

COMETS: Unexpected Guests of Space

Sowbhagya



Space Books Series for Children

U . R . Rao Satellite Centre

Bengaluru-560017

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Chairman's Message



Scientific literature for children is an essential and distinctive literary work. It is to observe all the happenings around us from a scientific point of view and explain it in simple words. This endeavour can make a high school student understand complex subjects like astronomy, satellite and rocket technology, which is highly appreciable.

In this regard, U R Rao Satellite Centre, a prestigious research Institute in Bengaluru, has launched a new program called "Space Books Series for Children" through which it plans to bring out pocket-books on "Space Technology Space Science and Space Scientists". This book,

which is now in your hands, is one such work. This work a significant step toward enriching science literature for children.

Explaining various scientific and technical topics in simple language is necessary to inculcate interest in science among children. Similarly, it is essential to explain the scientific achievements of our organization to the masses and create awareness about it. The "Space Books Series for Children" programme will fulfil these requirements.

I congratulate the Director of U R Rao Satellite Centre for conceiving and implementing this programme. I hope more topics will be covered and reach more children and commoners in the coming days.

S. Somanath

Chairman, ISRO

Director's Message



Satellite, space science, technology and related topics should be explained in simple language so everyone can easily understand them. Such a literary effort will provide essential and authentic information, especially to the young talents of rural areas. Thus, it is a significant step in providing them with better opportunities and building a great future.

This work should be done by the skilled and experienced scientists of U R Rao Satellite Centre who have been working in this field of technology for five decades. To educate children about space science and technology, U R Rao Satellite Centre is

bringing out the "Space Books Series for Children".

Our enthusiastic colleagues have written books on these topics in response to this idea. It is a pleasure to put seven pocket-books of this series in your hands today. I congratulate the authors for their efforts and wish the program success. I want the students to develop interest and curiosity in these subjects. I also hope they understand the principles, get inspiration and create a better future, thereby contributing to the country's and society's overall development. I am confident that our objective will be realized and the desired result will be achieved.

M Sankaran

Director

U R Rao Satellite Centre

Editorial Board

Space Books Series for Children

Dear Children,

U R Rao Satellite Centre (URSC) celebrated its Golden Jubilee in 2022. On this occasion, the Karnataka Rajyothsava Committee of URSC had taken up the task of publishing a series of Kannada books on Space and Space Scientists which have been translated into English for the benefit of students across the country.

Our committee plans to publish pocket-books in simple language to make school children easily understand many topics like space science, rocket and satellite technology, etc. These books are written by the scientists of our organization. As the first set of books in this series, seven books are published. Our aim is to provide electronic version of the books to children through our website.

Our committee is grateful to Shri M Sankaran, Director, URSC who is the key person behind the successful realization of these books. Our heartfelt thanks to Shri HN Suresh Kumar, Shri KV Govinda, Dr. M Ravindra, Smt. Lalitha Abraham, Smt. Anuradha S Prakasha and Smt. Sreedevi S for having reviewed all seven books in detail and suggested suitable modifications.

We are grateful to all the authors who took time off from their work and authored the books. We are thankful to all colleagues of our Centre who helped us to bring out these books.

If you read them and give your suggestions and comments, we will be able to incorporate the same in the next set of books in this series.

Ramanagouda V Nadagouda
President

Author's Note

The purpose of this book is to introduce children to comets, one of the wonders of space, in an effort by ISRO's U R Rao Satellite Centre to publish booklets to teach children the basics of space science.

What are comets? How did they originate? The secret of their creation, , their composition, benefits from their study and various satellite campaigns launched for their study are briefly described in this book.

The main purpose of this book is to create curiosity among students about these celestial bodies . Thus after reading this book, if the students want to study more about these celestial bodies then the aim of the book is fulfilled. May the attempt to understand this universe through the study of comets be successful. I hope that

the efforts to know this world and save it will be successful .

