NOVEMBER 2024
EDITION 5

ASTRO DIGEST

CETUS,
THE SEA MONSTER

ASTROBIOLOGY II

EXOPLANET DETECTION: AN EXTRAORDINARY PROCESS INDEED

HO'OLEILANA

DECODING ANCIENT COSMIC WAVES WITH A NEW DISCOVERY

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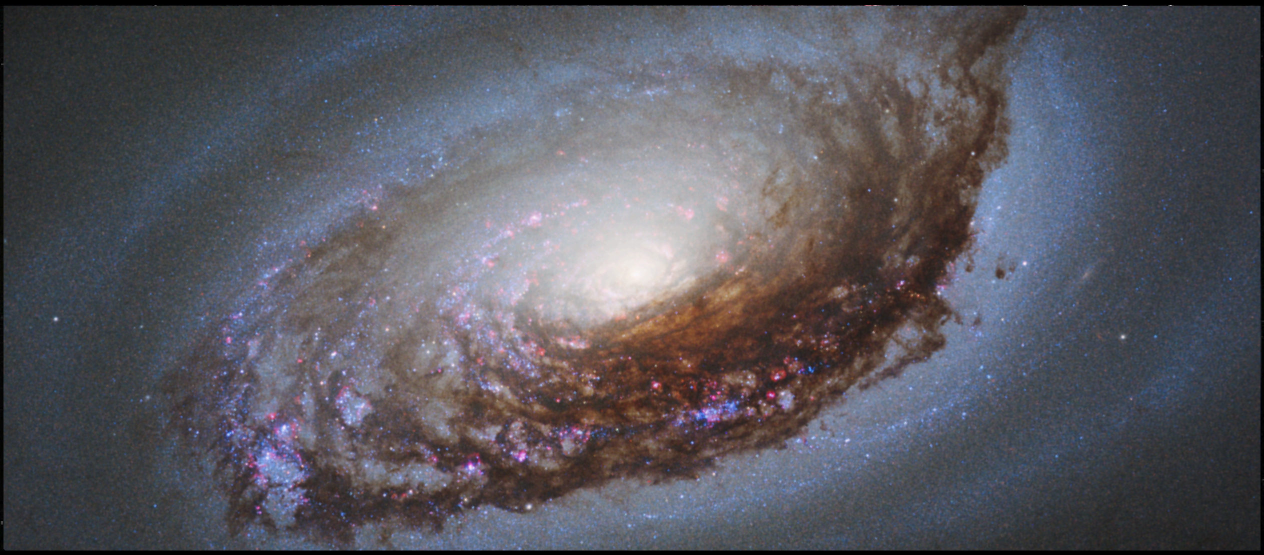
UNCOVERING A NEW AND HOPEFUL FOCAL POINT FOR STELLAR EVOLUTION STUDIES

TRIVIA

BECAUSE THE UNIVERSE LOVES TO KEEP US GUESSING!

EVENTS & STARGAZING

FEATURED STARGAZING LOCATION & OBJECTS
A ONCE-IN-A-DECADE COMET



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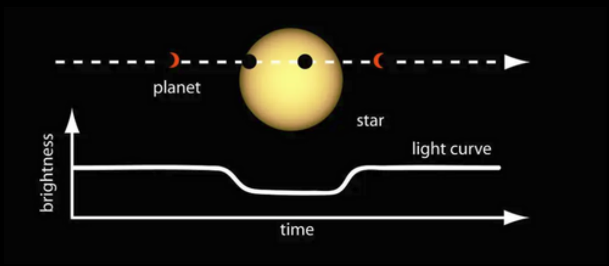
ASTROBIOLOGY II

Continuing from last month's newsletter, we will now discuss some of the main methods used to discover exoplanets.

Transits

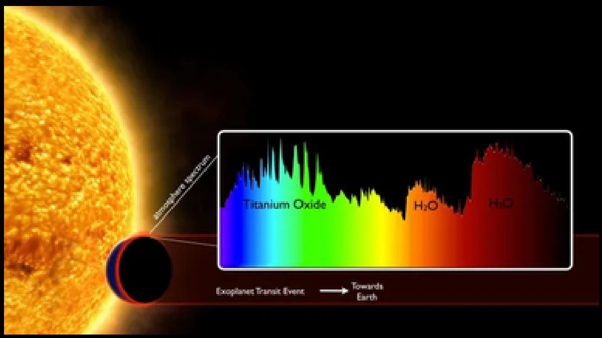
For planets whose orbital plane just happens to align with us here on Earth, astronomers are able to use the transit method to identify them. This is because the passage of the planet in front of the star will cause a significant dip in light intensity that we can observe here on Earth. And from that data, astronomers are then able to compute details of the planet such as its radius and orbital distance based on the light curve obtained.



