NWASNEWS

Volume28 Issue4

December 2022

Newsletter for the Wiltshire, Swindon, Beckington, Bath Astronomical Societies

Merry Christmas and Happy New Year

Sorry to report that John Arthurs, a long standing member of the society died in November. Peter Chappell has written a brief epitaph to him that appears in the Members section of this newsletter. Thank you for that Peter.

Before I move on to more enjoyable matters, I also have to report another blight to observational astronomy that is going to get worse. The Bluewalker range of cell phone communication satellites has unfurled its first sail. These are now visible in the evening sky and is as bright as the ISS. While at first it may seem like a nice sign of progress this is the first of many of these satellites due to be used. So much brighter than the annoying Musk system they may be fewer but they are going to destroy evening and morning imaging. I have included the timings for the current satellite in the end pages.

But lets get into a better mood. The last observing session for Lacock proved to be successful from the new site behind the Lacock café and toilets. It even has picnic tables laid out we can use. Thank you to the National Trust. We have 'normal' monthly observings sessions booked for the 188th and 23rd December evenings.

The 18th should still catch the tail of the profuse Geminid meteor shower… Do members want to do a Christmas week open viewing session earlier in the evening for children to attend or help people setting up their new equipment.. Just what is in that mysterious Sky Watcher box that appeared at your house Peter?

My arthritis is reaching strangling point for pain, but injections are due on the 21st December so I should be improved for this week after Christmas.

It has been taking time for the FAS and the bank to respond to our change of treasurer, but progress does seem to be happening! Some more signatures due tonight but thank you so much for your many years of service Bob Johnstone. And thank you Sam for filling the roll.

That leaves me to wish you all the best for the seasons greetings and I have brought some mince pies and bits for the coffee break.

Welcome Martin Griffiths again and bringing colleague from Dark Sky Wales over too. Move the goats off the field, Al is in town.

Merry Christmas and Happy New Year.

You never know, the price for lighting our skies may mean darker skies for all...

Clear Skies

Andy

Taurus is the constellation of the month and is rising in the west in the December evenings. Being on the fringe of the plane of the Milky Way we see a lot of clusters, and the Pleiades and Hyades are the biggest and most closest open clusters (with M44 the Beehive in Cancer the other close cluster. Here the Hyades open up, and the colour of the stars is enhanced by the misty conditions I take the picture under on the 18th of November.

Andy Burns.

Wiltshire Society Page

Wiltshire Astronomical Society

Web site: www.wasnet.org.uk

Facebook members page: https://www.facebook.com/groups/wiltshire.astro.society/

Meetings 2020/2021.

HALL VENUE the Pavilion, Rusty Lane, Seend

Some Speakers have requested Zoom Meetings we will try to hold these at the hall

Meet 7.30 for 8.00pm start

SEASON 2022/23

6 Dec Martin Griffiths How the Moon was formed

2023

3 Jan Mike Alexander Heaven's on Earth (zoom meeting)
7 Feb Prof. David Southwood JUICE
7 Mar Mary McIntyre Shadows in Space & the stories they tell
4 Apr Chris Starr Heavy Metal World
2 May Dr Paul A Daniels The Mega-constellation threat
6 Jun Andrew Lound Venus, Paradise Lost

Martin Griffiths

Martin Griffiths is an astronomer and science presenter with Dark Sky Wales, a former senior lecturer in Astronomy at the University of South Wales, and a founder member of NASA's Astrobiology Science Communication team. He assisted the Brecon Beacon national parks successful campaign to gain International dark sky status and in 2014 became Director of the Brecon Beacon Observatory, a public educational resource at the National Park Visitor Centre. He is the local representative for the BAA campaign for Dark Skies. Griffiths is a Fellow of the Royal Astronomical Society; a Fellow of the Higher Education Academy; a member of the British Astronomical Association; the Webb Deep-Sky Society; the Society for Popular Astronomy; The Astronomical Society of the Pacific and the Astronomical league. Astrobiology Society of Britain; The European Science Communication Network; The European Society for the History of Science; The Planetary Society and the British Science Association. Martin is a frequent speaker at Wiltshire AS and has been to the observatory in Spain many times, the Griffon observatory was set up to help the Glamorgan University students connect with the skies, but the astronomy course folded, but he still brings visitors from Dark Skies Wales out to the clearer skies.

Here he is preparing to do some solar imaging from the observatory hard standing with the blanket to allow viewing of the laptop.

Membership Meeting nights £1.00 for members £3 for visitors

Members can renew or new members sign up online via https://wasnet.org.uk/membership/ and also remind them they can pay in cash too on the door.

Wiltshire AS Contacts

Andy Burns Chair, anglesburns@hotmail.com

Andy Burns Outreach and newsletter editor.

