

Chandrasekhar limit; cepheid variables
gravitational lensing; x-ray Astronomy

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Dear Students,

"EARN WHILE YOU LEARN"

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Chapter-1

INTRODUCTION

ASTRONOMY AND ASTROPHYSICS

Our C.V.Raman, spoke like this about Astronomy “**Let me say here and now my belief that there is no science so grand, so elevating so intensily interesting as Astronomy**”. Behind the transient and confused pagent of nature there is a permanent and ordered reality. Thus order was first revealed to men on a vast and spectacular scale in the sky. What mysteries will be revealed as human turn their attention to the vastness of space? Our planet Earth is just a little speck in the infinity of space. Will ever more powerful telescopes provide answers to the origins of the Cosmos? How big is the universe? How far can we see into space? Will the huge radio aerials now scanning the skies find evidence of extra terrestrial civilizations? Will the Milky Way and the Andromeda galaxies collide in the distant future? Will the universe eventually become uninhabitable? Are there other universe over there? Is the universe controlled by dark forces? It all started with a big bang. Will it end by a by crunch? [See Figure 1.1].

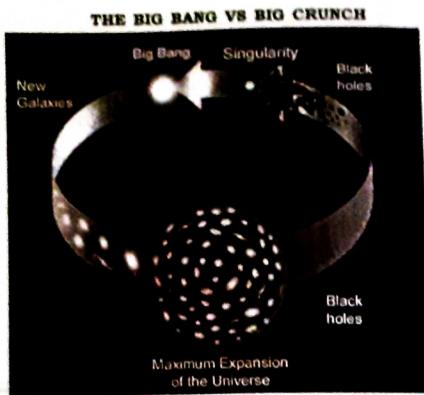


Figure 1.1

In astronomy and astrophysics we discuss and learn answers to questions given above and similar questions. To learn, some use logic, some only Mathematics and some physical equipments. Aristotle used logic. Indian astronomers used Mathematics during the Vedic age. Galileo used instruments to study the universe. Aristotle (384-322 B.C.) was the son of the physician to King Philip of Macedonic. He was one of the Plato's students and was the tutor of King's son, who became Alexander the great. Aristotle was occupying a high position. So he could not do any measuring or experimenting himself, for that was considered manual labour, which was the work of a slave. He is known as father of logic. According the so called father of logic, the Earth was spherical in shape because a sphere is the most nearly perfect configuration. He believed that the Earth is at rest, because rest is the most perfect position. His views were generally accepted without questions for nearly 2000 years. Nobody questioned. If questioned, their head will not rest exactly

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on their shoulders. Everything was under control of Mr.Pope. Physics was theological. So if you ask about the history of astronomy, and astrophysics to westerners they will say like this....

The mathematical and scientific astronomy began among the Babylonians first, who discovered the lunar eclipses recurred in repeated cycle. Then came Greeks who gave physical explanation for the celestial phenomena. In BC 200, Hipparchus calculated size and distance of the Moon, created a comprehensive catalog of 1020 stars. Until 13th century astronomy was almost stagnant in Europe. But, by the end of 9th century astronomical observations started in a few Muslim countries. The Persian astronomer Azopi discovered the Andromeda Galaxy, containing the Milky way. Ali ibn Ridwan, Egyptian Arabic astronomer observed the SN1006 supernova. Astronomers during this time introduced Arabic names for individual stars which are now used. Then came the scientific revolution during the Renaissance period. 'According to Ptolemy, the Earth was at the centre of the solar system' - geocentric model. [See Figure 1.2].

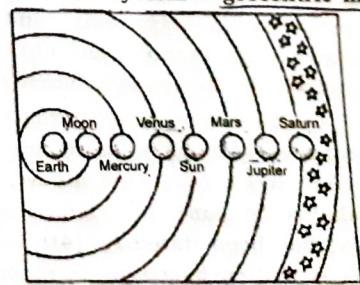


Figure 1.2
Earth Centred System
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Introduction
Copernicus introduced the heliocentric model of the solar system. Kepler derived laws of planetary motion.

