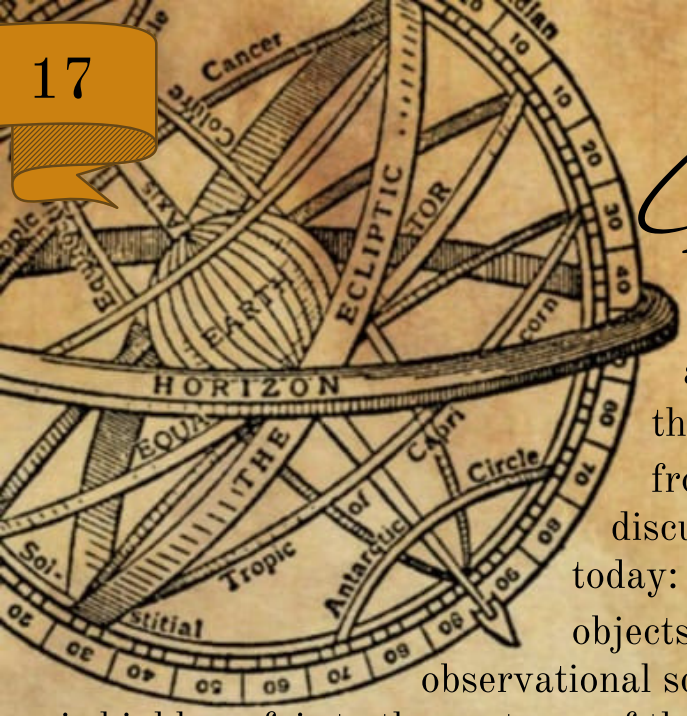


History of Astronomy

One often masters a science but forgets to appreciate how a theory of today has travelled through times and developed due to contributions from great minds across all time periods. What I discuss ahead is how Astronomy took the form it has today: a historical account of the science of celestial objects. Can we argue that Astronomy was the first observational science? To cover the subject in mere few pages is highly unfair to the vastness of the subject. With due apologies, I shall try to touch upon most of the aspects.

It would not have been hard for any human to notice the light dots in the sky, appearing every night just to disappear the next morning. Thus, we begin the search from the prehistoric era. One structure which particularly attracts widespread attention is the Stonehenge. Due to its apparent specific alignments, it was initially assumed to be an ancient 'observatory' until the claims were finally refuted. Similarly, sites of roughly 3000BCE such as the taula sanctuaries of Menorca and the Newgrange passage tomb of Ireland have been under debate for their astronomical symbolism. In 2004, an excavation re-established belief in prehistoric astronomy. It is the mesolithic calendar monument at the Warren Field in Scotland. Dating to 8000 BCE, the monument claims to be the oldest lunar calendar to be ever found, maybe the beginning of timekeeping itself!

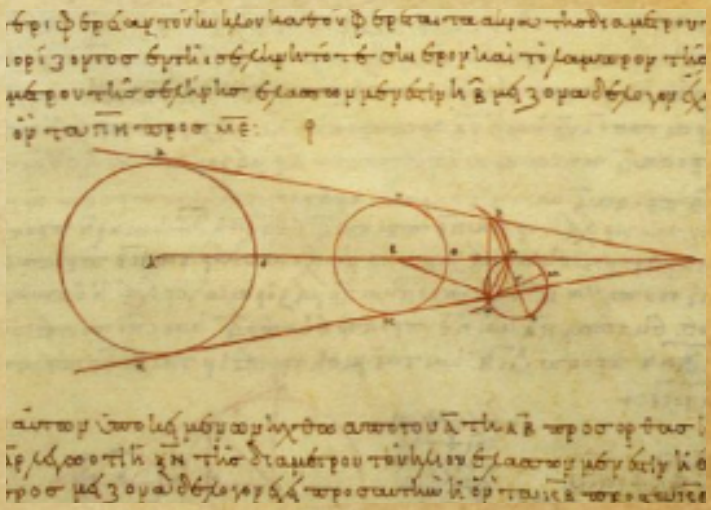
While talking about calendars, we come across several civilizations who tracked celestial objects for timekeeping. Unconventional to the solar and lunar calendars, Egyptians in the 3000 BCE controlled their calendar using Sirius, the brightest star. Sirius' heliacal rising occurred, by chance, when the Nile began to flood which was of utmost importance to the Egyptians. Similarly, the Mayan Codex based their calculations on Venus, the day 1 *Ahau* marked the beginning and end of the Venus' cycle of revolutions. The dark side to all of this being that these were mostly motivated by astrology (as in any calamity happening at that time) instead of pure astronomical reasons. A Mesopotamian stone dating to 1100 BCE contains engravings of a scorpion, a lion and Venus, Sun and Moon. One Babylonian clay tablet which needs special mention is that of 164 BCE, the year Halley's comet appeared and the Babylonians recorded the comet's

