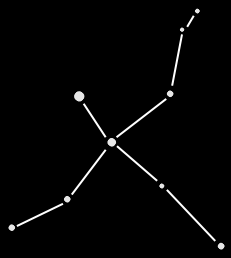
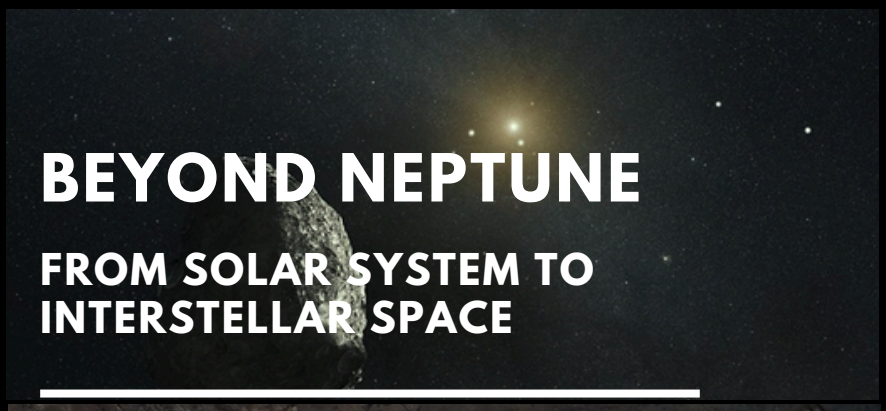
Astro SG

OCTOBER 2025
EDITION 14



CYGNUS,
THE SWAN

ASTRO DIGEST



BEYOND NEPTUNE

FROM SOLAR SYSTEM TO INTERSTELLAR SPACE

LATEST ON: MARTIAN LIFE

A STEP TOWARDS FINDING EXTRA-TERRESTRIAL LIFE, RIGHT IN OUR NEIGHBOURHOOD.

EARTH'S NEW SECOND MOON

A NEW COMPANION FOR OUR LONELY MOON?

TRIVIA

BECAUSE THE UNIVERSE LOVES TO KEEP US GUESSING!

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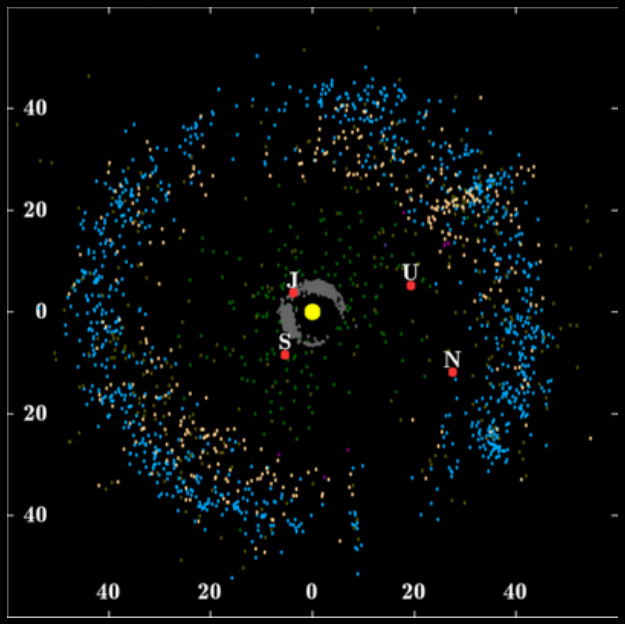
BEYOND NEPTUNE

The Solar System and its 8 planets, subject of many science projects and children's songs, and most often the first thing we learn about space. However, besides the properties and science of the planets and nearby objects, most of us will graduate far beyond the solar system to interstellar objects and phenomena. But let's circle back and dive deeper into our home star system!

Starting with the Sun, followed by Mercury, Venus, Earth, Mars, Jupiter and Saturn, these planets have been known to us for thousands of years, their movement against background stars apparent to the naked eye. Although Uranus was also visible to the naked eye, it was incredibly dim and was mistaken for a star due to technological limitations.



