FUNDAMENTALS OF ASTRONOMY AND ASTRONOMICAL FACTS

, FIRST EDITION

BY GEBRE KALUTE, JANUARY 2020

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Acknowledgment

First and above all I would like to praise God for all the help. Next I am deeply grateful and thankful to ESSTI for their active initiation in motivating me by carrying out researches on the application of physics in astronomy. I also would like to thank in particular Doctor Atakiliti (Arbaminch University) who has worked selflessly and tirelessly to provide me with valuable comments, corrections, and suggestions. My special thanks are also due to the following courteous users/readers who have provided me with lists of typos/errors they have detected in the former book: Shurala Milaso (Wolaita Sodo University), Orkaido Geresu (Dilla University), Tamirat Ontoro (Wolaita Sodo University), Getachew Keffyalew (Wachemo University), Estifanos Eslamo (Ambo University), Berhanu Aymalo (Wolaita Sodo University) and Bakano Basire (Jinka University). My deep sense of gratitude goes to Mr. Getahun Getachew (Wolaita Sodo University, head of physics department), for his immense appreciation and elite comments. Finally my gratitude goes to all who helped me in different circumstances for the success of this book.

Note to the students

"We are what we repeatedly do. Excellence, then, is not an act, but a habit."

[Aristotle]

No one expects to learn swimming without getting wet. Nor does anyone expect to learn it by merely reading books or by watching others swim. Swimming cannot be learned without practice. There is absolutely no substitute for throwing yourself into water and training for weeks, or even months, till the exercise becomes a smooth reflex. Similarly, astronomy cannot be learned passively. Without tackling various challenging problems, the student has no other way of testing the quality of his or her understanding of the subject. Here is where the student gains the sense of satisfaction and involvement produced by a genuine understanding of the underlying principles. The ability to solve problems concerning celestial bodies is the best proof of mastering the subject. As in swimming, the more you solve problems, the more you sharpen and fine-tune your problem-solving skills.

You might find a shorter or more elegant approach. One important observation: as the book is laden with a rich collection of fully examples, detailed explanations and review questions, one should absolutely avoid the temptation of memorizing the various techniques and solutions; instead, one should focus on understanding the concepts and the underpinnings of the formalism involved.

It is not my intention in this book to teach the student a number of tricks or techniques for acquiring good grades in astronomy classes without genuine understanding or mastery of the subject; that is, I didn't mean to teach the student how to pass astronomy exams without a deep and lasting understanding. However, the student who focuses on understanding the underlying foundations of the subject and on reinforcing that by solving numerous problems and thoroughly understanding them will doubtlessly achieve a double aim: reaping good grades as well as obtaining a sound and long-lasting education.

ASTRONOMY LEARNING OBJECTIVES AND STUDENT ACHIEVEMENT GOALS

I expect that after the completion of this book, readers (students) will:

- ✓ Be inspired to continue and share their interest in astronomical advances and discoveries throughout their lives.
- ✓ Have a solid grounding in the underlying principles and important conceptual models from core subject areas of astronomy and physics and demonstrate their ability to correctly draw logical conclusions from these principles and models, enabling them to make accurate quantitative predictions in astronomical contexts.
- ✓ Understand and have experience using observational and experimental techniques in various areas of astronomy and physics, designing, obtaining, analyzing, and interpreting quantitative data.

- ✓ Demonstrate their ability to read, understand, and critically analyze the astronomical/physical concepts presented in textbooks and journal articles, as well as be familiar with the available information and data-archival resources.
- ✓ Demonstrate their ability to communicate information clearly, logically, and critically, both orally and in writing, and to make presentations.
- ✓ Recognize and understand the interdisciplinary aspects of astrophysics as it pertains to, e.g., planetary science, chemistry, and computer science.
- ✓ Demonstrate both understanding and the practical application of the ethical standards implicit in science, such as appropriate attribution and citation, good recordkeeping, and truthful, unbiased presentation of data and conclusions.
- ✓ Be fully prepared for graduate study in astronomy or physics and/or careers in scientifically oriented jobs in the public or private sector.

Preface

Welcome to fundamentals of Astronomy and astronomical facts, an Open reliable resource. This textbook was written to increase student access to high-quality learning materials, maintaining highest standards of academic rigor at little to no cost. It has been many years now since the study of celestial bodies under gone. During this time, many courteous users, astronauts, professors who have been adopting the astronomical bodies, researchers, and students have taken the time and care to provide me with valuable feedback about the astronomy. In preparing the first edition, I have taken into consideration the generous feedback I have received from these users. To them, and from the very outset, I want to express my deep sense of gratitude and appreciation. The underlying focus of the book has remained the same: to provide a well-structured and self-contained, yet concise, text that is backed by a rich collection of fully examples and problems illustrating various aspects of celestial bodies. The book is intended to achieve a double aim: on the one hand, to provide instructors with a pedagogically suitable teaching tool and, on the other, to help students not only master the underpinnings of the theory but also become effective practitioners of astronomy.

CHAPTER ONE

1. Introduction to Astronomy

1.1 Definitions of astronomy

What is astronomy? When did it begin? Astronomy is a study of virtually everything beyond earth. The academic discipline includes studying planets, solar systems, stars, galaxies, comets, asteroids, nebulae, moons and the Universe itself. You will learn about these fields of study as you read this book. Astronomy has produced a relatively new field: astrobiology. So far, this scientific endeavor only speculates about possible alien life. But, as you will study in this book, there are possibilities of alien life even inside our solar system. Part of the astronomical science community is actively listening for new signs of life in the cosmos (Another word for universe.). This organization is called the SETI Institute. The abbreviation stands for: Search for Extra Terrestrial Intelligence. A very active part of astronomy consists of teams of astronomers looking for exoplanets. These exoplanets are circling stars outside our solar system. Literally hundreds of these planets have been found. Several new ones are discovered every month. Many new discoveries that have been made over the last 40 years have been heavily computer dependent. Modern astronomy relies upon technology, math and scientific method. Astronomy is a visually - based science. The skill of careful observation is essential to understanding and discovery. Many astronomical skills were developed as long as 5,000 years ago. Before written history began, people had noticed the interrelationships between the Sun, Moon and the Earth. Observations resulted in a rudimentary understanding of the timing of days, nights, monthly patterns of moonlit shapes and the seasons. Missing were scientific reasons for these events. When there were no answers for natural occurrences, observers concluded that it was caused by actions of the gods.

Astrology and its astrologers were cosmos based, religious fortune tellers and “the gods’ will”, messengers. They closely studied the stars, planets, the moon and sun and then tried to derive meaning for their movements. At times important decisions (war, marriages, coronations, etc.), were timed because of predictions put forth by these astrologers. Some of their observations were quite helpful. They could advise when to plant and harvest. They could determine when the next full moon night would occur. For those who lived near coasts, they could predict tides. They learned to use star patterns for day and night time navigation. The skills of writing and mapping drastically improved this combined religion and science of astrology and astronomy. By mapping and writing down observations, others were able to reutilize the saved information. Soon they were able to not only observe, but also record and predict astronomical events over long periods of time. The study of astronomy/astrology became an important development in the history of civilization. Skills of predicting weather patterns and seasons allowed man to time harvests. From this, each man no longer had to just hunt, gather and maintain flocks. Agriculture was developed, creating greater food supplies this led to larger populations, spare time to build, invent and develop communities. Star observation and mapping allowed for the navigation of new land and sea routes. Trade and exchanges of ideas developed between cultures. Over time, ancient civilizations gained wealth, power and improved technology based on the increased amounts of food and trade, that was inspired by studying the cosmos. Mathematics was integral to the advancement of astronomical studies. The ancient people of Egypt and Greece developed algebra and geometry. Through these math skills and little else, a Greek citizen named Aristarchus, in 270 BC first figured out how far the moon was from the earth.

1.2 Astronomy in Ancient India

The practice of astronomy in ancient India is mentioned in Rig Veda which was composed about 4000 years ago. Many Indian scholars have contributed to astronomy. One of the most well -known astronomers is Aryabhata. The work of Aryabhata on astronomy can be found in his writing 'Aryabhatiya'. He wrote it in 499 CE at the age of 23 years. The diameter of the Earth as stated by Aryabhata is close to its presently known value. Disregarding the popular view that Earth is 'achala' (immovable), Aryabhata stated that Earth is sphere and rotates on its own axis. His estimate about the sidereal period of Earth was 23 hours, 56 minutes and 4.1 seconds, which is very close to the presently known value. He also correctly stated that the moon and the planets shine due to reflected sunlight. He also gave a scientific explanation for solar and lunar eclipses. When the shadow of the Earth falls on the moon, it causes lunar eclipse. When the shadow of the moon falls on the Earth, it causes solar eclipse. Aryabhata also found the distance between the Earth and the moon, which is very close to the known value today.

1.3 Astronomy around the World

Ancient Babylonian, Assyrian, and Egyptian astronomers knew the approximate length of the year. The Egyptians of 3000 years ago, for example, adopted a calendar based on a 365-day year. They kept careful track of the rising time of the bright star Sirius in the predawn sky, which has a yearly cycle that corresponded with the flooding of the Nile River. The Chinese also had a working calendar; they determined the length of the year at about the same time as the Egyptians. The Chinese also recorded comets, bright meteors, and dark spots on the Sun. (Many types of astronomical objects were introduced in Science and the Universe: A Brief Tour.

If you are not familiar with terms like comets and meteors, you may want to review that chapter.) Later, Chinese astronomers kept careful records of “guest stars”—those that are normally too faint to see but suddenly flare up to become visible to the unaided eye for a few weeks or months. We still use some of these records in studying stars that exploded a long time ago. The Mayan culture in Mexico and Central America developed a sophisticated calendar based on the planet Venus, and they made astronomical observations from sites dedicated to this purpose a thousand years ago. The Polynesians learned to navigate by the stars over hundreds of kilometers of Open Ocean-a skill that enabled them to colonize new islands far away from where they began. In Britain, before the widespread use of writing, ancient people used stones to keep track of the motions of the Sun and Moon. We still find some of the great stone circles they built for this purpose, dating from as far back as 2800 BCE. The best known of these is Stonehenge, which is discussed in Earth, Moon, and Sky.

1.4 Early Greek and Roman Cosmology

Our concept of the cosmos—its basic structure and origin—is called cosmology, a word with Greek roots. Before the invention of telescopes, humans had to depend on the simple evidence of their senses for a picture of the universe. The ancients developed cosmologies that combined their direct view of the heavens with a rich variety of philosophical and religious symbolism. At least 2000 years before Columbus, educated people in the eastern Mediterranean region knew Earth was round. Belief in a spherical Earth may have stemmed from the time of Pythagoras, a philosopher and mathematician who lived 2500 years ago. He believed circles and spheres to be “perfect forms” and suggested that Earth should therefore be a sphere. As evidence that the gods liked spheres, the Greeks cited the fact that the Moon is a sphere, using evidence we describe later.

Aristotle also knew that the Sun has to be farther away from Earth than is the Moon because occasionally the Moon passed exactly between Earth and the Sun and hid the Sun temporarily from view. We call this a solar eclipse. Aristotle cited convincing arguments that Earth must be round. First is the fact that as the Moon enters or emerges from Earth's shadow during an eclipse of the Moon, the shape of the shadow seen on the Moon is always round. Only a spherical object always produces a round shadow. If Earth were a disk, for example, there would be some occasions when the sunlight would strike it edge-on and its shadow on the Moon would be a line. As a second argument, Aristotle explained that travelers who go south a significant distance are able to observe stars that are not visible farther north. And the height of the North Star-the star nearest the north celestial pole-decreases as a traveler moves south. On a flat Earth, everyone would see the same stars overhead. The only possible explanation is that the traveler must have moved over a curved surface on Earth, showing stars from a different angle. (See the How Do We Know Earth Is Round? feature for more ideas on proving Earth is round.) One Greek thinker, Aristarchus of Samos (310–230 BCE), even suggested that Earth was moving around the Sun, but Aristotle and most of the ancient Greek scholars rejected this idea. One of the reasons for their conclusion was the thought that if Earth moved about the Sun, they would be observing the stars from different places along Earth's orbit. As Earth moved along, nearby stars should shift their positions in the sky relative to more distant stars. In a similar way, we see foreground objects appear to move against a more distant background whenever we are in motion. When we ride on a train, the trees in the foreground appear to shift their position relative to distant hills as the train rolls by. Unconsciously, we use this phenomenon all of the time to estimate distances around us. The apparent shift in the direction of an object as a result of the motion of the observer is called parallax.

We call the shift in the apparent direction of a star due to Earth's orbital motion stellar parallax. The Greeks made dedicated efforts to observe stellar parallax, even enlisting the aid of Greek soldiers with the clearest vision, but to no avail. The brighter (and presumably nearer) stars just did not seem to shift as the Greeks observed them in the spring and then again in the fall (when Earth is on the opposite side of the Sun). This meant either that Earth was not moving or that the stars had to be so tremendously far away that the parallax shift was immeasurably small. A cosmos of such enormous extent required a leap of imagination that most ancient philosophers were not prepared to make, so they retreated to the safety of the Earth-centered view, which would dominate Western thinking for nearly two millennia.

1.5 OCCURRENCE OF DAY AND NIGHT

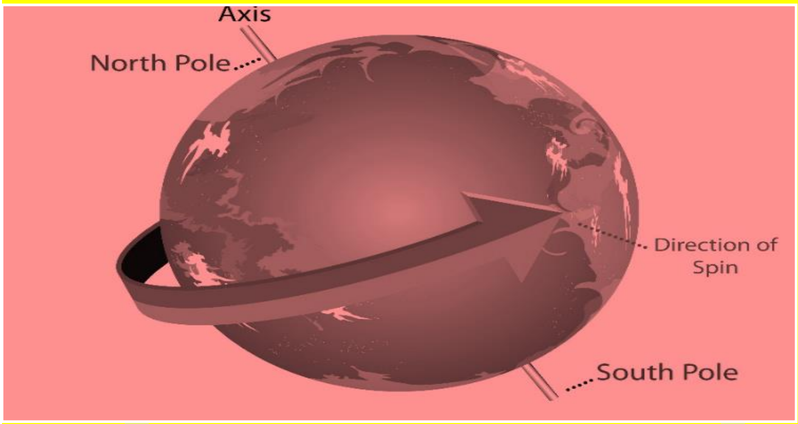
1.5.1 HOW DAY AND NIGHT OCCURS?

Day and night occur because of the rotation of a planet around its axis. The hemisphere of the planet that faces the sun at a particular moment experiences daylight, while the opposite side experiences darkness and so called night.

When a hemisphere of the planet is facing away from the sun, it does not receive sunlight, and night occurs because residual sunlight and heat from the previous period of daylight is being used up. When Earth rotates to bring that hemisphere back into the path of the sun's rays, sunlight once again heats and lights that hemisphere. Rotation around an axis is a feature common to all planets, all of which also experience days and nights of varying lengths. For example, a day on Mercury takes 58 Earth days and 15 hours, while a day on Uranus takes only 17 hours and 14 minutes.

1.5.2 ROTATION OF EARTH

Rotation is defined as the spinning of planets on their own axis. The Earth rotates counterclockwise from west to east. Earth takes 23 hours and 56 minutes on average to make a complete rotation with respect to the sun, which adds up to a single day every four years. This is why leap years exist, so the lost day can be made up. Day and night have different lengths throughout the year, depending on the latitude of a particular location and what season it is. For example, summer in the Northern Hemisphere has longer days than nights. At the poles, the days and nights last for six months because they are always pointed either toward or away from the sun. The imaginary line that separates light from the darkness and day from the night is known as the circle of illumination. Earth's axis refers to an imaginary line going through the center of the earth from top to bottom. The circle of illumination cuts all latitudes into half on the spring and autumnal equinoxes



spinning of earth on its own axis from west to east

Figure 1and **2.** Spinning of earth

1.6 REVOLUTION OF PLANETS

Revolution is defined as the movement of planets on their elliptical orbit around the sun. As the earth is among the nine planets, it also revolves around the sun .The time taken by the earth to complete one revolution is 365 days and 6hours which is exactly one year. In every four year this one fourth day (6hours) is added to give one full day which in turn gives 366 days' called leap year.