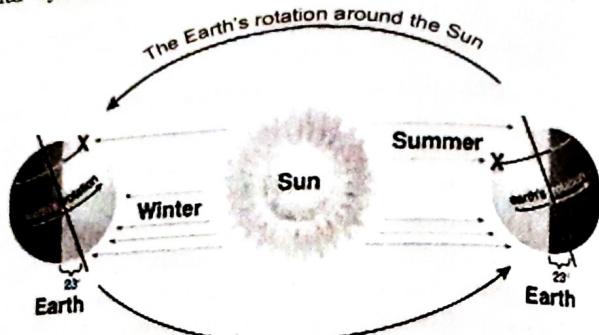


Figure 1.3

Newton invented celestial dynamics. Motion of moon and planets were well studied, during the 18th-19th centuries. It was during 20th century that the existence of external galaxies were confirmed. This was followed by the discovery of quasars, pulsars, radio galaxies, black holes and neutron stars. Invention of different types of telescope led to the observational astronomy, which was further divided into sub branches like optical astronomy, infrared astronomy, radio astronomy, and then gamma-ray astronomy, x-ray astronomy and ultra violet astronomy. It is primarily an observational science.

So all credits for the study of celestial objects went to Europeans, even though whatever discoveries made by them in A.D. were known to Indians even in B.C. 'Vedanga Jyotisha' is the name of the Indian text on astronomy. This text has been dated to 14th century B.C. The textbook is written based on astronomical studies in Sanskrit. After this came Aryabhatiyam, which contains

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121 sutras. Aryabhata stated that "Bogolah sarvato vruttah", means the Earth is circular in all directions. He also told that the Earth and planets are not self luminous. He gave accurate measurement of period of rotation of the Earth with reference to the fixed stars in the sky as 23 hours, 56 minutes, 4.1 seconds. Westerners have after so many years found this time period using physical instruments. Their value, is 23 hours 56 minutes and 4.091 seconds. Europeans used to say that the Indian astronomer's discoveries are not by scientific observations, ours are merely mathematical manipulations. Just listen to the words of George Ifrah, a French historian of Mathematics and author of the book, 'The Universal History of Numbers'.

"The Indian mind has always had for calculations and the handling of numbers an extraordinary inclination, ease and power, such as no other civilization in history ever possessed to the same degree. So much so that Indian culture regarded the science of numbers as the noblest of its arts.... A thousand years ahead of Europeans, Indian savants knew that the zero and infinity were mutually inverse notions."

The credit for the invention of zodiac of 360° is given to the Babylonians. But in Rigveda, the oldest Vedic text, written thousands of years before Babylonians discovery, there are clear references to chakra or wheel of 360 spokes placed in the sky. The number 360 and its related numbers like 12, 24, 36, 48, 60, 72, 108, 432 and 720 occur commonly in Vedic symbolism. The earliest reference on heliocentric model of the solar system is mentioned in a textbook written by Lagadha in 1350 BC.

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But these discoveries were made by the Europeans in 14th and 15th century. Those who uttered these truths were punished by the church people, Giordano Bruno was burned alive. Galileo Galilei was put under house arrest.

'Yajnavalkya' proposed a 95 year old cycle, based on heliocentric model to synchronize the motion of the Sun and the Moon which gives the average length of the tropical year as 365.246575 days which is only 6 minutes longer than the modern value of 365.24220 days. The value of this tropical year remained the most accurate anywhere in the world for over thousand years. In 'Surya Siddhanta', the cosmological cycle is very beautifully and elegantly explained, discovered by the great Indians. The time taken by Earth for one revolution around the Earth, called the sidereal year is 365.2563627 days which is only 1.4s longer than the modern value of 365.2563627 days. The tropical year is equal to 365.2421756 days, which is only 2 seconds shorter than the modern value of 365.2421988 days. This value remained the most accurate value for six centuries.

The heliocentric model was suggested by Aryabhata (476-550) [See Figure 1.4]. According to him, the Earth was taken to be sining on its axis and the periods of the planets were given with respect to the stationary Sun. But these observations are now world famous as Kepler's

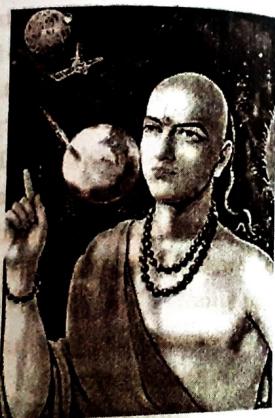


Figure 1.4

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laws of planetary motion. Kepler's first law as suggested by Aryabhata. Aryabhata told that the planets orbit around Sun in an elliptical orbit. He accurately calculated the time of solar and lunar eclipses.

In **Yajurveda** it is recorded that one year consists of 12 solar months and 6 seasons. The Vedic astronomers also found that the shortest day of an year was the winter solstic when the seasonal year, Sisira began with Uttarayana and rose to the maximum at the summer solstice. So, that was the most significant contributions of the Indians.