Heartfelt thanks to Shri M. Sankaran, Director, U.R. Rao Satellite Centre, for the opportunity to write this book. Heartfelt thanks to Mr. P. Jayasimha and Mr. Suresh Kumar H.N. for reviewing this book and providing useful information. Salutations to Shri Ramanagouda V Nadagouda, Chairman of the Editorial Board of this book series and to all the seniors and colleagues of the organization.

Sowbhagya

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1. Introduction

We have heard many stories about Julius Caesar, the dictator of Rome. Julius Caesar, a Roman general, rose in power step by step, after successfully holding many low-ranking posts in the government. He became dictator of Rome with a powerful military force in 49 BC. He was greatly loved by the common people of Rome because of his progressive social reforms. But many senators and nobles hated him because they were afraid of his ability. They thought he may use his dictatorship to change the Roman Republic into an imperial state. Some senators resorted to illegal means to prevent this. Caesar was assassinated in March 44 BC.

Four months later, a funeral festival called Ludi Victoriae Caesaris was held in his honour. During this festival, a very bright object appeared in the sky. The people of Rome then concluded that Caesar was an angel and that the bright object was a new star containing Caesar's soul. Since Caesar had already claimed to be a descendant of the goddess Venus, the people believed it even more strongly.

But was it really a new star? Or some other celestial body?

What was that bright object seen that day? What were its features? Let us find the answer to these questions.

That celestial body, which was bright and hidden in the sky, was nothing but a "comet".

The comet that appeared at the time of Caesar's death was later identified as Caesar's Comet. Its scientific name is C/-43K1.

Comets and meteors have fascinated the mankind since they were first spotted in the night sky. But without science and space exploration to aid understanding of what these were, ancient cultures often turned to myth and legend to explain them. The Greeks and Romans believed that the appearance of comets, meteors and meteor showers were portentous. They were signs



As of November 2021, there are 4,584 known comets. This number is constantly increasing and is only a fraction of reality.

that something good or bad had happened or was about to happen. The arrival of a comet could herald the birth of a great figure, and some people have even argued that the star in the sky which the Persian Magi followed to Bethlehem to see the new born Jesus was actually a comet.

The sight of comets is considered a bad omen in many cultures around the world. In an ancient Chinese book written around 300 BC, the arrival of comets is described as the cause of wars, the overthrow of powerful leaders, and death. Comets are also said to be responsible for various calamities such as the mysterious death of whales and shortage of essential items like rice, salt, fish etc.

The arrival of Halley's Comet was believed to be a great omen. It is believed that because of this reason, England was conquered by William the Conqueror. Coincidentally, in the year of Halley's Comet's arrival, Genghis Khan attacked the Western world.

Many religions believed that the appearance of a comet was a sign of the end of the world. People felt severe panic when Halley's Comet became visible in AD 1909. That time many people suffered from depression. They had to be treated with the help of medicines.

Indians also had many such beliefs about comets. A comet was believed to be responsible for the legendary Mahabharata war. It is said that the comet was also visible

during the slaying of Kamsa. Many ancient astronomers like VarahaMihira, Bhadrabahu and Bhattotpala studied comets. They had calculated and written down the time when they would appear. In Varahamihira's Brihat Samhita, it is stated that the rising and setting times of comets cannot be ascertained. This indicates that he was familiar with the movement of comets. Also, in the Bhadrabahu samhita it is mentioned that different comets have different periods. It is also mentioned that there are hundreds of comets.

The Greek philosopher Aristotle believed that comets are unique phenomena in the atmosphere. His argument was that it was not a celestial body. This theory was accepted until the truth was known when Newton showed

that these celestial bodies are a part of the solar system and revolve around the sun in elliptical orbits. It was then that a scientist named Edmund Halley studied several centuries of records of comet sightings on Earth and postulated that a particular comet appeared every 76 years. This comet was later given the name Halley's Comet.

What is the meaning of “comet”? Let's find the answer to this question and understand its structure and composition.

Meaning of the word Comet: our ancient native word for comet is 'dhoomakethu'. Dhoomaketu of Sanskrit origin is made up of two words "Dhooma" and "Ketu". Dhooma means smoke and Ketu means flag. In Sanskrit texts, meteor and comet are also referred to as

'Dhoomaketu'(comet). The English word comet is of Greek origin and means long hair.