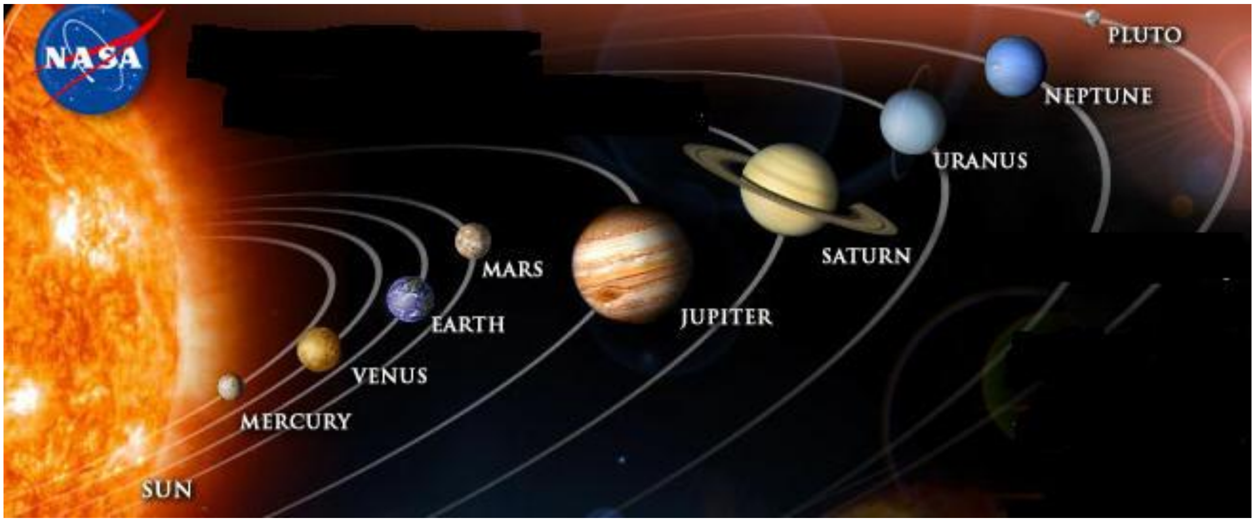


Figure 3.revolution of planets

1.7 How does the revolution of the earth cause seasons?

- **The Seasons**

The Earth is tilted. During its yearly orbit different parts of the planet are exposed to more daylight. During these same windows of time the opposite part of Earth has much less sun exposure. For the middle part of the earth, the equator, these changes are equal to approximately 12 hours of each all year long. During the winter in the northern half of our planet or Northern Hemisphere there is less sunlight. It gets darker and colder. At the very top of the planet, that we call the North Pole, there can be virtual darkness for a few months. During our summer, what is known as the South Pole has the same darkening and chilling experience. Meanwhile the warmth of the increased summer sunlight is heating up the northern hemisphere. In the northern and southern hemispheres spring starts on the day of the vernal equinox. A vernal equinox has a balance of hours between daylight and night. The Ancients rejoiced when this occurred; it was a day of celebration. For the growers of food this was the day to start the planting. The plant life of our planet has developed a rhythm based on the earth's orbit around the sun.

The plants wither, die or sleep during the winter and then begin a renewal of life with the advent of spring.

The revolution of the Earth does not directly cause seasons. Instead, the tilt of Earth's rotating axis causes seasons. The Earth is tilted 23.5 degrees, so it is never rotating completely "straight up or down". This tilt causes one half of the Earth, either the Northern or Southern Hemisphere, to be facing opposite directions as the Earth revolves around the Sun. At different times of the year, depending on where the Earth is in its revolution and where the tilt of each hemisphere is facing, the sun's rays will hit different hemispheres differently. In the summer for the Northern Hemisphere, the tilt of the Earth is facing the Northern Hemisphere towards the sun, causing more direct sun's rays to hit the Northern Hemisphere. When it's summer in the Northern Hemisphere, the Southern Hemisphere is tilted away from the sun, so they receive less direct sun's rays, so the temperatures are cooler and it is considered the winter season. Therefore **Seasons** are **caused** by the Earth's **revolution** around the Sun, as well as the tilt of the Earth on its axis. The hemisphere receiving the most direct sunlight experiences spring and summer, while the other experiences autumn and winter.

Key notes on Rotation and Revolution of Planets

	Planets	Mean distance from the Sun in millions of kilometers	Period of Revolution	Period of Rotation
1.	Mercury	57.9	88 days	59 days
2.	Venus	108.2	224.7 days	243 days
3.	Earth	149.6	365.2 days	23 hr, 56 min, 4 sec
4.	Mars	227.9	687 days	24 hr, 37 min
5.	Jupiter	778.3	11.86 years	9 hr, 55 min, 30 sec
6.	Saturn	1,427	29.46 years	10 hr, 40 min, 24 sec
7.	Uranus	2,870	84 years	16.8 hours
8.	Neptune	4,497	165 years	16 hr, 11 min

Table 1. Rotation and revolution of planets

Summary

- Day and night occur because of the rotation of a planet around its axis. The hemisphere of the planet that faces the sun at a particular moment experiences daylight, while the opposite side experiences darkness and so called night.
- Rotation is defined as the spinning of planets on their own axis. The Earth rotates counterclockwise from west to east. Earth takes 23 hours and 56 minutes on average to make a complete rotation with respect to the sun, which adds up to a single day every four years. This is why leap years exist, so the lost day can be made up. Day and night have different lengths throughout the year, depending on the latitude of a particular location and what season it is.
- Revolution is defined as the movement of planets on their elliptical orbit around the sun. As the earth is among the nine planets, it also revolves

around the sun .The time taken by the earth to complete one revolution is 365 days and 6hours which is exactly one year. In every four year this one fourth day (6hours) is added to give one full day which in turn gives 366 days' called leap year.

- The revolution of the Earth does not directly cause seasons. Instead, the tilt of Earth's rotating axis causes seasons. The Earth is tilted 23.5 degrees, so it is never rotating completely "straight up or down". This tilt causes one half of the Earth, either the Northern or Southern Hemisphere, to be facing opposite directions as the Earth revolves around the Sun.

Review questions

Dear readers, answer the following questions!

1. What is the measured distance in kilometers between Earth and the sun?
2. Describe how revolution is related with the formation of seasons?
3. What is rotation? Does rotation varies for each planets? If so, how?
4. Is the sun a star? If your response is yes, verify why and how?
5. Like the earth, the sun is comprised of different layers. Mention those layers and describe them in detail!

CHAPTER TWO

2. SOLAR SYSTEM

There are several aspects to our solar system. The mass of the solar system mostly lies on a disc - shaped flat plane called the plane of the ecliptic. Surrounding this is a gaseous, magnetic bubble. The Sun (our star) makes up most of the volume of the solar system's mass (99.86%) and on its measurable energy. It is also the gravity anchor. The gas planets account for over 99% of the remaining mass of our solar system. The majority of the planets, moons and asteroids follow the same basic gravitational rules that govern our solar system; they even travel in the same direction around the Sun.

If you looked down toward the north pole of the sun, these objects would be moving counter clockwise. The orbiting objects that dominate the Solar System can be classified into three groups: Planets: Earth, Jupiter, Neptune (all planets) and so on. Planetoids: Ceres, Pluto (all planetoids) and so on. Small Solar System Celestial Bodies: Halley's Comet, (all comets), the Moon, (all moons) and so on. The composition of these objects fall into three general areas: They contain one, some or all, of either types of rock, gas or ice. The rock can range from sandy (silicates), to minerals such as salts and metals such as iron or gold. Gases range from hydrogen, oxygen (a gaseous metal), ammonia and methane to molecules such as water vapor and other molecular compositions. Ice can be composed of not only water, but also carbon dioxide, methane, and even more exotic frozen gases. They can be large blocks or floating crystals. Throughout the Solar System's space there are flows of particles are coming from the Sun. They move quickly at speeds up to nearly 1,000,000 miles per hour, carried by what is called solar winds. This creates an atmosphere to the Solar System known as the heliosphere. If there is atmosphere, there should be weather! The Sun has magnetic storms and solar flares that result in solar winds of charged particles and of energy. If there is an atmosphere, does it protect and shield as ours does? The answer is yes. Our heliosphere shields out dangerous cosmic rays that emanate from outside our solar system.

2.1 Solar Regions

The **inner solar** system region beyond the sun is dominated by four rocky planets: Mercury, Venus, Earth and Mars. These are terrestrial planets. They are rocky and have very little to substantial amounts of atmosphere. In this area there are only three moons and about 1,000 other floating objects of any consequence.

They do have occasional intruders, such as comets that are either in elliptical orbit around the sun or are heading into one of the planets or the Sun itself. The next region is very distinct. Just beyond Mars and before the gas planets. This region is called the Asteroid Belt. It's filled with rocks that vary greatly in size and composition. There is speculation that this is debris left over from a planetary/planetoid collision or there were other influences such as gravity influences (Jupiter) that would not allow these rocks to coalesce into a planet. Beyond the asteroid belt lies the realm of the gas planets known as the outer solar system: Jupiter, Saturn, Uranus and Neptune. The Sun's influences dwindle here and the planets are very cold. There are multitudes of moons. Over 99% of all moons are found circling these planets. The moons vary from traditional in nature to captured asteroids with retrograde orbits, and there are even ice/water moons that have the potential to host life. Next is the Kuiper Belt, a cold and dark region that contains rocks, ice and is quite cold. This area contains dwarf planets also known as Trans - Neptunian planetoids. The most famous resident is the one time planet called Pluto that is now classified as a Trans Neptunian - plutoid. Not all of these objects, including Pluto, are found on the plane of the ecliptic. Pluto travels at a 17% angle of that plane while orbiting the Sun. It is populated by an estimated 100,000 objects that are 50 miles in diameter -or wider. Here, the Sun seems not much bigger or brighter than other stars. The sun's influence is limited. It is from 30 to 50 AU from the sun. (The measurement of 1AU is equal to 93,000,000 miles, or the distance from the Sun to the Earth.) The region dominated by the planets, heliosphere and Sun is called the interplanetary medium. It contains two regions of dust. They are flattened and are found on the plane of the ecliptic. The inner region is called the zodiacal dust cloud. It is found from outside the sun to the planet Jupiter.

The other zodiacal dust zone is found from the most outer gas planets to the Kuiper Belt. There is another region, called the Scattered Disk is found at the edge of the Solar System and is populated by icy objects that will find their way into the inner parts of the Solar System. Their orbits were affected by Neptune in early formation of the solar system. Their orbital paths tend to be erratic and range from within the Kuiper Belt to as far as 150 AU from the Sun. They also do not follow the plane of the ecliptic, but rather are angled to it. Its' most famous inhabitant is the planetoid called Pluto.

2.1.1The Outer Regions

Surrounding these regions is an area called the Oort cloud. This is composed of comets that eventually head towards the inner solar system, are composed of ice and dust and centaurs (Objects that can reach the size of planetoids and have unstable orbits that change over time. They can be composed of ice, carbonized and dusty materials.). It does not circulate on the plane of the ecliptic. It is found in all directions. That is why it is termed a cloud. It is inhabited by up to a trillions bits of dust and ice. Its outer borders may be as far out as one light year from the sun. A light year is the amount of time light takes (at 186,000 miles a second), to travel in a year, or about 19 trillion miles! It can be influenced by the passing slight gravity pulls of stars and by the galactic tidal force of our galaxy. Where does our Solar System end? Good question! It is not exact and varies according to the Sun's activities. It is very far from the Sun, about 155 to 160 AU. As the Sun and its system travels around the Galaxy, it has a bow shock that precedes it. This is much the same as a bow shock in front of a moving ship. In the direction that the sun is traveling, the bow shock is 200 AU in front of it. Behind the Sun's trail, or wake, it is only 100 AU out to the border. The border of the Solar System where it meets interstellar space and bow shock starts is called the heliopause.

Here, there is a collision of interstellar wind and electromagnetic particles from the Sun. It is a turbulent area. How do we know that? We have had our first probes reach this area (Voyagers 1 and 2), which were launched in the late 1970s to explore the outer planets and beyond. They are still transmitting! The Voyager 1 probe is now more than 9 billion miles from Earth. Voyager 2 is 7 billion miles away. Traveling at a speed of well over 3 AU a year, it takes many hours for their signal, traveling at light speed, to reach Earth. It will be several more years before they transverse the heliopause and enter interstellar space. In interstellar space, there are still particles of dust, plasma and ionized gas, are known as the interstellar cloud. It is found throughout the galaxy between the solar masses and their star systems. In 2009, Voyager detected a magnetic field at the edge of the Solar System that apparently holds the interstellar clouds together. Our solar system is currently passing through one of these clouds.

2.2 Planets

2.2.1 Definition of planets

Planets are relatively large natural bodies that revolve in an orbit around the Sun or around some other star and that are not radiating energy from internal nuclear fusion reactions. **Planets** emerge from the dense disk of gas and dust encircling young stars.

Scientists think **planets**, including the ones in our solar system, likely start off as grains of dust smaller than the width of a human hair. They emerge from the giant, donut-shaped disk of gas and dust that circles young stars. Planets vary in size and composition. Planets from rocks more than a few thousand miles wide to huge balls of gas that can approach star size. They may or may not have atmospheres. Distances from the central star can be near or far. Some have one moon, others have many, and still others have no moons at all. However, they all have something in common: they orbit stars and are round in shape.

Planets are thought to have been created from left over debris of star formations. There were pieces of colliding rock and dust that stuck together, and they became planetoids, or small planets, which evolved and gradually grew larger. As their masses grew, their increased gravitational pull caused more debris to be drawn in until there was one object only. Little else was left in the general area. Gradual cooling took place, and the planets ended up rocky or liquid/ gaseous or made of gases only.

How many planets are there in the Solar System?

There are 8 planets in our Solar System. These are (in order from the Sun):

1. Mercury
2. Venus
3. Earth
4. Mars
5. Jupiter
6. Saturn
7. Uranus
8. Neptune

The Sun is, of course, a star. It is one of a large number of stars in the galaxy that we are in, the *Milky Way*. More on this below.

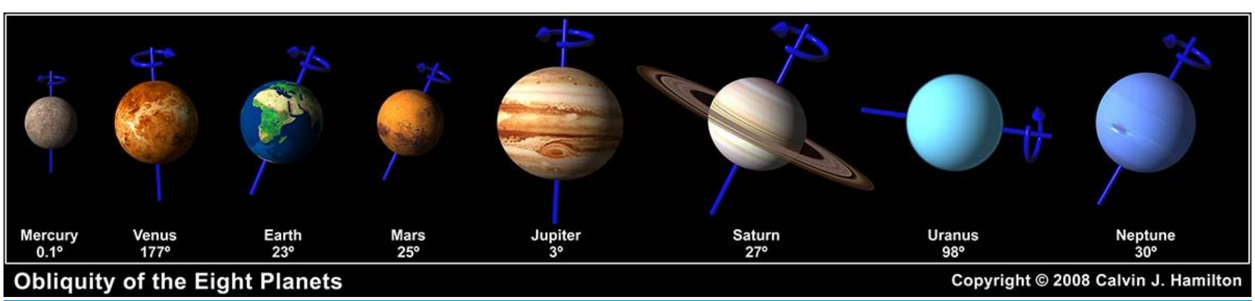


Figure 4. Planets

- **NOTE: -** There used to be nine planets in the Solar System, with Pluto being the additional one. However, in 2006 it was downgraded and taken off the list. This was because the definition of what makes a "planet" changed and Pluto was no longer considered one, essentially because it is too small:

  1. When Pluto was first discovered in 1930 nobody knew how big it was. Later in the 20th century, it was discovered that it was in fact tiny in comparison to the other planets of the Solar System. It is just one-sixth the size of Earth and smaller than our moon.
  2. The dwarf planet *Eris* was discovered by the astronomer Michael E. Brown in the same area of space (the Kuiper Belt). It is larger than Pluto, but not considered a planet itself.

Pluto was therefore downgraded to a *dwarf planet* when an official definition of a planet was agreed by the International Astronomical Union in 2006 (see *further information* below).

There are four dwarf planets in addition to Pluto in our Solar System. These are Ceres, Haumea, Makemake, and Eris.

2.3 Planet classification

There are four main categories of classifications when determining the type of celestial body an object is. These classifications are: **terrestrial planets** (Mercury, Venus, Earth, and Mars), **gas giants** (Jupiter and Saturn), **ice giants** (Uranus and Neptune), and **dwarf planets** (Pluto, Eris, Haumea, and Makemake). Ceres at this current time is still labeled as an asteroid though it has many characteristics of a dwarf planet. There are three rules that are applied to determine whether a celestial body can be classified as a planet. These rules were determined by the International Astronomical Union (IAU) and are as follows.

