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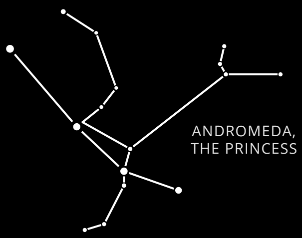

ASTRO DIGEST

WHAT IS COSMIC INFLATION

AND WHY IT IS NOT COSMIC EXPANSION

THE FLICKERS OF A BLACK HOLE

MULTI-INSTITUTIONAL COLLABORATION CRACKS 30 YEAR OLD BLACK HOLE MYSTERY

JUPITER'S MYSTERIOUS PLASMA SYMPHONY

WHAT MISCHIEF IS JUPITER'S PLASMA REALLY UP TO UP THERE?

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BECAUSE THE UNIVERSE LOVES TO KEEP US GUESSING!

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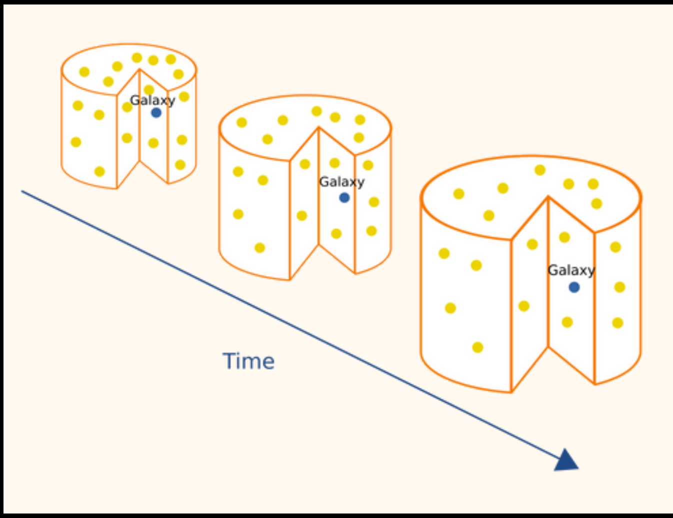
WHAT IS COSMIC INFLATION

It is very common that early on, in the education of a budding astronomer, they learn of the expansion of the universe at a large scale. If they are very curious, they may also learn that the expansion we observe now is determined by the overall densities of radiation, matter and dark energy of the universe. In the midst of their research, they may encounter terms such as “Cosmic Inflation” and “Inflation Theory.” As linguistic synonyms, one may be compelled to assume that Cosmic Inflation and Cosmic Expansion are one and the same. However, these 2 theories have their distinctions; from learning them one will discover a deeper understanding of the universe and its origins.



THE SCALING EFFECT OF COSMIC EXPANSION SOURCE: WIKIMEDIA

On Cosmic Expansion

Cosmic expansion, as defined by the large-scale expansion of the universe, was already well accepted by the astronomy community by the early 20th century following Hubble’s paper highlighting the proportionality between the recession velocity of distant galaxies and their distance from us. Following the discovery of the cosmic microwave background (CMB), which provided a snap shot of the early universe, it was acknowledged that the expansion of the universe as we see it now and for the majority of the universe's lifetime, from its early hot dense state, is believed to be driven by the balance of the density of 3 key players: radiation, matter (including both dark matter and normal matter) and dark energy. Radiation and matter both exert a positive pressure on the universe, decreasing its expansion, while physical evidence of the increasing expansion rate of the universe indicates the existence of a yet unknown dark energy that drives the expansion throughout the universe’s life.

WHAT IS COSMIC INFLATION

While cosmic expansion and its accompanying equations and models have been useful to predict and extrapolate the expansion of the universe from its initial hot dense state to the present day until its eventual end, there was little to explain its initial conditions. 2 highly mysterious aspects of the early universe are the flatness problem and horizon problem.