THE KUIPER BELT AGAINST THE ORBITS OF GAS PLANETS
SOURCE: WIKIMEDIA

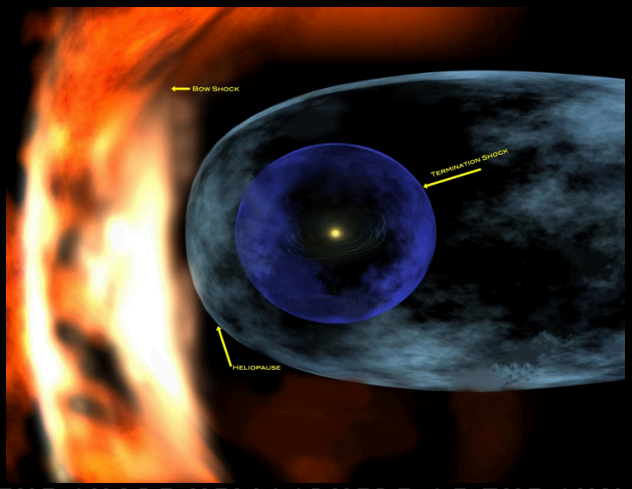
Following the invention of the telescope, Uranus was soon identified as a planet. Our final planet, Neptune, orbiting at 30 AU away from the Sun, could only be spotted through a telescope. Despite being visible even in Galileo's time, it would only be identified as a planet more than two centuries later.

Beyond our final planet, Neptune, we get to The Kuiper Belt, home to former planet, Pluto. The Kuiper belt is a ring of asteroids and comets, called Kuiper Belt Objects (KBOs), and ranges from 30 AU to 50 AU along the plane of the solar system.

The existence of this belt was proposed by Gerard Kuiper decades before the discovery of any KBOs. Given the relative short lifespans of comets with shorter periods, surviving up to a few hundred thousand years before being disintegrated by the Sun, it would be assumed that most of such comets would have evaporated long before the Solar System reached its current middling stage and long before we would be able to observe them. But we do. Gerard Kuiper proposed that a reservoir of asteroids and comets lying beyond Neptune is the solution to our constant stream of comets.

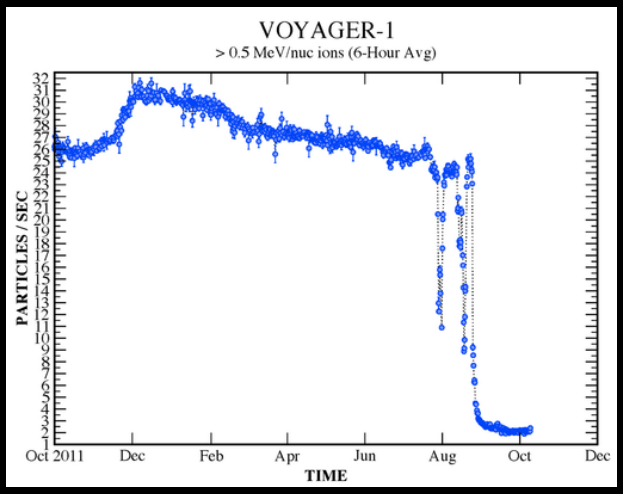
BEYOND NEPTUNE

Beyond the Kuiper Belt and its visible ring of asteroids, is an invisible border. Curiously, it is not a result of the gravity of our Sun, but by solar winds. High energy objects create a background of cosmic radiation. This cosmic radiation does not reach us however as the inner solar system lies within a bubble in this background, called the Heliosphere, “inflated” by the Sun’s constant streams of solar wind pushing back against this cosmic radiation. As we move further away from the Sun, solar winds slow down and decrease in energy density, and we arrive at the Heliopause, a region where the 2 forces balance.



THE SHAPE HELIOSPHERE OF THE SUN
SOURCE: NASA

This boundary was passed by both voyager 1 and voyager 2 at 121 AU and 119 AU respectively. This Heliopause was detected as a sharp drop in detection of charged particles characteristic of our Sun.



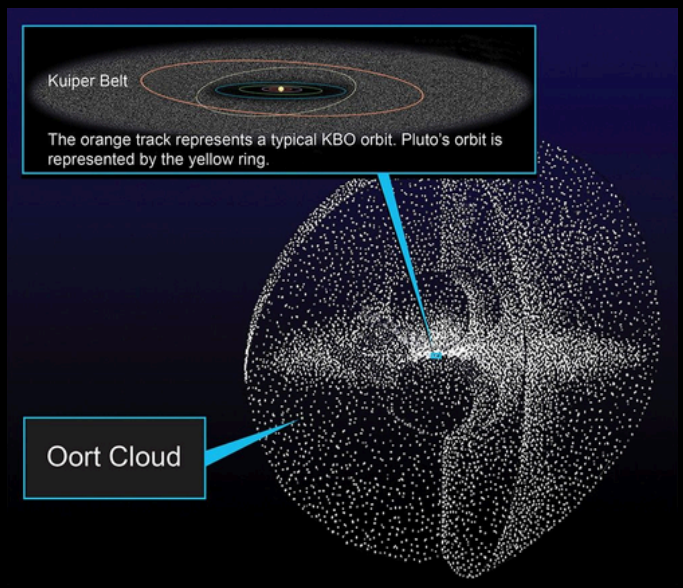
INSTRUMENT READINGS ON VOYAGER 1 AS IT EXITED THE HELIOSPHERE, A SHARP DECREASE IN HIGH ENERGY NUCLEI CHARACTERISTIC OF THE SUN
SOURCE: WIKIMEDIA

