First Edition

ASTRONOMY CLUB, IITK

CYGNUS

2021

"Somewhere, something incredible is waiting to be known."

-Carl Sagan

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ABOUT THE CLUB

What do we do?

- **Astronomy observation sessions:** Where we make an amateur astronomer out of you. We hold various discussions and quizzes to expand the trivial knowledge of the jewels of the sky. Most importantly, we use a telescope to observe the Moon, nebulae, planets like Saturn etc.
- **Planetarium Shows:** YES, we have an inhouse planetarium of our own, built entirely by yours truly. It was inaugurated on Jan 29th, 2012 and still stands to show the dedication of the members. Now we use it to conduct some marvelous planetarium shows.
- **Astrophotography:** One of the main things about astronomy is observation, and one of the most exciting bits of it is to capture the beauty of the world above in a photograph. The club has its own SLR camera to be used in various photometrical projects.
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The Observatory for Astronomical Research (OAAR): And we conduct astronomical research as well. The club has built its own observatory to make this possible, which was inaugurated in the summer of '14. It hosts a 14 inch Celestron EdgeHD which makes the images straight out of the camera look as clear as the results of heavily processed still frames.

THE HISTORY

The Astronomy Club, IIT Kanpur was formed all the way back in 1975! Yeah we're pretty ancient. One of the first aids used by us was donated by a faculty member, and it was a 138mm Newtonian Reflective Telescope, which we've been using to stalk the celestial bodies ever since.
So we set on a journey to explore more about this passion.


ASTRO
CLUB


NAVEEN
ASTRO

SUMMER PROJECTS '21

Like every year, the semester-long summer projects offered by the SnT Council were conducted. The Astronomy Club offered three SnT summer projects in 2021. The projects required very little prior knowledge of astronomy but an enthusiasm to learn and explore the cosmos.

R A D

The project aimed to study several astrophysical objects and phenomena from a theoretical astrophysical standpoint. Students were introduced to the basics of astronomy alongwith astronomical jargon and then explored the physics behind binary star systems, stellar structures, and galaxies, this also included a detailed analysis of their formations and various types of the same. The project concluded by exploring the greatest question posed to mankind, how did the universe begin?

COMPUTATIONAL ASTROPHYSICS

The project focused on analysing astronomical data and applying computational methods on data. Students were introduced to basic Python libraries like Pandas, NumPy and Matplotlib which are generally needed for data analysis. They were also introduced to the AstroPy and SciPy libraries of Python which are more specific to the field of astronomy. These were implemented in time domain astronomy, image processing and spectral analysis. The project concluded with an in-depth analysis of the Pleiades star cluster.

SPACE: THE FINAL FRONTIER

The project revolved around designing and planning a space mission. Students were introduced to the basics of space exploration and explored the basics of rocket design and propulsion systems as well as the mechanics behind it. The entire space mission planning was divided into various subsystems, each covered with attention. They also looked at possibilities for the future of space travel including interstellar and even intergalactic travel as well as the efforts to achieve it. They also with the help of simulation program Kerbal Space Program (KSP), designed the entire space mission from constructing the rocket to launching it to landing on other celestial bodies in virtual space of the program. They also studied some well-known space missions and prepared detailed reports, analysing each subsystem, as the major outcome.

HYPERION '21

On the occasion of Autumn Astronomy Day 9th October, Astronomy Club organised its first nation-wide case study challenge. It was a 48 hour challenge, with students from all over the country participating individually or with their teams. The case study titled 'Lightening up Dark Matter' with its fictional case orator 'Hyperion' to guide through the case study, was released on 8th October; the challenge ended on 9th October 23.59hrs with a relaxation of 1 hour due time. The case study was based on one of the concepts premised around 'Dark Matter' - 'Quantitative Analysis of Dark Matter Density'. The challenge received an overwhelming influx of report submissions from participants, making the event a huge success. The reports were duly compiled by all the teams, and each gave great insight on the topic. Nevertheless , they were closely examined and marked. The winners were announced in a felicitation ceremony conducted on 17th October. The winners were given away goodies worth 5000 INR, with winning certificates. The event received applause from Pankaj Jain, Professor at the Department of Physics of IITK and huge appreciation from participants. The Club intends to organise more such challenges for the Astro-junta.