TRANSIT LIGHT CURVE. CREDIT: NASA AMES

Graphic showing a transit and the light curve resulting from it.

Additionally, this transit will also allow astronomers to observe changes in the spectrum of the starlight passing through the planet's atmosphere, which can then be used to identify the different types of molecules/atoms present in the atmosphere.



EXOPLANET ABSORPTION SPECTRUM. CREDIT: EUROPEAN SOUTHERN OBSERVATORY.

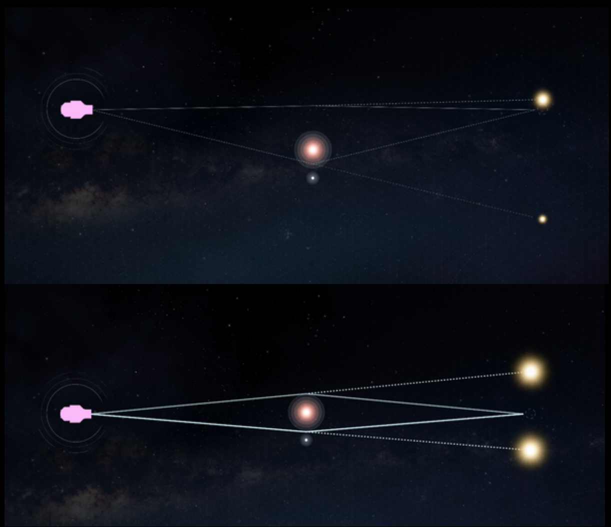
Astronomers can infer the composition of the exoplanet's atmosphere through comparing spectra before and during transits.

However, light curves obtained from the transit of multiple planets can get messy and make the data harder to discern. Regardless, it is still one of the most successful ways to detect exoplanets, with more than 4000 exoplanets detected in total.

ASTROBIOLOGY

Gravitational microlensing

Those that have learnt Einstein's theory of relativity might know that gravity possesses the ability to bend light, and in fact, this can at times act as a lens. As mentioned in one of our previous newsletters which featured an article on gravitational lensing, gravitational microlensing is a phenomenon that occurs when a less massive body like a star acts as a lens, rather than a galaxy/supermassive black hole.



MICROLENSING CAUSED BY EXOPLANET. SOURCE: NASA ROMAN SPACE TELESCOPE

Graphic showing the mechanics of how gravitational microlensing works.

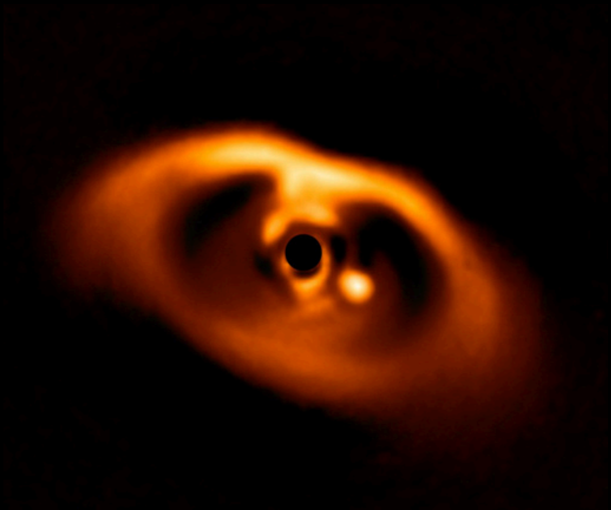
When this happens, exoplanet(s) of the lensing star can momentarily pass through as a tiny speck, resulting in a bump in the light curve of the source star being observed. If this sounds confusing, more detailed diagrams can be found online that does a better job at explaining but this was the best one we found that can be placed here due to copyright reasons.

The light from the background star(s) doesn't just illuminate the lensing star system. In fact, quite a number of rogue planets have been discovered via this method due to the unpredictable nature of these events – you never know what shows up through these cosmic lenses. However, it is also due to its unpredictability that less exoplanets have been observed in this manner.

ASTROBIOLOGY

Direct imaging

Direct imaging is a rather "lavish" form of discovery for astronomers, granted that the exoplanet would first have to be close enough to Earth to ensure that one can even resolve it from the depths of space. It is otherwise pretty self-explanatory, since the exoplanets being discovered simply show up in images taken by telescopes.