The small celestial bodies orbiting the Sun can be divided into three categories namely asteroids, comets and meteors. Celestial bodies smaller than ten meters are called meteors. Asteroids are naturally occurring small solid objects, larger than meteors and smaller than planets. They don't have atmosphere. Also, they do not emit any kind of dust and gases. Asteroids are found in the belt of asteroids which lies in between Mars and Jupiter. Comets, on the other hand, come from outside the solar system, beyond Neptune and are celestial bodies with a dusty atmosphere and hair like tails. Figure 1 introduces various celestial bodies.

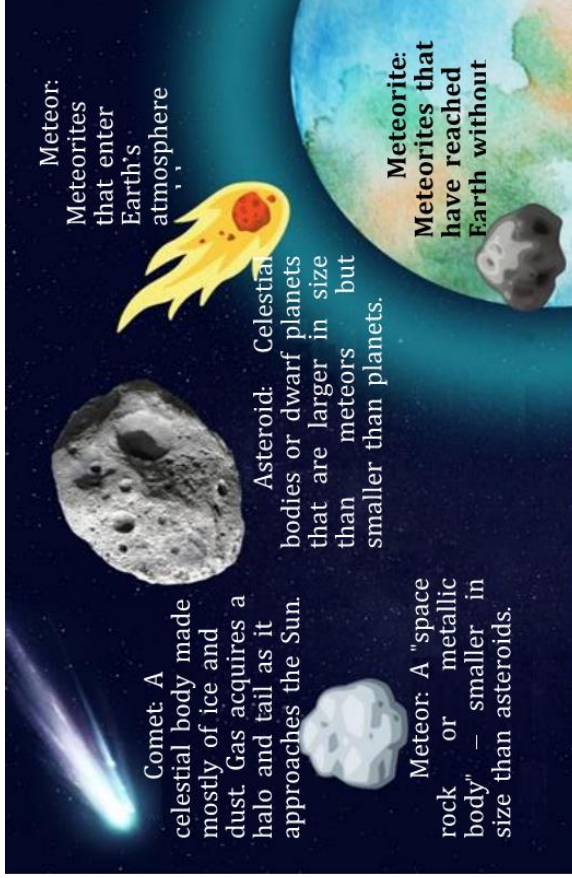


Fig1: Introduction to various celestial bodies

2. Structure of Comets

Comets are parts of the solar system. These are debris and fragments that were left over during the formation of the solar system about 4.6 billion years ago. They are made of condensed gases, rock and dust. When frozen, their size is approximately the size of a small town. That means they have an area of few kilometres.

Comets mainly have three parts, namely

- Nucleus
- Coma
- Tail-Dust tail and Electron tail

Figure-2 shows the depiction of various parts of comets.

Nucleus:

Each comet has a tiny frozen part, called a nucleus. The nucleus of a comet is a solid core structure and is usually a few kilometres in size. It contains chunks of ice and condensed gases mixed within it. More precisely, Cometary nuclei are composed of an amalgamation of rock, dust, water ice, and frozen gases such as carbon dioxide, carbon monoxide, methane and ammonia.

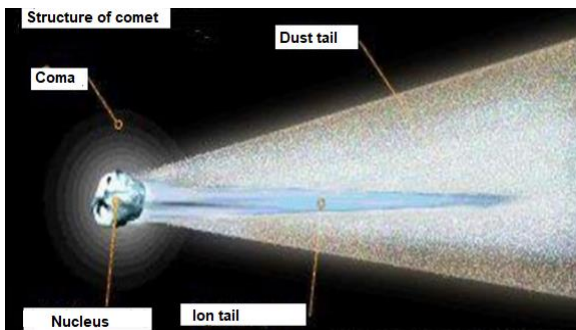


Fig2: Structure of comet

The surface of the nucleus is generally dry, dusty or rocky, suggesting that the ice is hidden beneath its surface crust several metres thick. In addition to the gases already mentioned, the nuclei contain a variety of organic compounds, which may include methanol, hydrogen cyanide, formaldehyde, ethanol and ethane and perhaps more complex molecules. This is why comets are also called "dirty snowballs".