ASTROPHOTOGRAPHY WORKSHOP

The Astronomy Club organized an astrophotography workshop where the campus junta was familiarised with the basics of astrophotography and how to start with it. The workshop was conducted by Soumyadeep Mukherjee, a PhD student at IIT Kanpur who has been involved with astrophotography for quite some time. Soumyadeep's images have appeared on platforms like NASA APOD, Earthsky, Spaceweather, etc. And have been published in BBC Sky at Night, Sky and Telescope, Astronomy Magazine etc. He was also shortlisted for Astronomy Photographer of the Year 2021. The session was conducted over Zoom. Soumyadeep started off by describing the basic equipments required and the terminologies related to photography like: shutter speed, ISO, aperture, etc. Then he moved on to topics like types of astrophotography, setting up the gear, shooting, pre and post-processing techniques and phone astrophotography processing techniques and phone astrophotography. Throughout, he explained everything using the pictures taken by himself and his colleagues as examples. Many students, motivated by this workshop, took part in the amateur astrophotography challenge organized by the club and captured the beautiful night skies.

ASTROPHOTOGRAPHS

ORION NEBULA

The Orion Nebula (aka. M42) located right below Orion's Belt, can be seen with the naked eye as a fuzzy patch surrounding the star Theta. It is nearly a degree across in the sky, which makes it even larger than the full moon (although the moon appears to be larger because it is brighter). It is one of the brightest HII regions, being composed mainly of ionized hydrogen which gives off the dominant red glow. The energy to keep the nebula glowing comes from the very hot young stars in a formation called The Trapezium.

RHO-OPHIUCHI

Rho Ophiuchi (ρ ophiuchi) is a multiple star complex, found rising above the plane of the milky way in the sky, as a part of the constellation Ophiuchus – The Serpent Bearer. It is one of the most vibrant and colourful nebulas in space, and one of the nearest star-forming regions to earth, about 400 light years away; allowing us to resolve much more detail.The interstellar clouds of gas and cosmic dust that make up Rho Ophiuchi contain emission nebulae that are rich in red, glowing hydrogen gas and blue reflection nebulas that reflect starlight from their surroundings.

THE DOUBLE CLUSTER

At a distance of about 7650 light years, within the Perseus Arm, lies the Double Cluster, consisting of two open clusters NGC 689(h Persei) and NGC 884(Chi Persei). An open cluster is a group of up to a few thousand loosely bound stars that were formed from the same giant molecular cloud and have roughly the same age. Based on their individual stars, the two clusters are relatively young, both about 12.8 million years old. The clusters are blue-shifted which means that they are moving towards earth.

The Moon is a spherical rocky body, probably with a small metallic core, revolving around Earth in a slightly eccentric orbit at a mean distance of about 384,000 km. Its equatorial radius is 1,738 km, and its shape is slightly flattened in a such a way that it bulges a little in the direction of Earth. Its mass distribution is not uniform—the centre of mass is displaced about 2 km toward Earth relative to the centre of the lunar sphere, and it also has surface mass concentrations, called mascons for short, that cause the Moon's gravitational field to increase over local areas.

THE MOON

HERCULES GLOBULAR CLUSTER

It is a globular cluster of several hundred thousand stars in the constellation of Hercules. What a globular cluster means is that it is a spherical collection of stars that orbits a galactic core. Globular clusters are very tightly bound by gravity, which gives them their spherical shapes, and relatively high stellar densities toward their centres. To make the point clearer, the stellar density in the M13 is more than a hundred times more than that in the neighbourhood of the sun.

VENUS TRANSIT

Venus transit takes place when the planet Venus passes directly between the Sun and a superior planet. During a transit, Venus can be seen from Earth as a small black dot moving across the face of the Sun. The duration of such transit is usually several hours. The last transit of Venus was on 5 and 6 June 2012, and it was the last transit of the 21st century; the next transit will take place on 10-11 December 2117. A transit is similar to a solar eclipse by the Moon. Venus appears smaller and travels more slowly across the face of the Sun, because it is much farther away from Earth.

TRIFID NEBULA

Discovered by Charles Messier in 1764, M20 is a star-forming nebula located 9,000 light-years away from Earth in the constellation Sagittarius. Also known as the Trifid Nebula, M20 has an apparent magnitude of 6.3 and can be spotted with a small telescope.The nebula's name means "divided into three lobes," and refers to the object consisting of three types of nebulae and an open star cluster. The open cluster is surrounded by an emission nebula, a reflection nebula, and a dark nebula within the emission nebula. The dark nebula consists of dust clouds that absorb and block light from the bright objects behind them. It is responsible for the apparent gaps in the larger emission nebula that give M20 its trifurcated look.

THE STARTRAILS

© Mahavir Agrawal

Star trails reflect Earth's rotation, or spin, around its axis. The Earth makes a complete rotation relative to the backdrop stars in a period of about 23 hours and 56 minutes. So, as seen from Earth, all the stars go full circle and return to the same place in the sky after this period of time, which astronomers call a sidereal day – a revolution with respect to the stars.

