2. ANCIENT ASTRONOMY

Astronomy is the science of understanding everything that goes on beyond Earth’s boundaries. It is one of the oldest of sciences. Every civilization, through antiquity to the recent past, had stunning views of stars night after night, as sightings of the cosmos would not have been hampered by the light pollution and an indoor life style, both of which hide much of the heavens from observers today. All over the world some sort of the understanding of the celestial sphere was an integral part of civilization, whether or not they opted for scientific explanations of the observed phenomena.

We must remember, however, that for more than nine-tenths of the last five thousand years of our study of the heavens, we have had to rely on the unaided eye. The Mediterranean people who set the constellations in the sky, the Babylonians, Egyptians and Greeks, the Arabian astronomers who flourished during the Dark Ages of Post-Roman Europe, the Chinese, the Mayan, the Indians and other early American astronomers, all built their theories of the Universe on naked eye observations.
2.1 EARLY ASTRONOMY

Ancient China

Ancient Chinese civilizations paid close attention to the night sky because an important part of the culture’s philosophy was the idea of harmony between man and nature.

- Oldest established culture with recorded astronomical observations.
- First people to record solar eclipse, Super Nova, Stellar positions in a catalogue.

Chinese mythology held that an eclipse occurred when a dragon was eating the sun and that only way to defeat the dragon was to make as much noise as possible. In the event of an eclipse, people would make a mighty racket, which would scare the dragon off, & (naturally) the Sun would return.

Ancient Egypt

- Pyramids are thought to have been aligned with the stars in Orion Belt to help facilitate the passage of the ‘Pharaohs’ into the afterlife.
• Used the star Isis (Sirius) to predict the flooding of the Nile for planting the crops & keep track of their year.
• Many temples & structures built to honour Gods & keep track of heavenly movements.

Ancient Babylonians

The Babylonians, an ancient Mesopotamian people who flourished between the Tigris & Euphrates rivers, in the area of modern day Iraq, were one of the earliest civilizations known to have adopted a scientific outlook towards the stars & planets.

• Created the first recorded constellations
• Created Zodiac (12 constellations, the Sun passes through each year)
• Invented degree system used for positions in the sky

The Mayans

• Built many structures to keep track of solstices & equinoxes.
• Astronomy was an integral part of their culture & day to day life.
• Seriously obsessed with Venus- conducted wars based on the planet’s position & brightness.

The Ancient Greek

The Ancient Greeks greatly advanced the scientific study of astronomy by placing an emphasis upon observations and data collections. Greece was hotbed for astronomical theories & observations as well as philosophy, mathematics, ethics, drama, politics & other scholastic pursuits.

➢ Aristotle (384-322 BC, Greek)

• Proved the earth is sphere using sailing ships & eclipse shadows
• Geocentric view (the idea that the Earth lies at the centre of the universe)

➢ Aristarchus (310-230 BC, Greek)

• First suggested the Heliocentric model
• Used simple geometry to calculate distance to Sun from the Earth
➢ Eratosthenes (276-195 BC, Greek)

- Calculated the Earth’s circumference with almost exact accuracy

➢ Hipparchus (190-120 BC, Greek)

- Created the first star catalogue
- Calculated the accurate distance to the Moon
- Invented trigonometry

Islamic Astronomers

During the middle ages, in Western Europe the scientific development of astronomy stagnated. Most scientists, thinkers and ordinary people were content to support many of the ideas propounded by the Greeks, especially as it usually had the firm backing of the Church, with the result that to question the orthodox view was considered heresy.

While the advance of astronomy lost momentum in Western Europe, it accelerated in the Islamic empire which spanned a wide area & population, from the Middle East, through North Africa and into Spain. Many of the works by Greek astronomers were translated into Arabic.

Knowledge of astronomy was useful in Islamic rituals, which interpreted the heavens as a guide to ensure prayers five times a day, to date religious festivals correctly & also to accurately locate Mecca.
2.2 Ancient Indian Astronomy

Indian astronomy was heavily tied to their religious and spiritual outlook of the world, but it contained many accurate observations of phenomena. This acted as a catalyst for the growth of mathematics in the subcontinent, one of the greatest legacies passed on by India to the western world.