Coma:

As the comet approaches the Sun, some of the ice begins to melt and boil off.



Comets reflect only 4 percent of the light that falls on them, the rest being absorbed.

Along with that, dust and gas particles also start expanding. These particles and gases create a kind of cloud structure around the comet's nucleus. This is called a coma. The Sun's heat causes the comet's ices to vaporize, and so the coma gets larger. The coma may extend to hundreds of thousands of kilometres. Sunlight and the pressure of high-velocity solar particles (solar wind) can detonate the dust and gas in the coma.

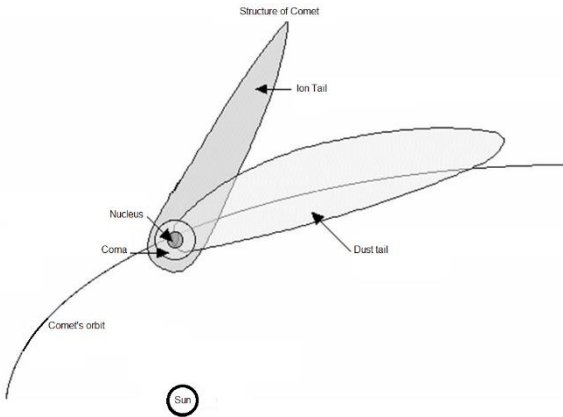


Fig3: Structure of Comet



Fig4: Rosetta Philae

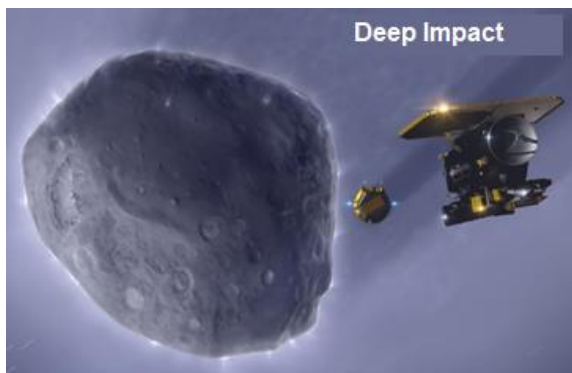


Fig5: Deep Impact Mission



Fig6: Stardust mission

An invisible layer of hydrogen surrounds the coma. This hydrogen can come from water molecules. It usually has an irregular shape because it is deformed by the solar wind. As the comet approaches the Sun, the hydrogen envelope becomes larger. Coma is not self-limiting. It reflects sunlight like the moon.



Comet Halley's peanut-shaped nucleus is only 15 kilometres long and 8 kilometres wide. Due to its small size and low mass, its gravity is very low, which means you can jump from its surface into space.

Tail:

Objects ejected from the coma form a long, bright tail. The tail extends millions of miles from the Sun. Comets actually have two tails—a dust tail and an ion (gas) tail. When the distance between the comet and the Sun is less than 3 to 4 AU (AU-Astronomical Unit) many materials are vaporized and ejected from the nucleus.

These account for approximately 90 percent volatility. Pushed away by the sun's particles, these particles stretch out in one direction, giving us a tail-like appearance. A comet's tail, thus visible, can extend for



An astronomical unit (AU) is the distance between the Earth and the Sun. Approximately 149597871 km.

several million kilometres. This is the most prominent part of the comet visible to the naked eye without the aid of any binoculars. A comet's tail gets bigger as it gets closer to the Sun and gets smaller as it moves away from the Sun.

Comets also have another tail called an ion tail (also known as a plasma/gas tail). The solar wind ionizes the particles of the nucleus and ejects electrically charged gas molecules (carbon dioxide, nitrogen, water) from the nucleus. This forms a tail of



When a comet comes close to the Sun, it heats up very quickly, causing solid ice to turn directly into gas. This process is an example of sublimation. Due to this, the comet slowly loses mass.

electrically charged particles which always extends in the direction of the solar wind. The Sun's magnetic field affects the tail of charged particles and hence the tail follows the direction of the Sun's magnetic field.