Earth's spin makes star trails What this means is that, if you're standing out under the stars, you see them move across the sky as the night progresses. The stars – like the sun during the daytime – move from east to west across the sky every night.

NEEDLE GALAXY

First spotted in 1785 by Uranus' discoverer, Sir William Herschel (1738-1822), NGC4565 is one of the most famous example of an edge-on spiral galaxy, oriented perpendicularly to our line of sight so that we see right into its luminous disc. Also known as the Needle Galaxy for its narrow profile, bright NGC 4565 is a stop on many telescopic tours of the northern sky, in the faint but well-groomed constellation Coma Berenices(refers to a classical story concerning the hair of Berenice, the wife of Ptolemy III of Egypt). At a distance of only about 40 million light-years, NGC 4565 is relatively close by, making it more luminous than Messier 31, the Andromeda Galaxy.

WHIRLPOOL GALAXY

Messier 51a is popularly known amongst stargazers and astro-enthusiasts as the Whirlpool Galaxy! In a dark sky, it can be resolved through modern-day amateur telescopes. Located near the easternmost star of Ursa Major, Alkaid, the extensive spiral arms of this mystic galaxy have been the foremost point of study for researchers. These were believed to be formed due to its close interaction with M51b, which is a dwarf galaxy as seen in the picture. The winding arms are actually long lanes of stars and gas, laced with dust.

THE PLEIADES

"The Pleiades star cluster", also known as the seven sisters and Messier 45 is a conspicuous object in the night sky which is open star cluster nearest to earth and visible with the unaided eye in the night sky located in constellation of Taurus which is approximately 445 l.y. away from earth with magnitude 1.6 declined at 24 degrees and 7 minutes,has a core of approx 8 l.y. radius.Galileo Galilei was the first astronomer to observe M45 through telescope.Contains a number of hot luminous B-type stars . The 9 brightest stars in the messier taken from greek mythology represent the seven sisters-Asterope, Electra, Mereope, Maia, Caleno, Taygeta and Alcyone and their parents,Pleione and Atlas.

The Milky Way is a barred spiral galaxy some 100,000–120,000 light-years in diameter, which contains 100–400 billion stars. It may contain at least as many planets as well. The Solar System is located within the disk, about 27,000 light-years away from the Galactic Center, on the inner edge of one of the spiral-shaped concentrations of gas and dust called the Orion Arm. The stars in the inner ≈10,000 light-years form a bulge and one or more bars that radiate from the bulge. The very center is marked by an intense radio source, named Sagittarius A*, which is likely to be a supermassive black hole.

THE MILKY WAY

DYSON SPHERE

Energy has been used in various stages throughout human history, each stage was followed by an increase in energy harvest never seen before . And now our aim is a complete transition to renewable sources and also to fusion technology if fortunate. If we are lucky enough to survive and use our resources judiciously, we may gain complete control of the resources of our planet and may start looking towards the Solar System to expand into. However this will require a huge amount of energy, and one of the only possible sources is our Sun. If we want to collect most of the sun's energy possible, it will require us to construct the most ambitious megastructure ever imagined: The Dyson Sphere. Contradicting its name it will not be a solid shell enclosing the sun as it'll be vulnerable to impacts and may crash into the sun. The viable design will be swarm of orbit panels that will beam out energy that they collect from the Sun. This task is followed by a lot of challenges which can be split into three main categories: Material, Design, and Energy. Mostly they will be enormous mirrors that will refocus the light to collecting station. They must be light and durable. The energy requirement is so enormous that it may itself require a Dyson Sphere to disassemble a planet, but for now let's assume there is plenty light on mercury.First, the Solar collector will give us the energy needed to disassemble the planet, the miners'll use this energy to mine the surface and the valuable metals will eventually be extracted by the refiners and fabricated into the satellite. Lastly, we will have to launch them into space using sort of railgun. Soon from this we are going to have an ex-ponential growth as each panel provides energy to build another. This feat of building a Dyson Sphere could be achieved in a decade if we assume a square km long satellite takes a month to build. Even 1% of the sun's energy will bring an unbelievable change as we would be able to create infrastructure anywhere in the solar system, travel to other stars, and inhabit other planets without worrying about energy consumption. Scientists believe that there may be other Dyson Sphere already present in our galaxy. With the short-term political gains and conflicts, it may not be possible for humanity to achieve this feat, but if we come together the only limit will be our imagination.