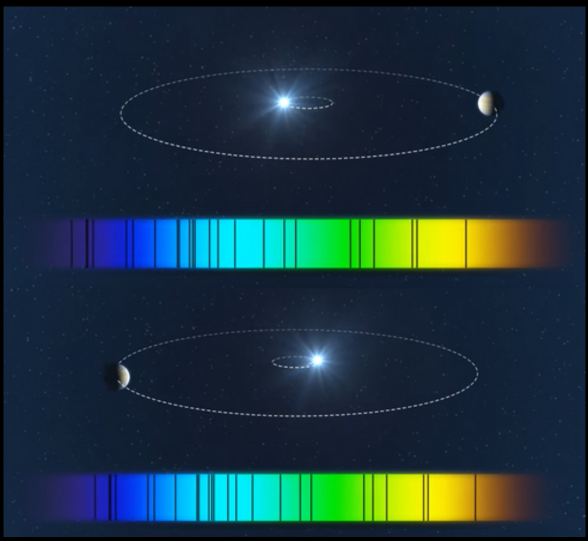


A DIRECT IMAGE OF A PLANET FORMING AROUND THE STAR SOURCE: ESO/A. MÜLLER ET AL

This is an image of the star system PDS 70 (whose light is blocked by a coronagraph) taken by the SPHERE instrument at the ALMA telescope. The bright yellow blob is the exoplanet currently being formed.

Radial velocity

For planets that don't have their planes aligned with our line of sight, this is the method that astronomers prefer to use. The mechanic behind this method of discovery is actually quite simple – Newton's third law. When a planet is orbiting a star, it also applies a force to the star that it is orbiting. Depending on the ratio of their mass and their orbital distance, this can actually cause the star to either move or wobble significantly enough to be captured by us via the doppler shift in its radial velocity.



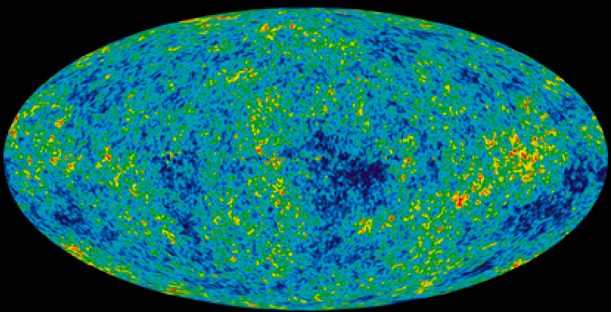
RADIAL VELOCITY METHOD. SOURCE: ESO/L. CALÇADA

Depiction of the shift in wavelength that can be captured by the radial velocity method, the bottom image has its absorption spectrum shifted to the right

HO'OLEILANA

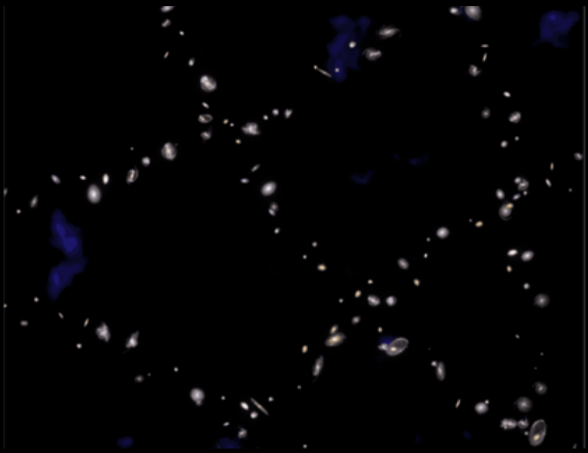
In a recent landmark study, scientists have discovered the largest individual Baryon Acoustic Oscillation (BAO) at a redshift of 0.068. Dubbed Ho'oleilana from the Hawaiian creation chant, Kumulipo, its name means to have sent murmurs of awakening. Ho'oleilana was chosen as a symbolic reference to BAOs in general since they are a relic of the creation of the universe.

Some of you may be wondering what BAOs are. You may have heard this term multiple times in your study or read up on cosmology, with either vague explanations or a deeply technical coverage with little motivation for its basis–and nothing in between. Fear not, for we will help to fill this gap in this article. Let us first break it down into its more fundamental clauses - Baryons and Acoustic Oscillations.



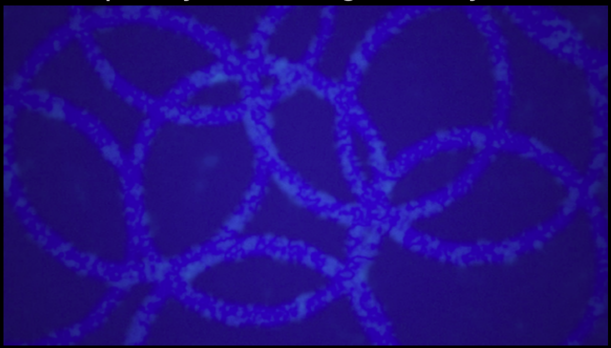
COSMIC MICROWAVE BACKGROUND. SOURCE: WIKIMEDIA
The tiny blotches seen in the cosmic microwave background are the precursors to what will eventually become BAOs.