3. Characteristics of Comet's Orbit

The path of celestial bodies is called orbit. Comets also travel in their specific orbits. But Unlike the orbit of planets, the orbits of comets are extremely elliptical and their orbital periods are very long. Figure 7 shows the orbit of comets. The time taken by celestial bodies to complete one revolution around the Sun in their particular orbit is known as orbital period. Orbital periods of comets can range from a few years to thousands of millions of years. Some comets have shorter orbits. They revolve around the sun in a short period of time.

Other comets take hundreds of years to complete their orbit. Interestingly, the tail of a comet is always pointed away from the sun throughout its orbit.

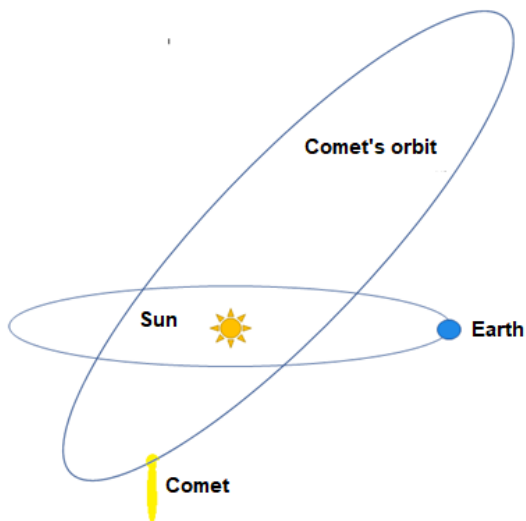


Fig 7: Introduction to Comet's orbit

Since the orbit of the comet is highly elliptical, one part of their orbit is a few million km near the Sun and the other end of the orbit is several billion km away from the Sun. Comets are generally classified based on their orbital period.

Short-period comets:

These have relatively small orbits with orbital periods of less than 200 years. Their orbits are usually below 10 AU. Comets with an orbital period of less than 20 years are called Jupiter family comets.

These originate in the Kuiper Belt. Comets with an orbital period of 20 years to 200 years are known as Halley type comets. These originate in the Oort cloud. In Figure 8, the origin sites of the comets are depicted in detail.

Long period comets: These are called nearly isotropic comets. They have a longer elliptical orbit with a higher apogee



The point in a comet's orbit closest to the Sun is called 'Perihelion'. The farthest point is called 'Aphelion'.



measurement. These have huge orbits that can reach thousands of AU, taking them far beyond the orbit of the dwarf planet Pluto. They also appear from any given point in the sky and are very unpredictable.

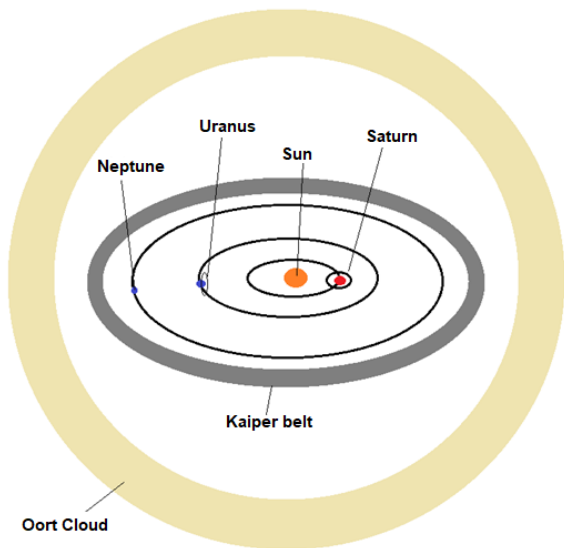


Fig 8: Originating places of comets

As mentioned earlier, short-period comets take less than 200 years to orbit the Sun. In many cases their arrival time is predictable because their arrival has been observed before. The arrival of long-period comets is

difficult to predict. Many of them come from a region called the Oort Cloud, about 1 lakh AU from the Sun. It is estimated that these Oort cloud comets can take up to 30 million years to complete one trip around the Sun.