- Is in orbit around a Sun.
- Has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and
- Has cleared the neighborhood around its orbit.

I. Terrestrial planets – **primarily comprised of a rocky type surface**

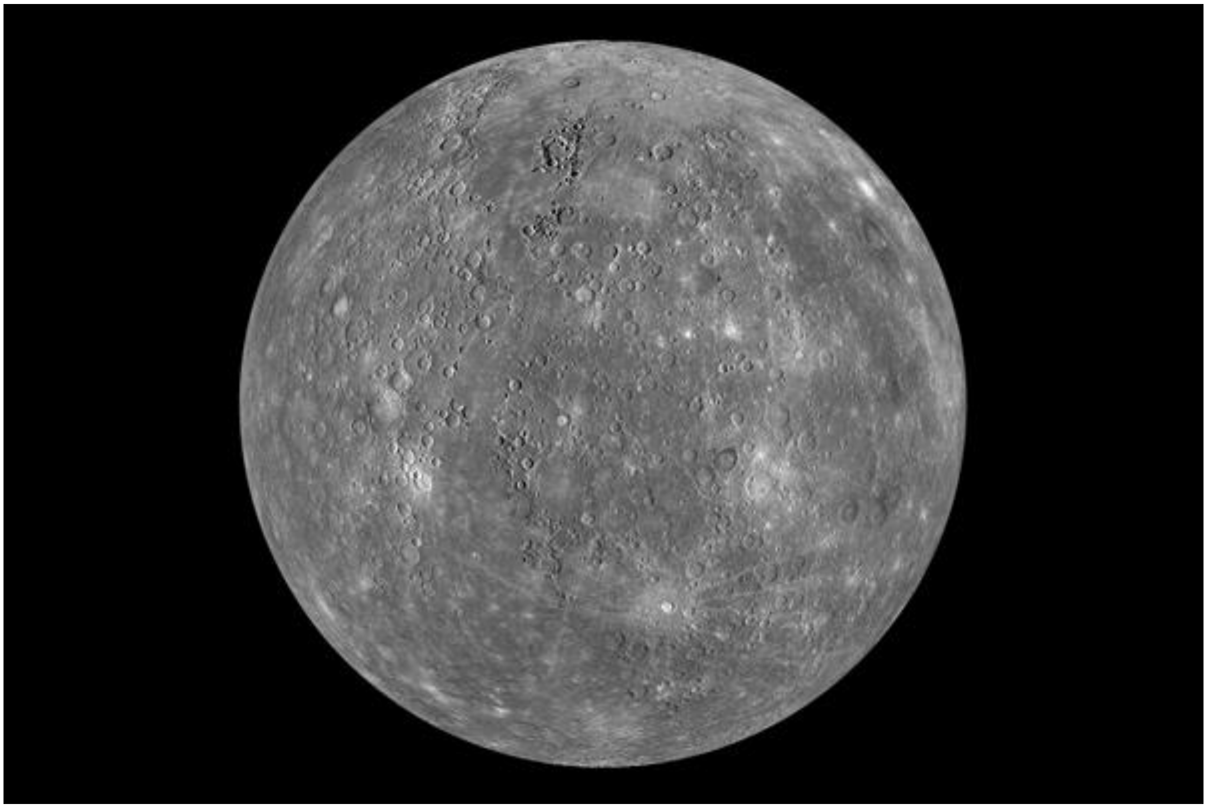


Figure 5. Mercury / nasa.gov

Mercury — the closest to the sun and the second smallest planet in our solar system, Mercury has a rotation of only 88 days around the sun. Because of its close proximity to the celestial giant, the surface of the planet reaches temperatures as high as 840°F during the day and hundreds of degrees below the freezing point at night. There is no atmosphere due to the intense temperatures so the planet's surface is covered with pock marks and craters from meteor impacts.

Figure 6. Venus / nasa.gov

Venus — this toxic planet, primarily consisting of carbon dioxide, is next in line from the sun and contains a pressure index that would crush anyone who landed on its surface. Though it is further away from the sun then Mercury, Venus is the hottest planet in the solar system and is able to be seen by the naked eye from Earth. A thick cloud shrouds the planet, making it difficult to see its surface which attributes to its brilliance.

Figure 7. Earth / nasa.gov

Earth — is the planet in which we live on and is the 3rd planet from the sun. Also known as "Terra" the Earth is the only planet within our solar system that is capable of sustaining advanced life forms, such as humans. The Earth's rotation around the sun is approximately 365 days and it is believed that the Earth is approximately four thousand million years.

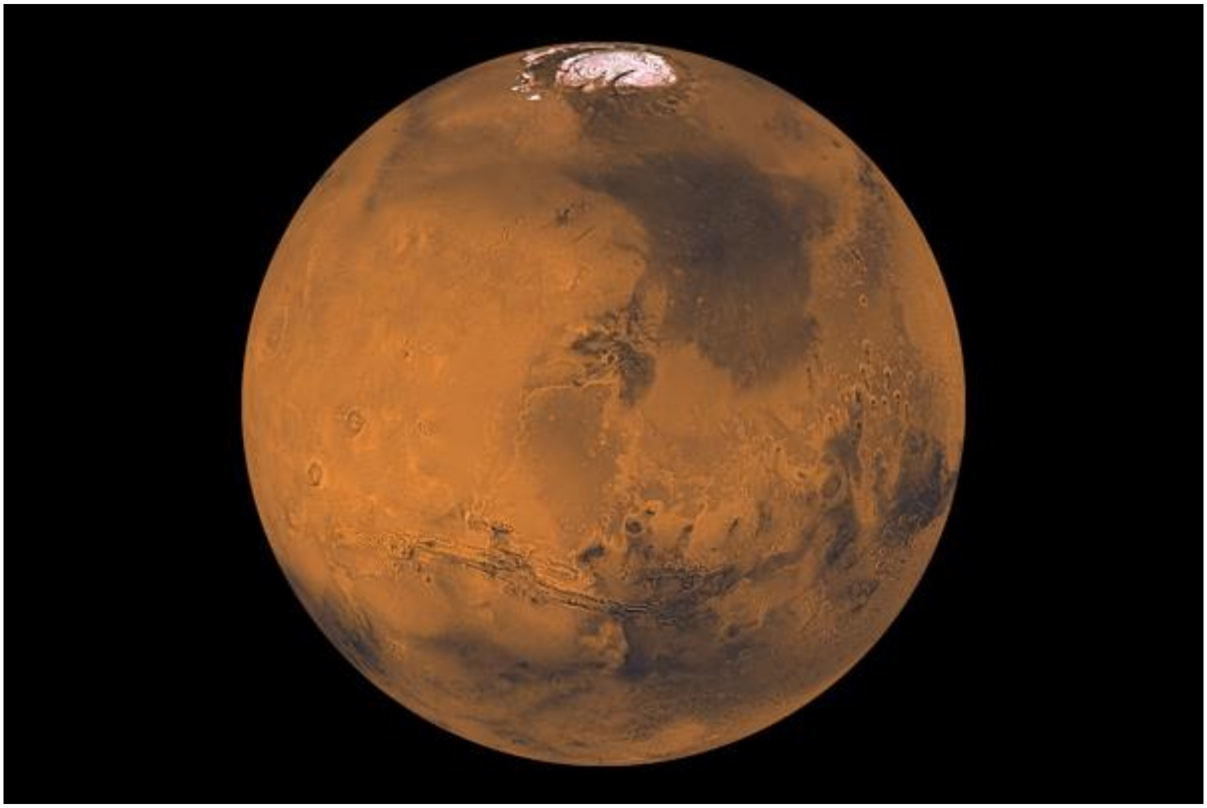


Figure 8. Mars / nasa.gov

Mars — the fourth planet from the sun the "red planet", so named for its reddish color due to the high iron content in its soil, has a rotation around the sun of 686 days. Its thin atmosphere, consisting primarily of carbon dioxide, makes it unsuitable for sustaining life, but is believed to have at one time been capable of it and might still be able in the future.

II. Gas Giants – **massive planets primarily comprised of a mixture of gases in place of a solid surface**

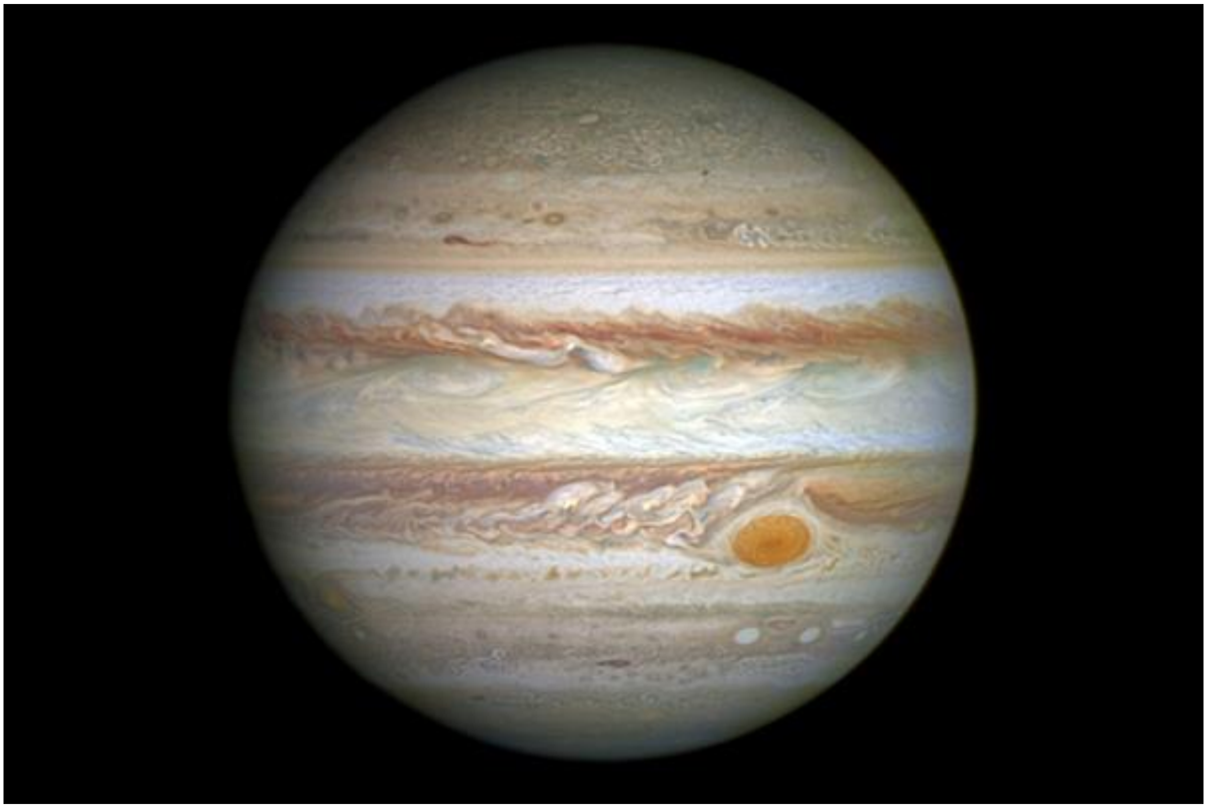


Figure 9. Jupiter / spacetelescope.org

Jupiter — the largest planet in our system, the mysteries of Jupiter has fascinated astronomers and non-astronomers alike for centuries. Poisonous gases completely cover its surface, hiding what lies beneath and violent storms prevent any landings of probes onto or images taken of the giant planet. Jupiter's atmosphere has been determined to be similar to that of the sun containing elements of hydrogen and helium.

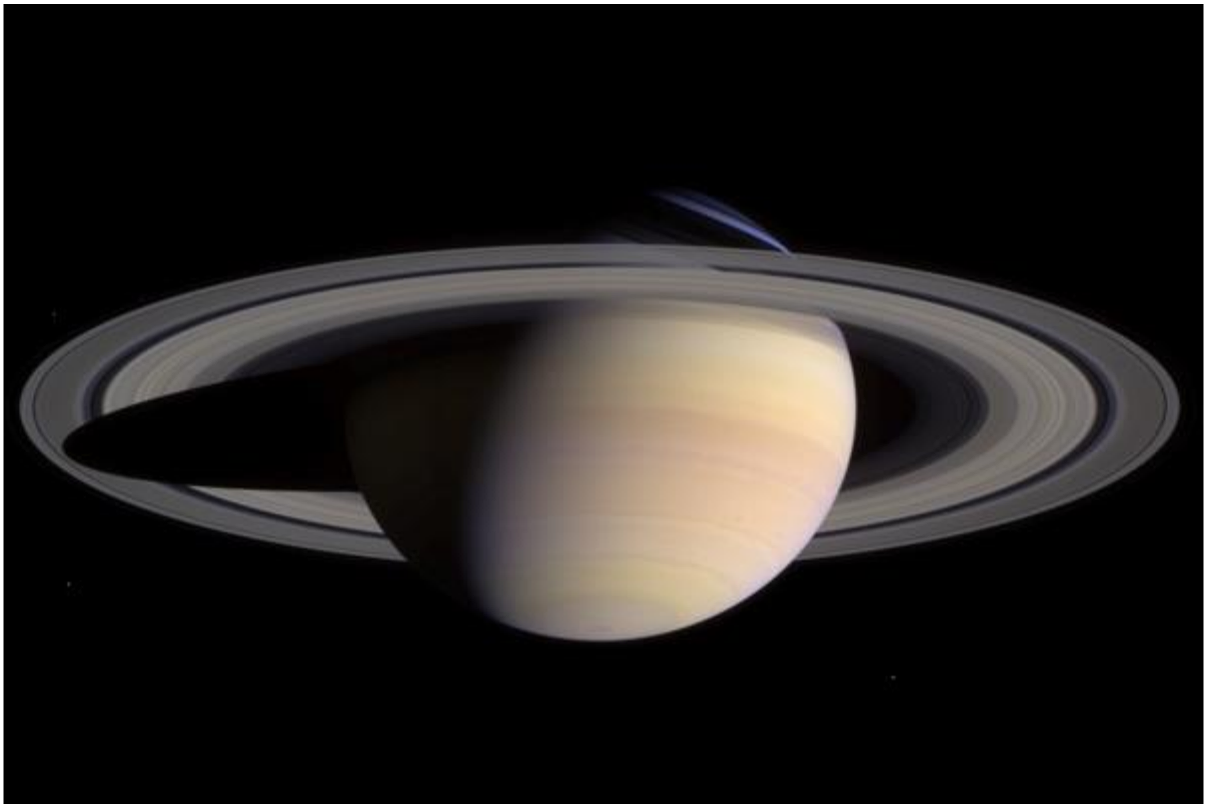


Figure 10. Saturn / nasa.gov

Saturn — first viewed via telescope in 1610 by Galileo Galilei, is the 6th planet in our solar system from the sun. Like Jupiter, its atmosphere is composed primarily of helium and hydrogen and it is the only planet discovered so far that has a lower density than water, approximately 30% lower. It is surrounded by a set of 9 whole rings and 3 broken rings that are comprised mainly of ice, rock, and space "dust".