The *Nebra* sky disk from 1600 BCE in Germany. Can you spot the Pleiades?

positions on a tablet. In India, the *Vikrami* calendar started in 57 BCE which is a lunisolar calendar.

A major motivation for Astronomy was navigation, particularly astronavigation which meant using celestial objects for determining the directions, specially at sea. The Caroline Islands navigators used the Polaris in the north and the Southern Cross in the south, along with a set of rising/setting points for stars, to navigate through the sea at night. The Greek poet, Homer, talks about celestial navigation in his work *Odyssey* where Calypso tells Odysseus to keep watch of the Ursa Major, the Pleiades, the Bootes and the Orion. An excerpt from the *Odyssey* reads:

"...as he watched the Pleiads, and late-setting Bootes, and the Bear, which men also call the Wain, whichever circles where it is and watches Orion..."



Aristarchus' calculations on the relative sizes of the Sun, the Moon & the Earth

Astronomy got a kick-start in Greece when Thales of Miletus (of the fame of Thales' theorem for circles) predicted a solar eclipse of the year 585 BCE. Plato, around 380 BCE and after that, his pupil, Aristotle attempted to describe nature and the cosmos. Both believed that the Earth is still (geocentrism) and all other bodies orbited the Earth in circular orbits, as proposed by Plato. Dwelling on this thought, Eudoxus of Cnidus used concentric spheres to explain the retrograde motion of planets.

Aristotle also proved Earth to be a sphere by observing lunar eclipses. Surprisingly, in 270 BCE Aristarchus of Samos proposed heliocentrism, a celestial model with Sun at the center but the idea was not received well as there seemed to be a lack of observational proof. He also devised a method to measure the distances to the Sun and the Moon. The ideas were carried forward by Hipparchus in 100 BCE and Ptolemy in 140 CE, whose great treatise on Astronomy, *Almagest*, contains even a star catalogue which was made by Hipparchus and later improved by

Ptolemy. The concentric spheres idea by Eudoxus was replaced by the concept of epicycles introduced by Apollonius and further formalized by Ptolemy.

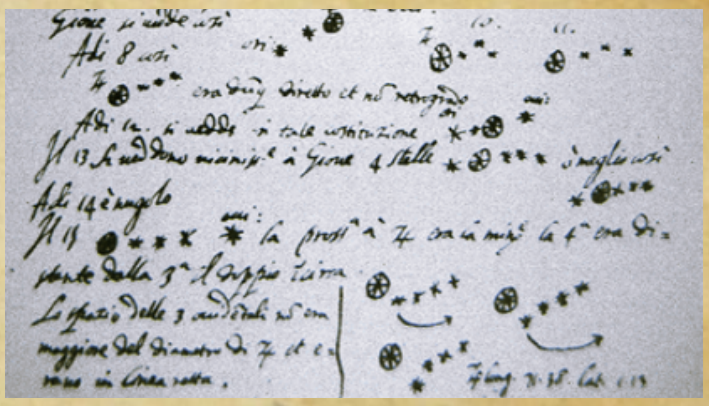
Meanwhile, a mathematics genius set his foot in Astronomy. Around 510 CE, Aryabhata produced his treatise *Aryabhatiya*, in which he described Earth's rotation and explained the cause of solar and lunar eclipses as well as calculated the sidereal rotation period fairly accurately. The ideas were carried forward by Varahamihira and Brahmagupta, the latter gave the correct equations for parallax. In 629 CE, Bhaskara I described planetary longitudes and conjunctions among planets and stars. The Jantar Mantar of Jaipur, built in the 18th century, is a mark of the excellence of Indian Astronomy as it houses several astronomical tools and is famed to be an astronomical observatory.