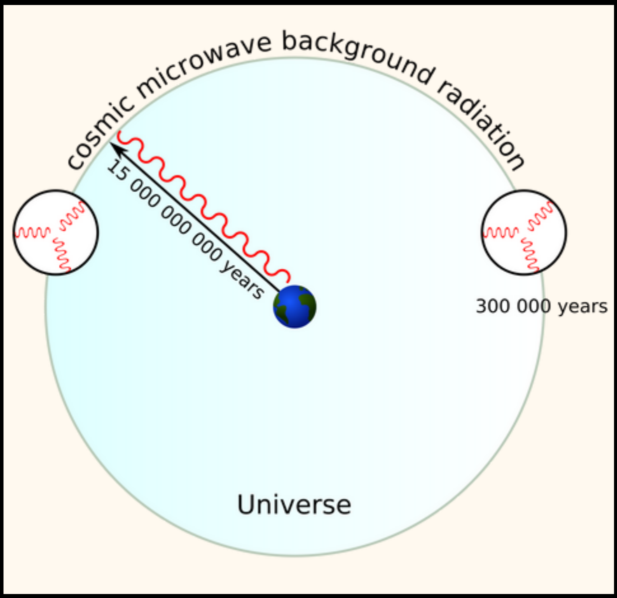
The flatness problem

The flatness problem addresses the curvature of the universe. As shown by Einstein's Theory of general relativity, space can be curved by the things in it. Any initial curvature in the universe's early state will be accentuated through cosmic time. However, observations of the CMB now show a wholly flat, uncurved universe. As a snapshot of the early universe, the light from the CMB has travelled great distances to reach us, coming from the literal edge of our observational universe. If any such large scale curvatures in the universe were to exist, it would be evident in the difference between our observation of the CMB and its extrapolated form from our observation of the universe now. However, no such curvature was observed! Given the age of the universe, such an observation appears to us as one of the greatest cosmic coincidences we have ever observed.

The horizon problem

The horizon problem highlights the uniformity of the CMB everywhere. Opposite poles of the CMB correspond to great distances in the early universe, a universe that is far too early to equilibrate at such distances and yet these points are largely uniform.

An immediate explanation for these 2 great coincidences are that this is just the universe existing or that these initial conditions are the only way for the universe in a way for us to observe it. However, we wouldn't be scientists if we didn''t try to find the mechanism and explanation for everything around us.

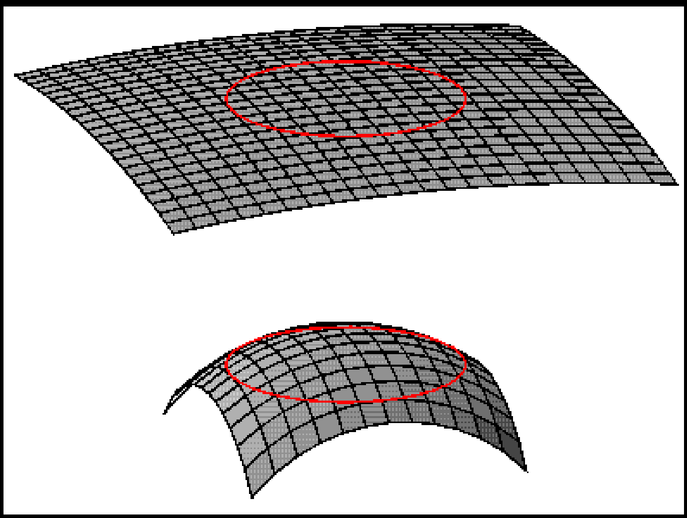


THE HORIZON PROBLEM ILLUSTRATED: SMALLER CIRCLES SHOWING DISTANCE LIGHT HAS TRAVELLED AFTER THE AGE OF THE UNIVERS SOURCE: WIKIMEDIA

WHAT IS COSMIC INFLATION

In the late 1970s to 1980s, cosmologists, Alan Guth, Andrei D Linde, and Alexi A. Starobinsky proposed a separate period of expansion in the early universe, distinct from the way our universe expands now. Instead of directly extrapolating the universe from the now till the limit of physics, Guth proposed a short period of extreme scaling of the universe that helped set up the initial conditions for cosmic expansion. This brief expansion is what we now know as cosmic inflation.