III. Ice Giants – massive planets with a solid ice surface

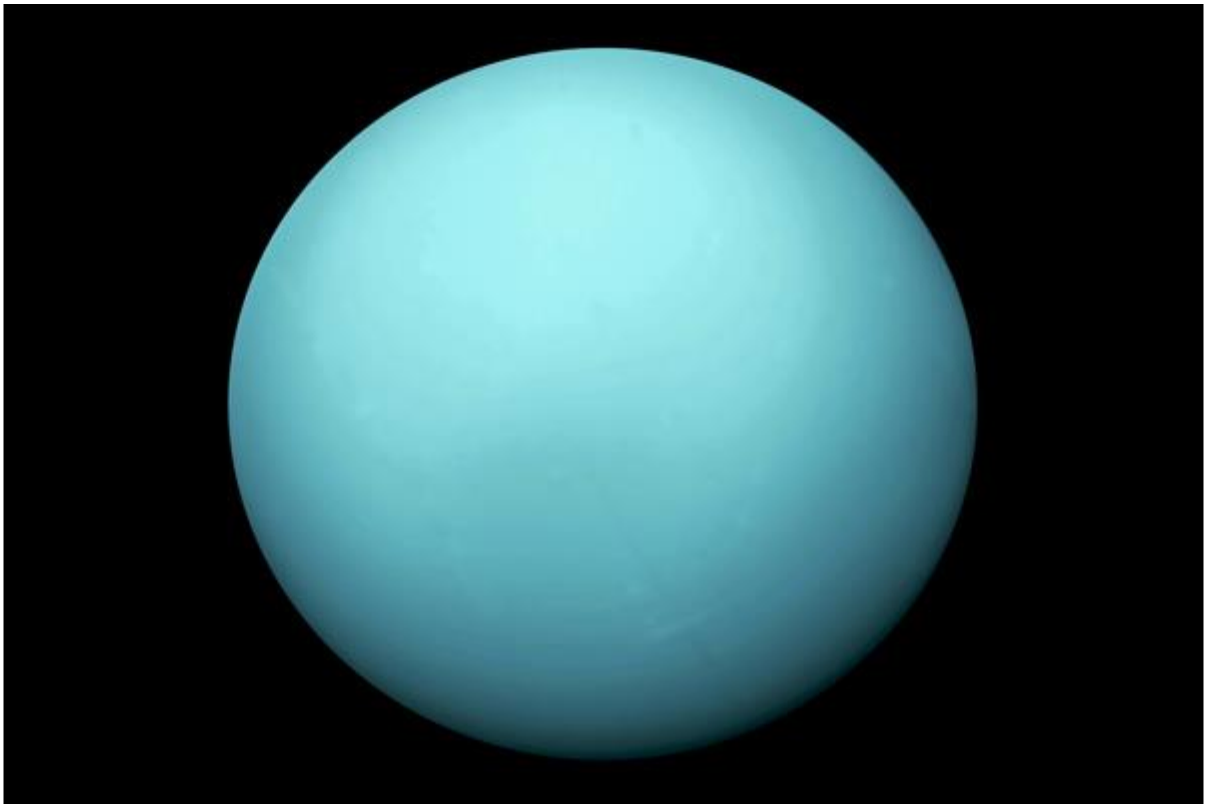


Figure 11. Uranus / wikimedia.org

Uranus — also known as the "sideways planet" because of its awkward rotation, is the 7th planet in our solar system from the sun. Its North and South poles are located where other planets equators are, given to its strange rotation and its 20 yearlong seasons. The level of methane gases in its atmosphere account for its bluish color, but the main elements in Uranus' atmosphere is helium and hydrogen.

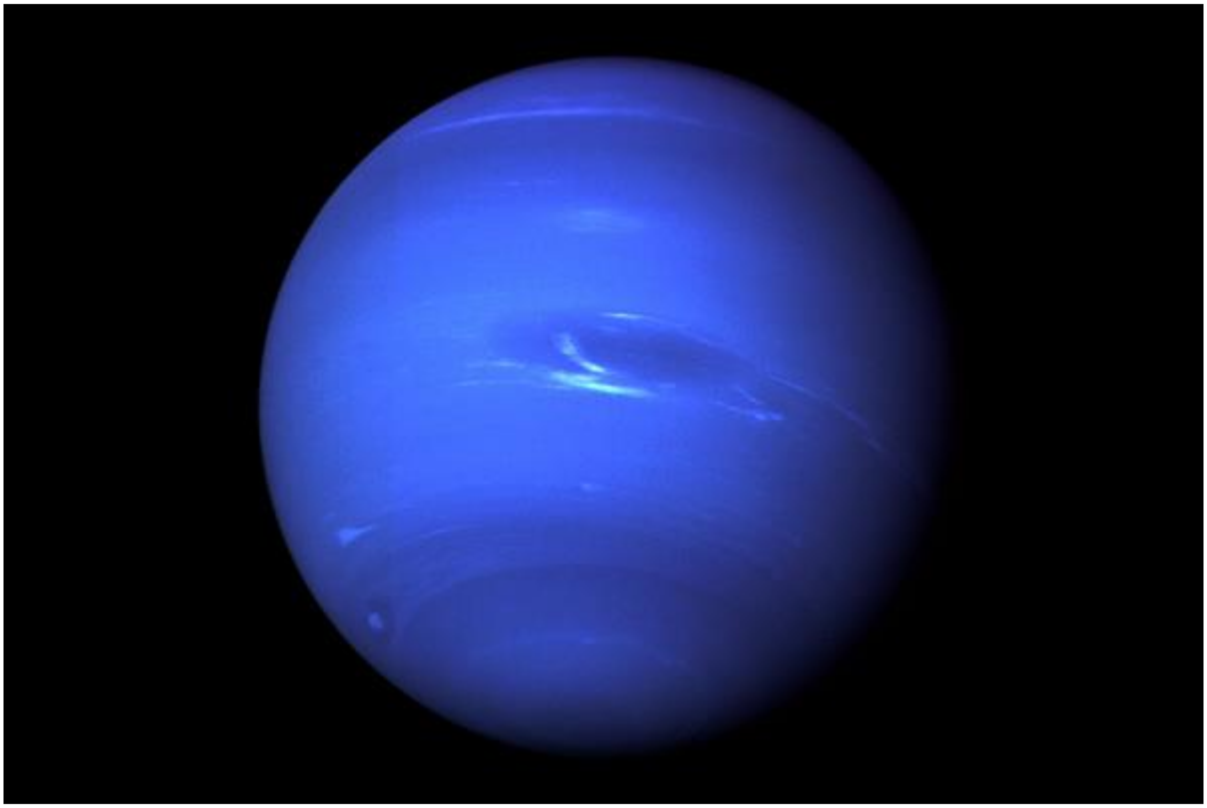


Figure 12. Neptune / nasa.gov

Neptune — is known as the windiest planet in our solar system and 8th furthermost known "planet" from our sun. It has a revolution around the sun of 165 Earth years. Like Uranus, Neptune has high traces of methane in its atmosphere, which contributes to its blue color. It is believed there is a second "unknown" element, though, that makes it a much brighter blue than Uranus.

Iv. Dwarf Planets

Dwarf Planets are smaller in mass to their bigger "brothers" but still hold some qualifications to list them as planets rather than as just celestial objects, such as asteroids and meteors. There are currently 4 planets in this category, all of which are currently located in the Kuiper Belt. These planets are Pluto, Eris, Haumea, and Makemake. These rules determine the classification of a dwarf planet:

- *Is in orbit around the Sun,*
- *Has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape,*
- *Has not cleared the neighborhood around its orbit, and*
- *Is not a satellite, aka not caught in an orbit around a planet*.

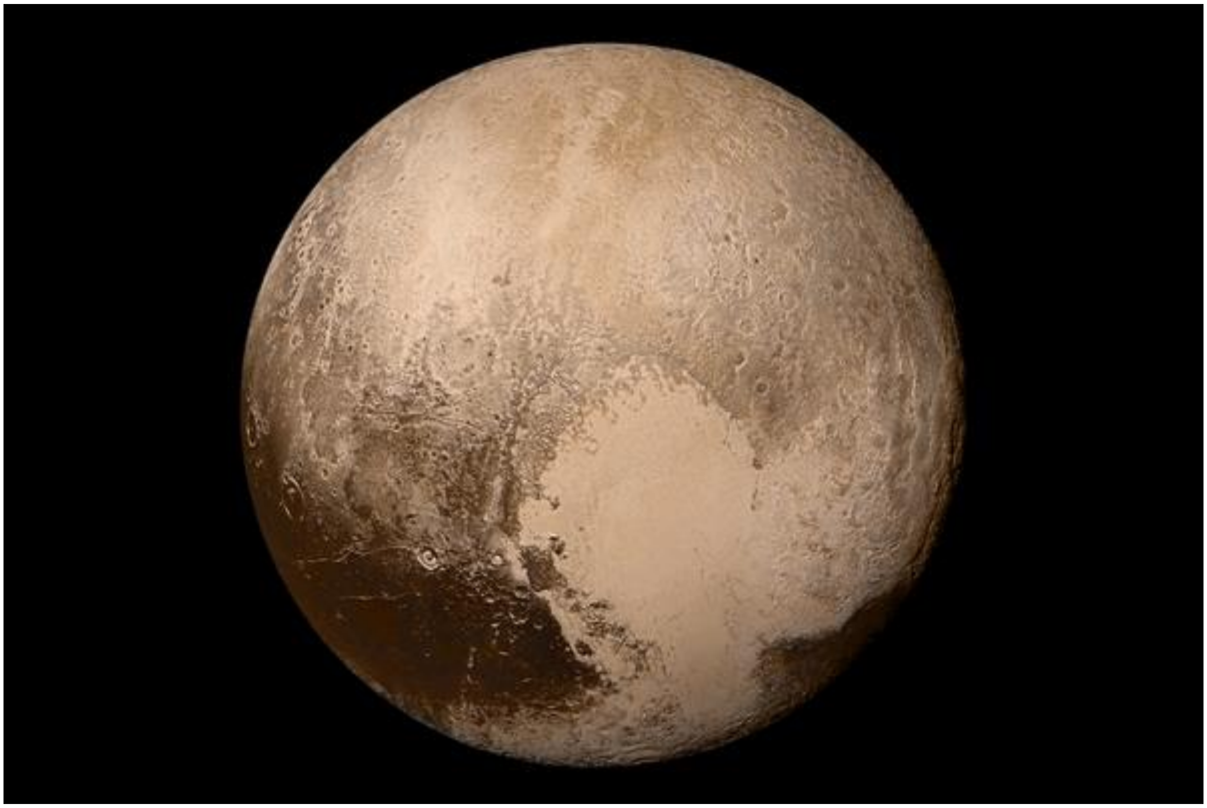


Figure 13. Pluto / jhuapl.edu

Pluto — at one time known as the 9th planet in our solar system, due to the new astronomy rules Pluto is no longer considered a planet but is now a "dwarf" planet. Located beyond Neptune in the Kuiper Belt (ring of bodies past Neptune), Pluto is smaller than our own moon and reaches temperatures of -387°F (-233°C).

Figure 14. Haumea / deviantart.com

Haumea — because of its distance, little is truly known about Haumea other than its odd elongated shape and it is roughly the same size as Pluto. Its orbit path around the sun takes 285 Earth years and it is made up of rock with an icy coating over the surface. This coating causes the dwarf planet to appear bright, similar to the effect of sunlight on snow on Earth.

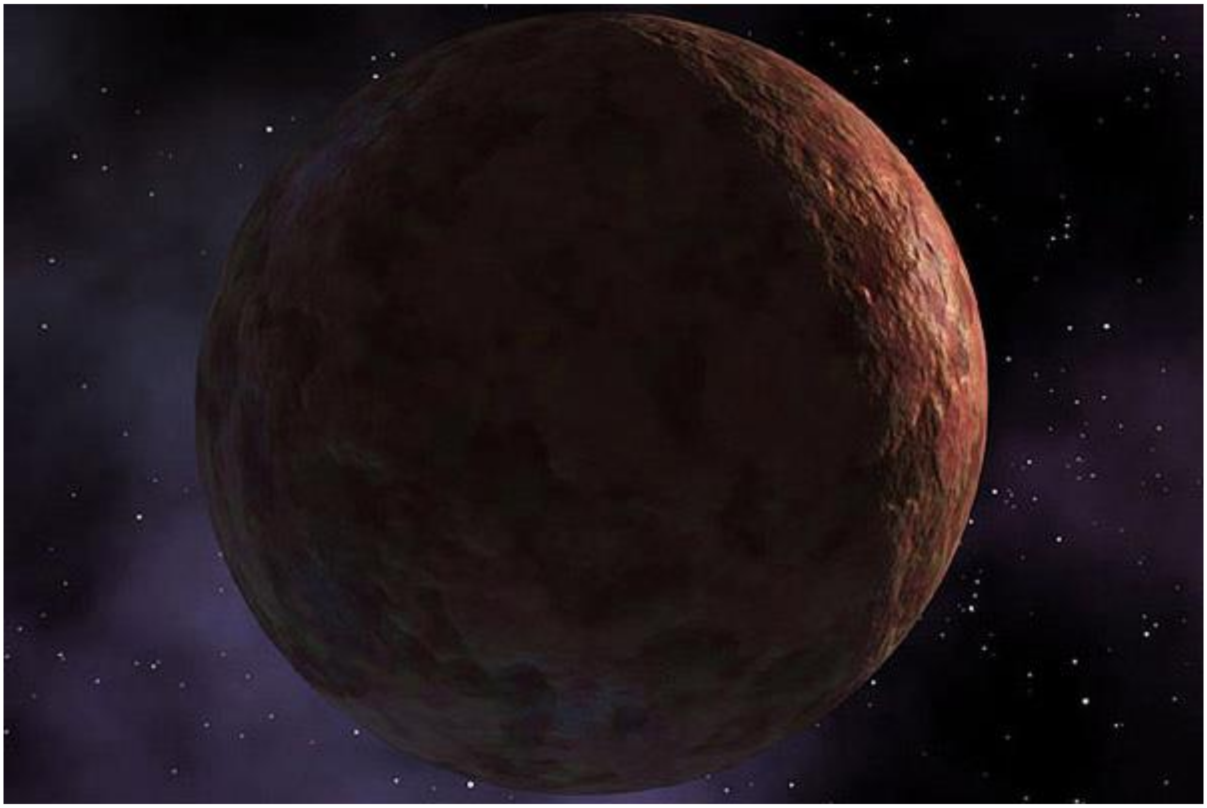


Figure 15. Makemake / nasa.gov

Makemake — is a recently discovered, March of 2005, dwarf planet located in the Kuiper Belt. Slightly smaller than Pluto, Makemake's surface consists of primarily frozen nitrogen, ethane, and methane. Makemake's orbital path around the sun is approximately 310 Earth years and it, along with Eris, is responsible for the new classifications of what constitutes as a planet.

Figure 16. Eris / eso.org

Eris — the next "dwarf" planet within the Kuiper Belt is Eris and it has the most extreme orbital path that extends well outside of our solar system. It is believed that its surface temperatures varies from -359°F (-217°C) to -405°F (-243°C). Its surface is covered in ice but as it comes closer to the sun and the ice melts, its surface is closely similar to Pluto's.

Up In the Air Classification

These "objects" are currently under scrutiny as to whether they can be classified as a planet or as "Small Solar System Bodies". Currently there is only one body in our solar system that falls under this classification, Ceres.

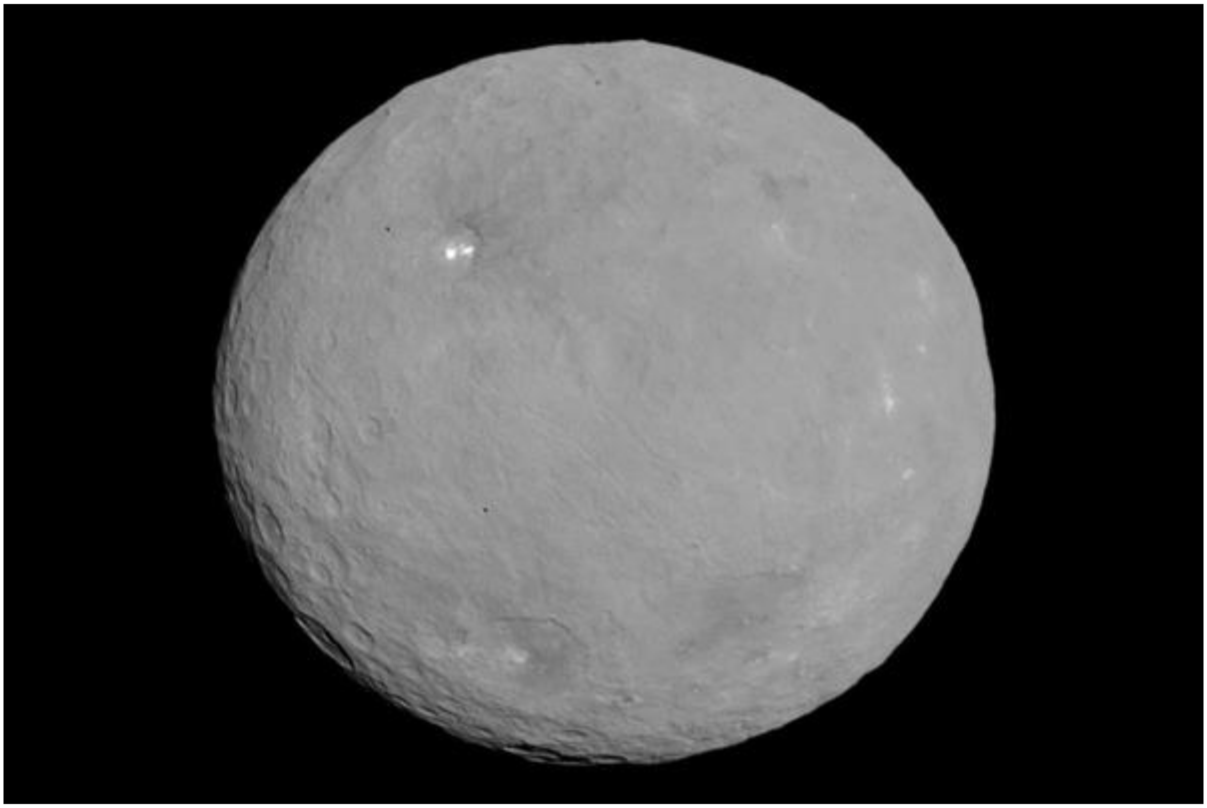


Figure 17. Ceres / nasa.gov

Ceres — upon its first discovery in January of 1801, was believed to be a comet then it was determined to be the missing planet between Mars and Jupiter. However, it is nested in an asteroid belt (the largest in our solar system) and so it was reclassified to be an asteroid. It is now considered as a "dwarf" planet, but is still labeled as an asteroid, because in reality, like Pluto, they have no idea how to truly classify this mysterious object.