The Heliopause

The Heliopause is defined by the equilibrium of the Sun’s solar winds and the solar wind of surrounding stellar objects. Thus, it is subject to factors such as the Sun’s orbit around the Galactic Center, resulting in a tail-like shape. It is also subject to the Sun’s surrounding stellar activity; it is theorized that 3 million years ago, the Solar System passed through a dense interstellar cloud, causing the Heliopause to shrink all the way to Earth’s orbit! This exposure to cosmic interstellar radiation is linked to peaks in the deposition of rare radioactive isotopes right here on Earth.

BEYOND NEPTUNE

Moving even further away, at the edge of the Sun's gravitational influence, lies a theoretical sphere of asteroids and comets, similar to the Kuiper Belt, called the Oort Cloud. The inner portion of the Oort cloud, also called the Hills Cloud, spans from 250 AU to 1500 AU, and is aligned with the plane of the Solar System. As we move towards the edge of the Oort Cloud, objects start to slowly deviate from this plane, ultimately forming an outer spherical portion of the Oort Cloud which encloses the entire solar system. The outer Oort cloud lies between 10,000 to 100,000 AU.



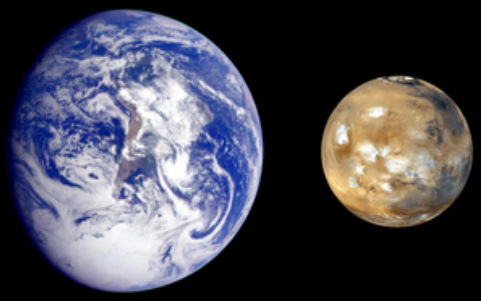
THE OORT CLOUD; THE SHAPE OF THE CLOUD IS LARGELY SPHERICAL, GETTING THICKER WHEN APPROACHING THE PLANE OF THE SOLAR SYSTEM
SOURCE: NASA

COMET MCNAUGHT, AN OORT CLOUD OBJECT
SOURCE: S. DEIRIES/ESO

Sedna, the furthest known dwarf planet in our solar system with an orbit ranging from 76 AU to 937 AU is proposed to be a member of the Hills cloud. While no known members of the outer Oort Cloud have been identified, multiple comets have been identified to originate from the region. Comet McNaught, also known as the great comet of 2007, and the brightest comet in over 40 years, is said to originate from the outer Oort Cloud, having traveled for 6 million years. It was then captured by the gravity of the inner solar system and now follows an orbit around the Sun with a period of 92 600 years. This was a similar case to one of the most famous comets known, Halley's Comet which is also theorised to have originated from the Oort Cloud as well, before being captured.

LATEST ON: MARTIAN LIFE

Thus far, Mars is one of the most explored and researched celestial bodies, and for good reason – it holds the highest potential to one of the most pressing questions in astronomy: are we alone? It might be a cold and barren planet now, but we have reasons to believe that there was a time wherein our red neighbour was a lot warmer and wetter. Recently, NASA's Mars rover Perseverance, might have brought us closer than ever to discovering a smoking gun for alien life.



COMPOSITE IMAGE OF EARTH (LEFT) AND MARS (RIGHT)
SOURCE: NASA/JPL

Confidence of Life Detection (CoLD) scale

Before diving into the details of this exciting news, we must familiarise ourselves with the system with which the scientific community classifies discoveries of extraterrestrial life. The volatility of the media makes it imperative that science communication, especially one regarding something as complex as alien life, is done with utmost caution to avoid sensationalisation.

CoLD is a seven-step scale proposed to characterize astrobiological discoveries. It aims to facilitate clear communication to the public regarding progress made in the search for potential life in space. By placing focus on the quality of evidence and lingering uncertainties, it presents every report of a potential biosignature as a new rung in the ladder towards finding alien life, rather than having it risk being labeled as a false alarm when disproved. The scientific method relies on process more than it does results, and 'false alarms' of the past have in fact led to significant progress in this field in the form of clarification on what constitutes evidence for life.