Bob Johnston, Sam Franklin (Treasurer)

Rebecca Rowan (Hall coordinator)

??? (Teas and Projector)

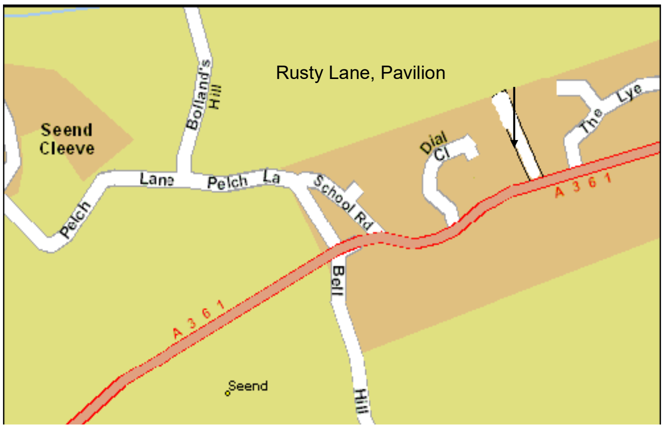
Peter Chappell (Speaker secretary) Retiring

Nick Howes (Technical Guru)

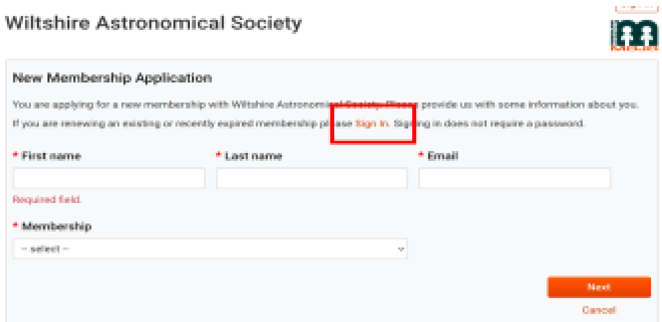
Observing Sessions coordinators: Chris Brooks, Jon Gale,

Web coordinator: Sam Franklin

Contact via the web site details.



Observing Sessions see back page



Swindon's own astronomy group

Physical meetings continuing!

Following the relaxation of the Covid rules we are continuing physical meetings.

Friday, 9 December - Christmas Social

A meal at The Sun Inn, Coate, Swindon

Ad-hoc viewing sessions
Regular stargazing evenings are organised near Swindon. The club runs a WhatsApp group to notify members in advance of viewing sessions, usually at short notice. Anyone can call a meeting. To join these events please visit our website on the link below.

Information about our evenings and viewing spots can be found here:

http://www.swindonstargazers.com/noticeboard/noticeboard06.htm

Meetings at Liddington Village Hall, Church Road, Liddington, SN4 0HB – 7.30pm onwards

The hall has easy access from Junction 15 of the M4, a map and directions can be found on our website at:

http://www.swindonstargazers.com/clubdiary/directions01.htm

Friday, 9 December 19.30 onwards

Programme: Christmas Social

Meeting Dates For 2023

Friday, 20 January 19.30 onwards

Programme: Peter Williamson FRAS: From Herschel to Hawkwind - Music and the Cosmos

Friday, 17 February 19.30 onwards Programme: Simon Holbeche: Frankenscope Reborn

Friday, 17 March 19.30

Programme: AGM

Friday, 21 April 19.30 onwards

Programme: Prof Matt Griffin: Far Infrared Astronomy from Space

Friday, 19 May 19.30 onwards

Programme: Prof Nick Evans - Dark Energy - a cosmological overview of empty space and links to particle physics

Friday, 16 June 19.30 onwards

Programme: Bob Mizen MBE - Stars over the Nile - Ancient Egyptian Astronomy and star lore

Friday, 15 September 19.30 onwards -

Programme: First Light Optics: Product trends / changes / news and upcoming products

Friday, 20 October 19.30 onwards Programme: Prof Martin Hendry MBE - The Science of Star Wars

Friday, 17 November 19.30 onwards Programme: Dr Lillian Hobbs: Eisa Esinga - The Planetarium in the Bedroom

Friday, 8 December 19.30 onwards Programme: Christmas Social

Website:

http://www.swindonstargazers.com

Chairman: Robin Wilkey

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Address: 61 Northern Road
Swindon, SN2 1PD

Secretary: Hilary Wilkey

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BECKINGTON ASTRONOMICAL SOCIETY

Society Details & Speakers programme can be found on our Website www.beckingtonas.org

General enquiries about the Society can be emailed to chairman@beckingtonas.org.

Our Committee for 2016/2017 is

Chairman: Steve Hill (email chairman@beckingtonas.org)
Treasurer: John Ball
Secretary: Sandy Whitton
Ordinary Member: Mike Witt

People can find out more about us at www.beckingtonas.org

Meetings take place in Beckington Baptist Church Hall in Beckington Village near Frome.

See the location page for details of how to find us on our website…………

Post Code for Sat Nav is BA11 6TB.

Our start time is 7.30pm No hall meetings.

STAR QUEST ASTRONOMY CLUB

This young astronomy club meets at the

Sutton Veny Village Hall.

Second Thursday of the Month.

Meet at Sutton Veny near Warminster.

BATH ASTRONOMERS

Bath Astronomers

A friendly bunch of stargazers and enthusiastic astronomers who share experiences and know-how as well as offer an extensive outreach programme of public and young people's observing. As a partner to Bath Preservation Trust, they are the resident astronomers at the Herschel Museum of Astronomy, 19 New King Street, Bath, BA1 2BL and partner with Bath Abbey to showcase the skies above the city.