Let us see the meaning of the words astronomy and astrophysics. Astronomy is coined from two Greek words, astron meaning star and nomos meaning law. So astronomy means law of stars. The dictionary meaning is something like this "the study of objects and matter outside the Earth's atmospheres and of their physical and chemical properties". Astrophysics is the branch of physics dealing with the behaviour, physical properties and dynamic processes of celestial objects and phenomena. According to Frank Shu astronomy is used to describe the qualitative study of the subject whereas astrophysics is used to describe the physics - oriented version of the object. If you ask some juvenile students doing research they will say, astronomy is the science of merely recording celestial observations and cataloging objects, but astrophysics is the study of what those objects are, what they are made of and how they behave. They will also say that all astronomers are astrophysicists as well. Astronomy was originally more concerned with observations, while astrophysics has its emphasis on theory. Big bang is a phenomena, where the theory is

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astrophysics and the observational evidence cosmic microwave background is astronomy. A branch of physics called Quantum mechanics is used by astrophysicists to describe many different phenomena like how stars shine to supernova as well as the big bang and other allied processes. Historically, astronomy was more concerned with just mapping and cataloging observations. Astrophysics is one aspect of astronomy. Other aspects or categories of branches include planetary science, observational astronomy, radioastronomy, a space astrophysics, cosmology etc.

Of course there is overlapping of the different categories. You need a good telescope to be a good astronomer and a good mathematical skills to be an astrophysicist. Before 1900, astronomy was pretty much observations, the theory used was classical mechanics. Models were built through observation and theories were used to confirm the same. With the development of relativity, nuclear physics, particle physics and quantum mechanics, there was an explosion in the astronomy and astrophysics world.

IMPORTANCE OF ASTRONOMY

Astronomy has led to different branches in Physics. Galileo's discovery of telescope has led to optics. Falling of apple on the 'head' of Newton has led to mechanics, the Universal law of gravitation. Celestial mechanics is based on the Kepler's laws of planetary motion. The branch called spectroscopy was developed through the study of stellar spectra. Space flights would not have been possible without the progress made in electronic instrumentation. Through astronomical observations only,

the theory of relativity was verified. If the existence of dark matter and dark energy is confirmed, then new branches of physics will be developed.

Astronomy is related to other branches of science. It was for solving the equations connected with the law of gravitation that Newton developed calculus in Mathematics. For computing the ephemerides of planets Gauss developed methods of numerical analysis. For solving problems in Celestial mechanics and Cosmology, Euclidean and Riemannian geometries are used. Most of the celestial problems are solved by using statistical methods. In theoretical astronomy computer or analytical models are used to describe astronomical objects and phenomena. The astronomical study has led to the 'observational astronomy branch which has several sub branches starting from radio astronomy and ending with ultraviolet astronomy. The universal Newton's law of gravitation was confirmed by applying it to the motion of comets.

Astronomy is related to chemistry. The detection and analysis of infrared radiation is called infrared astronomy. The infrared spectrum is used for studying the objects which are very cold to radiate visible light, like the distant planets. Long infrared rays can penetrate clouds of dust which block visible light. Thus the young stars in the molecular clouds and the cores of galaxies can be studied. There are molecules which radiate strongly in the infrared. This is used to study chemistry in space. This method is used to detect water in comets.

Geology and other branches related to it including meteorology are needed to describe planetary interiors

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Introduction

and planetary atmosphere. Even biologists are trying to explain the origin of life in the universe and also trying to answer the questions like where in the universe is life possible and also the question could we discover life on another planet?. Physicists can join hands with chemists and biologists to detect intelligent life on distant worlds if, like us, the extra terrestrials have polluted their atmosphere with artificially produced chemicals.

METHODS OF ASTRONOMY AND ASTROPHYSICS

Gazing up at the star-studded heavens inspires awe like nothing else, it is so cute and wonderful. The starry sky makes the humans to ask questions about the nature of universe like this. How did it all begin? How does it work? What is our place in it? Are there living beings out there? To solve all these questions and to understand various exciting and fascinating phenomena in the macroscopic universe, various methods are used.

Man learned to read and write by the middle of the fourth millennium B.C. By that time it is told that at least two written languages appeared. People noticed that nature followed definite patterns from which they could predict future. First, for the study of space, people used eye and brain. Indians topped the list. But... The Babylonians recorded the solar eclipses, and from this they observed that the eclipses occurred at definite intervals of time. They used this observation for predicting future eclipses. Then came Egyptians.