The Chinese didn't fall short of observing the stars. It is believed that the Chinese astronomer Gan De, along with Shi Shen, had been one among the first to compile a star catalogue, as early as 4th century BCE. In 120 CE, Zhang Heng explained solar and lunar eclipse in his publication *Ling Xian*. They even recorded instances of supernovae sightings, the most popular one being that of 1054 CE, the supernova which created the Crab Nebula. Star charts belonging to 940 CE have been excavated depicting constellations such as Ursa Major. Armillary spheres had been in use to measure celestial coordinates. Shen Kuo of the 11th century CE was a major contributor to Chinese astronomy by devising instruments and theories for astronomical phenomena.

The period of 8th-15th century CE came to be known as the "Islamic Golden Age" due to major scientific advancements taking place in the Middle East during this period. Around 830 CE, inspired by

A page from the Hindu calendar (leftmost) and pages from the book *Kitaab Suwar Al-Kawaakib*. The Ursa Major can be seen.

Indian astronomy, the Persian polymath Al-Khwarizmi published Arabic's first *Zij*, an astronomical handbook. Over fifteen *Zijs* exist today. Al-Khwarizmi's landmark work on algebra established it as an independent discipline. In 964 CE, Abd al-Rahman al-Sufi's (Azophi) work Kitaab Suwar Al-Kawaakib was a comprehensive star catalogue describing major constellations. Al-Farghani's work made several corrections to Ptolemy's Almagest such as Earth's axial tilt, the apsides of the Sun and the Moon, etc. He also wrote about astronomical instruments, giving an in-depth analysis of the astrolabe which was widely in use. In 1006 CE, Ali ibn Ridwan observed the brightest supernova in history, the SN1006. In 994 CE, Al-Khujandi measured Earth's axial tilt with a huge precision using a huge mural sextant which was for the first time constructed by him. In the 11th century, Ibn-al-Haytham, a leading figure in Optics, penned down twenty five works of astronomy and separated natural philosophy from Astronomy, which led to the development of astronomical physics. Extending Apollonius' theorem, Al-Urdi came up with his own lemma which was later used by Copernicus in his heliocentric model. Having traveled across several cultures, we take the



Galileo's notes. One can spot the Galilean moons of Jupiter.