Gatherings and talks are held on the last Wednesday of each month at 7:30pm at the Herschel Museum of Astronomy (excluding December, July, and August). These are usually hybrid events with live access via Zoom for members and the curious, and on demand access via Bath's Youtube channel, https://www.youtube.com/@bathastronomers.

Next Meetings:

Wednesday, 7th December commencing 19:30

Talk by **Lee Pullen** entitled "Taking your astrophotography to the next level"

Wednesday, 25th January 2023 commencing 19:30

Talk by **Dr David Tsang** on Neutron Stars

More information and news is available via:

https://bathastronomers.org.uk

https://www.facebook.com/BathAstronomers

https://twitter.com/BathAstronomers

https://www.instagram.com/bathastronomers/

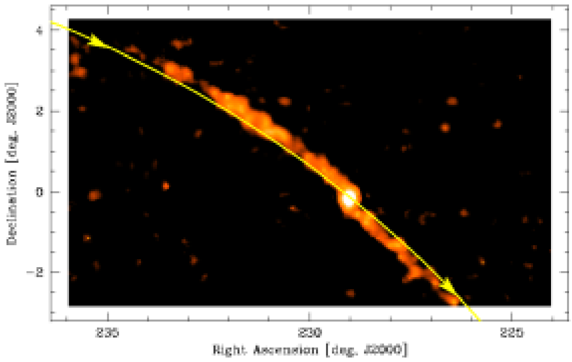
Public stargazing is scheduled twice a month on Saturday evenings as well as during school holidays to promote astronomy in Bath and Somerset area. Locations vary to bring telescopes to local communities.

Member's observing is conducted from the Monkton Combe Community Observatory using the 1860 Refractor and more modern telescopes. We try to avoid school nights but will run member's sessions when the clouds look like they'll recede long enough to align a Celestron Goto Scope.

Get in touch by email hello@bathastronomers.org.uk whether you'd like to find out more, pop in for a visit, share the stars, or have Bath Astronomers visit your school, young persons' group (rainbows, beavers, brownies, cubs, guides, scouts, rangers etc) or your community.

SPACE NEWS TO DECEMBER 22

The evidence for stellar ejection from GCs is in the tidal tails that stream out from them.



Palomar 5 is a globular cluster being torn apart by the Milky Way. Palomar 5 is the white blob at the center, and the orange is streams of stars. The yellow line with arrows represents the cluster's orbit around the Milky Way. Image Credit: Odenkirchen, Grebel, et al. 2002/Sloan Digital Sky Survey

A new study based on data from the ESA's Gaia mission aims to understand how GCs eject stars. Its title is "Stellar Escape from Globular Clusters I: Escape Mechanisms and Properties at Ejection." It's been submitted to the Astrophysical Journal, and the lead author is Newlin Weatherford, an astronomy Ph.D. student at Northwestern University in Illinois.

"Recent exquisite kinematic data from the Gaia space telescope has revealed numerous stellar streams in the Milky Way (MW) and traced the origin of many to specific MWGCs, highlighting the need for further examination of stellar escape from these clusters," the authors write. This study is the first of a series, and the authors examine all the escape mechanisms and how each one contributes to GC star loss.

GCs are some of the oldest stellar associations in the Milky Way. Individual GC stars are also older and have lower metallicity than the Milky Way's general population. Nearly all galaxies host GCs, and in spiral galaxies like ours, the GCs are mostly found in the halo. The Milky way hosts more than 150 of them. Astronomers used to think that stars in a GC form from the same molecular cloud, but now they know that that's not true. GCs contain stars of different ages and metallicities.

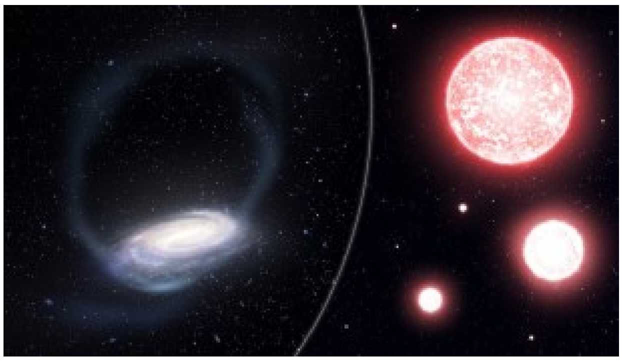
GCs are different from their cousins, the open clusters (OCs). OCs are most often found in the disks of spiral galaxies, have more heavy elements, and are less dense and also smaller than GCs. OCs have only a few thousand stars, and there are more than 1100 of them in the Milky Way.

NGC 6441 is one of the most luminous and massive globular clusters in the Milky Way. Image Credit: ESA/Hubble & NASA, G. Piotto

GCs are unique, and astronomers consider them tracers of galactic evolution. Thanks largely to the ESA's Gaia spacecraft, we know more about GCs. Gaia helped reveal the presence of numerous stellar streams coming from the Milky Way's globular clusters. As the authors explain in their paper, "These drawn-out associations of stars on similar orbits are likely debris from disrupted dwarf galaxies and their GCs, shorn off by Galactic tides during accretion by the MW (Milky Way.)"