Cosmic inflation would explain the lack of any large scale curvature of the universe even after billions of years by expanding space such that any curvature in the early universe would get stretched out to the point it is unobservable to us even till now. Furthermore, in inflationary theory, the regions that were casually linked and in equilibrium prior to cosmic inflation would arrive at the points we observe in the CMB.



THE FLATTENING EFFECT OF COSMIC INFLATION ON A CLOSED UNIVERSE
SOURCE: NED WRIGHT'S COSMOLOGY TUTORIAL

Furthermore, as we extrapolate the timeline of the universe, it gets denser and hotter, inevitably reaching extreme conditions that would result in the production of exotic matter particles not yet observed, as predicted by the standard model of particle physics. The lack of any of such particles suggests that the conditions when such particles were produced were quickly skipped over, something a rapid cooling and expansion in the early universe would explain.

The necessary scaling required for cosmic inflation to solve the above problems would be at the scale of a doubling of length every 10^-37 seconds for at least 10^-35 seconds. A patch measuring 3 x 10^-44 m would grow to 1m in that period! The driving force for such an expansion is evidently wholly separate from cosmic expansion. This theoretical field dubbed the Inflaton is currently still unknown and awaits further research!

THE FLICKERS OF A BLACK HOLE

Recent work through a cross-collaboration between Indian Space Research Organisation (ISRO), Haifa University, and the Indian Institute of Technology-Guwahati (IIT-G) has shone light on a long suspected link in black hole behaviour. Chiefly, their corona's X-ray flickering and brightening-dimming cycle have proven to be but two facets of the same cosmic process. In this article, we will dive into the overarching mechanism responsible for the phenomenon as a whole. However, it would be pertinent to get a few basic details out of the way.

INDIAN SPACE RESEARCH ORGANISATION. SOURCE: WIKIMEDIA

The basics

Black holes, for the uninitiated, are extremely dense regions from which no form of matter or energy can escape. They form when the cores of supermassive stars collapse, such that the pressure holding atomic nuclei stable is overcome by the force of gravity of infalling matter. The matter is believed to collect entirely in the center of the black hole, also called its singularity. We cannot see this singularity because the gravity of a black hole is so powerful, it sucks in even light itself. This happens up to a certain radius, also called the event horizon.

If a black hole sucks in everything, how is it that we just mentioned it emitting light through X-ray flickers and brightness cycles?

The answer to that is actually very simple. These X-ray flickers and the said brightness is emitted by extremely hot matter near, but crucially out of, the black hole's event horizon. As long as the matter remains outside the event horizon, we can see the light it emits. While this disc, also known as the accretion disc due to the matter it accretes from its companion, extends out to a large radius, our phenomena of interest occur in the region known as the corona, which is the innermost and most energetic region of the disc. Here, matter approaches close to the speed of light. In effect, it is similar to the Sun's corona but much hotter and brighter.

Let's get back to the meat of the article; the phenomena themselves, as well as the crucial link brought to the fore by the observations.

THE FLICKERS OF A BLACK HOLE

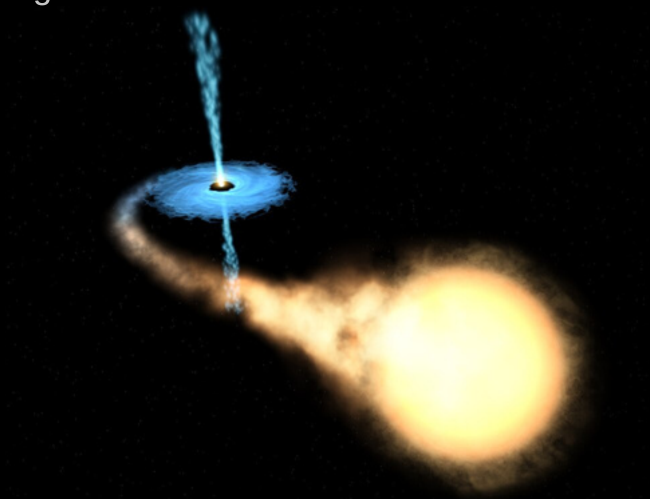
What causes the X-ray flickers?