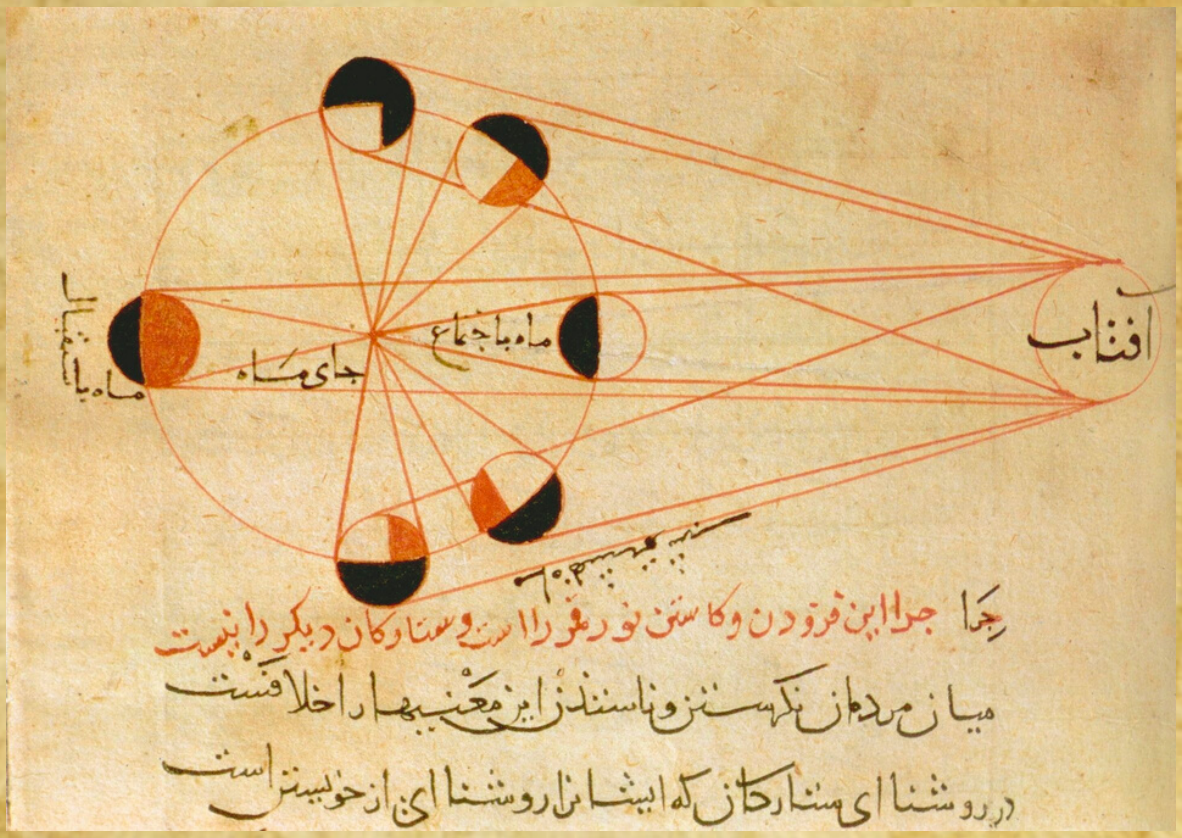
voyage back to Europe but in the medieval period, where Copernicus challenged Ptolemy's geocentrism in 1543 in his work De revolutionibus orbium coelestium, though he still made use of Plato's circular orbits which made him use even more epicycles than Ptolemy had to. In the 1580s, astronomy's first true observer, Tycho Brahe, built his Danish observatory and used it to measure positions of celestial objects to the highest accuracy. He even went on to propose a hybrid model, geo-heliocentrism. Neither Brahe's nor Copernicus' model succeeded in predicting planetary motion. It was the breakthrough in 1609 by Brahe's student, Johannes Kepler, which revolutionized astronomy. He gave up the idea of circular orbits and instead used elliptical orbits which fit perfectly to Brahe's observational data without using epicycles and deferents. His three laws of planetary motion provided a mathematical structure for his proposal. The final blow to geocentrism was given by Galileo Galilei when he started astronomical observations using a refracting telescope which he himself made.

He observed the terrain of the Moon's crust: spotted mountains and craters. His observation of four of Jupiter's moons, later termed to be Galilean Moons, destroyed geocentrism as he showed that these four bodies revolved around Jupiter instead of Earth. Working upon Kepler's ideas, one of the most proclaimed geniuses in history, Isaac Newton published his *Philosophiæ Naturalis Principia Mathematica* and formulated the law of gravitation, finally geocentrism came to an end. After Newton, astronomy was further carried forward by great minds such as Edmun Halley, Charles Messier and William Herschel, to name a few.

Soon modern astronomy took over and transformed into what we know today. The stories of that era can be a talk of some other time, maybe another installment? It does seem that astronomy has been one of the earliest observational sciences.

PS: To slightly cover up for the grave injustice I mentioned at the beginning, I recommend all the interested readers to go through *The Cambridge Concise History of Astronomy* by Michael Hoskin. Also, if you have any anecdotes regarding the history of science, do share with me! If you know IITK's Astronomy Club, you'd know where to find me.

-by Mohammad Saad



An illustration from al-Biruni's astronomical works, explains the different phases of the moon, with respect to the position of the sun.