Theoretical Planets

These planets have yet to be physically discovered, but are hypothesized based on scientific calculations as to exist. They may exist beyond our range of view or are hidden by other objects. Currently there is only one "possible" planet listed in this area which has been named Planet X (X does not signify the Roman numeral 10) or Planet Nine.

Figure 18. Planet Nine / wikimedia.org

Planet X — according to Caltech researchers, there is a strong possibility that there is another planet in the far reaches of our solar system Planet X. Nicknamed "Planet Nine", as it is theorized it is the 9th planet in our system, there is no direct evidence that the planet exists, but there are several mathematical models and computer simulations that point to its existence. It is believed that the planet may be larger than Neptune and have a rotation of 10 - 20 thousand Earth years around the sun.

Summary

- Planets are relatively large natural bodies that revolve in an orbit around the Sun or around some other star and that are not radiating energy from internal nuclear fusion reactions. **Planets** emerge from the dense disk of gas and dust encircling young stars. There used to be nine planets in the Solar System, with Pluto being the additional one. However, in 2006 it was downgraded and taken off the list. This was because the definition of what makes a "planet" changed and Pluto was no longer considered one, essentially because it is too small:

- When Pluto was first discovered in 1930 nobody knew how big it was. Later in the 20th century, it was discovered that it was in fact tiny in comparison to the other planets of the Solar System. It is just one-sixth the size of Earth and smaller than our moon.
- The dwarf planet *Eris* was discovered by the astronomer Michael E. Brown in the same area of space (the Kuiper Belt). It is larger than Pluto, but not considered a planet itself.

There are four main categories of classifications when determining the type of celestial body an object is. These classifications are: **terrestrial planets** (Mercury, Venus, Earth, and Mars), **gas giants** (Jupiter and Saturn), **ice giants** (Uranus and Neptune), and **dwarf planets** (Pluto, Eris, Haumea, and Makemake). Ceres at this current time is still labeled as an asteroid though it has many characteristics of a dwarf planet. There are three rules that are applied to determine whether a celestial body can be classified as a planet. These rules were determined by the International Astronomical Union (IAU) and are as follows.

- Is in orbit around a Sun.
- Has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and
- Has cleared the neighborhood around its orbit.

Dwarf Planets are smaller in mass to their bigger "brothers" but still hold some qualifications to list them as planets rather than as just celestial objects, such as asteroids and meteors. There are currently 4 planets in this category, all of which are currently located in the Kuiper Belt. These planets are Pluto, Eris, Haumea, and Makemake. These rules determine the classification of a dwarf planet:

- Is in orbit around the Sun,
- Has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape,
- Has not cleared the neighborhood around its orbit, and
- Is not a satellite, aka not caught in an orbit around a planet.

Did you know? A key to discovering the distance from the Sun to the Earth was the measuring of distances between Venus and our star. This was done by Mikhail Lomonosov of Russia in the 1700s.

Review questions

Dear readers, answer the following questions!

1. What is planet and how they are formed?
2. Except earth why other planets are not favorable for supporting life?
3. Jot down the main characteristics of dwarf planets?
4. Planets are very large bodies lying on their own axis .so how some one measure the mass of planets?
5. Explain how the big bang theory is related with the formation of planets?
6. Write a short essay on why it may be important as to the distance a planet is from the Sun and the size a planet is when considering a chance of it harboring life.

CHAPTER THREE

3. MOON AND THE SUN

3.1 Why is the moon sometimes bright and sometimes dark?

The moon is a fascinating object for poets and story-tellers. But when astronauts landed on the moon, they found that the moon's surface is dusty and barren. There are many craters of different sizes. It also has a large number of steep and high mountains. Some of these are as high as the highest mountains on the Earth. Actually moon a non-luminous object i.e has no its own source of light and that is why its heat energy is less than that of the sun. When the **Moon is** close to the Sun in the sky, the Sun is too **bright** for us to see as it moves away from the Sun in the sky each day, we see it emerge as a thin crescent. This called the New **Moon**. If you look closely, you can see the faint glow of the "**dark**" part of the **Moon**.

If you look at the Moon during different days of the month, then you might notice that the moon looks a little different every day. Why do we see these different phases of the Moon? The phases of the Moon depend on the moon's position compared to the Earth and the Sun. Remember that the moon revolves around the Earth. As the moon goes around the Earth, half of the moon is always illuminated by the Sun. Meanwhile, the other half of the moon is always in darkness. Sometimes we see the parts being illuminated, and sometimes we do not. The moon looks bright because we see sunlight reflecting off of it. Depending on the position, we can only see fractions of the illuminated surface.

For instance, when the Moon is between the Earth and the Sun, the side of the moon facing Earth is not illuminated by the Sun. Therefore, to us humans on Earth, the moon is dark, and we call this a New Moon.

As the Moon then moves away from the Sun, we begin to see more of the surface illuminated. The Moon then appears brighter and fuller as we see the sun reflecting and shining on its surface. In these phases, the Moon looks like it is growing. When the Moon appears half full, it has then reached its First Quarter. Then, when the Earth is positioned between the Moon and the Sun, we see a Full Moon.

The lunar cycle, which means it is going from one New Moon to another New Moon, takes about 30 days to complete. That means all the phases happen once a month.

The Moon's shape does not change, and it cannot cast light by itself. Instead, we only see a change in shape because we can only see the parts of the Moon that are being lit by the Sun. The parts we do not see are simply in There are few different reasons why notice different phases of the Moon darkness or shadow.

Below is a listing of planets and planetoids along with how many moons they have.

	Planet/dwarf planet	Number of moon it contains
1	Mercury	0
2	Venus	0
3	Earth	1
4	Mars	2

5	Jupiter	63
6	Saturn	61(+ 150 moonlets)
7	Uranus	27
8	Neptune	13
9	Pluto	1
10	Eris	1
11	Haumea	2
12	Ceres	0

Table 2. Planets and moons they contain

There are different types of moon – satellites. The size and roundness of them vary. Most are formed near their partner planet. Some are asteroids that were captured by a planet's gravity. Here are some terms that are used in the moon exploration business that concerns how moons orbit their planets:

Inclination: Describes the orbital path of the satellite compared to the equatorial latitude of the planet.

Prograde: Is orbiting the planet in the way that a planet orbits the Sun while it is circling between 0 and 90 degrees compared to the planet's equator. The vast majority of moons are prograded. They circle counter clockwise if looking down at the planet's North Pole.

Retrograde: Is orbiting the opposite direction of the way planet travels around the sun and/or has an orbital path that is more than a 90 degree angle than the equator. Most, if not all retrograde moons are captured asteroids.

Irregular: Moons that have elliptical orbits and are still within the 90 degree equatorial angle.

Regular: moons are all prograde, but not all prograde moons are regular. Some are irregular. Our Moon had different names during ancient times when many thought of it as a goddess. Some of the given names were: Diana, Lunea, Cynthia, and Selene. It has been both worshipped and feared. It was an object representing romance. It was a light for harvesting at night. It was thought of as a factor in transforming people into werewolves. It was believed that the Moon could even cause people to become "lunatics." (Derived from the Latin word luna.) We have only one moon. In English, we call it the Moon. It is one of many in the solar system. Here are some of additional Moon facts: It has a 2,160 mile diameter at its equator. The Moon is a little more than one quarter the size of Earth. Its density is about sixty percent of the density of the Earth. Its average distance is about 221,423 miles from Earth. Its orbit is elliptical (an oval shaped path). The farthest point the Moon is from Earth is 252,667 miles. There are tremendous temperature swings on the Moon because there is a very slight atmosphere to hold or release heat and cold. The Moon travels around the Earth at a rate of nearly 1.5 miles per second! There is water ice on the Moon. Evolutionists age the Moon at 4.4 billion years. It has 17% percent of earth's gravity.

Galileo thought that the dark areas on the Moon were oceans. He called them maria, (plural), or mare, (singular). The mare is actually basalt rock lava beds that have cooled from the pouring out of magma, were caused by meteorite impacts cracking the surface. The largest mare is the Mare Imbrium, 1,700 miles across. The highest areas on the moon are known as “The Highlands” and are some of the oldest surfaces on our Moon formed, during the period of volcanism. As the Moon cooled, there were flows of volcanic basalt, which were most active between 3.2 and 1.2 billion years ago. Igneous (volcanic), rock areas covers almost 80% of the Moon’s surface. Some smaller features exhibit geographical features that appear to be caused by out - gassing. (An explosive leakage from subsurface gas pockets.) Virtually all of the Moon’s mountains are walls of craters. Very few high hills or mountains are from volcanic episodes, since the Moon has no tectonic plates; no mountains were caused by plate movement. The Moon is mostly covered with silicon dioxide, magnesium, calcium, glass and dust, which form a layer called the lunar regolith, ranging in depth from 5 to 50 feet. It is created by the smashing of the surface that result in debris from the impacts of meteorites and micrometeorites being strewn over the surface. When brought back to earth and studied, scientists said it had the scent of gunpowder. The crust is made of 45% oxygen, 21% silicon, 6% magnesium, 13% iron, 8% calcium and 7% aluminum. The mantle: underneath is made up of olivine, orthopyroxen and clinopyroxen. The core of the Moon is only 255 miles in diameter and seems to be made of partly molten iron and nickel. Some of the basalts on the surface also contain titanium. The Moon is the second least dense moon in the solar system. (Only Io is less dense.) The Moon has a magnetic field that is much less potent than the one form emanating from Earth. The moon looks a little beat up! In a way it is just that. It has small craters called craterlets, larger craters, some extremely large craters more than a hundred miles across, called “walled plains”. Most of these craters were the result of meteor hits.

The larger pieces of material ejected by these collisions caused more craters to be formed. Smaller particles blasted out, called “rays”, formed patterns that stretch out for hundreds of kilometers. The far side of the moon looks far different from that facing the earth. It does not have large maria, but it does have craters and highlands. The Moon, (La “Luna” in Spanish), is being hit constantly by space debris. With no atmosphere to protect it, the surface is the surface is bombarded by large as well as sand-sized rocks, small meteors called “micrometeorites” they hit the moon at speeds up to 70,000 miles per hour. This makes the moon’s surface a very dangerous place for humans. A small grain could go right through the body of an exploring astronaut!

Did you know?

- The Moon has a synchronized rotation. A moon day rotation equals the same amount of time it takes the Moon to go around the Earth (27.3 days). Therefore, we can only see one side of the Moon at any given time.
- When seen on Earth, the Moon is 25,000 times brighter than the nearest star, other than our Sun. But it only reflects 11% of the sunlight shown on it.

- ***Why can we see the outline of the dark part of the moon?***

There are two main reasons. The dark part of the moon is merely the lunar night, that part of the moon that is shaded from the sun by the moon itself, and which marches slowly across the lunar surface as it revolves in lock step with its orbit around the earth.

We see the daylight part of the moon because a fraction of the sunlight striking it is reflected back through space to us. We can also (often, but not always) just barely see the nighttime part because a fraction of the sunlight striking the Earth reflects back through space to strike the moon, and then is reflected back again to us.

Obviously, this presents some timing problems. Reflected earthshine is necessarily dim. In fact, it's not much above the limits of healthy human eyes to detect under the best of circumstances.

It's brightest when the Moon is near perigee (closest in its orbit to Earth) at the same time it's near to being a new moon, but not so near as to be too close to the sun for us to observe.

At this time of month, we see only a sliver of the lunar day, and someone on the moon will see only a sliver of Earth's night. But…when the moon is fully new and a lunar observer will see a fully "full Earth" it's also not visible for much, if any, of the night because it's so near the sun.

But when the timing is right, when a sliver of crescent moon is near the horizon, we can often see the earthshine:

Figure 19. Day light part of the moon

Figure 20. Dark part of the moon

Though photographers generally overexpose the phenomenon (as here) to make it easier to see.

The other reason, of course, is that the mass of the moon blocks our view of any stars, nebulea, and interplanetary dust behind it.

To the extent the “edge” sometimes seems brighter, that’s an optical illusion arising from our brains penchant for detective edges.

Therefore the 'dark side' of the Moon refers to the hemisphere of the Moon that is facing away from the Earth. In reality it is no darker than any other part of the Moon's surface as sunlight does in fact fall equally on all sides of the Moon.

Lunar Eclipse

During a lunar eclipse, Earth gets in the way of the Sun's light hitting the Moon. That means that during the night, a full moon fades away as Earth's shadow covers it up.

The Moon can also look reddish because Earth's atmosphere absorbs the other colors while it bends some sunlight toward the Moon. Sunlight bending through the atmosphere and absorbing other colors is also why sunsets are orange and red.

During a total lunar eclipse, the Moon is shining from all the sunrises and sunsets occurring on Earth! It's easy to get these two types of eclipses mixed up. An easy way to remember the difference is in the name. The name tells you what gets darker when the eclipse happens. In a solar eclipse, the Sun gets darker. In a lunar eclipse, the Moon gets darker.

3.2 The sun

What is the Sun? Why does the Sun shine? Is it just a ball of burning gas? To us on Earth, it is much more than that; it is an anchor and protector, a heater and source of constant energy. It is dangerous and, at the same time, life providing. It is the center of our solar system. It may prove to be the instrument of doom to our Earth. The Sun is huge. It is the most dominant object in our solar system.

About 99.8% of all the mass of our solar system is in the Sun. If one adds up all the planets, moons, asteroids, comets and dust in our system, the total would equal little more than 1% of the Sun. It is not a huge star. After all, the largest stars can be as much as 1,000 times larger than ours. But the Sun is more massive and brighter than 95% of the stars in our galaxy. The Sun sends out lots of energy. But what kind energy does it emit? Most of it is light (photons) and infrared rays. The infrared rays are not only seen but are also felt. We call it heat. These are forms of electromagnetic radiation. The Sun is very dangerous. Not only does it send out light, heat and radio waves, but dangerous ultraviolet rays, gamma and X rays emitted from it would kill us if it were not for the protection of our atmosphere. The Sun is hot, so hot that it can burn our skin from 93,000,000 miles away! It is a blazing nuclear furnace. Not only is it hot, but it shoots out flames for more than two hundred thousand miles before pulling back to the Sun’s fiery surface. The Sun produces light. It creates photons that speed out beyond our solar system, even beyond our galaxy. Some of these photons have now traveled nearly 5 billion years, moving at 186,000 miles per second. Someone far out in the Universe could be just now receiving this light message. It is the story of the beginning of our solar system and of the star that rules it. It pulls in debris that could otherwise hit circling objects. Our star keeps us from wandering away and smashing into other objects. The Sun spins, just as other large bodies in space. It takes the star’s equator about 25 days to rotate. The upper and lower regions take about 28 earth days for a complete turn. Why? Because the object is made of gas is not a solid. The Sun is violent. It does not have a stable surface area. Portions as big as Texas come to the surface, then cool and disappear in less than 5 minutes. Solar storms and explosions push out flames and winds that contain cosmic particles, known as solar cosmic rays that have effects for hundreds of millions of miles. The rays made up of mostly ejected protons, have some heavier nuclei and electrons.