by Soumith Batta

RECENTLY DISCOVERED PLANETARY FORMATION DISC

by Anshul Agarwal

A new Alma image has revealed extraordinary fine detail that has never been seen before in the planet forming a disk around a young star. These are the first observations that have used Alma with its antenna at almost their maximum extent. This has resulted in the sharpest picture ever made at submillimeter wavelengths. The new results are a huge step forward in the observation of how protoplanetary discs develop and how planets form. This is the esocast cutting-edge science and life behind the scenes at ESO, the European Southern Observatory. Alma the Atacama Large millimeter/submillimeter Array is the world's most powerful telescope for observing the cold universe it consists of 66 high-precision antennas that can be placed in different configurations for the first time the Alma array has now been configured with the antennas up to 15 kilometers apart this is close to the maximum possible baseline of 16 kilometers and allows Alma to discern much finer detail than has ever been possible up to now for Alma's first observations in this powerful new mode research has pointed the antennas at HL Tauri a young star about 450 light years away which is surrounded by a dusty disc the resulting image exceeds all expectations and is sharper than images routinely obtained by the NASA/ESA Hubble Space Telescope it reveals unexpected fine detail in the HL Tauri protoplanetary disc which consists of material left over from the birth of the star the image shows a series of concentric bright rings with enigmatic dark patches these structures are clear signs of the presence of multiple planets as they sweep up material from the disk HL Taurus disk appears to be a lot more developed than would be expected from the age of the system this suggests that the process of planet formation may be faster than previously thought young stars like HL Tauri are born in clouds of gas and fine dust in regions which have collapsed under the effects of gravity dense hot cos form and eventually ignite to become young stars these baby stars are initially cocooned in the remaining gas and dust which eventually settles into a protoplanetary disc through many collisions the dust particle will stick together growing into clumps the size of sand grains and pebbles and ultimately asteroids comets and even planets can form in the disk the young planets will then disrupt the disk and create rings gaps and holes such as those structures now observed by Alma the investigation of these protoplanetary disks is essential to our understanding of how earth formed in the solar system observing the first stages of planet formation around HL Tauri may show us how our own planetary system may have looked during its formation more than four billion years ago by operating in its close to final configuration Alma has demonstrated its enormous observational potential this starts a new era in our exploration of how stars and planets were formed.

THE UNSEEN SKIES

by Kalash Talati

An exoplanet is any planet beyond our solar system. Most orbit other stars, but free-floating exoplanets, called rogue planets, orbit the galactic center and are untethered to any star. It's really tricky to observe and distinguish an exoplanet from its star, as they look the same to a telescope. We only see the sum total of the brightness of the star and the planet. So astronomers observe the planet when it passes behind the star, when the light shining from the planet is blocked. By measuring the change in total brightness, we can figure out how bright the planet is, which tells us its temperature. The temperature is susceptible to whether an atmosphere is there or not. If you have a thick atmosphere, it's really good at transporting heat from the hot, illuminated side of the planet to the dark night side. If you have no atmosphere, all of this starlight hits just one hemisphere, and you would measure a really hot dayside. Whereas a cooler dayside suggests an atmosphere is there.

Till now, most exoplanets observed have been like Jupiter, gas giants. Very few rocky Earth-like planets have been detected. Even then, details like weather, atmosphere, geology, etc have been complicated to measure. But things are about to change; the launch of the James Webb Space Telescope (JWST) will potentially help the astronomers observe much more habitable planets, see through their clouds and see the exact wavelengths in the planet's colour spectrum that are getting absorbed by molecules in its atmosphere, which lets us determine the chemical composition of atmospheres more precisely.

Soon after the launch of JWST, a team led by Laura Kreidberg will observe the TRAPPIST-1 system, a star system 40 light-years away that's famous for having seven roughly Earth-size planets, and we will have our first look at the skies that were never seen before.

JWST

The next generation space telescope

by Kavish Priolkar

The James Webb Space Telescope (JWST) is being jointly developed by NASA, the European Space Agency (ESA), and the Canadian Space Agency (CSA). Yet, this Hubble successor will have to wait a little longer. After a handful of major delays spanning years for this ambitious project, it's been delayed by yet another couple of weeks. James Webb was scheduled for a launch on Oct 31, which got delayed to Dec 18 due to problems with the Ariane 5 launch vehicle. The telescope will be launching on the same (VA256), from Europe's Spaceport in French Guiana. NASA said the telescope co-mpleted testing in Calif-ornia and was moving into the packing-up and shipping phase as of late August. Unlike the Hubble Telescope, wh-ich observes in the near ultraviolet, visible, and near infrared spectra, the JWST will observe in low frequency range, from long-wavelength visible light through mid infrared , which will allow it to observe objects that are too old and too distant for Hu-bble to observe. James Webb is co-nsidered the next step in space ob-servation, especially at a time when Hubble is showing its age and battling serious technical glitches. The telescope is incredibly complex. It must be folded up like origami for launch and will open itself back up once it's safely in space. Surprisingly, early in its development which had begun in 1996, it was scheduled for launch in 2007 but then underwent major redesigns. After many delays, the telescope was finally launched successfully on 25th December, 2021, a Christmas gift to entire Astronomy community across the globe.