Baryons in Baryon Acoustic Oscillations are a classification of subatomic particles that make up most of the universe, two famous examples of which are neutrons and protons. Conventionally, baryons are signified to represent the ordinary matter in the universe. Hence, in the



DEPICTION OF BAOS IN PRESENT DAY UNIVERSE. SOURCE: GODDARD SPACE FLIGHT CENTER
Multiple concentric clumps of galaxies form the BAOs we see today.

context of BAOs, baryons are merely a more technical placeholder for ordinary matter (as opposed to dark matter, radiation and dark energy). The next component, 'Acoustic Oscillations', is also of great importance in understanding BAOs and is the basis for how they form–yes, the very medium you use to communicate with your fellow humans is the very basis for the formation of large-scale structures in the universe. To understand this, we must go to the early universe when everything was much closer together and packed in a hot soup of particles and radiation. In this compact medium, quantum fluctuations led to well-defined clusters of matter. This clustering caused pressure waves to transmit through the hot soup as the universe expanded. Well, what are these pressure waves? They're sound! That's right, these are precisely the early acoustic oscillations of what will eventually become BAOs. Namely, as the universe was expanding rapidly during this period and consequently cooled significantly, the



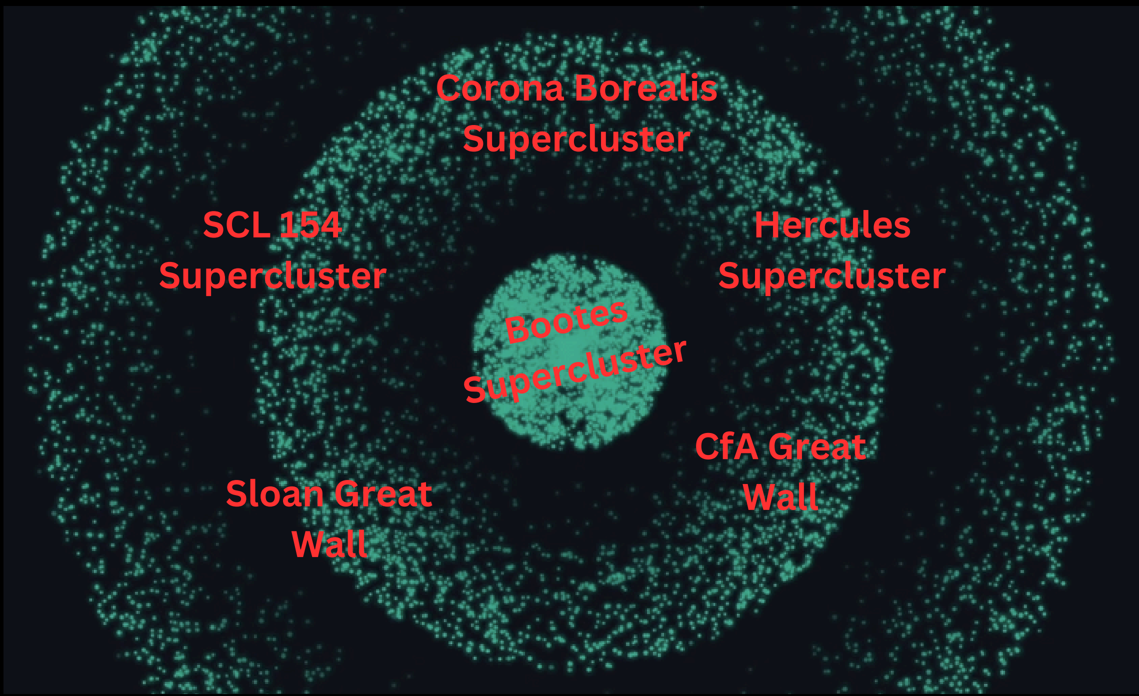
PRESSURE WAVES TO BAOS. SOURCE: NASA/GODDARD SPACE FLIGHT CENTER
A simulation depiction of multiple pressure waves that are to become Baryon Acoustic Oscillations, as they collide together to form intersecting bubbles of matter in the early universe.

pressure waves stopped transmitting just as quickly. These pressure waves froze into the structure of the Universe we see today. This freezing effect locked in the overdensities of matter, which we previously referred to as clustering, which then caused more surrounding matter to clump together. These clumps of matter overdensities eventually formed the stars and galaxies seen today. In other words, if we can map the positions of galaxies and galaxy clusters in our local space within the universe, we can observe these oscillations that have been locked into the grand structure of the universe through the positioning of galaxies. These are precisely what are called Baryon Acoustic Oscillations - the distribution of galaxies governed by the freezing of early-universe matter fluctuations into the large-scale structure of the universe.