They were extensive and well organized, as authenticated by two papyri. The evidence is their great pyramids constructed with great astronomical orientations. They used these stone structures to study

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the star Sirius. They connected the star with the flooding of Nile each spring, which enriched the soil. They thought Sirius was a good omen. They erected seven temples in its honour.

Nineteenth century BC was the time of English people. The circles of the giant stones at Stonehenge, England were arranged to allow accurate observations of Sun and Moon and give exact determination of the season. Eventhough they were not aware of writing and reading



Figure 1.5

still they used these stones to maintain astronomical information. They were able to predict lunar eclipses from the positions of shadows formed by these stones. In South America the Incas erected a large stone at Machu Picchu to study the beginning of seasons. This was the situation for thousands of years before Christ, all over the world. With the invention of telescope things changed.

For the exploration of the solar system, unmanned and manned spacecrafts were used. Many discoveries would not have been possible without robot space probe.

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In April 1961, the Soviet Union sent the first human being into space aboard the Vostok 1 rocket. Yuri Gagarin and his space capsule circumnavigated earth only once and after a flight lasting for one hour and 48 minutes he landed safely back on Earth in Southern Russia. USA succeeded in sending their own astronaut John Glenn into orbit in February 1962. US Apollo Space project sen

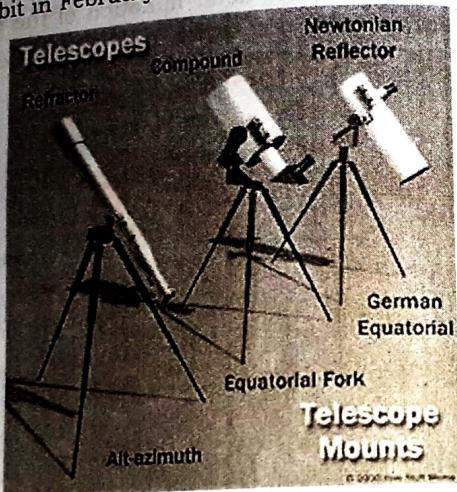


Figure 1.6

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To study the stars, nebulae and galaxies spectroscopic methods are used. Different types of radiations are received from them and are analysed to arrive at conclusions about them. The data are also collected using satellites to study the surface of Earth and the environment. The stellar radiation collected by telescopes are analysed by making use of photographic plates, photoelectric photometers, spectrographs etc. The accessories are either kept on the ground or they are carried above the Earth's atmosphere using balloons, rockets and satellites. There are different types of instruments to cover the different regions of electromagnetic spectrum from ultraviolet to radio waves. Thus we have different subfields of astronomy from radio astronomy to ultraviolet astronomy. Radiation received are studied by noting, the time of reception of radiation. For example in gamma-ray astronomy, gamma rays are observed directly by satellites like Compton Gamma Ray Observatory or by specialized, telescopes called atmospheric Cherenkov telescopes. The gamma rays are emitted by pulsars, neutron stars, black holes and active galactic nuclei. From different types of radiations emitted the properties of the emitter like distance, size, mass, luminosity, temperature, chemical composition, age, its origin etc. can be studied. Final conclusions are drawn after repeated observations.

~~THE SCIENTIFIC METHOD~~

Astronomy and astrology are entirely different. "Astrology is the foolish daughter of wise mother astronomy", these are the Kepler's words. The Babylonians believed sincerely that person's life was

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more people, about 12 to Moon in between 1969 and 1970. The first to reach the Moon, on 20th July 1969, were the Apollo 11 astronauts. Astronomical bodies other than Earth was studied by the space flights. The existence of comet, asteroids were studied in a direct manner. Venus spacecrafsts studied Venus. To perform direct experiments on Mars Viking Spacecrafts were used. Mariner, Pioneer, Voyager and Venera class vehicles were sent close to the planets Mercury, Jupiter, Saturn. Also the Halley's comet was closely studied.

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1.14 affected by the positions of the planets and the configuration of stars with respect to Sun. They called astrology a science and it was the most important branch of science.

Astronomers also follow scientific method. The various steps involved are

- i) Careful, systematic and repeated observations
- ii) Classification of the data collected from the observations
- iii) Logical and quantitative reasoning
- iv) Arriving at general empirical laws
- v) Formulation of a theory based on basic postulates and mathematical modelling
- vi) Applying the theory to explain the observed results and make new predictions.
- vii) Verification of the predictions through new observations
- viii) Correction of the theory if there is an error
- ix) Repetition of the above processes until the predictions and conclusions agree with the observations

The planetary model based on geocentric theory was wrong. Later it was replaced by heliocentric theory. The details about the motion of planets, stars, comets, asteroids, galaxies are explained in the next chapters.