Currently, there are only theories, albeit to a high degree of confidence, behind the flickering mechanism. The most widely believed model states that it occurs in certain black hole binary systems. Particularly, in the subclass of X-ray binaries. In these systems, the black hole's companion loses mass to the black hole. The infalling matter heats up due to the extreme acceleration it undergoes as it approaches the event horizon, forming a hot flow of matter around the black hole with temperatures hot enough to emit X-rays. However, this process by itself is insufficient to get the flickering effect. The flickering occurs if the axis of rotation of the disc of matter is misaligned with the black hole's own axis of rotation. This misalignment is the essential cause behind the flickering, though the exact process is a highly complex general relativistic process. For interested readers, you may check out Fragile, Straub & Blaes, 2016 in the references for the in-depth explanation of this process.

How does this relate to the brightening cycles?

The driver behind the brightening cycles also doubles as a switch for the X-ray flickers. Naturally, we need to understand the mechanism of this driver.

The pulsations occur due to an interplay of radiation pressure, gravity and mass accretion rate from the binary companion. Suppose we start our analysis when the corona is at its maximum size and its brightness is minimum. The process starts when mass accretion from the companion builds up, causing cooling in the hot corona which causes it to recede in size. The disc of matter approaches a characteristic black hole radius known as the Innermost Stable Circular Orbit (ISCO). Below this distance, all matter and energy enters a decaying orbit into the black hole. Note that this is different from the earlier mentioned event horizon of a black hole, as matter and energy can still escape from the region between the ISCO and event horizon. However, we digress.



X-RAY BINARY. SOURCE: WIKIMEDIA
This depiction of an X-ray binary shows gas and plasma from a main sequence star getting sucked into the accretion disc of a black hole, whose extreme temperatures lead to the release of alot of X-ray radiation.

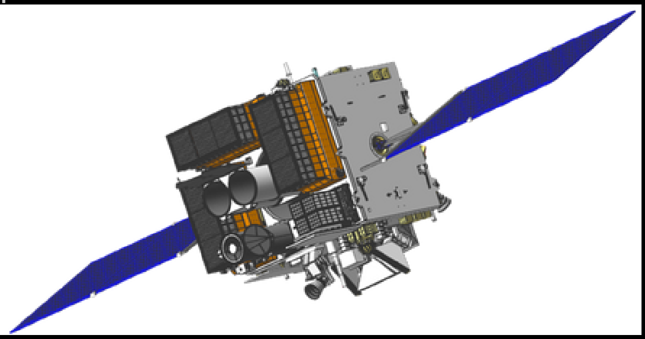
THE FLICKERS OF A BLACK HOLE

As the disc approaches the ISCO, the conditions for X-ray flickering are met, causing it to start. The flickering occurs over a large range of frequencies; from millihertz to up to 450 Hz. At this point, the high accretion rate does the reverse: it heats up the disc instead of cooling it. This is because of the much more extreme gain in kinetic energy as the matter falls into a deeper orbit around the black hole as compared to the earlier, outer radius. The gas heats up greatly, to the point that radiation pressure forces the disc outward, making it expand and dim. The earlier conditions for X-ray flickering are thus lost, leading it to stop. The process eventually repeats, leading in turn to a cyclical brightening and dimming that matches up with the starting and stopping of the X-ray flickering.

How the ISRO-Haifa University-IITG team's recent observations play into this

The hybrid team used AstroSat to observe a 10 solar mass black hole labelled GRS 1915+105, located 28,000 light years away in the constellation Aquila. AstroSat is India's first multi-wavelength space observatory, developed and launched indigenously by ISRO. Using the satellite's X-ray capabilities, the team managed to observe the telltale X-ray flickers occurring about 70 times per second.