The immediate follow-up question is then: Can we see these fluctuations? The answer is yes and no (just like all nuanced topics)! To some degree, because when we look at the positioning of galaxy clusters and superclusters, we can see the wisps and edges of BAOs. A few good examples of this would be the Great Sloan Wall (GSW) and the CfA2 Great Wall–you can immediately see where the galaxies have clustered, and thereby figure out the edges of the BAOs.

But generally, also no, because BAOs are more often than not characterised by statistical calculations based on galaxy densities than actual physical structures. BAOs are characterised by their length scale or angular diameter (relative to us/The Milky Way).

HO'OLEILANA



HO'OLEILANA. ADAPTED FROM NASA/GODDARD SPACE FLIGHT CENTER
Ho'oleilana contains many of the largest known structures. A true Goliath on the cosmological scale. Note that BAOs also overlap, this is merely showing a single one.

Going back to Ho'oleilana, this particular BAO happens to be bubble-shaped as seen in the image above. This is precisely what one would expect given the primordial sound that formed it travelled uniformly in all directions (this extends to all BAOs in general). It is centred 820 million light years away from us, and is about a billion light years across; its closest edge thus still being a fair bit away from us even on the cosmological scale. Moreover, the Bootes Supercluster lies at its centre. If you were to look in its direction in the Bootes constellation, it's pretty large in the sky, about 62.7° across. Though, you would not see anything as it's far too faint to be seen by the naked eye.

Aside from being prominent supporting evidence for our current understanding of the universe's evolutionary history, Ho'oleilana is also a significant data point in the ongoing crisis in cosmology regarding the Hubble Tension, a topic covered in depth in the August & September 2024 newsletters. That is because calculations based on it registered a Hubble constant of 76.9kms^{-1}Mpc^{-1}, which is at the upper end of H0 values and in line with local (cosmologically speaking of course) measurements of the Hubble constant. Ultimately, as more researchers study this fascinating structure and continue their search for and classification of new BAOs, we will continue to unlock the mysteries of the universe.

THE MILKY WAY

Over the last couple of years, there has been a lot of excitement surrounding JWST incessantly breaking the record for the farthest galaxy observed, or questions being raised about dark matter and dark energy after peculiar observations pertaining to galactic mass and how much light they gravitationally lens, amongst many more mind-boggling narratives that galaxies far away from us seem to provide. But do not think for a moment that we have forgotten our own galactic home, our very own Milky Way!

A research paper published in June 2024 presents some very exciting observations from star formation regions near the edge of the Milky Way galaxy. These regions, called Extreme Outer Galaxy (EOG) regions, are defined to be regions of the Milky Way that are a distance of 18 kiloparsecs or more from the galaxy centre. They host a different environment from what we are used to in the solar neighbourhood as they have lower metallicity and lower gas densities, making for much better observations and analysis of a star formation region different to what we know.

This project also permitted the study of galaxy evolution as EOGs have less intense ultraviolet fields and a smaller cosmic-ray flux, which are trends that are characteristic of dwarf galaxies, as well as to galaxies like the Milky Way during the earlier stages of its formation. This allows astronomers to study galaxy formation and evolution in much clearer detail at a closer distance instead of observing more distant galaxies.

The two star formation clusters in the EOG that were observed using JWST were previously observed using the Subaru 8.2m telescope, which, as a ground-based telescope constructed in the 1990s, did not provide astronomers with the same clarity of imaging and data that JWST was able to. However, it was able to confirm that the Initial Mass Function (or IMF, which is a function that describes the distribution of masses of stellar objects in a given region) of the star forming clusters in the EOG was not significantly different from the IMF of neighbouring clusters. It also yielded data showing that the lifetime of circumstellar disks during star formation in the EOG are shorter than the ones in nearby clusters. The forming stars in these clusters are known as Young Stellar Objects (or YSOs), and JWST was able to spatially resolve every YSO, thus enabling

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astronomers to investigate the evolutionary state and disk lifetimes of all the YSOs in the 2 EOG regions observed, which is something that the Subaru telescope previously was not able to do. This aided astronomers in investigating the peak value of the IMF of these clusters as well as plotting the shape of the low-mass end of the IMF of the EOG.

Imaged with 9 different filters in the infrared wavelength, which provided a more comprehensive insight into the finer details that ground-based telescopes would miss, the survey found 3 isolated reddened individual sources that had not been detected before by the Subaru telescope. It also detected several new nebular structures around the main clusters and 2 sources of radiation exhibiting much higher intensity at longer radiations compared to their surroundings, indicating that these 2 sources are very likely in the very early stages of stellar evolution, possibly in the class 0 stage. This is essentially the first stage after the prestellar core collapses (most of their mass would still be in the form of a dense, collapsing envelope surrounding the young protostar. Through multiple processes and time, these young protostars will eventually develop into main sequence stars.