These rays can cause great harm to space travelers, probes and satellites. They cannot enter the earth's protective atmosphere but can create a magnetic storm when colliding with the upper atmosphere. This may lead to interference or disruptions in our electrical power grids and communications. More than 70 elements (atoms) can be found in the Sun. The main ingredients are hydrogen (72%) and helium (26%); the core is thought to be 38% helium. The Sun orbits the center of our galaxy every 250 million earth years. Our Sun is known as a "population one", star. There are three generations of stars, "population ones" being the youngest generation. They have the highest amounts of helium and heavier elements inside them. The Sun is a G-type main-sequence star that constitutes about 99.86% of the mass of the Solar System. The Sun has an absolute magnitude of +4.83, estimated to be brighter than about 85% of the stars in the Milky Way, most of which are red dwarfs. The Sun is a Population I, or heavy-element-rich, star. The formation of the Sun may have been triggered by shockwaves from one or more nearby supernovae. This is suggested by a high abundance of heavy elements in the Solar System, such as gold and uranium, relative to the abundances of these elements in so-called Population II, heavy-element-poor, stars. The heavy elements could most plausibly have been produced by endothermic nuclear reactions during a supernova, or by transmutation through neutron absorption within a massive second-generation star.

The Sun is by far the brightest object in the Earth's sky, with an apparent magnitude of −26.74. This is about 13 billion times brighter than the next brightest star, Sirius, which has an apparent magnitude of −1.46.

One astronomical unit (about 150,000,000 km; 93,000,000 mi) is defined as the mean distance of the Sun's center to Earth's center, though the distance varies as Earth moves from perihelion in January to aphelion in July. The distances can vary between 147,098,074 km (perihelion) and 152,097,701 km (aphelion), and extreme values can range from 147,083,346 km to 152,112,126 km. At its average distance, light travels from the Sun's horizon to Earth's horizon in about 8 minutes and 19 seconds, while light from the closest points of the Sun and Earth takes about two seconds less. The energy of this sunlight supports almost all life on Earth by photosynthesis, and drives Earth's climate and weather.

The Sun does not have a definite boundary, but its density decreases exponentially with increasing height above the photosphere. For the purpose of measurement, the Sun's radius is considered to be the distance from its center to the edge of the photosphere, the apparent visible surface of the Sun. By this measure, the Sun is a near-perfect sphere with an oblations estimated at 9 millionths which means that its polar diameter differs from its equatorial diameter by only 10 kilometers (6.2 mi). The tidal effect of the planets is weak and does not significantly affect the shape of the Sun. The Sun rotates faster at its equator than at its poles. This differential rotation is caused by convective motion due to heat transport and the Coriolis force due to the Sun's rotation. In a frame of reference defined by the stars, the rotational period is approximately 25.6 days at the equator and 33.5 days at the poles. Viewed from Earth as it orbits the Sun, the apparent rotational period of the Sun at its equator is about 28 days. Viewed from a vantage point above its north pole, the Sun rotates counterclockwise around its axis of spin.

The Sun is the star at the center of the Solar System. It is a nearly perfect ball of hot plasma, heated to incandescence by nuclear fusion reactions in its core, radiating the energy mainly as visible light, ultraviolet light, and infrared radiation.

It is by far the most important source of energy for life on Earth. Its diameter is about 1.39 million kilometers (864,000 miles), or 109 times that of Earth. Its mass is about 330,000 times that of Earth, and it accounts for about 99.86% of the total mass of the Solar System. Roughly three quarters of the Sun's mass consists of hydrogen (~73%); the rest is mostly helium (~25%), with much smaller quantities of heavier elements, including oxygen, carbon, neon and iron.

According to its spectral class, the Sun is a G-type main-sequence star (G2V). As such, it is informally, and not completely accurately, referred to as a yellow dwarf (its light is closer to white than yellow). It formed approximately 4.6 billion years ago from the gravitational collapse of matter within a region of a large molecular cloud. Most of this matter gathered in the center, whereas the rest flattened into an orbiting disk that became the Solar System. The central mass became so hot and dense that it eventually initiated nuclear fusion in its core. It is thought that almost all stars form by this process.

The Sun's core fuses about 600 million tons of hydrogen into helium every second, converting 4 million tons of matter into energy every second as a result. This energy, which can take between 10,000 and 170,000 years to escape the core, is the source of the Sun's light and heat. When hydrogen fusion in its core has diminished to the point at which the Sun is no longer in hydrostatic equilibrium, its core will undergo a marked increase in density and temperature while its outer layers expand, eventually transforming the Sun into a red giant. It is calculated that the Sun will become sufficiently large to engulf the current orbits of Mercury and Venus, and render Earth uninhabitable – but not for about five billion years. After this, it will shed its outer layers and become a dense type of cooling star known as a white dwarf, and no longer produce energy by fusion, but still glow and give off heat from its previous fusion.

The enormous effect of the Sun on Earth has been recognized since prehistoric times. The Sun was thought of by some cultures as a deity. The synodic rotation of Earth and its orbit around the Sun are the basis of some solar calendars. The predominant calendar in use today is the Gregorian calendar which is based upon the standard 16th Century interpretation that the Sun's observed movement is primarily due to it actually moving.

3.2.1 The Structure of the Sun

The structure of the Sun contains the following layers:

- **Core –** the innermost 20–25% of the Sun's radius, where temperature and pressure are sufficient for nuclear fusion to occur. Hydrogen fuses into helium (which cannot itself be fused at this point in the Sun's life). The fusion process releases energy, and the core gradually becomes enriched in helium. The core of the Sun extends from the center to about 20–25% of the solar radius. It has a density of up to 150 g/cm3 (about 150 times the density of water) and a temperature of close to 15.7 million kelvins (K). By contrast, the Sun's surface temperature is approximately 5800 K. Through most of the Sun's life, energy has been produced by nuclear fusion in the core region through a series of nuclear reactions called the p–p (proton–proton) chain; this process converts hydrogen into helium. Only 0.8% of the energy generated in the Sun comes from another sequence of fusion reactions called the CNO cycle, though this proportion is expected to increase as the Sun becomes older.

The core is the only region in the Sun that produces an appreciable amount of thermal energy through fusion; 99% of the power is generated within 24% of the Sun's radius, and by 30% of the radius, fusion has stopped nearly entirely. The remainder of the Sun is heated by this energy as it is transferred outwards through many successive layers, finally to the solar photosphere where it escapes into space through radiation (photons) or advection (massive particles).

- **Radiative zone** – Convection cannot occur until much nearer the surface of the Sun. Therefore, between about 20–25% of the radius, and 70% of the radius, there is a "radiative zone" in which energy transfer occurs by means of radiation (photons) rather than by convection. From the core out to about 0.7 solar radii, thermal radiation is the primary means of energy transfer. The temperature drops from approximately 7 million to 2 million kelvins with increasing distance from the core. This temperature gradient is less than the value of the adiabatic lapse rate and hence cannot drive convection, which explains why the transfer of energy through this zone is by radiation instead of thermal convection. Ions of hydrogen and helium emit photons, which travel only a brief distance before being reabsorbed by other ions. The density drops a hundredfold (from 20 g/cm3 to 0.2 g/cm3) between 0.25 solar radii and 0.7 radii, the top of the radiative zone.
- **Tach cline** – the boundary region between the radiative and convective zones. The radiative zone and the convective zone are separated by a transition layer, the tach cline. This is a region where the sharp regime change between the uniform rotation of the radiative zone and the differential rotation of the convection zone results in a large shear between the two—a condition where successive horizontal layers slide past one another. Presently, it is

hypothesized (see Solar dynamo) that a magnetic dynamo within this layer generates the Sun's magnetic field

- **Convective zone** – Between about 70% of the Sun's radius and a point close to the visible surface, the Sun is cool and diffuse enough for convection to occur, and this becomes the primary means of outward heat transfer, similar to weather cells which form in the earth's atmosphere.

Because the Sun is a gaseous object, it does not have a clearly defined surface; its visible parts are usually divided into a "photosphere" and "atmosphere": The Sun's convection zone extends from 0.7 solar radii (500,000 km) to near the surface. In this layer, the solar plasma is not dense enough or hot enough to transfer the heat energy of the interior outward via radiation. Instead, the density of the plasma is low enough to allow convective currents to develop and move the Sun's energy outward towards its surface. Material heated at the tach cline picks up heat and expands, thereby reducing its density and allowing it to rise. As a result, an orderly motion of the mass develops into thermal cells that carry the majority of the heat outward to the Sun's photosphere above. Once the material diffusively and radioactively cools just beneath the photosphere surface, its density increases, and it sinks to the base of the convection zone, where it again picks up heat from the top of the radiative zone and the convective cycle continues. At the photosphere, the temperature has dropped to 5,700 K and the density to only 0.2 g/m3 (about 1/10,000 the density of air at sea level).

The thermal columns of the convection zone form an imprint on the surface of the Sun giving it a granular appearance called the solar granulation at the smallest scale and supergranulation at larger scales. Turbulent convection in this outer part of the solar interior sustains "small-scale" dynamo action over the near-surface volume of the Sun. The Sun's thermal columns are Bernard cells and take the shape of roughly hexagonal prisms.

- **Photosphere** – the deepest part of the Sun which we can directly observe with visible light. The visible surface of the Sun, the photosphere, is the layer below which the Sun becomes opaque to visible light. Photons produced in this layer escape the Sun through the transparent solar atmosphere above it and become solar radiation, sunlight. The change in opacity is due to the decreasing amount of H− ions, which absorb visible light easily. Conversely, the visible light we see is produced as electrons react with hydrogen atoms to produce H− ions. The photosphere is tens to hundreds of kilometers thick, and is slightly less opaque than air on Earth. Because the upper part of the photosphere is cooler than the lower part, an image of the Sun appears brighter in the center than on the edge or limb of the solar disk, in a phenomenon known as limb darkening. The spectrum of sunlight has approximately the spectrum of a black-body radiating at 5,777 K (5,504 °C; 9,939 °F), interspersed with atomic absorption lines from the tenuous layers above the photosphere. The photosphere has a particle density of ~1023 m−3 (about 0.37% of the particle number per volume of Earth's atmosphere at sea level). The photosphere is not fully ionized—the extent of ionization is about 3%, leaving almost all of the hydrogen in atomic form.

- **Atmosphere** – a gaseous "halo" surrounding the Sun, comprising the chromosphere, solar transition region, corona and heliosphere. These can be seen when the main part of the Sun is hidden, for example, during a solar eclipse.

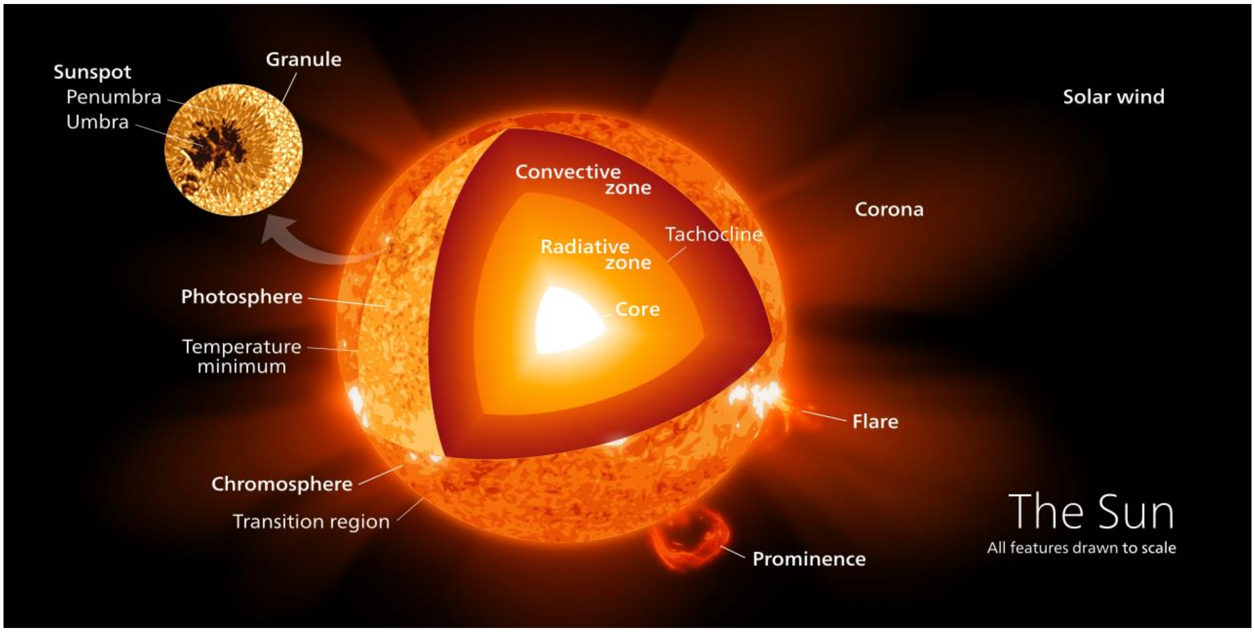


Figure 21. Layers of the sun

- **Facts about the Sun**
  - Average distance from Earth: 93 million miles (150 million kilometers)
  - Radius: 418,000 miles (696,000 kilometers)
  - Mass: 1.99 x 1030 kilograms (330,000 Earth masses)
  - Makeup (by mass): 74 percent hydrogen, 25 percent helium, 1 percent other elements
  - Average temperature: 5,800 degrees Kelvin (surface), 15.5 million degrees Kelvin (core)
  - Average density: 1.41 grams per cm3
  - Volume: 1.4 x 1027 cubic meters
  - Rotational period: 25 days (center) to 35 days (poles)

- Distance from center of Milky Way: 25,000 light years
- Orbital speed/period: 138 miles per second/200 million years

3.3 Solar eclipse

A solar eclipse occurs when a portion of the Earth is engulfed in a shadow cast by the Moon which fully or partially blocks sunlight. This occurs when the Sun, Moon and Earth are aligned. Such alignment coincides with a new moon (syzygy) indicating the Moon is closest to the ecliptic plane. In a total eclipse, the disk of the Sun is fully obscured by the Moon. In partial and annular eclipses, only part of the Sun is obscured.

If the Moon were in a perfectly circular orbit, a little closer to the Earth, and in the same orbital plane, there would be total solar eclipses every new moon. However, since the Moon's orbit is tilted at more than 5 degrees to the Earth's orbit around the Sun, its shadow usually misses Earth. A solar eclipse can occur only when the Moon is close enough to the ecliptic plane during a new moon. Special conditions must occur for the two events to coincide because the Moon's orbit crosses the ecliptic at its orbital nodes twice every draconic month (27.212220 days) while a new moon occurs one every synodic month (29.53059 days). Solar (and lunar) eclipses therefore happen only during eclipse seasons resulting in at least two, and up to five, solar eclipses each year; no more than two of which can be total eclipses.

Total eclipses are rare because the timing of the new moon within the eclipse season needs to be more exact for an alignment between the observer (on Earth) and the centers of the Sun and Moon.

In addition, the elliptical orbit of the Moon often takes it far enough away from Earth that it's apparent size is not large enough to block the Sun entirely. Total solar eclipses are rare at any particular location because totality exists only along a narrow path on the Earth's surface traced by the Moon's full shadow or umbra.

An eclipse is a natural phenomenon. However, in some ancient and modern cultures, solar eclipses were attributed to supernatural causes or regarded as bad omens. A total solar eclipse can be frightening to people who are unaware of its astronomical explanation, as the Sun seems to disappear during the day and the sky darkens in a matter of minutes.

Since looking directly at the Sun can lead to permanent eye damage or blindness, special eye protection or indirect viewing techniques are used when viewing a solar eclipse. It is safe to view only the total phase of a total solar eclipse with the unaided eye and without protection. This practice must be undertaken carefully, though the extreme fading of the solar brightness by a factor of over 100 times in the last minute before totality makes it obvious when totality has begun and it is for that extreme variation and the view of the solar corona that leads people to travel to the zone of totality (the partial phases span over two hours while the total phase can last only a maximum of 7.5 minutes for any one location and is usually less). People referred to as eclipse chasers or umbraphiles will travel even to remote locations to observe or witness predicted central.

There are four types of solar eclipses:

1. Total eclipse

2. An annular eclipse

3. Hybrid eclipse

4. Partial eclipse

1. Total eclipse

Occurs when the dark silhouette of the Moon completely obscures the intensely bright light of the Sun, allowing the much fainter solar corona to be visible. During any one eclipse, totality occurs at best only in a narrow track on the surface of Earth. This narrow track is called the path of totality solar eclipses.