SCOPE OF ASTRONOMY

The scope of astronomy and astrophysics is wide and varied. The study starts from the Earth, then moon, planets and satellites our Sun, star clusters, galaxies, interstellar medium, nebulae, comet, asteroid, novae and supernovae, pulsars, quasars, blackholes etc. So the scope is very vast.

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introduction

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MODEL QUESTIONS

SECTION-A

BUNCH-I

OBJECTIVE QUESTIONS

1. "Let me say here and now my belief that there is no science so grand, so elevating, so intensely interesting as Astronomy". Who spoke this?
a) Kepler b) Newton
c) Aristotle d) C.V.Raman
2. To study Astronomy Aristotle used the method of
a) Induction b) Deduction
c) Experiment d) Logic
3. According to Aristotle the shape of Earth was
a) Flat b) Spherical
c) Cube d) None of the above
4. A large amount of information about stars were obtained after the discovery of
a) Comet b) Asteroid
c) Telescope d) Pendulum
5. Astronomy is not related to
a) Astrophysics b) Cosmology
c) Chemistry d) Magic
6. Integral calculus was invented by.....
a) Einstein b) Newton
c) Aristotle d) Galileo
7. The spacecraft which penetrated into the atmosphere of Venus is
a) Venera b) Pioneer
c) Apollo d) Mariner

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8. Stellar radiations are first collected by
 - a) Telescope
 - b) Photometer
 - c) Ammeter
 - d) Voltmeter
 9. For astronomical studies the recording of exact of observation is very important
 - a) Mass
 - b) Depth
 - c) Time
 - d) Type
 10. Spectroscopic methods are used in astronomy to study mainly
 - a) Earth
 - b) Moon
 - c) INSAT
 - d) Galaxies

BUNCH-II

FILL IN THE BLANKS

1. Aristotle's idea that Earth is at rest was taught in schools for years.
2. The mathematical and scientific astronomy began among the
3. The time taken by Earth for one revolution around the Earth is called.....
4. In India, the heliocentric model of the solar system was first suggested by
5. The universality of Newton's law of gravitation was verified by applying it to the motion of
6. To perform experiments on Mars..... spacecrafs were first used.
7. Careful, systematic and repeated observation is a part of method
8. In it is recorded that one year consists of 12 solar months and 6 seasons.

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9. Astronomy is used to describe the study of the universe.
10. Astronomy is more concerned with observation.

BUNCH-III

TRUE OR FALSE

1. There is no difference between astronomy and astrophysics
2. Astronomy is related to chemistry
3. Newton developed the methods of numerical analysis
4. Infrared astronomy is used to detect water in comets
5. In South America, the Incas erected a large stone at Machu Picchu to study the beginning of seasons
6. John Glenn was the first to navigate around the Earth in a spacecraft.

SECTION-B

VERY SHORT ANSWER QUESTIONS

1. What is astronomy?
2. What is astrophysics?
3. Name an instrument used to observe stars
4. Name a branch of astronomy developed after the invention of radio telescope
5. Mention two importance of astronomy
6. Name two subjects which are related to astronomy?
7. Write down two steps involved in the scientific method
8. What is heliocentric theory?
9. What is geocentric theory?

SECTION-C**SHORT ANSWER QUESTIONS**

1. Distinguish between astronomy and astrophysics
2. Mention the various importance of Astronomy
3. Explain the methods of astronomy and astrophysics
4. Write a note on the scientific method used in astronomy
5. What do you know about the scope of astronomy

SECTION-D

1. a) Discuss the importance of astronomy
- b) Explain the methods of astronomy and astrophysics
- c) What are the steps involved in the scientific method

ANSWERS**OBJECTIVE QUESTIONS**

1. d. 2.d 3.c. 4.c 5.d
 6.b. 7.a 8.a 9.c. 10.d

FILL IN THE BLANKS

- | | | |
|-----------------|----------------|------------------|
| 1. 2000 | 2. Babylonians | 3. Sidereal year |
| 4. Aryabhatta | 5. Comets | 6. Viking |
| 7. Scientific | 8. Yajurveda | 9. qualitative |
| 10. Observation | | |

TRUE OR FALSE

- True → 2, 5
 False → 1, 3, 4, 6