THE COLD SCALE
SOURCE: NASA

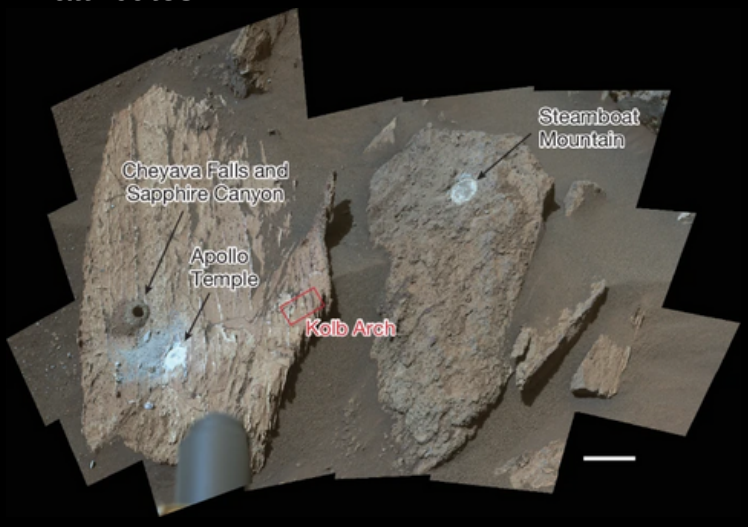
LATEST ON: MARTIAN LIFE

Starting with detection of a potential sign of biological process at level 1, to a confirmation at level 7, anything that claims to be “proof of life” has to undergo vigorous study, align with further independent findings and produce future observations consistent with predictions in order to be declared as a confirmation of presence of biology.

This will be the framework used as we discuss the potential biosignature found on mars.

The Findings

Samples were taken from a rocky formation known as the “Bright Angel” Formation. These different samples were given the names “Cheyava Falls”, “Sapphire Canyon”, “Apollo Temple” and “Steamboat Mountain”. Studies done on these samples revealed some interesting attributes.



MASTCAM-Z MOSIAC IMAGE OF WORKSPACE WHERE SAMPLES WERE COLLECTED
SOURCE: HUROWITZ ET AL. 2025, FIG 2

CLOSE-UP OF CHEYAVA FALLS
Dark, irregularly shaped spots (circled in red) and leopard-spots (circled in blue) contain traces of minerals that could have microbial origins
SOURCE: HUROWITZ ET AL. 2025, FIG 3

As seen in the images, there are some curious features on these rocks. Firstly, there are dark, irregularly shaped spots. These masses are enriched in Fe, P and Zn. And, more importantly, have molar ratio Fe:P of around 3:2, which is consistent with Vivianite crystals $\left(Fe_3^{2+}(PO_4)_2 \bullet 8H_2O\right)$ or some lower-hydration-state ferrous phosphates and their oxidation products. The dark spots also appear to have formed on the rocks themselves (as opposed to being deposited).

Another feature are the leopard-like spots, with dark-toned rims and lighter toned cores. They are theorised to be reaction fronts. The darker rims are also enriched with Fe, P and Zn.

LATEST ON: MARTIAN LIFE

The lighter coloured cores have chemical and colour properties consistent with the mineral Greigite.$(Fe^{2+}Fe_2^{3+}S_4)$

Formation of vivianite and greigite can be associated with the oxidation of organic matter, as the process is coupled with the reduction of Fe-phosphate and Fe-sulfide respectively. The mudstone colour would also have its red colour bleached as Fe and S were being reduced.

On Earth, Vivianite and Greigite nodules are formed in fresh water and marine settings as a by-product of microbially mediated reactions. Such processes also promote incorporation of Zn and other heavy metals into vivianite nodules, which is consistent with the Zn enrichment found in the nodules on Bright Angel samples. Such minerals are thought to be some of the earliest chemical evidence for life on Earth and are also thought to be potential biosignatures to look out for when exploring alien terrain. The detection of such features and studies done on them brought these features to Level 3 of the CoLD scale: *Demonstration or prediction of biological production of signal in the environment of detection*.

However, abiotic means must be thoroughly considered before these findings can be move onto Level 4.

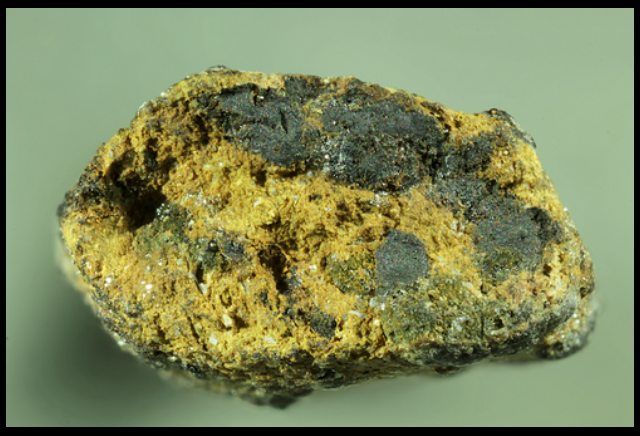
Possible non-biological processes to consider

VIVIANITE CRYSTALS
SOURCE: WIKIMEDIA

Vivianite production:
Many organic compounds are able to promote the abiotic reductive dissolution of ferric iron oxide minerals. Organic matter is present on the Bright Angel formation so such abiotic reactions could have occurred. Without further analysis, it cannot be determined for sure if the organic compounds present on Bright Angel could drive such reactions.