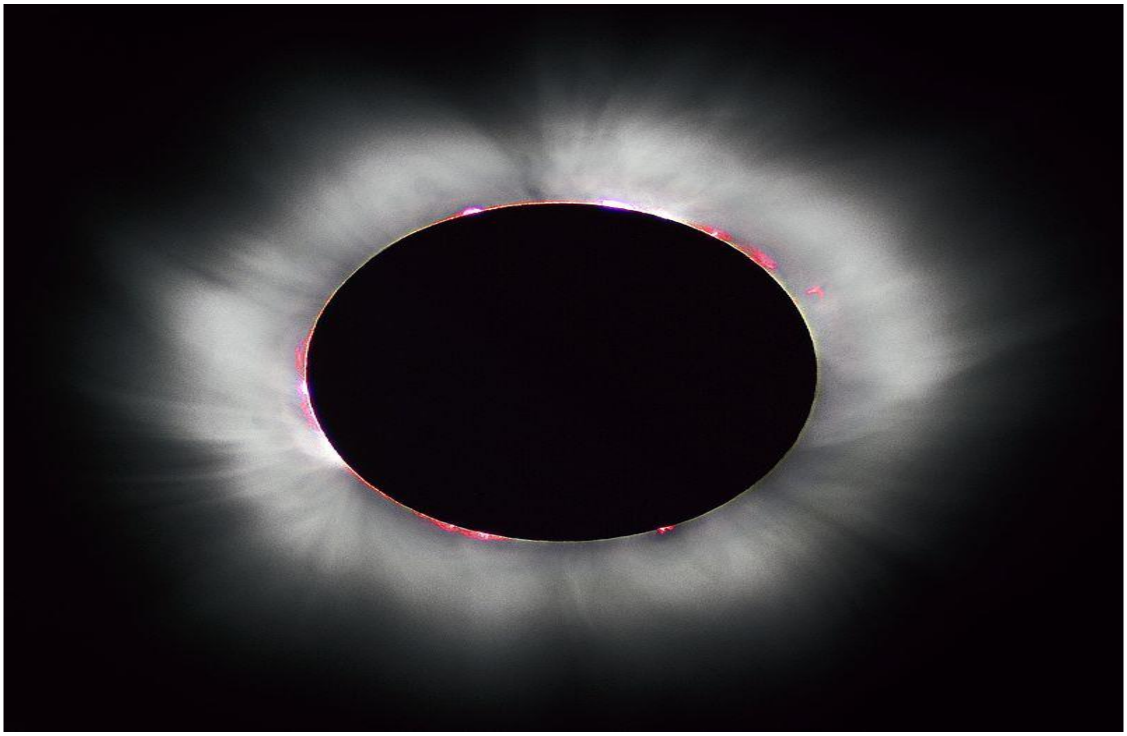


Figure.22 A total solar eclipse occurs when the Moon completely covers the Sun's disk, as seen in this 1999 solar eclipse. Solar prominences can be seen along the limb (in red) as well as extensive coronal filaments.

2. An annular eclipse

Occurs when the Sun and Moon are exactly in line with the Earth, but the apparent size of the Moon is smaller than that of the Sun. Hence the Sun appears as a very bright ring, or annulus, surrounding the dark disk of the Moon.

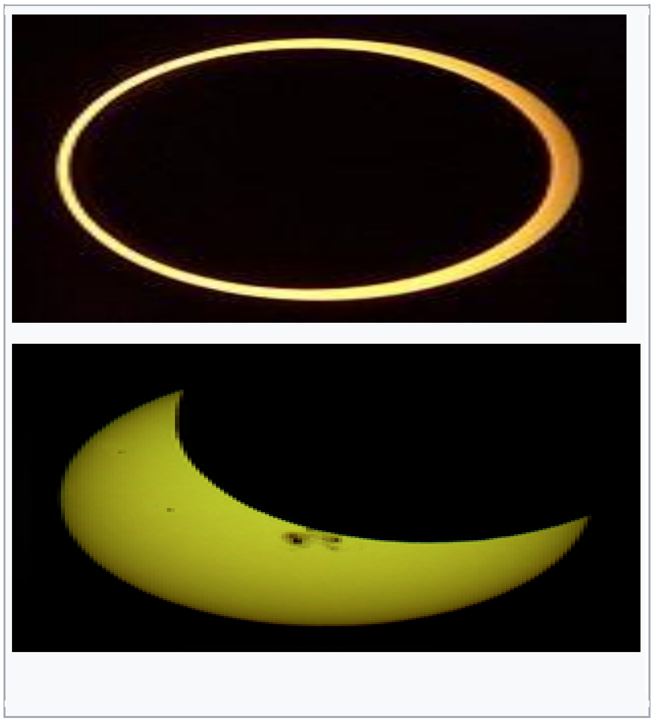


Figure 23. An annular solar eclipse (top) and partial solar eclipse (bottom)

3. **A hybrid eclipse**

Also called annular/total eclipse, shifts between a total and annular eclipse. At certain points on the surface of Earth, it appears as a total eclipse, whereas at other points it appears as annular. Hybrid eclipses are comparatively rare.

4. A partial eclipse

Occurs when the Sun and Moon are not exactly in line with the Earth and the Moon only partially obscures the Sun. This phenomenon can usually be seen from a large part of the Earth outside of the track of an annular or total eclipse. However, some eclipses can be seen only as a partial eclipse, because the umbra passes above the Earth's Polar Regions and never intersects the Earth's surface. Partial eclipses are virtually unnoticeable in terms of the Sun's brightness, as it takes well over 90% coverage to notice any darkening at all. Even at 99%, it would be no darker than civil twilight. Of course, partial eclipses (and partial stages of other eclipses) can be observed if one is viewing the Sun through a darkening filter (which should always be used for safety).

Summary

- Moon a non-luminous object i.e has no its own source of light and that is why its heat energy is less than that of the sun. When the **Moon is** close to the Sun in the sky, the Sun is too **bright** for us to see as it moves away from the Sun in the sky each day, we see it emerge as a thin crescent. This called the New **Moon**. If you look closely, you can see the faint glow of the "**dark**" part of the **Moon**.
- ***Why can we see the outline of the dark part of the moon?***

There are two main reasons. The dark part of the moon is merely the lunar night, that part of the moon that is shaded from the sun by the moon itself, and which marches slowly across the lunar surface as it revolves in lock step with its orbit around the earth.

We see the daylight part of the moon because a fraction of the sunlight striking it is reflected back through space to us. We can also (often, but not always) just barely see the nighttime part because a fraction of the sunlight striking the Earth reflects back through space to strike the moon, and then is reflected back again to us.

The sun is composed of gas. It has no solid surface. However, it still has a defined structure. The three major structural areas of the sun are shown in the upper half of **Figure 21**. They include:

- **Core--** The center of the sun, comprising 25 percent of its radius.
- **Radiative zone** --The section immediately surrounding the core, comprising 45 percent of its radius.
- **Convective zone--** The outermost ring of the sun, comprising the 30 percent of its radius.

Above the surface of the sun is its atmosphere, which consists of three parts, as shown above in the lower half of **Figure 21**:

- **Photosphere** -- The innermost part of the sun's atmosphere and the only part we can see.
- **Chromosphere** -- The area between the photosphere and the corona; hotter than the photosphere.

Corona -- The extremely hot outermost layer, extending outward several million miles from the chromosphere.

Solar Eclipse

A solar eclipse happens when the Moon gets in the way of the Sun's light and casts its shadow on Earth. That means during the day, the Moon moves over the Sun and it gets dark. Isn't it strange that it gets dark in the middle of the day?

This total eclipse happens about every year and a half somewhere on Earth. A partial eclipse, when the Moon doesn't completely cover the Sun, happens at least twice a year somewhere on Earth.

Review questions

Dear readers, please try to do the following questions.

1. Among Photosphere, Chromosphere and Corona which can be seen by our necked eyes irrespective of eclipses?
2. Describe luminous and non-luminous bodies and list an examples for each.
3. Corona, the outer layer of the sun is very hotter than that of its inner layer, photosphere. What would be the reason for this phenomena?
4. At night time the moon gives us light, so how could it be considered as a non-luminous body?
5. What is an eclipse and how it occurs whether in solar or moon?

CHAPTER FOUR

4. STARS AND THE BIG BANG THEORY

4.1 definitions of stars

A star is a big ball of gas. It is not star-shaped. Stars give off heat and light.

A **star** is an astronomical object consisting of a luminous spheroid of plasma held together by its own gravity. The nearest star to Earth is the Sun. Many other stars are visible to the naked eye at night, but due to their immense distance from Earth they appear as fixed points of light in the sky. The most prominent stars are grouped into constellations and asterisms, and many of the brightest stars have proper names. Astronomers have assembled star catalogues that identify the known stars and provide standardized stellar designations. The observable universe contains an estimated 10^{22} to 10^{24} stars, but most are invisible to the naked eye from Earth, including all individual stars outside our galaxy, the Milky Way.

A star's life begins with the gravitational collapse of a gaseous nebula of material composed primarily of hydrogen, along with helium and trace amounts of heavier elements. The total mass of a star is the main factor that determines its evolution and eventual fate. For most of its active life, a star shines due to thermonuclear fusion of hydrogen into helium in its core, releasing energy that traverses the star's interior and then radiates into outer space. At the end of a star's lifetime, its core becomes a stellar remnant: a white dwarf, a neutron star, or, if it is sufficiently massive, a black hole.

Almost all naturally occurring elements heavier than lithium are created by stellar nucleosynthesis in stars or their remnants. Chemically enriched material is returned to the interstellar medium by stellar mass loss or supernova explosions and then recycled into new stars. Astronomers can determine stellar properties including mass, age, metallicity (chemical composition), variability, distance, and motion through space by carrying out observations of a star's apparent brightness, spectrum, and changes in its position on the sky over time.

Stars can form orbital systems with other astronomical objects, as in the case of planetary systems and star systems with two or more stars. When two such stars have a relatively close orbit, their gravitational interaction can have a significant impact on their evolution. Stars can form part of a much larger gravitationally bound structure, such as a star cluster or a galaxy.

Figure 24. *Stars in the galaxy*

4.2 How is a star made?

Stars are born in nebulas. Nebulas are clouds found in space. They are made of gases and dust.

A star's color tells us how hot or cold it is. The bluish stars are the hottest ones. The reddish stars are the coolest. But they are still very hot!

Stars are the most widely recognized astronomical objects, and represent the most fundamental building blocks of galaxies. The age, distribution, and composition of the stars in a galaxy trace the history, dynamics, and evolution of that galaxy. Moreover, stars are responsible for the manufacture and distribution of heavy elements such as carbon, nitrogen, and oxygen, and their characteristics are intimately tied to the characteristics of the planetary systems that may coalesce about them. Consequently, the study of the birth, life, and death of stars is central to the field of astronomy.

Stars are born within the clouds of dust and scattered throughout most galaxies. A familiar example of such as a dust cloud is the Orion Nebula. Turbulence deep within these clouds gives rise to knots with sufficient mass that the gas and dust can begin to collapse under its own gravitational attraction. As the cloud collapses, the material at the center begins to heat up. Known as a protostar, it is this hot core at the heart of the collapsing cloud that will one day become a star. Three-dimensional computer models of star formation predict that the spinning clouds of collapsing gas and dust may break up into two or three blobs; this would explain why the majority the stars in the Milky Way are paired or in groups of multiple stars. As the cloud collapses, a dense, hot core forms and begins gathering dust and gas. Not all of this material ends up as part of a star — the remaining dust can become planets, asteroids, or comets or may remain as dust.

In some cases, the cloud may not collapse at a steady pace. In January 2004, an amateur astronomer, James McNeil, discovered a small nebula that appeared unexpectedly near the nebula Messier 78, in the constellation of Orion. When observers around the world pointed their instruments at McNeil's Nebula, they found something interesting — its brightness appears to vary. Observations with NASA's Chandra X-ray Observatory provided a likely explanation: the interaction between the young star's magnetic field and the surrounding gas causes episodic increases in brightness.

Stars are huge celestial bodies made mostly of hydrogen and helium that produce light and heat from the churning nuclear forges inside their cores. Aside from our sun, the dots of light we see in the sky are all light-years from Earth. They are the building blocks of galaxies, of which there are billions in the universe. It’s impossible to know how many stars exist, but astronomers estimate that in our Milky Way galaxy alone, there are about 300 billion. The life cycle of a star spans billions of years. As a general rule, the more massive the star, the shorter its life span.

Birth takes place inside hydrogen-based dust clouds called nebulae. Over the course of thousands of years, gravity causes pockets of dense matter inside the nebula to collapse under their own weight. One of these contracting masses of gas, known as a protostar, represents a star’s nascent phase. Because the dust in the nebulae obscures them, protostars can be difficult for astronomers to detect.

As a protostar gets smaller, it spins faster because of the conservation of angular momentum—the same principle that causes a spinning ice skater to accelerate when she pulls in her arms. Increasing pressure creates rising temperatures, and during this time, a star enters what is known as the relatively brief T Tauri phase.

Millions of years later, when the core temperature climbs to about 27 million degrees Fahrenheit (15 million degrees Celsius), nuclear fusion begins, igniting the core and setting off the next—and longest—stage of a star's life, known as its main sequence.

Most of the stars in our galaxy, including the sun, are categorized as main sequence stars. They exist in a stable state of nuclear fusion, converting hydrogen to helium and radiating x-rays. This process emits an enormous amount of energy, keeping the star hot and shining brightly.

Some stars shine more brightly than others. Their brightness is a factor of how much energy they put out–known as luminosity–and how far away from Earth they are. Color can also vary from star to star because their temperatures are not all the same. Hot stars appear white or blue, whereas cooler stars appear to have orange or red hues.

By plotting these and other variables on a graph called the Hertzsprung-Russell diagram, astronomers can classify stars into groups. Along with main sequence and white dwarf stars, other groups include dwarfs, giants, and supergiants. Supergiants may have radii a thousand times larger than that of our own sun.

Stars spend 90 percent of their lives in their main sequence phase. Now around 4.6 billion years old, Earth's sun is considered an average-size yellow dwarf star, and astronomers predict it will remain in its main sequence stage for several billion more years.

As stars move toward the ends of their lives, much of their hydrogen has been converted to helium. Helium sinks to the star's core and raises the star's temperature—causing its outer shell of hot gases to expand. These large, swelling stars are known as red giants. But there are different ways a star's life can end, and its fate depends on how massive the star is.

The red giant phase is actually a prelude to a star shedding its outer layers and becoming a small, dense body called a white dwarf. White dwarfs cool for billions of years. Some, if they exist as part of a binary star system, may gather excess matter from their companion stars until their surfaces explode, triggering a bright nova. Eventually all white dwarfs go dark and cease producing energy. At this point, which scientists have yet to observe, they become known as black dwarfs.

4.3 Big bang

The Big Bang theory developed from observations of the structure of the universe and from theoretical considerations. In 1912, Vesto Slipher measured the first Doppler shift of a "spiral nebula" (spiral nebula is the obsolete term for spiral galaxies), and soon discovered that almost all such nebulae were receding from Earth. He did not grasp the cosmological implications of this fact, and indeed at the time it was highly controversial whether or not these nebulae were "island universes" outside our Milky Way. Ten years later, Alexander Friedmann, a Russian cosmologist and mathematician, derived the Friedmann equations from Einstein field equations, showing that the universe might be expanding in contrast to the static universe model advocated by Albert Einstein at that time.

In 1924, American astronomer Edwin Hubble's measurement of the great distance to the nearest spiral nebulae showed that these systems were indeed other galaxies.

Starting that same year, Hubble painstakingly developed a series of distance indicators, the forerunner of the cosmic distance ladder, using the 100-inch (2.5 m) Hooker telescope at Mount Wilson Observatory. This allowed him to estimate distances to galaxies whose redshifts had already been measured, mostly by Slipher. In 1929, Hubble discovered a correlation between distance and recessional velocity—now known as Hubble's law. By that time, Lemaître had already shown that this was to be expected, given the cosmological principle.

Independently deriving Friedmann's equations in 1927, Georges Lemaître, a Belgian physicist and Roman Catholic priest, proposed that the inferred recession of the nebulae was due to the expansion of the universe. In 1931, Lemaître went further and suggested that the evident expansion of the universe, if projected back in time, meant that the further in the past the smaller the universe was, until at some finite time in the past all the mass of the universe was concentrated into a single point, a "primeval atom" where and when the fabric of time and space came into existence.