ORIGIN OF LIFE

by Aryan Vora

There are many theories about how life on our planet began; some are mundane and boring while others are crazy, but they just might be true. The current most widely accepted theory for the creation of life on our planet is the Primordial Soup Theory. We shall also explore Panspermia and other speculations of life on our world and even outside it.

PRIMORDIAL SOUP THEORY

The most widely accepted theory on the origin of life on Earth states that soon after the Earth formed, many inorganic and organic molecules were floating in the primordial oceans. This theory is also referred to as Abiogenesis. When exposed to light, heat, and electricity (in the form of lightning), the various molecules recombined to give rise to primitive life, self-replicating molecules.

PANSPERMIA

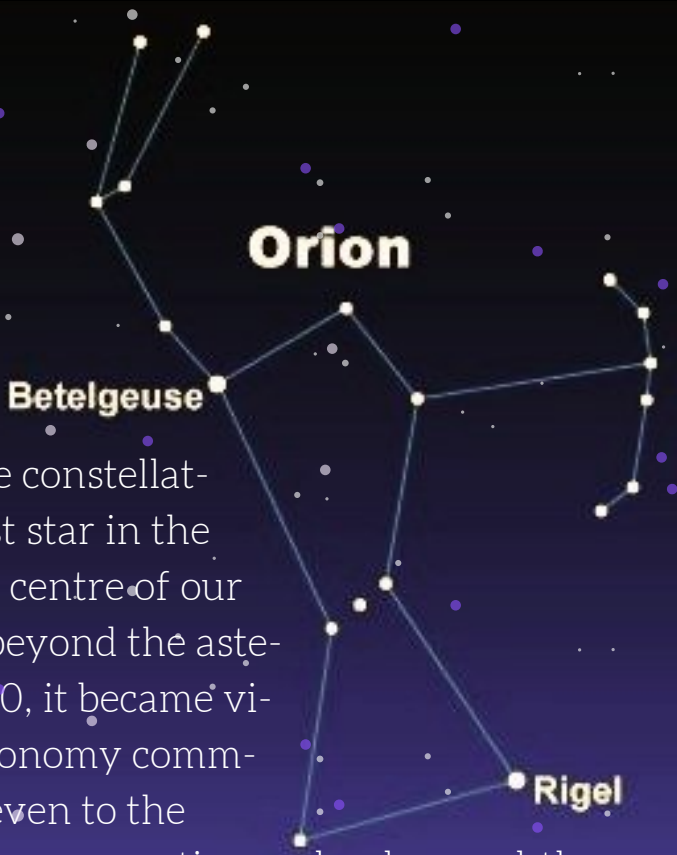
It is possible that we may be aliens. The theory behind this is that life may have begun off the planet and may have been carried over to the third rock from the sun on a comet or meteor. The meteor may have originated from our system. Mars has shown signs that life may have existed on the red planet in prehistoric times. The meteor may have been from another system, which suggests that life might exist in other systems. This theory is not far-fetched as bacteria have been observed to survive on the ISS after being exposed to space for long periods.

THE FERMI PARADOX

We have always wondered that if life could begin on Earth or some other planet, why can't we observe life throughout the cosmos. This paradox is known as the Fermi Paradox, and the consequences are dire. The lack of life in the universe we have observed implies that there are hurdles that life must cross to survive. These hurdles are limitations to the creation of life or maybe extinction events. If life on Earth has crossed the hurdle, that may be a good sign, but that means we will be very lonely. If the hurdle is behind us, then maybe the creation of life is sporadic, or the transition from unicellular to multicellular life is rare, and our life is one of the few that was able to cross it. However, if the hurdle is ahead of us, then we may be in trouble because that means that a life-ending event is looming in the future.