Secondly, this black hole has cyclical changes in brightness, with two distinct luminosity states. Strikingly, the black hole's corona only displayed th characteristic X-ray flickering during the bright phase, just as theory predicts! Remarkably, this marks the first direct observational confirmation of the phenomenon.



ASTROSAT. SOURCE: WIKIMEDIA
Astrosat is ISRO's first multi-wavelength space observatory. It's capabilities include observation in the visible, near UV, far UV, soft X-ray and hard X-ray regions. It has been involved in a wide scale of studies, from Solar System objects to cosmological studies.

Why it matters

This landmark observation ties together two long studied mysteries of X-ray binaries: rapid X-ray flickers and their slower bright-dim cycles. As this discovery is in its early stages, further confirmation and studies by other X-ray binary teams have yet to arrive. However, the initial results from the study look incredibly promising. To give a sense of idea, this has been an open problem for about three decades. All through that time, GRS 1915+105, and its characteristic QPOs were well known.

THE FLICKERS OF A BLACK HOLE

However, there was no consensus between its observed QPOs and bright-dim cycles through much of that time, let alone any observational link. QPOs were discovered in many other X-ray binary systems, albeit their cause was not agreed upon. It thus goes to show the significance of this milestone observation. The ISRO–Haifa University–IIT-Guwahati team's finding of the direct link in GRS 1915+105 therefore marks a milestone. It brings coherence to decades of puzzling observations and opens the door to a deeper understanding of how black holes feed.

HAIFA UNIVERSITY. SOURCE: WIKIMEDIA

Haifa University is a public research university located in Haifa, Israel specialising in various domains. The relevant department involved in this study would be the Center for Theoretical Physics and Astrophysics Center, which specialises in cutting-edge basic research regarding the fundamental nature of the cosmos.

INDIAN INSTITUTE OF TECHNOLOGY, GUWAHATI. SOURCE: WIKIMEDIA

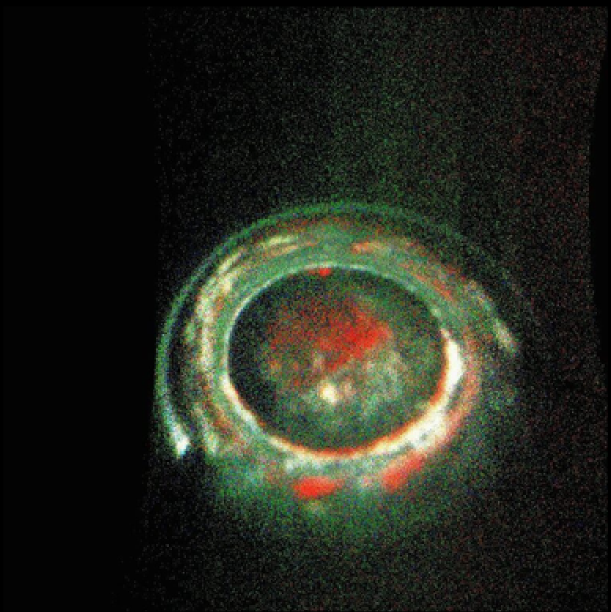
IIT-Guwahati is one of the pre-eminent engineering and technology institutions of India. Researchers from its Department of Physics played an important role in this study, contributing expertise in black hole accretion and high energy astrophysics.

JUPITER'S MYSTERIOUS PLASMA SYMPHONY

The discovery that electrified Jovian skies

Jupiter, the largest planet in our solar system, has always been a world of superlatives—bigger storms, stronger gravity, and a magnetic field that dwarfs Earth's. Now, scientists have added another extraordinary feature to its resume: a newly discovered plasma wave unlike anything seen before in planetary science.