In the 1920s and 1930s, almost every major cosmologist preferred an eternal steady-state universe, and several complained that the beginning of time implied by the Big Bang imported religious concepts into physics; this objection was later repeated by supporters of the steady-state theory. This perception was enhanced by the fact that the originator of the Big Bang theory, Lemaître, was a Roman Catholic priest. Arthur Eddington agreed with Aristotle that the universe did not have a beginning in time, *viz*., that matter is eternal. A beginning in time was "repugnant" to him. Lemaître, however, disagreed:

If the world has begun with a single quantum, the notions of space and time would altogether fail to have any meaning at the beginning; they would only begin to have a sensible meaning when the original quantum had been divided into a sufficient number of quanta. If this suggestion is correct, the beginning of the world happened a little before the beginning of space and time.

During the 1930s, other ideas were proposed as non-standard cosmologies to explain Hubble's observations, including the Milne model, the oscillatory universe (originally suggested by Friedmann, but advocated by Albert Einstein and Richard C. Tolman) and Fritz Zwicky's tired light hypothesis.

In 1968 and 1970, Roger Penrose, Stephen Hawking, and George F. R. Ellis published papers where they showed that mathematical singularities were an inevitable initial condition of relativistic models of the Big Bang. Then, from the 1970s to the 1990s, cosmologists worked on characterizing the features of the Big Bang universe and resolving outstanding problems. In 1981, Alan Guth made a breakthrough in theoretical work on resolving certain outstanding theoretical problems in the Big Bang theory with the introduction of an epoch of rapid expansion in the early universe he called "inflation". Meanwhile, during these decades, two questions in observational cosmology that generated much discussion and disagreement were over the precise values of the Hubble Constant[and the matter-density of the universe (before the discovery of dark energy, thought to be the key predictor for the eventual fate of the universe).

In the mid-1990s, observations of certain globular clusters appeared to indicate that they were about 15 billion years old, which conflicted with most then-current estimates of the age of the universe (and indeed with the age measured today).

This issue was later resolved when new computer simulations, which included the effects of mass loss due to stellar winds, indicated a much younger age for globular clusters. While there still remain some questions as to how accurately the ages of the clusters are measured, globular clusters are of interest to cosmology as some of the oldest objects in the universe.

Significant progress in Big Bang cosmology has been made since the late 1990s as a result of advances in telescope technology as well as the analysis of data from satellites such as the Cosmic Background Explorer (COBE), the Hubble Space Telescope and WMAP. Cosmologists now have fairly precise and accurate measurements of many of the parameters of the Big Bang model, and have made the unexpected discovery that the expansion of the universe appears to be accelerating.

The **Big Bang** theory is the prevailing cosmological model explaining the existence of the observable universe from the earliest known periods through its subsequent large-scale evolution. The model describes how the universe expanded from an initial state of high density and temperature, and offers a comprehensive explanation for a broad range of observed phenomena, including the abundance of light elements, the cosmic microwave background (CMB) radiation, and large-scale structure.

Crucially, the theory is compatible with Hubble–Lemaître law—the observation that the farther away a galaxy is, the faster it is moving away from Earth. Extrapolating this cosmic expansion backwards in time using the known laws of physics, the theory describes an increasingly concentrated cosmos preceded by a singularity in which space and time lose meaning (typically named "the Big Bang singularity").

Detailed measurements of the expansion rate of the universe place the Big Bang singularity at around 13.8 billion years ago, which is thus considered the age of the universe.

After its initial expansion, an event that is by itself often called "the Big Bang", the universe cooled sufficiently to allow the formation of subatomic particles, and later atoms. Giant clouds of these primordial elements—mostly hydrogen, with some helium and lithium—later coalesced through gravity, forming early stars and galaxies, the descendants of which are visible today. Besides these primordial building materials, astronomers observe the gravitational effects of an unknown dark matter surrounding galaxies. Most of the gravitational potential in the universe seems to be in this form, and the Big Bang theory and various observations indicate that this excess gravitational potential is not created by baryonic matter, such as normal atoms. Measurements of the redshifts of supernovae indicate that the expansion of the universe is accelerating, an observation attributed to dark energy's existence.

Georges Lemaître first noted in 1927 that an expanding universe could be traced back in time to an originating single point, which he called the "primeval atom". Edwin Hubble confirmed through analysis of galactic redshifts in 1929 that galaxies are indeed drifting apart; this is important observational evidence for an expanding universe. For several decades, the scientific community was divided between supporters of the Big Bang and the rival steady-state model which both offered explanations for the observed expansion, but the steady-state model stipulated an eternal universe in contrast to the Big Bang's finite age.

In 1964, the CMB was discovered, which convinced many cosmologists that the steady-state theory was falsified, since, unlike the steady-state theory, the hot Big Bang predicted a uniform background radiation throughout the universe caused by the high temperatures and densities in the distant past. A wide range of empirical evidence strongly favors the Big Bang, which is now essentially universally accepted.

The Big Bang Theory is an astrophysical model of the universe that can be observed by human senses. The theory gives details about the origins of the universe from its early formations to its modern-day evolutions.

The Big Bang Theory explains how the universe expanded from an initial state of extremely high density and high temperature by offering a detailed explanation of observed phenomena, radiation, an abundance of light elements, and large-scale structures.

The Big Bang Theory is an astrophysical model of the universe that can be observed by human senses. The theory gives details about the origins of the universe from its early formations to its modern-day evolutions.

Figure 25. The explosion of big bang

4.3.1 What is the common misconception about the Big Bang Theory?

The most frequent misunderstanding regarding the Big Bang Theory is that it gives the complete origin of the universe but it does not describe the energy, time, and space involved in the creation of the universe. It only explains how the universe emerged from its initial high-temperature state. It would be false to draw parallels to everyday objects when trying to explain the Big Bang Theory, especially where size is concerned. The theory only describes the size of the observable universe and not the universe as a whole.

Accurate derivation requires the use of general relativity, and while treatment using simpler Doppler Effect arguments gives nearly identical results for nearby galaxies, interpreting the redshift of more distant galaxies as due to the simplest Doppler redshift treatments can cause confusion.

The Big Bang theory is the prevailing cosmological model explaining the existence of the observable universe from the earliest known periods through its subsequent large-scale evolution. The model describes how the universe expanded from an initial state of high density and temperature, and offers a comprehensive explanation for a broad range of observed phenomena.

The Big Bang Theory is a very important concept for the UPSC exam science and technology segment. A lot of research is going on in this field by both Indian and global scientists, to find out exactly how the universe began billions of years ago.

Massive stars eschew this evolutionary path and instead go out with a bang—detonating as supernovae. While they may appear to be swelling red giants on the outside, their cores are actually contracting, eventually becoming so dense that they collapse, causing the star to explode.

These catastrophic bursts leave behind a small core that may become a neutron star or even, if the remnant is massive enough, a black hole.

Because certain supernovae have a predictable pattern of destruction and resulting luminosity, astronomers are able to use them as “standard candles,” or astronomical measuring tools, to help them measure distances in the universe and calculate its rate of expansion. In the year 1979, Alan Guth introduced the idea that, in the very first seconds of the Universe's existence (before 10-32 s), it was very hot and dense, so it would have undergone extreme expansion during this period.

After these initial phases, the Universe slowed down its expansion speed and began to cool down to its current temperature, which is around 3K (three Kelvin).

Galaxies as we know them today began to form 109 years after the Big Bang and life on planet Earth emerged around 1010 years after the beginning of the Universe.

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho}{3} - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}$$

The equation above is considered one of the most important equations in cosmology. The left side tells us how the Universe expands or contracts as a function of time.

On the other side is everything else, that is, all matter, radiation and all other forms of energy that make up the Universe.

The term termo in the equation is a cosmological constant that can be a property of space or a form of energy.

The Universe was in a singularity condition "before" the Big Bang (notice the quotes), meaning that it was infinitesimally small. All distance separations were zero, meaning that there was no space. Since there was no space in the Universe's singularity condition, it is impossible to accurately express how small it was. As a consequence of the absence of space, there was no time, either. The law of conservation of energy prohibits the spontaneous formation from nothing. You cannot create or destroy energy or momentum.

There is a finite amount of energy (matter and energy are two forms of the same thing by $E=mc^2$) in the Universe that is always the same. If the Big Bang theory proposed that everything was created in an explosion, it would violate the most fundamental law of physics. The only reason science can even exist is if we make the assumption that the laws of physics are constant anywhere and everywhere at all times, and this is a quite reasonable assumption. There's no evidence of a period when the laws of physics were not in effect. However, it is impossible to say for sure, because our current physics does not take us back past 10^{-43}s after the big bang. In that small amount of time, virtually anything can happen. No one really knows what caused the explosion, but that's certainly no reason to defer to some sort of divine intervention. The early Universe could have existed as a very unstable, very massive particle that underwent its decay with the Big Bang as its mechanism. The other common question that everyone has is, "Where did the mass in the Universe come from?" The answer, simply, is nowhere. The mass in the Universe has always existed. General relativity postulates that the Big Bang would have begun time because, in a singularity state (like what the Universe was in just before the Big Bang), there is no time.

The Universe has, quite literally, existed for all time. The relativity of time and its consequences is by far one of the most difficult concepts for the scientific layman to grasp. Most people say that they know time is relative, but they have no idea what that implies for the early Universe. The relativity of time means that there was no "before" the Big Bang. Time is not a straight line concept. Time on the sun passes at a different rate than it does here on Earth due to the difference in the gravitational disturbance that it creates. There is a reason why we call it "spacetime." Space and time are interconnected. Since we know that mass creates warps in space, it creates warps in time, as well. There is no "absolute time." In other words, there is no "correct" timeline. As such, there is no correct spot to watch an event take place from.

So, in a way, Einstein's Relativity disallows for the existence of God. If there was an omniscient God, he'd be in an absolute frame of reference, on an absolute timeline. According to Relativity, this cannot exist. Time's existence really can't even be accurately described. Time simply exists, as does the universe. There was no point where the Universe's mass just popped into existence. The Universe is infinitely existing. It has always existed, and will always exist.

SUMMARY

A star is a big ball of gas. It is not star-shaped. Stars give off heat and light.
A **star** is an astronomical object consisting of a luminous spheroid of plasma held together by its own gravity. The nearest star to Earth is the Sun. Many other stars are visible to the naked eye at night, but due to their immense distance from Earth they appear as fixed points of light in the sky. The most prominent stars are grouped into constellations and asterisms, and many of the brightest stars have proper names. Astronomers have assembled star catalogues that identify the known stars and provide standardized stellar designations.

The observable universe contains an estimated 10^{22} to 10^{24} stars, but most are invisible to the naked eye from Earth, including all individual stars outside our galaxy, the Milky Way.

A star's life begins with the gravitational collapse of a gaseous nebula of material composed primarily of hydrogen, along with helium and trace amounts of heavier elements. The total mass of a star is the main factor that determines its evolution and eventual fate. For most of its active life, a star shines due to thermonuclear fusion of hydrogen into helium in its core, releasing energy that traverses the star's interior and then radiates into outer space.

At the end of a star's lifetime, its core becomes a stellar remnant: a white dwarf, a neutron star, or, if it is sufficiently massive, a black hole. Stars can form orbital systems with other astronomical objects, as in the case of planetary systems and star systems with two or more stars. When two such stars have a relatively close orbit, their gravitational interaction can have a significant impact on their evolution. Stars can form part of a much larger gravitationally bound structure, such as a star cluster or a galaxy. Stars are born in nebulas. Nebulas are clouds found in space. They are made of gases and dust.

A star's color tells us how hot or cold it is. The bluish stars are the hottest ones. The reddish stars are the coolest. But they are still very hot!

Stars are the most widely recognized astronomical objects, and represent the most fundamental building blocks of galaxies. The age, distribution, and composition of the stars in a galaxy trace the history, dynamics, and evolution of that galaxy.

Moreover, stars are responsible for the manufacture and distribution of heavy elements such as carbon, nitrogen, and oxygen, and their characteristics are intimately tied to the characteristics of the planetary systems that may coalesce about them. Consequently, the study of the birth, life, and death of stars is central to the field of astronomy.

Stars are born within the clouds of dust and scattered throughout most galaxies. A familiar example of such as a dust cloud is the Orion Nebula. Turbulence deep within these clouds gives rise to knots with sufficient mass that the gas and dust can begin to collapse under its own gravitational attraction. As the cloud collapses, the material at the center begins to heat up. The Big Bang theory developed from observations of the structure of the universe and from theoretical considerations. In 1912, Vesto Slipher measured the first Doppler shift of a "spiral nebula" (spiral nebula is the obsolete term for spiral galaxies), and soon discovered that almost all such nebulae were receding from Earth. He did not grasp the cosmological implications of this fact, and indeed at the time it was highly controversial whether or not these nebulae were "island universes" outside our Milky Way. Ten years later, Alexander Friedmann, a Russian cosmologist and mathematician, derived the Friedmann equations from Einstein field equations, showing that the universe might be expanding in contrast to the static universe model advocated by Albert Einstein at that time.

In 1924, American astronomer Edwin Hubble's measurement of the great distance to the nearest spiral nebulae showed that these systems were indeed other galaxies. Starting that same year, Hubble painstakingly developed a series of distance indicators, the forerunner of the cosmic distance ladder, using the 100-inch (2.5 m) Hooker telescope at Mount Wilson Observatory.

This allowed him to estimate distances to galaxies whose redshifts had already been measured, mostly by Slipher. The **Big Bang** theory is the prevailing cosmological model explaining the existence of the observable universe from the earliest known periods through its subsequent large-scale evolution. The model describes how the universe expanded from an initial state of high density and temperature, and offers a comprehensive explanation for a broad range of observed phenomena, including the abundance of light elements, the cosmic microwave background (CMB) radiation, and large-scale structure. The Big Bang Theory explains how the universe expanded from an initial state of extremely high density and high temperature by offering a detailed explanation of observed phenomena, radiation, an abundance of light elements, and large-scale structures.

The Big Bang Theory is an astrophysical model of the universe that can be observed by human senses. The theory gives details about the origins of the universe from its early formations to its modern-day evolutions. The most frequent misunderstanding regarding the Big Bang Theory is that it gives the complete origin of the universe but it does not describe the energy, time, and space involved in the creation of the universe. It only explains how the universe emerged from its initial high-temperature state. It would be false to draw parallels to everyday objects when trying to explain the Big Bang Theory, especially where size is concerned. The theory only describes the size of the observable universe and not the universe as a whole. The Universe was in a singularity condition "before" the Big Bang (notice the quotes), meaning that it was infinitesimally small. All distance separations were zero, meaning that there was no space. Since there was no space in the Universe's singularity condition, it is impossible to accurately express how small it was.

As a consequence of the absence of space, there was no time, either. The law of conservation of energy prohibits the spontaneous formation from nothing. You cannot create or destroy energy or momentum. There is a finite amount of energy (matter and energy are two forms of the same thing by $E=mc^2$) in the Universe that is always the same. If the Big Bang theory proposed that everything was created in an explosion, it would violate the most fundamental law of physics.

REVIEW QUESTIONS

Dear readers, please do the following questions!

1. How big was the Universe at the beginning?
2. Did the Big Bang create everything in the Universe?
3. What caused the explosion in the Big Bang? Something must have created all that matter and energy and caused it to explode.
4. How stars are formed and list the basic types of stars?
5. Unlike moon stars are luminous bodies. What are the reasons behind this reality?
6. What are the contributions of big bang theory in formation of planets, universe and the like?

FOR FURTHER EXPLORATION, PLEASE REFERE THE FOLLOWING!

- Books Miller, Ron, and William Hartmann. The Grand Tour: A Traveler's Guide to the Solar System. 3rd ed. Workman, 2005. This volume for beginners is a colorfully illustrated voyage among the planets.
- Sagan, Carl. Cosmos. Ballantine, 2013 [1980]. This tome presents a classic overview of astronomy by an astronomer who had a true gift for explaining things clearly. (You can also check out Sagan's television series Cosmos: A Personal Voyage and Neil DeGrasse Tyson's current series Cosmos: A Spacetime Odyssey.) Tyson, Neil DeGrasse, and Don Goldsmith. Origins:
- Fourteen Billion Years of Cosmic Evolution. Norton, 2004. This Chapter 1 Science and the Universe: A Brief Tour 29 book provides a guided tour through the beginnings of the universe, galaxies, stars, planets, and life.