Gaia did more than spot these streams. It was able to connect some streams to specific GCs. "Gaia's exquisite kinematic data has firmly tied the origins of ~10 especially thin streams to specific MWGCs," the authors write. The Palomar 5 GC and its streams are well-known examples. The streams are excellent tracers of the Milky Way's evolution. (Palomar 5 gained even more notoriety in astronomy recently when a 2021 paper found more than 100 black holes in its center.)

Observations of these types of tails, both from stars ejected from GCs, and from interacting and merging galaxies, are an extremely active area of research. There are many astounding images of these interactions. But as the authors point out, "… the theoretical study of stellar escape from GCs has a longer history." Astronomers have come up with different mechanisms for these escapes, and this paper starts with a review of each one.



Artist's impression of the thin stream of stars torn from the Phoenix globular cluster, wrapping around our Milky Way (left). Red giant stars make up a significant portion of the stream and helped astronomers map it. Credit: James Josephides (Swinburne Astronomy Productions) and the S5 Collaboration.

The authors divide escape mechanisms into two categories: Evaporation and Ejection. Evaporation is gradual, while ejection is more abrupt. The following are brief descriptions of each of the ejection methods, beginning with the Evaporation category.

Two-Body Relaxation: the motions of each body induce granular perturbations that create exchanges in energy and momentum in the bodies. Over time, stars can be ejected from GCs.

Cluster mass loss: stars lose mass over time, and that can affect the gravitational binding that holds stars in the cluster.

Sharply time-dependent tides: MWGCs orbit the Milky Way in eccentric and inclined orbits. The galactic tide will be stronger at some points in the orbit. The changing gravity can allow stars to exit the GCs.

The second broad category is Ejection. These are events typically involving single stars that are ejected rapidly and dramatically.

Strong Encounters: a close passage between two or more bodies that provides a strong enough kick to eject a star.

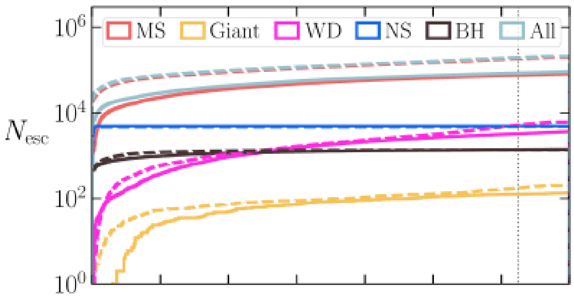
(Near)-Contact Recoil: encounters so close that tides, internal stellar processes, and/or relativistic effects are relevant. This includes collisions and gravitational waves.

Stellar Evolution Recoil: This includes the powerful forces unleashed when a star goes supernova, for example, or when a black hole or neutron star is formed.

Since there was no way to go and observe a statistically significant number of GC ejections, the team of researchers took what data was available and performed simulations. They used what's called the CMC Cluster Catalog.

The study is concerned with the two types of GCs: non-core collapsed and core-collapsed. They're different from each other and are a fundamental property of GCs, so the team simulated both types.

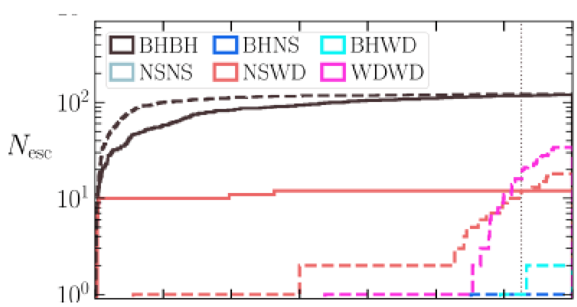
Core collapse in GCs occurs when the more massive stars in a GC encounter less massive stars. This creates a dynamic process that, over time, drives some stars out of the center of the GC towards the outside. This creates a net loss of kinetic energy in the core, so the remaining stars in the GCs core take up less space, creating a collapsed core.



This figure from the study shows the number of escaped single stars and stellar objects for the archetypal core-collapse GCs and non-core-collapse GCs. The x-axis is unlabelled but measures time in Gyrs. Each black marker is two Gyrs. Dashed lines are results from core-collapsed GCs, while solid lines are non-core-collapsed GCs. The plotted lines are colour coded according to the legend at the top. As the figure shows, most ejected stars are main-sequence stars, mirroring the population of the GCs themselves. Image Credit: Weatherford et al. 2022.

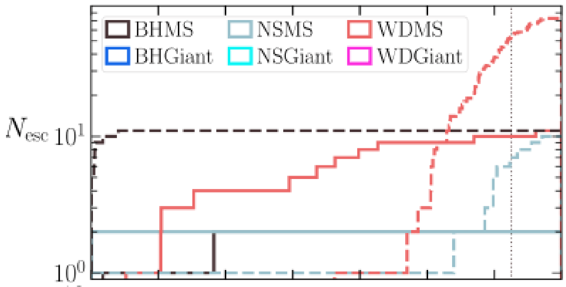
An important astronomical principle plays a role in the team's results. Two-body relaxation is a fundamental aspect of stellar associations that has far-reaching effects. It's a complicated topic, but it basically describes the ways that stars in stellar associations, such as GCs, interact gravitationally and share kinetic energy with each other. It shows that star-to-star interactions drive GCs to evolve during the lifetime of the galaxy they're attached to.