The finding, detailed in Physical Review Letters earlier this year, comes from data collected by NASA's Juno spacecraft, which has been orbiting Jupiter since 2016. As Juno swooped over the giant planet's north polar auroral region, its instruments picked up strange plasma oscillations—a new type of quasi-monochromatic burst that ripples through the upper atmosphere.



An image of Jupiter's auroras, taken by Juno's Ultraviolet Spectrograph.
Source: NASA/JPL-Caltech

This is not just another item in Jupiter's long list of atmospheric oddities. It may reshape how scientists understand planetary magnetospheres, plasma physics, and even the broader question of how magnetic environments shape habitability.

What is plasma and why does it matter here?

Plasma is often called the fourth state of matter—an electrified soup of charged particles that behaves in complex, often counterintuitive ways. Unlike the solid, liquid, and gas phases we're familiar with on Earth, plasma can sustain waves, interact with magnetic fields, and create phenomena like auroras, lightning, and even solar flares.

On Jupiter, plasma is everywhere. The planet's powerful magnetic field traps charged particles from the Sun, from Jupiter's volcanic moon Io, and from the surrounding space environment. These particles swirl around the planet in radiation belts and plunge along magnetic field lines into the polar regions, where they crash into the atmosphere and generate Jupiter's dazzling auroras.

JUPITER'S MYSTERIOUS PLASMA SYMPHONY

The newly discovered plasma wave adds a surprising twist: instead of chaotic, broadband noise that scientists expected, Juno detected coherent, rhythmic oscillations, almost like a cosmic musical note resonating through Jupiter's magnetic field.

The Auroral Stage - Nature's plasma laboratory

The auroras of Jupiter are more powerful than anything on Earth. While our own auroras are powered by solar wind particles channeled into Earth's poles, Jupiter's auroras are fed by a combination of solar input and the constant volcanic activity on Io, which pumps over a ton of material per second into Jupiter's magnetosphere.

This unique fueling mechanism means that Jupiter's auroras act as a giant plasma physics experiment, naturally producing conditions that no Earth-based laboratory could replicate. And it was in this setting that Juno's Waves instrument detected the plasma oscillations that scientists now believe represent a new category of plasma behaviour.

The signature of a cosmic wave

According to the study, these new waves are characterized by narrowband, quasi-monochromatic bursts. That's a fancy way of saying they're highly ordered signals, confined to specific frequencies, and lasting long enough to be distinct from random noise.

The discovery raises intriguing questions:

- What excites these plasma waves?
- Are they driven by Io's volcanic plasma, by solar wind bursts, or by some deeper process inside Jupiter's magnetic field?
- Could they carry energy that helps power Jupiter's auroras or drive atmospheric heating?

One of the most exciting possibilities is that these waves act as **energy transport channels**, funneling power across Jupiter's magnetosphere in ways not previously understood.

Why this discovery matters

At first glance, a plasma wave on Jupiter may sound like a small detail in a giant cosmic puzzle. But zoom out, and the implications become clear:

- Planetary Magnetospheres: By studying Jupiter's plasma waves, scientists refine models of how magnetic environments work—not only around gas giants but also around Earth and exoplanets.

JUPITER'S MYSTERIOUS PLASMA SYMPHONY

- Space Weather: Plasma behavior drives storms in Earth's magnetosphere that can disrupt satellites and power grids. Insights from Jupiter's extreme environment may improve space-weather forecasting here at home.
- Habitability of Exoplanets: Exoplanets orbiting close to their stars are bombarded by stellar winds. Understanding plasma shielding mechanisms helps researchers gauge whether such planets could maintain atmospheres, a prerequisite for life.