In previous studies, the Subaru telescope detected multiple sources of radiation at the edges of the regions that were thought to be associated with small aggregations of intermediate-mass stars. However, JWST was able to resolve some of these sources such that astronomers now know that they are in fact isolated single stars, while the remaining sources were confirmed to be complex star systems with multiple stars. This shows that the same region of star formation activity can give rise to both high mass isolated stars as well as complex star formation systems including aggregations of intermediate mass stars.

The study used 2 criteria (which delves into the mathematics of how the different filters used are related to each other) in order to classify sources as class 0 stage protostars or not. At lower wavelengths, these sources are virtually undetected, so the survey focussed on the longer wavelength filters, which they used to analyze two particular sources found on the fringes of 2 different star clusters in the region. These were the 2 candidate class 0 protostars, and while the first one met both criteria, the second one narrowly missed criterion number 2. However, given its close proximity to the star cluster, it is very likely that it will also be classified as a class 0 protostar.

THE MILKY WAY

Both of these conformations however, are subject to further studies eliminating the possibility that these may be objects in foreground/background planetary nebulae or active galactic nuclei as these objects also exhibit similar colors and characteristics. This would be a huge breakthrough, enabling us to study stellar evolution right from the earliest stages using protostars that are relatively more accessible to us in terms of clarity and information as compared to other candidate class 0 protostars in other galaxies.

Another interesting phenomenon detected thanks to JWST were jet outflows of radiation at various regions surrounding the observed clusters, which were represented by bow shock and knot structures. With regards to star formation clusters, these are usually attributed to young, rotating protostar systems which are accreting material and have magnetic fields. They consist of oppositely-directed beams of radiation near the source that break into chains of bow shocks and knots further out. The study of the outflows can help contribute to our understanding of more distant and energetic cosmic ray sources such as Active Galactic Nuclei, as well as being a major source of feedback in the self regulation of star formation. However, due to the high source density of these outflows, it was unclear whether it was a single star or a cluster of stars that were responsible for this occurrence.

The last aspect of the EOG that was observed were the nebular structures, which consisted of cliff or pillar-like formations, primarily detected at the longer wavelength filters. The Nobeyama Radio Observatory also studied the CO gas distribution within these nebulae, which revealed the anisotropic distribution of the gas, with more closely spaced CO contours appearing in the eastern part of the cluster, signifying potential higher densities or temperatures in this part of the cluster. This may support a theory from the 1970s, presented by Kobayashi and collaborators published in 2008 on how star formation is induced as a shock, which triggers the star formation process due to induced compression from supernovae remnant shells.

There is an obvious advantage of focussing time and resources to observing more EOG areas, as just by analyzing this study, multiple avenues are open for more investigations into the stellar formation that would ultimately contribute to our understanding of star lifetimes and evolution. The authors are keen to identify further clusters, using JWST to investigate their spatial distributions and begin to incorporate multi-wavelength data.

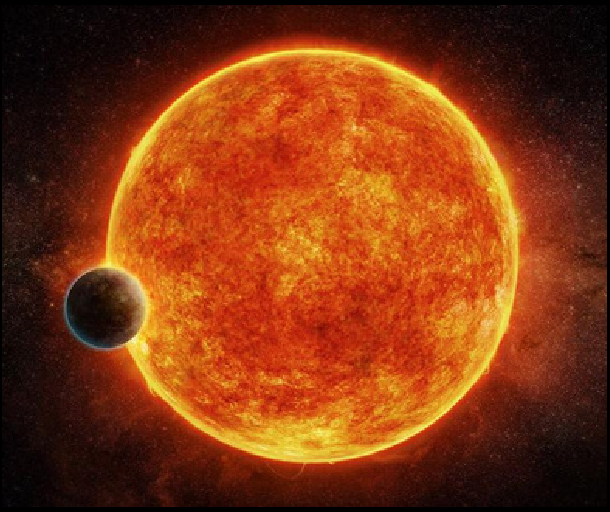
TRIVIA

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

Earlier in this newsletter, we took a look at the different methods of exoplanet detection. Amidst the several options, the 2 most common methods are Transit method and Radial Velocity method. We covered how the methods worked, but we intentionally did not cover the limitations in detail. What are the limitations of the 2 most common methods, and in what specific cases does one method have an advantage over the other?



Artist's impression of LHS 1140b
Source: Melissa Weiss/CfA

Problem II

Earlier in this newsletter, yet again, we looked at the detection of Baryon Acoustic Oscillations (BAOs) and observations of star formation in the Milky Way's Extreme Outer Galaxy (EOG). Considering these two scales of cosmic structure, discuss how studying both BAOs and EOG star formation clusters could contribute to a more comprehensive understanding of cosmic evolution.