Comets usually travel at a safe distance from the Sun. For example, the famous Halley's Comet's closest distance to the Sun is 89 million km. However, some comets, called sungrazers, crash straight into the Sun or get so close that they break up and evaporate. Comets can be attracted by other planets as they orbit. It can cause changes in their orbits. For example, Jupiter has the highest gravitational force compared to other planets.

Comets are attracted to it when they pass near it. Then they may collide with Jupiter and shatter into pieces. Comet Shoemaker-Levy9 similarly collided with Jupiter in July 1994 and broke into 20 pieces. This was one of the most spectacular examples of interplanetary impacts on the orbits of comets. Recently Comet Linear



The famous Halley's Comet appears once every 75 or 76 years. This is responsible for the Orionid meteor shower that occurs in October. It was last seen in April 1986. Calculate for yourself when it will appear next. (For answer please refer the last page)

also broke into pieces due to the Sun's gravity when it passed the Sun.

From where do these comets come?
Where do they originate? Let's find out.



The gravitational force on Jupiter is 24.79 m/s^2 . That is 2.5 times higher than Earth (9.8 m/s^2).

There are two answers to this question. Comets have two origins, the Kuiper Belt and the Oort Cloud.

Kuiper Belt: The Kuiper Belt is a region of the Solar System that lies beyond the orbit of Neptune. It is far larger than the asteroid belt. The Kuiper Belt consists of millions of icy objects, including some large objects such as the dwarf planets Pluto and Eris. This belt starts at a distance of 30 AU from the Sun and extends to a distance of 50 AU. Short-period comets come from the

Kuiper belt. Objects in the Kuiper Belt are sometimes occasionally pushed by gravity into orbits that bring them closer to the Sun.

Oort cloud: The Oort cloud lies beyond the Kuiper belt. Scientists believe there is another collection of billions of comets known as the Oort cloud. The outer limit of the Oort cloud defines the outer boundary of the Solar System. Long-period comets come from the Oort cloud, and some of them take several million years to orbit the Sun. The Oort cloud is about one lakh astronomical units away from the Sun.

4. Impact of comets on life

These small celestial bodies can shed light on many mysteries of our solar system. Many scientists are eagerly researching on this as these small celestial

objects hold many important clues and information on our Solar System. Comets are remnants of the birth of the solar system, which occurred about 4.6 billion years ago. They consist mostly of ice, coated with dark organic material.

Comets may have brought water and organic compounds, the building blocks of life, to the early Earth and other parts of the Solar System for the first time which is believed to be the cause of the origin of life.

Many scientists believe that comets which bombarded the young Earth about 4 billion years ago brought about the vast quantity of water that now fills the Earth's oceans, or at least a significant portion of it.



About 66 million years ago, dinosaurs suddenly disappeared from the earth. The main cause is assumed to be impact of the Chicxulub asteroid or comet on earth.

The detection of organic molecules, including polycyclic aromatic hydrocarbons, which is present in significant quantities in comets, has led to the speculation, that comets or meteorites may have brought the precursors of life—or even life itself—to Earth.

Similarly, it is suspected that comet impacts have, over long timescales, also delivered significant quantities of water to the Earth's Moon, some of which may have survived as lunar ice.

5. Exploration of comets:

A comet may be discovered photographically using a wide-field telescope or visually with binoculars. However, even without access to optical equipment, it is still possible for the amateur astronomer to discover a sun grazing comet online by downloading images accumulated by some satellite observatories. Amateur astronomers can find sun grazing comets online by studying images collected by satellite observatories, such as SOHO.

Polish amateur astronomer Michal Kusiak discovered a comet on 26 December 2010 using data from SOHO. It is the 2000th comet discovered using SOHO. Both astronomers who discovered Hale-Bopp also used amateur instruments.



SOHO (Solar and Heliospheric observatory): A satellite observatory developed by the European Space Agency. Mainly developed for observation of Sun and Heliosphere.