Not surprisingly, the researchers found that two-body relaxation plays a powerful role. That conclusion lines up with the established theory. "Consistent with longstanding theory and numerical modelling, we find that two-body relaxation in the cluster core dominates the overall escape rate," they write.



This figure from the study shows binary compact objects ejected in the simulation. The number of objects is on the y-axis, and time in two-Gyr increments is on the x-axis. Dashed lines are results from core-collapsed GCs, while solid lines are non-core-collapsed GCs. Image Credit: Weatherford et al. 2022.

They also found that "… central strong encounters involving binaries contribute especially high-speed ejections, as do supernovae and gravitational wave-driven mergers." This also lines up with other research.



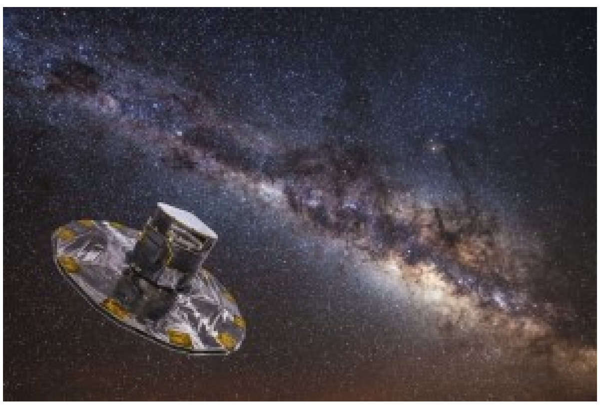
This figure from the study shows binary objects containing a compact object and a main-sequence or giant star ejected from GCs. The number of objects is on the y-axis, and time in two-Gyr increments is on the x-axis. Dashed lines are results from core-collapsed GCs, while solid lines are non-core-collapsed GCs. Image Credit: Weatherford et al. 2022.

But one of their results is new. It concerns three-body binary formation (3BBF.) 3BBF is when three bodies collide to form a new binary object. "We have also shown for the first time that three-body binary formation plays a significant role in the escape dynamics of non-core-collapsed GCs typical of those in the MW. BHs are an essential catalyst for this process," they write. "3BBF dominates the rate of present-day high-speed ejections over any other mechanism," they explain, as long as significant numbers of BHs remain in the GCs core. 3BBFs also produce a significant number of hypervelocity stars.

In their conclusion, the authors explain that "… this study provides a broad sense of the escape mechanisms and demographics of escapers from GCs," while also noting that the results are "not immediately comparable to Gaia observations." That's why this work is the first in a series of papers. In their follow-up paper, they intend to integrate the trajectories of escaped stars and construct their velocity distributions to reproduce tidal tails. After that work, they hope that they'll have a clearer understanding of how stars escaping from GC contribute to galactic evolution.

In a third paper, they intend to "… identify likely past members ('extratidal candidates') of specific MWGCs and directly compare the mock ejecta from our cluster models to the Gaia data." This will get closer to some of the core questions surrounding GCs and the Milky Way's evolution: how do stellar streams form? How many BHs are there in GCs? What role do supernovae play?

"Ultimately, we hope to better understand stellar stream formation and, in an ideal case, leverage the new observables from Gaia to better constrain uncertain properties about MWGCs, such as BH content, SNe kicks, and the initial mass function, which affect ejection velocities and the cluster evaporation rate."



The ESA's Gaia spacecraft doesn't make a lot of headlines in regular media because it doesn't take gorgeous images. But as this study shows, its contribution to important topics like galactic evolution can't be overstated. (Those who know, know.) Artist's impression of the ESA's Gaia Observatory. Credit: ESA

This study is an interesting look at how a number of natural phenomena all contribute to galactic evolution. The evolution of individual stars, how individual stars interact gravitationally and how they form binary objects, the tidal interactions between globular clusters and their host galaxies, two-body relaxation, and even three-body binary formation. Throw in supernovae and hypervelocity stars.

Each one of these topics can form the basis of an entire career in astrophysics. It's easy to see why follow-up studies are needed. Once they're completed, we'll have a much better picture of how galaxies, specifically our own Milky Way, evolve.

New Images of Titan From JWST and Keck Telescopes Reveal a Rare Observation

Planetary scientists have greatly anticipated using the James Webb Space Telescope's infrared vision to study Saturn's enigmatic moon Titan and its atmosphere. The wait is finally over and the results are spectacular. Plus, JWST had a little help from one of its ground-based observatory friends in helping to decode some strange features in the new images. Turns out, JWST had just imaged a rare event on Titan: clouds.

In these new images, the white areas near the top of Titan are clouds, likely made from methane. The clouds appear to have formed over Titan's northern region, known to have lakes made of liquid hydrocarbons.