Another means to produce Fe^{2+} would be through the abiotic oxidation of pyrite (an iron sulfide mineral). However, this process requires a highly acidic environment, which has no evidence of being present on the Bright Angel formation.

LATEST ON: MARTIAN LIFE



GREIGITE MINERAL
SOURCE: ANTONIO ZORDAN

Greigite production:

Greigite production could have been facilitated by dissolved sulfide. Dissolved sulfide can be abiotically produced from two sources: magma degassing into local groundwater, or an abiotic reduction of sulfate to sulfide under high temperatures $(150 - 200^{\circ}C)$. No magmatic systems have been found near this site, nor is there any evidence that these rocks have been in contact with necessary conditions for sufficiently high temperatures to be reached.

Conclusions

With alternate, abiotic reaction routes shown to be implausible, considering a biological scenario would be reasonable. Oxidized iron and sulfate would be reduced as organic matter is consumed, resulting in Vivianite (from iron reduction) and Greigite (from sulfide reduction) being produced as chemical by-products. This puts the biosignatures on CoLD scale Level 4.

However, Perseverance has exhausted all its analytical capabilities and further probing into the possibility of these findings as proof of life is impossible. The only way we could conduct further studies and move up the CoLD scale would be to study the samples in laboratories on Earth.

The good news: One of the missions of the Perseverance rover is to prepare samples to be brought to Earth for more in depth analysis.

The bad news: The White House recently announced a 47% cut to NASA's funding, which would lead to the cancellation of up to 41 planned space missions, including the return of Martian samples to Earth. If the planned budget cuts were to be enacted, this would be as far as scientists can go with the study of these samples. Scientists are protesting this budget cut, so we'll have to wait and see how this will play out.

THE PERSEVERANCE ROVER ON MARS
SOURCE: NASA/JPL-CALTECH/MSSS

EARTH'S NEW SECOND MOON

Sometimes, on a good day, if you look up into the clear night sky, you'll see a bright ball of luminous emittance much like our Sun. That brilliant ball of rock, which has accompanied the Earth in its orbit for tens of millions of years, is our Moon. Our Moon, in all its tireless brilliance, has been central to human history, responsible for how we used to track the passage of time, and mark agricultural seasons. Hence, it is not surprising that it has attained godhood countless times across countless human civilisations.

This sole and inextricably divine position is now coming under threat. On the 2nd of August 2025, the Pan-STARRS1 (PS1) telescope at the Haleakala Observatory in Hawaii observed a small celestial body of magnitude ~26 - so dim as not to be visible even by large Earth-based telescopes. This body, 2025 PN7, was found to be orbiting exceptionally close to Earth, having a semi-major axis of approximately 1.003 AU (almost exactly the distance from the Sun to the Earth). In other words, 2025 PN7, having an orbit around the Sun exceptionally similar to that of the Earth, looks as though it is orbiting the Earth itself. And that makes it a second Moon, right?

How exciting to imagine the empyrean Moon finally bestowed with a companion!

Does this mean the Earth now actually has two moons? Unfortunately, we must turn to terminology for answers, and as usual, the answers we get are not as we might expect.

THE MOON, TAKEN BY NASA'S GALILEO SPACECRAFT
SOURCE: NASA/JPL

What is a moon?

To begin with, it turns out that the layman definition of a moon as "a thing which orbits a planet" is not incredibly scientifically precise. A more scientific term is often used - "natural satellite" - which means "an astronomical body orbiting a planet, dwarf planet, or Solar System body (or sometimes another natural satellite" - is also not completely precise. Even the International Astronomical Union (IAU), the sole arbiter of astronomical nomenclature and style, does not yet have a concrete definition of what a moon, or a natural satellite, is. So what is a moon, really? Scientists haven't really thought it through yet.