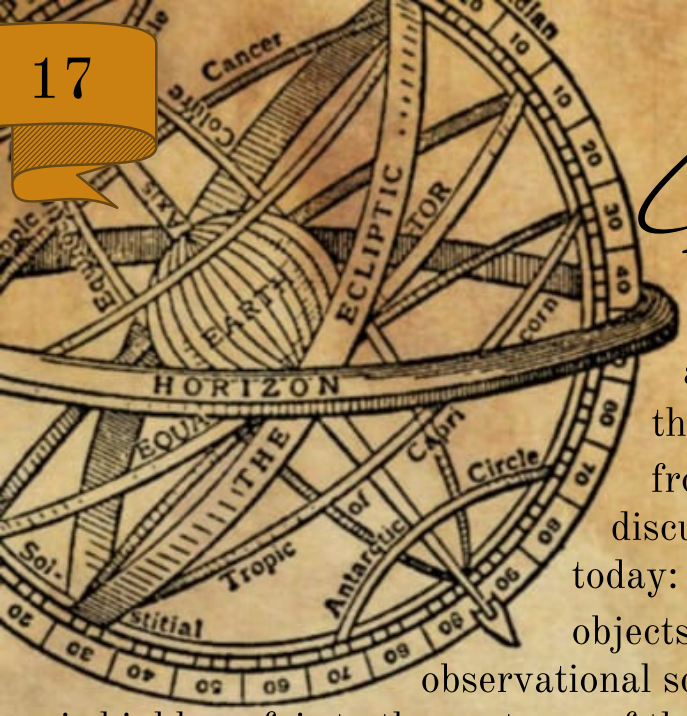
DIMMING OF BETELGEUSE

by Kalash Talati



Betelgeuse is a red supergiant in the constellation of Orion. It is the tenth brightest star in the night sky. Fun fact: If it were at the centre of our Solar System, its surface would lie beyond the asteroid belt! In late 2019 and early 2020, it became visibly darker, which baffled the astronomy community. This change was noticeable even to the naked eye. Many teams of astronomers continuously observed the star during its Great Dimming. By April 2020, the star had returned to its normal brightness. Several theories were put forward to explain this phenomenon which happened over a scale of weeks (which is a really short time for astronomical events).

The most plausible explanation given was; the star was partially concealed by a cloud of dust formed when the star ejected a large gas bubble that cooled down enough for the gas to condense into solid dust. This, maybe, was the first time scientists observed the formation of stardust which is usually rich in elements like carbon which become the building blocks of new generations of stars and terrestrial life on planets. Many scientists believed that this event is a precursor to a supernova because Betelgeuse is a dying supergiant. But this notion was discontinued as the star regained its brightness. Fun fact: As Betelgeuse is approximately 725 light-years away so this event actually happened around the 1300s.



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!

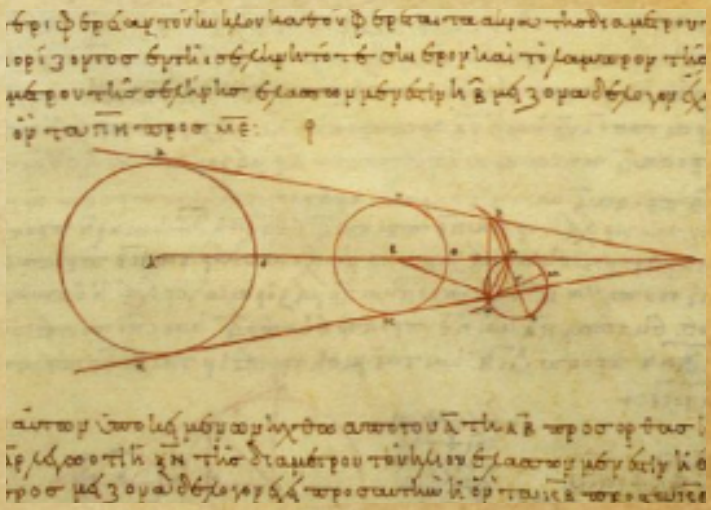
While talking about calendars, we come across several civilizations who tracked celestial objects for timekeeping. Unconventional to the solar and lunar calendars, Egyptians in the 3000 BCE controlled their calendar using Sirius, the brightest star. Sirius' heliacal rising occurred, by chance, when the 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.

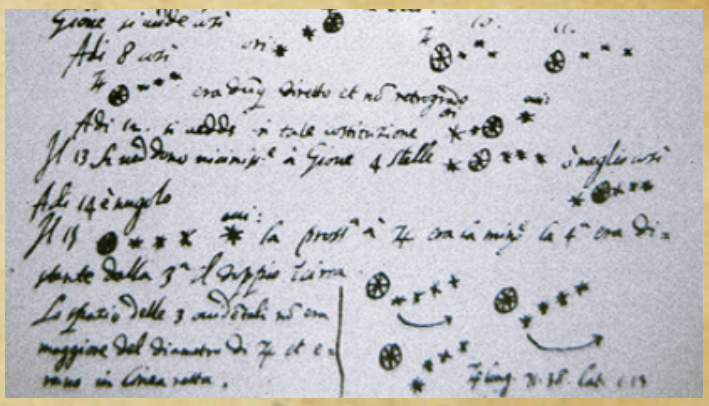
Meanwhile, a mathematics genius set his foot in Astronomy. Around 510 CE, Aryabhata produced his treatise *Aryabhatiya*, in which he described Earth's rotation and explained the cause of solar and lunar eclipses as well as calculated the sidereal rotation period fairly accurately. The ideas were carried 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.