Ancient India's contributions in the field of astronomy are well known and well documented. The earliest references to astronomy are found in the Rig Veda, which are dated 2000 BC. During next 2500 years, by 500 AD, ancient Indian astronomy has emerged as an important part of Indian studies and its affect is also seen in several treatises of that period. In some instances, astronomical principles were borrowed to explain matters, pertaining to astrology, like casting of a horoscope. Apart from this linkage of astronomy with astrology in ancient India, science of astronomy continued to develop independently, and culminated into original findings, like:

- The calculation of occurrences of eclipses
- Determination of Earth's circumference
- Theorizing about the theory of gravitation
- Determining that sun was a star and determination of number of planets under our solar system

The Jyotish Vedanga, the first Vedic text to mention astronomical data, records events going back as far as 4000 BC. This period saw many advances in measuring time and the procession of the heavens, with a few proto-theories about the structure of the universe. More importantly, this period saw the transmission of
ideas between the Indians, Babylonians, Greeks, and Persians. This exchange of theories and philosophy was extremely important to the development of astronomy.

**Aryabhata (500 CE)**

In this period, a new branch of astronomy, diverging from the Vedas began. Called the Siddhantic Era, it began with a series of books called the Siddhanta, which charted the solar year, including solstices, equinoxes, lunar periods, solar and lunar eclipses, and planetary movements.

The first properly recorded Siddhantic astronomy began in the 5th Century CE, where Indian astronomers such as Aryabhata began to adopt a more rigorous, mathematical approach to astronomy, directing it away from mysticism and its emphasis on the calendar. Aryabhata added to the heliocentric theory, proposing the idea that the moon reflects the light of the sun, a theory also proposed by some Greeks but not widely adopted. He also proposed that the earth rotated rather than the skies, although this theory lay undiscovered until the European Renaissance and Copernicus.

His idea, which included mathematical models about how to forecast eclipses, eventually found its way into Europe and influenced Renaissance thought. His book, the ‘Aryabhatia,’ was translated into Latin in the 13th Century. This work gave the Europeans some methods for measuring the volume of spheres and the area of triangles, as well as methods for calculating square roots and cube roots.
Varahmihir (505 CE)

In the 6th Century, Indian astronomers proposed that the same force holding objects to the Earth also held the celestial bodies in place. This was an advance upon Anaximander’s idea of equilibrium and the recognition of a proto-gravitational theory, long before Newton. Varahamihira proposed that there must be some type of attractive force keeping objects stationary.

Brahmagupta (591 CE)

The Siddhantic astronomers also understood that the earth was spherical and attempted to calculate the circumference of the planet. In the 7th Century CE, the astronomer Brahmagupta arrived at a figure of 36 000 kilometers for the circumference of the earth, which is very close to the actual figure.

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<th>Astronomers</th>
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2.3 The Copernican Revolution

The Ancient Greek philosopher, Aristotle, believed that the Earth was at the centre of the universe & all the bodies in the sky orbited the Earth. This is known as the ‘Geocentric Theory’.

However upon closer inspections, Aristotle’s idea of ‘perfect circles’ seemed to be flawed. Some planets, Mars in particular, seemed to switch briefly in retrograde orbits- as if they were temporarily doubling back upon themselves. Also the brightness of the planets appeared to vary as they orbited the earth. This all seemed to contradict Aristotle’s theory.

An answer, proposed by Claudius Ptolemy, was held as truth for centuries; he continued to advocate a geocentric system, arguing that the varying brightness & brief retrograde motion were result of epicycles.

All the theories & discoveries in that era were made with the background assumption that the Earth was the centre of universe. In Western Europe too, Ptolemaic theory was unchallenged & backed by the Church as it placed humanity as the central fact in the universe. Shortly after Aristotle’s death, Aristarchus proposed a heliocentric theory, but this was unpopular at that times.