EARTH'S NEW SECOND MOON

To make matters worse, it turns out that objects which appear from the Earth's perspective to orbit the Earth may not actually strictly be orbiting the Earth. It may simply be following a trajectory around the Sun which is very similar to the Earth's, such as in the case of 2025 PN7. Such objects are (more precisely, thankfully) termed quasi-satellites. These objects stay in a co-orbital configuration, also known as a 1:1 mean-motion resonance, with their associated planet. In essence, this means that for every full orbit a planet makes around the Sun, a quasi-satellite makes a full orbit as well. The distinction between quasi-satellites and true natural satellites, however, is that quasi-satellites orbit too far away from Earth to be gravitationally influenced by it.

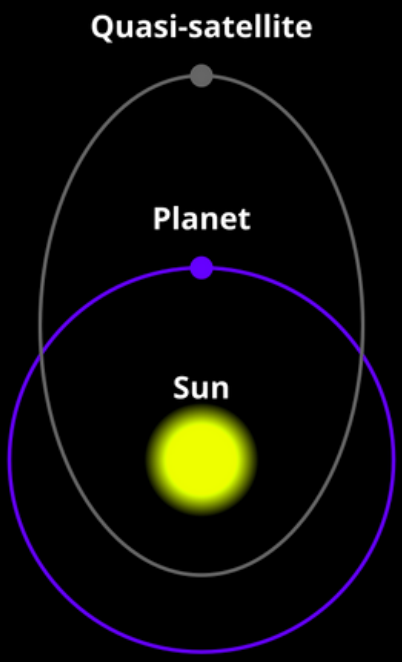


DIAGRAM OF GENERIC ORBIT OF A QUASI-SATELLITE
SOURCE: WIKIMEDIA

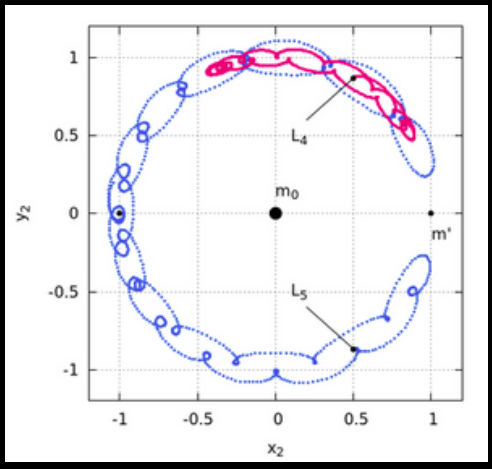
As of writing this article, it is recognised by the scientific community that the Earth has not merely one, but eight quasi-satellites sharing its orbit - including 2025 PN7. Many of these objects reside within the Arjuna asteroid belt, a dynamical class which carries a group of asteroids with very similar orbits to Earth's.

So what makes 2025 PN7 so interesting?

In addition to 2025 PN7 being recognised so recently by the scientific community, it does in fact have some significance. In particular, it has a rather stable orbit, and is likely to remain in this stable orbit for about another 60 years. This gives scientists ample time to study its characteristics and dynamics, which helps us understand the specifics of how near-Earth objects orbit around Earth. Though admittedly, the incredible dimness of the object makes it exceptionally difficult for amateur astronomers to observe - even in ideal conditions, large observatory telescopes with apertures meters long are required.

2025 PN7 is interesting for its orbital characteristics as well. In the past, it followed a horseshoe orbit: an orbit with the appearance of a horseshoe when viewed from the Earth's rotating perspective.

EARTH'S NEW SECOND MOON



AN EXAMPLE OF A HORSESHOE ORBIT
SOURCE: RESEARCHGATE

At present, as a result of dynamical interactions with the Earth, it follows a typical quasi-satellite orbit. In the far future, it is predicted to once again return to a horseshoe orbit.

2025 PN7 is also a relatively small object, standing at 19 metres in diameter. This size isn't to be looked down upon, however, as it's similar to that of the Chelyabinsk superbolide meteor, which shone as bright as the Sun upon entry into the Earth's atmosphere and caused a blast, equivalent to the explosion of more than 400 thousand tonnes of TNT (trinitrotoluene explosive). Thankfully, 2025 PN7 isn't predicted to enter Earth's atmosphere at any time in its orbit.

To conclude: the Moon's symbolic status as the Earth's sole true natural satellite appears not to be at threat for the time being.

Chang'e may, for now, recline to rest on her laurels; Selene on her chariot; and Khonsu in his Theban pantheon, at the very least until scientists of the modern era, with their instruments pointed indefatigably toward the heavens, divine or intuit a never-before-observed dimly lit rock - which they may say has orbited our Earth for the longest time - to threaten the divinity of the ethereal Moon, and to agitate the very foundations of the heavens themselves.

TRIVIA

Welcome to the Trivia! Here, we will include interesting facts and problems that we have curated for you, the reader, along with answers for problems in the previous newsletter. Enjoy!

