unravelled quite a few phenomena, yet what is known is a fragment of the infinite.

ISBN 81-7011-892-1

9 798170 118922

E 378