Images of Saturn's moon Titan, captured by the James Webb Space Telescope's NIRCam instrument Nov. 4, 2022. Left: Image using F212N, a 2.12-micron filter sensitive to Titan's lower atmosphere. The bright spots are prominent clouds in the northern hemisphere. Right: Color composite image using a combination of NIRCam filters: Blue=F140M (1.40 microns), Green=F150W (1.50 microns), Red=F200W (1.99 microns), Brightness=F210M (2.09 microns). Several prominent surface features are labeled: Kraken Mare is thought to be a methane sea; Belet is composed of dark-colored sand dunes; Adiri is a bright albedo feature. Image credit: NASA, ESA, CSA, A. Pagan (STScI). Science: Webb Titan GTO Team.

Titan's nitrogen-rich atmosphere covers the moon like a shroud, as it is 50% denser than Earth's atmosphere and visible light cannot penetrate it. But astronomers have figured out ingenious ways to see through the atmosphere – using radar, infrared techniques, and other tricks (more on that later), enabling them to see details in Titan's atmosphere and amazingly, even down to surface to see features like dunes, as well as the hydrocarbon rivers and lakes. While astronomers have been able to detect clouds in Titan's atmosphere since 1995, according to planetary scientist Sarah Hörst, it's rare and Titan can go years and years without detectable clouds.

For JWST to see them at its first go at Titan is remarkable – with maybe a little luck thrown in.

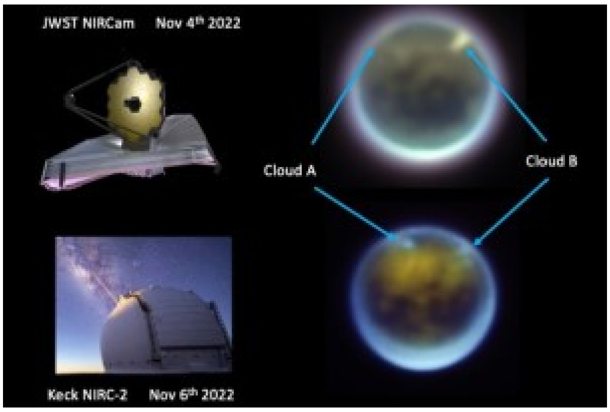
JWST imaged Titan on November 4. A NASA blog post details how Sebastien Rodriguez from the Universite Paris Cité was the first to see the new images when the data arrived to Earth, and Rodriguez alerted the rest of the team in an email:

"What a wake-up this morning (Paris time)! Lots of alerts in my mailbox! I went directly to my computer and started at once to download the data. At first glance, it is simply extraordinary! I think we're seeing a cloud!" JWST Solar System GTO Project Lead Heidi Hammel, from the Association of Universities for Research in Astronomy (AURA), had a similar reaction: "Fantastic! Love seeing the cloud and the obvious albedo markings. So looking forward to the spectra! Congrats, all!!! Thank you!"

The team quickly called in colleagues at the Keck Telescope on Mauna Kea in Hawai'i to perform follow-up observations. A series of Keck images taken about 30 and 54 hours after JWST's showed similar clouds — likely the same ones — but slightly displaced because of the moon's rotation relative to Earth.

"We were concerned that the clouds would be gone when we looked at Titan one and two days later with Keck, but to our delight there were clouds at the same positions, looking like they might have changed in shape," said Imke de Pater, a UC Berkeley Professor of the Graduate School, in a press release.

The astronomers cautioned, however, that since clouds are not long-lasting on Titan or Earth, so those seen on November 4 by JWST may not be the same as those seen on November 7 by Keck.



Evolution of clouds on Titan over 30 hours between Nov. 4 and Nov. 6, as seen by near-infrared cameras on the James Webb Space Telescope (top) and Keck Telescope. Titan's trailing hemisphere seen here is rotating from left (dawn) to right (evening) as seen from Earth and the sun. Cloud A appears to be rotating into view, while Cloud B appears to be either dissipating, or moving behind Titan's limb. Clouds are not long-lasting on Titan or Earth, so those seen on Nov. 4 may not be the same as those seen on Nov. 6. (Image credit: NASA/STScI/Keck Observatory/Judy Schmidt)

Titan is the only moon in the Solar System with a dense atmosphere and the only planetary body other than Earth that currently has surface features like rivers, lakes and seas. Unlike Earth, however, the liquid on Titan's surface is composed of hydrocarbons including methane and ethane, not water.

The new and continued observations of Titan from JWST, combined with those from Earth-bound telescopes, will help astronomers understand the weather patterns on Titan. Additionally, the upcoming mission to this moon, scheduled for launch in 2027 called Dragonfly, will also provide more insights. Dragonfly has a multirotor lander and will assess the habitability of Titan's unique environment.

For some additional info on how astronomers use every trick the book to see through Titan's thick atmosphere — and how clouds were first seen on that moon — the Planet Dr, Sarah Hörst has a great thread on Twitter explaining it all:

The science team that used JWST to study Titan are still working through their data, and so these observations are still a work in progress, and the team stressed their work has not yet been through the peer-review process.

A Black Hole Consumed a Star and Released the Light of a Trillion Suns

When a flash of light appears somewhere in the sky, astronomers notice. When it appears in a region of the sky not known to host a stellar object that's flashed before, they really sit up and take notice. In astronomical parlance, objects that emit flashing light are called transients.

Earlier this year, astronomers spotted a transient that flashed with the light of a trillion Suns.