Problem I

Moons, or natural satellites, were discussed in detail earlier in this newsletter. As of 25th March 2025, our solar system has 421 planetary moons and 471 more orbiting other solar system bodies, giving a total of 891 moons. With such a high number, it is pretty odd how the terrestrial planets seem incredibly moon-poor. Why don't Mercury and Venus have any moons?

Problem II

Despite not being able to directly observe the big bang, astronomers and cosmologists seem very confident that there was, in fact, a big bang. What are the observational evidence that supports this theory?

TRIVIA

Fun Fact of the Month

UY Scuti is one of the largest stars ever discovered, with estimates of its radius going up to 1700 times the radius of our Sun! To put this into perspective, if it was in the centre of our Solar System, it would engulf the orbit of Jupiter!

Most of the stars in the running for the title of “largest star” are Red Supergiants, stars that have left the Main Sequence branch. (i.e. No longer fusing Hydrogen into Helium in their cores) The fusion of heavier elements produces more energy, which blows outer parts of the star outward and causes the star to swell, often to massive sizes hundreds of times larger than it was before. There is a limit to the size, though, if the surface gets too far from the center, gravitational forces holding it to the star is too weak and it will be blown away by the radiation. They are also relatively cool. UY Scuti has a surface temperature of about 3550K, which is almost 2000K cooler than the Sun.

ANSWERS FOR THE PREVIOUS NEWSLETTER

Problem I: Drake Equation

This is the Drake Equation:

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

It is a tool to estimate the number of alien civilizations in the Milky Way galaxy with which communication might be possible, formulated by astronomer Dr Frank Drake in 1961.

- $N =$ *the number of civilisations in our galaxy with which communication is possible*
- $R_e =$ *average rate of star formation*
- $f_p =$ *fraction of stars that have planets*
- $n_e =$ *average number of planets that can potentially support life per star that has planet(s)*
- $f_l =$ *fraction of planets that could support life that actually develop life at some point*
- $f_i =$ *fraction of planets with life that could develop intelligent life*
- $f_c =$ *fraction of intelligent life (civilisations) that could develop technology that releases detectable signals into space*
- $L =$ *length of time for which such civilisations release detectable signals into spcae*

Lower estimates have N at 9.1 × 10−13 while the higher bound is 15 600 000, which is quite a huge range! This is due to how many of the factors for N, like the fraction of life that would evolve intelligence, is hard to estimate. (We currently have a sample size of one.) So whatever value you might have come up with, fret not, it could very well be a valid interpretation of the Drake equation.

ANSWERS FOR THE PREVIOUS NEWSLETTER

Problem II: Possible sources of oxygen on Mars

Currently, there are two feasible methods of generating oxygen in space. The first is electrolysis of water. This is also the main source of oxygen on long-term manned space missions like the ISS. While Mars might appear dry on the surface, it is thought that there might be reservoirs of water deep underground. If true, water can be harvested from these underground reservoirs and turned into oxygen.

The second is from the carbon dioxide in the Martian atmosphere. Mars' atmosphere is mostly comprised of carbon dioxide, making it an abundant source of oxygen. In fact, scientists over at MIT have created a device called MOXIE (Mars Oxygen In-situ Resource Utilisation Experiment), which is currently onboard the Perseverance rover on Mars. Since the rover's landing on Mars back in 2021, a total of 122g of oxygen has been generated.

EVENTS AND STARGAZING

Featured Stargazing Location: Singapore Botanic Gardens

SOURCE: NPARKS

You might be familiar with Botanic Gardens in the day, but did you know that at night, it also makes a great stargazing spot? Separated from the city buzz, it is one of the least light-polluted areas on the mainland. Receiving most of its food traffic in the day, at night, it becomes a tranquil retreat for a relaxing night of stargazing. In addition, it is located near Botanic Gardens MRT, making it incredibly convenient to get to.

There are large open-areas near Swan Lake where you can set up telescopes, or just lay out a picnic mat and stargaze. The horizon might be blocked by trees, but you'd also be far from any pesky skyscrapers.

Happy stargazing!

EVENTS AND STARGAZING

The October skies open the chapter for winter constellations and some very interesting deep-sky objects. Keep reading to find out!

Free-hand stargazing

- **Mercury -** Her position between the Sun and the Earth makes sighting problematic as it elongates no more than ~25°. It doesn't help that we are hemmed in by ranks upon ranks of high-rise buildings. Fortunately, on 29th October, Mercury will appear as far away from the Sun as it will be in 2025. At an eastwards elongation of ~23° just before sunset, a perfect opportunity to catch a glimpse of our intrasolar sibling has arisen!