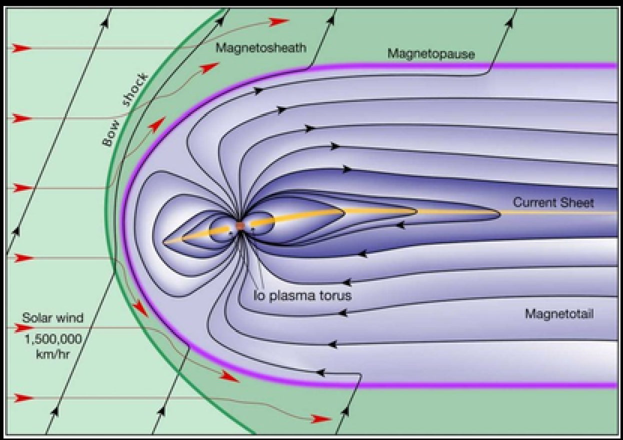
The role of Juno - Spacecraft or detective?

NASA's Juno spacecraft has become an invaluable detective in this planetary mystery. Launched in 2011 and arriving in 2016, Juno's mission was to map Jupiter's gravity, magnetic fields, and atmospheric dynamics.

The Waves instrument, built to measure electric and magnetic fields, wasn't originally designed to find a new class of plasma oscillations—but science thrives on surprises. By recording radio emissions and plasma wave signatures, it stumbled across a phenomenon that could only exist in the unique laboratory of Jupiter's polar skies.

From laboratory to cosmos, the bigger picture

One of the most exciting aspects of this discovery is its reach beyond Jupiter. Plasma waves are a universal phenomenon—occurring wherever magnetic fields and charged particles interact.



Schematic of Jupiter's magnetosphere
Source: Springer

That means lessons learned at Jupiter can apply to:

- Earth's space environment, helping to explain radiation belt dynamics.
- Other giant planets, like Saturn and Uranus, where auroras and plasma processes are still poorly understood.
- Exoplanetary systems, where plasma interactions with host stars may determine whether planets keep their atmospheres—or lose them entirely.

TRIVIA

Welcome to the Trivia! Here, we will include interesting facts and problems that we have curated for you, the reader.

The answers to the problems can be found in the next newsletter, but for now, we hope you'll enjoy this new segment!

Problem I

Play with Drake's equation and come up with your own estimate for the lower probability bound for life on other planets to exist in our universe.

Problem II

Suppose you are on the planning committee for an upcoming manned mission to Mars. You are assigned the task of finding all possible sources of oxygen on Mars. What are you going to recommend to your higher ups?

TRIVIA

Fun Fact of the Month

Your eyes are cosmic ray detectors. You read that right! In space, astronomers often see streaks of light in their eyes, called Light Flashes (LF). These are believed to occur due to Cherenkov radiation from cosmic rays.

Cherenkov radiation occurs when highly relativistic particles travelling faster than the speed of light get decelerated by the fluid in your eyes. This energy from this deceleration is converted into radiation, which gives off a characteristic blue hue.

But wait – is not faster-than-light travel impossible? Yes, but only for light travelling in a vacuum in which its speed is exactly 299,792,458 m/s. For dense media such as glass, minerals, or in this instance, the fluid in your eyes, light travels considerably slower than the speed of light in a vacuum. This allows particles to be faster than light in such media, until they lose sufficient energy through Cherenkov radiation.

ANSWERS FOR THE PREVIOUS NEWSLETTER

Problem I

The moon's trajectory would remain the same. This is because the force acting on it remains exactly the same as before, since the equation for Newtonian is only concerned with the mass of the interacting objects and their distance with respect to each other – all of these remain the same if the Earth were to be replaced with a black hole of the same mass.

ANSWERS FOR THE PREVIOUS NEWSLETTER

Problem II

Given the suggestive nature of the question, the answer indeed is yes. A spinning fluid forms a perfectly parabolic surface, which is precisely identical to a Newtonian reflector. The secondary mirror would serve to redirect the light to be observed from a suitable point, from where the magnified image could be observed.

EVENTS AND STARGAZING

Featured Stargazing Location: Saint John's Island

SOURCE: GOOGLE MAPS

Unlike our previous featured spots, this one happens to be a far more adventurous recommendation. Saint John's Island is located near the southern edge of Singapore's exclusive economic zone. In addition to its layered history as a former quarantine center, its lush flora and fauna that offer a kind of ecotherapy, and its present role as a recreational haven, the island also serves as one of Singapore's finest stargazing spots.