In this case, it was the Zwicky Transient Facility (ZTF) that spotted the flash. The ZTF is an all-sky survey aimed at the northern night sky. It's hosted at the Palomar Observatory, and it's a systematic study using an extremely wide-field optical light camera to scan the entire northern sky every two days. It's part of what's known as Time-Domain Astronomy, the study of astronomical objects that change over time.

The Zwicky Transient Facility is housed at California Institute of Technology's Palomar Observatory. Image: CIT/Palomar Observatory.

When the ZTF spots a new transient in the sky, other astronomers are alerted. The ZTF isn't suited to studying objects in detail. It just finds them and then passes the baton to other facilities that are better suited for observing astronomical objects in greater detail. In this case, a whole group of facilities took part.

Hubble Space Telescope observations in optical and infrared combined with data from the Jansky Very Large Array pinpointed the flash's precise location. The European Southern Observatory's (ESO) Very Large Telescope (VLT) determined that it was 8.5 billion light-years away. Observational data from other facilities followed, giving astronomers a picture of the flash across a wide swath of the electromagnetic spectrum.

The results of all those observations, and the analysis that followed, are published in a new paper in Nature Astronomy. The paper is "The Birth of a Relativistic Jet Following the Disruption of a Star by a Cosmological Black Hole." The first author is Dheeraj Pasham, a research scientist at the Kavli Institute for Astrophysics and Space Research at MIT.

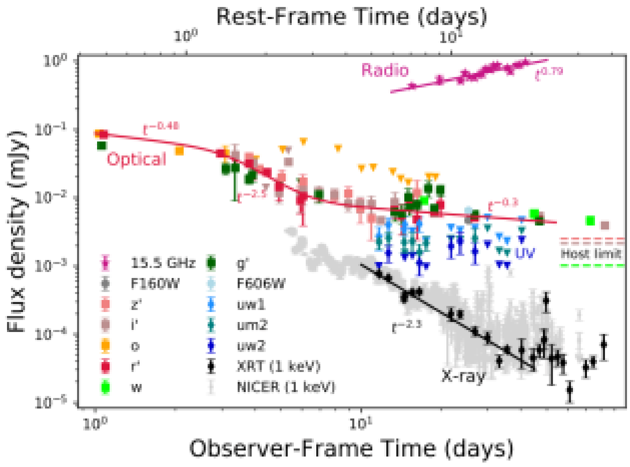
As the title tells us, the transient light source was a jet of matter emitted from a supermassive black hole (SMBH) at 99.9% of the speed of light. The light signal has a name, AT 2022cmc, and the SMBH responsible for it is halfway across the Universe. What caused it? Something extraordinary, according to lead author Pasham.

"This particular event was 100 times more powerful than the most powerful gamma-ray burst afterglow. It was something extraordinary."

Dheeraj Pasham, lead author, Kavli Institute

A behemoth supermassive black hole (SMBH) at the heart of a distant galaxy is responsible. The SMBH is swallowing a star that got too close. This is called a Tidal Disruption Event (TDE) and it's the first one observed since 2011. It's also the first one spotted in optical light, and the 78th one that ZTF has detected.

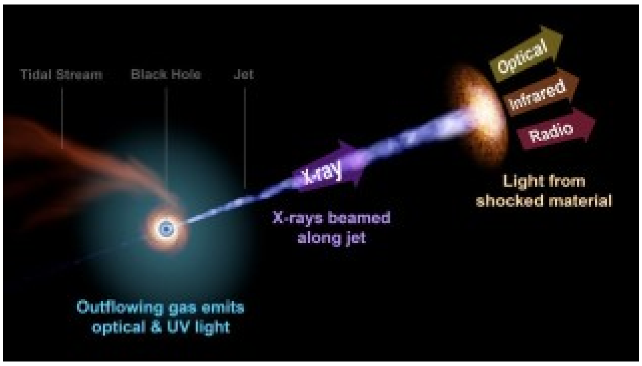
AT 2022cmc is the most distant TDE ever seen, and also the brightest. Gamma Ray Bursts (GRB) are the brightest objects in the Universe, second only to the Big Bang. So it's natural to assume that the event was a GRB. But it wasn't. The jet's high x-ray luminosity helped rule that out.



There's a lot of information in this figure from the study. Take note of the black and grey area in the lower right. It shows the TDE's luminous x-ray emissions. Their strength and duration ruled out a Gamma Ray Burst as the cause of the flash. Image Credit: Pasham et al. 2022

"This particular event was 100 times more powerful than the most powerful gamma-ray burst afterglow," lead author Pasham said in a press release. "It was something extraordinary."

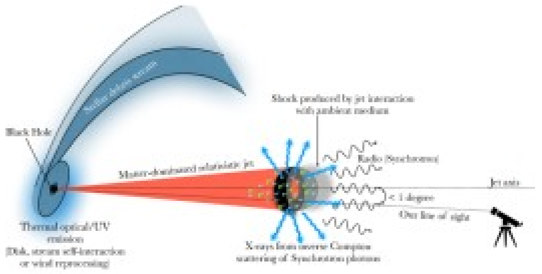
The TDE just happened to point its searing jet of material directly at Earth, like a flashlight shone right in our eyes. Rough calculations showed that the jet was as bright as a trillion Suns.