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Fun-Fact-of-the-Month:
Comet C/2023 A3 (Tsuchinshan-ATLAS), the comet that was visible from Singapore last month, takes a very long time to orbit the Sun, with an orbital period estimated to be about 80,000 years. This means that the previous time it flew through our solar system was during the Stone Age!

ANSWERS FOR THE PREVIOUS NEWSLETTER

Problem I

'Given the surface temperature, mass and radius of the sun and the orbital radius of the earth, calculate the change in the orbital radius of the Earth in meters in 100 years. Comment on whether we should be worried about this.'

Three concepts combine together to make this elegant question - energy mass equivalence, Stefan-Boltzmann Law and conservation of angular momentum. Using the first 2, we can calculate the mass lost through radiation (assumed here to be the only source of mass loss) over the 100 years and then calculate orbital radius changes from there.

$\Delta M = (4\pi R^2\sigma T^4)/c^2 * t$

$L/m = vr = \sqrt{(GM/r)}r \rightarrow Mr = \text{constant}$

$\Delta r = M_1 r_2/(M_1 - \Delta M) - r_1 = 1$ m

Earth's orbital radius would increase by 1 m.

Problem II

'In the previous newsletter, we discussed at length about the Hubble Tension. Much research in reducing the tension surrounds reducing the size of the sound horizon. Why is that the case?'

The sound horizon is inversely related to the value of H_0. In other words, if new physics is discovered in the early universe such that the sound horizon is reduced, this would cause the calculated value of H_0 to increase. Since the current early-universe H_0 is the lower of the 2 distinct values in tension, having it increase would lessen the tension.

Bonus information

Some of you are probably wondering why the tension is only reduced, that is, not totally removed. The answer to this is that all the current proposed mechanisms for reducing the tension cause other measured values from the early universe to also change. Adjusting H_0 too much would thereby throw other values into tension!

EVENTS AND STARGAZING

Expand Space: A 'Deep Tech Playground' for Young Innovators

Space Faculty, Asia's pioneer in creating opportunities for experimentation, learning and leadership through space, is set to host a groundbreaking event, Expand Space, designed to inspire and empower the next generation of STEM leaders. Through this platform, they also hope to connect young minds with the exciting world of deep technology, such as Artificial Intelligence, Space Exploration and Robotics.

For those interested, make sure to use 'Code: AstronomySG' when signing up for a free 20 dollar discount!

Website: https://expandspace.com/
Registration:
https://www.eventbrite.com/e/expand-space-tickets-976027714167

Leavitt Lectures sign ups!

Given the new IOAA advisory regarding increasing inclusivity in future team selections as well as the low percentage of female participation in the Singapore Astronomy Olympiad, Astronomy.SG will comply by organising special lectures available for girls to attend.

Tentative details of the Lectures are as follows, with further information available in the form below.
First lecture: 15 December (Sunday)
Last Lecture: 2 March (Sunday)
Held from 7:00 - 9:30pm

Female participants of the 2025 SAO can register interest via this link below:
https://tinyurl.com/leavitt-lectures

For more details, feel free to email fish@astronomy.sg

We look forward to seeing you there!

EVENTS AND STARGAZING

Inaugural SAND Bingo Challenge

Join us for another round of our astrophysics-themed Bingo, where you can take on challenges and help your school collect points. With SAND 2025 still more than half a year away, there's still time to complete as many challenges as possible and aim for stellar prizes! The Bingo Challenge is still live on our Discord channel—come join the fun! Not sure how to enter? Just drop us an email/message and we'll get back to you!

Please note: This event is only eligible for secondary and tertiary schools that are open to participate in SAND 2025.

Featured Stargazing Location:
West Coast Park

West Coast Park, which is parallel to the West Coast Highway, has been a long-time popular spot for astronomy and astrophotography enthusiasts. With it being located along the southwestern coastline, enthusiasts can enjoy the open coastal views looking out into the ocean, minimal obstructions due to the park's open lawns and clear sight lines, and reduced light pollution thanks to the fewer obstructive light sources. With ample space to set up equipment and easy accessibility, West Coast Park has also had a few local astronomy club gatherings in which enthusiasts could stop by and join in, and is widely regarded as one of Singapore's best spots for stargazing.

WEST COAST PARK. CREDIT: WIKIMEDIA
Experience the celestial showcase at West Coast Park's Grand Lawn. With its wide open space, you and your friends are guaranteed a spot for stargazing, even amidst the evening crowd.