- **The Hunter's Supermoon** - the brightest moon of 2025 is about to rise. In about a week's time, on 5th November, the Moon will reach the apogee of its revolution. Watch as the vista of Singapore is enveloped by the pale lunar irradiance from the supermoon hanging high in the sky.

MERCURY
SOURCE: PETE LAWRENCE

FULL MOON
SOURCE: TOMRUEN

EVENTS AND STARGAZING

Binoculars

- **Messier 31 -** Andromeda Galaxy. Once believed destined to merge with our Milky Way in a paroxysm of cosmic brilliance, revised models of the collision considering gravitational influences from satellite galaxies now paint a different story.
  In any case, while imaging our galactic neighbour in 2023, astrophotography hobbyists incredulously discovered what would now be known as the Strottner-Dreschler-Sainty-Object 1, a wide region of doubly-ionised oxygen atoms (O-III). Researchers are now trying to uncover the origins of the mysterious blue arc. Despite the futility in trying to spot the object with the naked eye, you can still enjoy Andromeda's bright core by pointing your binoculars northwards.

- **Caldwell 14 -** the Double Cluster in Perseus is a pair of open clusters that sits between the constellations of Perseus and Cassiopeia. The two clusters are easily resolved through even low-powered binoculars.

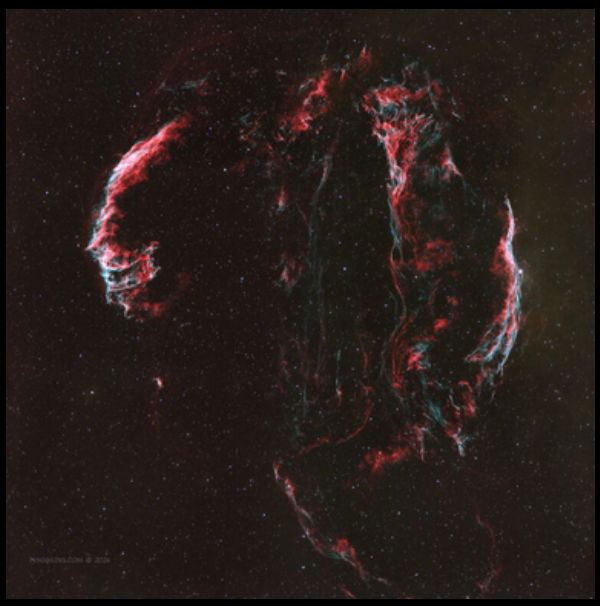
ANDROMEDA GALAXY (M31)
SOURCE: GRAN TELESCOPIO CANARIAS , BRAY FALLS

DOUBLE CLUSTER IN PERSEUS (CALDWELL 14)
SOURCE: DARK ATMOSPHERE, ROTH RITTER

EVENTS AND STARGAZING

Telescope

- **The Cygnus Loop -** Spanning an area six times that of the full moon, the mosaical supernova remnant is sliced into countless individual parts – each with its own catalogue number and deserving of its own feature. That said, the Eastern Veil remains one of the most popular targets for amateur astronomers due to its striking blueish-green tendrils attributed to ionised oxygen. Find it by tracing the constellation of Cygnus eastwards.



THE CYGNUS LOOP
SOURCE: TVHIGGINS

- **Messier 45 -** Pleaides is one of many mainstays of the winter sky. There are no regions of light-emitting ionised gases; instead, its wispy nebulousity comes from the light radiated by stars in the cluster reflecting off the dusty cloud enveloping them. This soft blanket of the *Seven Sisters* is faint, requiring amateur equipment to observe. The bright star 27 Tauri, being in its immediate vicinity, can be used to locate the iconic cosmic beauty.

PLEIADES (M45)
SOURCE: EARTHSKY, HARSHWARDHAN PATHAK

SOURCES

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IMG: Perseverance rover selfie

Earth's New Second Moon
Research paper: Meet Arjuna 2025 PN7, The Newest Quasi-satellite of Earth
Pan-STARRS
IAU FAQs
The Moon
IMG: The Moon
IMG: Quasi-satellite orbital diagram
IMG: Horseshoe orbit diagram

SOURCES

Trivia
Red supergiants
Drake equation (NASA)
Drake equation estimates
Oxygen sources on the ISS
MOXIE

Featured Stargazing Location
IMG: Singapore Botanic Gardens

Events and Stargazing
IMG: Mercury
IMG: Full Moon
Emission Nebula near Andromeda Galaxy
IMG: The Double Cluster in Perseus
IMG: The Cygnus Complex
IMG: Pleiades