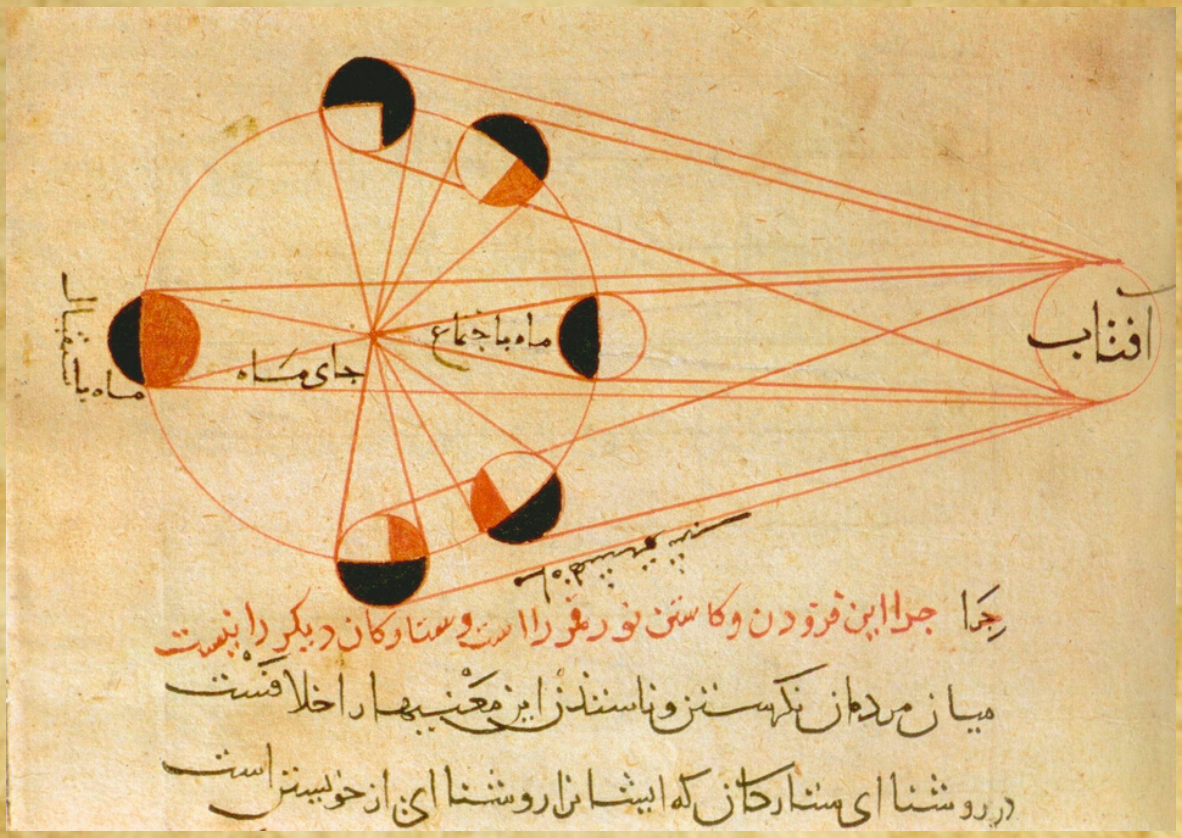
voyage back to Europe but in the medieval period, where Copernicus challenged Ptolemy's geocentrism in 1543 in his work De revolutionibus orbium coelestium, though he still made use of Plato's circular orbits which made him use even more epicycles than Ptolemy had to. In the 1580s, astronomy's first 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.