EVENTS AND STARGAZING

COMET TSUCHINSHAN–ATLAS. CREDIT: NEO XUAN CHE, KIERAN HO JIANMING

Taken at West Coast Park on the evening of 21 October, many would believe such a surreal image of the increasingly faint Tuschinshan-ATLAS would not be possible from our Singapore skies. Yet, the avid astrophotographers Xuan Che and Kieran managed to pull this off with their trusty camera.

EVENTS AND STARGAZING

The month of November brings a mix of crispy clear skies and highly dense cloud covers, but it does bring a wealth of celestial wonders. As autumn transitions toward winter, new constellations and hidden gems emerge, inviting stargazers to explore fresh sights in the night sky. Whether you're using a telescope, binoculars, or simply looking up, November offers exciting opportunities for all levels of astronomy enthusiasts.

Source: Stellarium

Free-hand stargazing

- **Betelgeuse.** One of the brightest stars in the night sky, this orange-red jewel is visible to the naked eye in the night sky. In the constellation Orion, it is considered to be on the hunter's right shoulder. This is definitely a star worth observing.

- **Jupiter.** Venus is one of the brightest objects that can be seen in the night sky. Its atmosphere is primarily composed of carbon dioxide and has lots of sulphuric acid clouds, giving it a light yellow appearance. Given its brightness, it would be hard to miss this one.

Source: Stellarium

EVENTS AND STARGAZING

Free-hand stargazing (Cont'd)

- **Rigel.** The blue supergiant star of Orion and the brightest star in Orion despite popular belief, Rigel is the brightest of 4 stars that appear as a single blue-white point light to the naked eye. About 850 light years away from us, this star can be easily spotted opposite Betelgeuse in the constellation Orion. It is worth looking at if you can.

Source: Stellarium

- **Aldebaran.** This is a red giant that can be found in the constellation of Taurus. You can find Aldebaran to be in close proximity to Jupiter in the night sky. This star is definitely worth some attention.

Binoculars

- **Pleiades (M45).** This star cluster, also known as the "Seven Sisters," is starkly visible in Singapore's night sky in November. It can be spotted in the east just after sunset and climbs higher as the night progresses. Known for its striking blue stars, the cluster is easily visible to the naked eye and makes for a great viewing target, even without equipment. Look for it near the constellation Taurus.

Source: Stellarium

EVENTS AND STARGAZING

Binoculars (Cont'd)

- **The Great Square of Pegasus.** As a square asterism representing the torso region of the great horse Pegasus, this is one of the most iconic asterisms of the sky! Formed by four bright stars (Markab, Scheat, Alpheratz, and Algenib), this square is famously known for being a gateway to other beautiful sky objects, like the famous Andromeda Galaxy, the Southern Fish, and more.

Source: Stellarium

- **Leonids Meteor Shower.** This meteor shower should be visible for most of November (6th to 30th November), with a peak on 18th November. It has been very active in recent years, reaching up to thousands of meteors per hour. Due to its long duration, there are plenty of opportunities to view this beautiful shower, so get away from the light pollution, grab a binocular (it can also been seen with the naked eye), and enjoy!

Source: Stellarium

EVENTS AND STARGAZING

Telescope

- **Orion Nebula.** This nebula in the constellation of Orion will be visible for roughly the entire month of November. One of the most popular targets for astrophotographers, viewing the nebula through a telescope reveals a spectacular form of dust, gas and colours, even in more light-polluted areas. Inside the nebula is a Trapezium cluster of the 4 brightest stars in the nebula, making it an intrinsic addition to any stargazers' catalogue of observed objects.

Source: Stellarium

- **Perseus Double Cluster.** Located about 7500 light years away in the Perseus arm of the Milky Way, this double cluster consists of clusters NGC 869 and NGC 884, and is home to hundreds of hot supergiant stars that are a thousand times more luminous than our Sun. To find it, look in-between Perseus the Hero and Cassiopeia the Queen!

Source: Stellarium

SOURCES

Front page
Dall-E
Baryon Acoustic Oscillations - NASA Science

Content page
File:NGC 4826 - HST.png - Wikimedia Commons

Astrobiology II
Dall-E
Light Curve of a Planet Transiting Its Star - NASA
Planetary atmospheres |
Microlensing - NASA Science
First Confirmed Image of Newborn Planet Caught with ESO's VLT
The radial velocity method for finding exoplanets | ESO

BAO
Baryon Acoustic Oscillations - NASA Science
NASA SVS | Baryon Acoustic Oscillations
File:WMAP 2012.png - Wikimedia Commons

The Milky Way
EOG study
Jet, outflows and explosions in stars

Trivia

Artist Illustration of LHS 1140b https://www.cfa.harvard.edu/research/topic/exoplanets

Events and Stargazing
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Forbes: See Northern Lights, A 'Supermoon' And Venus: November's Night Sky
Astronomy.com: November 2024: What's in the Sky this Month?
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