Its darker skies away from the mainland make up for its distance and difficulty of access. But do not take our word for it – using a light pollution map, such as this and a Sky Quality Meter (SQM) to Bortle Scale chart, we can find out the Bortle scale for Saint John's island. The northernmost point of the island, being closer to the mainland, comes in at Bortle Scale 6. The southernmost point is darker, with a SQM of 19.22 mag/arcsec^2 and thus comes in at a visible better Bortle Scale of 5. In other words, the Milky Way is visible from both these spots!!

So what are you waiting for? Grab your pals, find a suitable period when the Teapot is up in the night sky, pre-check the weather forecast and have a celestial time!

EVENTS AND STARGAZING

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

Free-hand stargazing

- **The Constellations of Pegasus and Andromeda** are deeply intertwined. In mythology, the princess Andromeda was chained to a rock, and awaited the cruel fate of being devoured by Poseidon's sea monster. In a serendipitous twist of fate, the demigod Perseus arrives on his shining winged-horse Pegasus. Enamoured by the beautiful princess, he swiftly dispatches of the sea monster and rescues her. The two constellations even share a common star, that is until the International Astronomical Union fixed boundaries and decided it belonged to Andromeda alone.

CONSTELLATIONS OF PEGASUS & ANDROMEDA
SOURCE: STELLARIUM

- **Total Lunar Eclipse** will peak at around 2 am on 7-8 September. Most people know how total lunar eclipses occur, but do you the reason for its appearance? It turns out that there are two factors at work. The first is the refraction of sunlight at the Earth's fringe atmosphere. The second is the dispersion of more energetic blue light, which explains its reddish-hue.

TOTAL LUNAR ECLIPSE
SOURCE: COSMOTOGRAPHY, SERGEI MUTOVKIN

EVENTS AND STARGAZING

Binoculars

- **The Wild Duck Cluster (Messier 11)** is extremely rich and densely populated, so much so that of all open clusters in the messier catalogue, it is the most distant one still able to be seen with the naked eye. Its common name derives from its brightest stars forming a "V" shape that makes it look like a flock of ducks in flight. It can be found near the constellation of Scrutum.

THE WILD DUCK CLUSTER (M11)
SOURCE: LA SILLA OBSERVATORY, ESO

- **The Pyramid cluster (Messier 39)** is a loose open cluster that has a larger apparent size than even the full moon. You will eventually arrive at it by star-hopping from Deneb of the Summer Triangle to a relatively bright star Rho Cygni. Its ease of finding makes it a perfect target for beginners.

THE PYRAMID CLUSTER (M39)
SOURCE: STARGAZERSLOUNGE, GEEKLEE

EVENTS AND STARGAZING

Telescope

- **Saturn's** ring is made up of many individual ones. The conspicuous gap that separates the "A" and "B" rings is given the name "Cassini Division". Additionally, the material comprising the ring is stretched so thin that you can fit an astonishing 22 earth-diameters in the ring's width. Unfortunately, its iconic ring will "disappear" for a short while due its edge-on orientation as seen from the Earth.

SATURN
SOURCE: ESA, NASA

- Saturn's position in the sky relative to the background stars varies by night; generally, look for a bright unblinking "star" with a pale-yellow hue.

- **The Dumbbell Nebula (Messier 27)** is the first planetary nebula to be cataloged by Messier. Despite what "planetary nebula" might suggest, it is unrelated to planets. Rather, it is the consequence of a dying star exciting the gas around it, resulting in a short-lived kaleidoscope of colours, much like the once stellar giant's swansong. It lies in the Summer Triangle, and near the constellation of Vulpecula. An O-III pass filter is recommended.

DUMBBELL NEBULA (M27)
SOURCE: NOIRLAB

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