Nicolaus Copernicus (1473-1543, Polish)

Copernicus was born in the Renaissance era, which saw an emphasis placed upon careful, scientific observations is Astronomy. Copernicus believed that the Ptolemaic system did not properly account for
what he observed in the heavens. He explained the Mars’s retrograde motion as an optical illusion, caused by the fact that the Earth is orbiting the Sun faster than Mars.

Copernicus became the first realize the true order of the planets in the solar system; Earth was demoted from the centre of the universe to the third rock from the Sun. He published his findings in the book *De Revolutionibus Orbium Coelestium*, in 1543, the year of his death.

The Church was not too bothered by such heresy. Copernicus died before he could be challenged and, moreover, he had asserted that the planets orbited the Sun in perfect circles. However observational evidence suggested this was not the case. It fell to another scientist Johannes Kepler, to make sense of this problem.
Johannes Kepler (1571-1630, German)

Using the observational data compiled by Danish astronomer, Tycho Brahe, Kepler first suggested that the orbits of the planets were ellipses rather than circles. When Brahe moved to Prague, Kepler became his assistant. The men were great rivals, but Brahe’s observations & Kepler’s theory made for a fruitful collaboration as Kepler was able to prove the elliptical orbits of the planets.

Kepler’s laws of planetary motion:

1. The orbit of a planet is an ellipse with the Sun at one of the two foci.
2. A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time.
3. The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.

Galileo Galilei (1564-1642, Italian)

This new wave of astronomical thinking did not arouse the interest of the Church until it reached Italy at the beginning of 17th century. Galileo was unwilling to commit to a heliocentric model until there was sufficient observational evidence. To gather such evidence, Galileo pioneered the use of Telescope in astronomy by advancing the new Dutch invention for studying the heavens.

Many of the things he saw through his telescope seemed to rule against the geocentric model. He identified four moons (Ganymeda, Callisto, Europa & Io) orbiting Jupiter. He also observed the sunspots.
Sir Isaac Newton (1643-1727, English)

Although Kepler had described how planets orbit the sun, he never managed to explain why they do so in such fashion. That was an unknown for over half a century until the English physicist, Isaac Newton, established his three laws of motion & a law of Universal Gravitation in his book *Principia* published in 1678.

Newton’s law of Universal Gravitation:

Every point mass attracts every single other point mass by a force pointing along the line intersecting both points. The force is proportional to the product of the two masses and inversely proportional to the square of the distance between them.

\[ F_1 = F_2 = G \frac{m_1 \times m_2}{r^2} \]

Newton’s ideas were groundbreaking. They explained why an apple fell to the ground as well as why the planets were held in orbits around the Sun. However Newton’s theory of gravity did not account for every eventuality. It was unable to explain the perihelion (closest point to the Sun) shift of Mercury. It was calculated that the gravitational pull of the sun & other seven known planets was not sufficient to explain the advancing perihelion of Mercury. The puzzle was not solved until a young German-born physicist, Albert Einstein, established a new theory of Gravity.
Albert Einstein (1879-1955, German)

In 1905, while working as a desk clerk for a Swiss patent office, Einstein published his ‘Special theory of Relativity’. Essentially, Einstein had proved that, in a vacuum, light always travels at a constant speed of 300,000 km/s, relative to an observer. His theory also states that the velocity of light in vacuum is the fastest speed attainable in the universe. The special relativity had shown that distance as well as time was variable.

In General relativity (published in 1915), Einstein adopted the view that space & time are linked in a four-dimensional unit called ‘spacetime’. General theory of Relativity holds that the mass distorts spacetime. It is the distortion of the spacetime by mass rather than the mass itself that is responsible for the gravitational attraction.

Einstein had worked out the mathematics behind General Relativity & it even accounted for advancing perihelion of Mercury. The scientific community was understandably sceptical; Einstein needed a proof that his theory worked in practice. The result of observations of eclipse of May 1919 showed that the actual position of stars behind the sun did not match their apparent position. Such an occurrence could only be explained by General Relativity; the Sun was distorting the fabric of spacetime & the light from the stars was being bent. Einstein turned into an overnight celebrity & became the most prominent scientist of the 20th century.