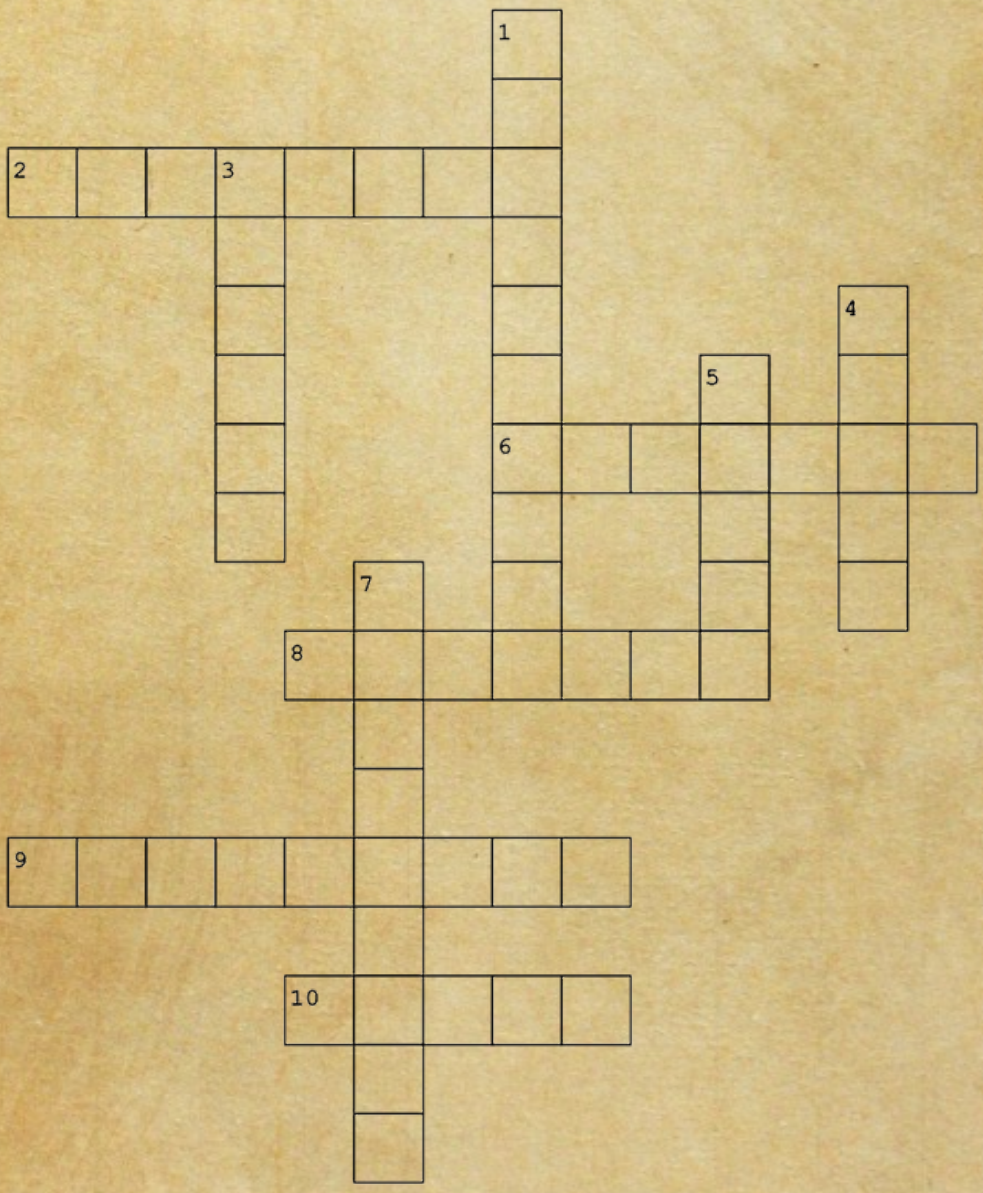
PS: To slightly cover up for the grave injustice I mentioned at the beginning, I recommend all the interested readers to go through *The Cambridge Concise History of Astronomy* by Michael Hoskin. Also, if you have any anecdotes regarding the history of science, do share with me! If you know IITK's Astronomy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

Constellations Crossword



Across

2. A roman strongman who completed the 12 labours as a curse. (8)
6. Minor immortal bird in the southern sky. (7)
8. Named after this northern constellation was a weapon of the protagonist of the Beyblade Metal series.(7)
9. Depicted on a northern kingdom ensign with a starry plough, Saptarishi. (4, 5)
10. A great mythical beast that breathes fire, circumpolar constellation. (5)

Down

1. Five stars in northern heavens, named after a narcissist queen (10)
3. Swan on one corner of summer triangle (6)
4. Situated near the celestial equator, contains
5. 2 of the 10 brightest star, with a bright nebula in the south of the constellation visible to the naked eye (5)
7. Located in the Sea, contains the first discovered variable star (5)
   Half-human, lived in the Forbidden Forest, near Hogwarts School (9)

“Remember to look up at the stars and not down at your feet. Try to make sense of what you see and wonder about what makes the universe exist. Be curious. And however difficult life may seem, there is always something you can do and succeed at. It matters that you don’t just give up.”

— Stephen Hawking

Thanking the Cygnus team

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