Scientists have wanted to study comets in detail from time immemorial. Many plans are being made for the same. NASA's Deep Space 1 spacecraft flew by

comet Borrelly in 2001 and photographed its nucleus, which is about 8 kilometres (5 miles) long.

Stardust was the first spacecraft to return to Earth with a sample of a comet and samples from beyond the lunar orbit. In 2004, the Stardust spacecraft made a close flyby of comet Wilde-2. It collected



Comet Hale-Bopp was discovered in 1995 by Alan Hale of New Mexico and Thomas Bopp of Arizona as it passed far from Jupiter's orbit.

cometary and interstellar dust in aerogel. It operated for two consecutive years. Later it landed in the Utah desert with the collected materials. Samples from the Stardust project suggested that some comets may

contain material ejected from the early Sun. This signalled that the universe may have formed differently than that of the theoretical hypothesis of scientists.

Analysis of stardust patterns suggest that comets may be more complex than what was thought originally. Minerals that formed near the Sun or other stars were found in these samples. This suggested that material from the inner regions of the solar system travelled to the outer regions where comets formed.

The Stardust satellite had the following instruments.

- Comet and interstellar dust analyser
- Dust flux monitor

- Aerogel dust collector
- Navigation Camera

Another project that studied comets was NASA's Deep Impact. It was a flyby spacecraft consisting of an impactor. In July 2005, the probe was launched as scheduled, on its way to the nucleus of Comet Temple-1. This impactor scooped up massive amounts of fine, powdery material from the comet's surface. In this case, the impactor camera imaged the comet in great detail. Many other details were recorded with the help of two cameras and a spectrometer on the flyby spacecraft.

After successful preliminary missions, the Deep Impact spacecraft and Stardust spacecraft were still healthy, so they were used for further research.

Another mission that studied comets was Rosetta-Philae. The campaign included the satellite Rosetta and the lander Philae. This campaign has the glory of landing on a comet. A lander named "Philae" landed on Comet 67P and achieved this feat. It carried out many experiments during its limited life and provided useful information.

Launched from the Kourou Space Field on March 2, 2004, the spacecraft reached the orbit of Comet 67P in 2014 after a long journey of 10 years and 5 months. In the next 2-3 months it searched

for a suitable landing spot on the comet. using Rosetta's cameras. Finally, it was decided to land the Philae at a place marked as "Agilkiya". But due to some glitches it landed about 1 km away from the predetermined place. It was a narrow gorge where sunlight did not reach. So, it could not produce the electricity required for its life. But with the help of its batteries, till its last moment, (for three days) it carried out scientific experiments. With the help of its camera, it took many photographs detailing the surface features of the comet and sent them to Earth through the orbiter. Experiments were carried out to find out the features of the ground, the type of minerals and their quantity present, along with its magnetic atmosphere. It then lost contact with its orbiter. After seven months,

they managed to get in touch with it again. Then, in a period of about ten days, a small message was sent for six times. Then it lost contact forever.

Similarly, many satellite projects have helped us to understand comets. But our understanding is still like a drop in the ocean. The thirst for knowledge about these celestial bodies is indeed overwhelming. That is why many plans for further research in the future are taking shape. Illustrations of various satellite schemes are given in Figure 4, 5, 6.

6. Conclusion

Comets hold many mysteries about the origin of the solar system. Their study can shed light on the structure of the universe. That's how, we can understand

our universe even better. Let's hope that the efforts to understand the world and save the world will be successful. I hope that the next generation will join hands in this work. I wish more efforts and success in the study of comets.



Halley's Comet is estimated to reappear in July 2061.

NOTES

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Mrs. Sowbhagya has been working in the U. R. Rao Satellite Centre since 2005. She works in the controls and digital electronics group. She holds a B.E degree in Electronics and Communication from MAHE, Manipal.

Ms. Sowbhagya is recipient of ISRO Young Scientist Award and ISRO team award for the design of electric propulsion control system.

She has published more than fifteen Kannada and English articles related to space science.

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