The jetted tidal disription event AT2022cmc was first observed in the ZTF optical data and was followed by 21 other astronomical facilities that saw it shine in X-ray, UV, infrared and radio. Image credit: Zwicky Transient Facility/R.Hurt (Caltech/IPAC)

The Universe is full of transient events, but observing TDEs is still rare. It helps when the jet is aimed right at Earth, as it was in this case. But when a SMBH consumes a star that got too close, it doesn't always emit jets. TDEs like this one give astronomers an opportunity to learn more about the SMBHs that cause them.

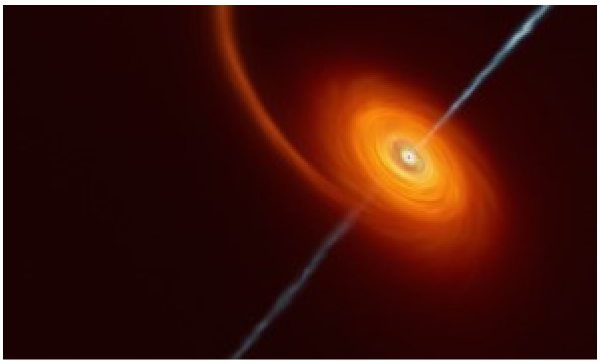
"The last time scientists discovered one of these jets was well over a decade ago," said Michael Coughlin, an assistant professor of astronomy at the University of Minnesota Twin Cities and co-lead on the paper. "From the data we have, we can estimate that relativistic jets are launched in only 1% of these destructive events, making AT2022cmc an extremely rare occurrence. In fact, the luminous flash from the event is among the brightest ever observed."



This schematic from the paper illustrates the team's proposed scenario behind the TDE. For a detailed explanation, see the study. Image Credit: Pasham et al. 2022

Supermassive Black Holes are, obviously, extraordinarily huge. The most massive ones are several billions of times more massive than the Sun. Even in astronomy, a subject known for large numbers, something several billion times more massive than our star is almost incomprehensible.

But as it turns out, even something that large can't eat a star in one bite. It's taking its time devouring the star. The jet was probably emitted during an intermittent 'feeding frenzy,' according to Pasham. "It's probably swallowing the star at the rate of half the mass of the sun per year," Pasham estimates. "A lot of this tidal disruption happens early on, and we were able to catch this event right at the beginning, within one week of the black hole starting to feed on the star."



This artist's impression illustrates how it might look when a star approaches too close to a black hole, where the star is squeezed by the intense gravitational pull of the black hole. Some of the star's material gets pulled in and swirls around the black hole forming the disc that can be seen in this image. In rare cases, such as this one, jets of matter and radiation are shot out from the poles of the black hole. Image Credit: ESO/M.Kornmesser

Astronomers can't yet see the galaxy that emitted it. The jet's light is so powerful that it's outshining its host galaxy. But astronomers think that once the jet dims they'll be able to spot the galaxy with the Hubble and the James Webb Space Telescope.

That might lead them partway to answering an important question: All SMBHs are bound to eat stars, why do so few of them emit jets? Observations show that the ones that emit these types of jets are likely spinning rapidly. The rotation helps power these ultraluminous jets.

The rapid rotation might be only one factor, perhaps the factor that's easiest to observe. But it does bring researchers one step closer to understanding the awesome forces at work in SMBHs.

"We know there is one supermassive black hole per galaxy, and they formed very quickly in the universe's first million years," says co-author Matteo Lucchini, a postdoc in MIT's Kavli Institute for Astrophysics and Space Research. "That tells us they feed very fast, though we don't know how that feeding process works. So, sources like a TDE can actually be a really good probe for how that process happens."

What astrophysicists need, is to find more of these jets, TDEs, and SMBHs. They'll probably get their wish in the near future.

"Scientists can use AT2022cmc as a model for what to look for and find more disruptive events from distant black holes."

Igor Andreoni, Department of Astronomy at UMD and NASA Goddard Space Flight Center

With facilities like the Vera Rubin Observatory coming online soon, we're bound to spot more transients like AT2022cmc. The Vera Rubin should see first light in 2023, and will perform a synoptic survey that will image the entire visible night sky every few nights. One of its four science goals is to find transients and notify other observatories for follow-up observations. And it should find a lot of them.

"Our new search technique helps us to quickly identify rare cosmic events in the ZTF survey data. And since ZTF and upcoming larger surveys such as Vera Rubin's LSST scan the sky so frequently, we can now expect to uncover a wealth of rare, or previously undiscovered cosmic events and study them in detail," says Igor Andreoni, a postdoctoral associate in the Department of Astronomy at UMD and NASA Goddard Space Flight Center.

"Astronomy is changing rapidly," Andreoni said. "More optical and infrared all-sky surveys are now active or will soon come online. Scientists can use AT2022cmc as a model for what to look for and find more disruptive events from distant black holes. This means that more than ever, big data mining is an important tool to advance our knowledge of the universe."

Gone are the days when professional astronomers spend long cold nights looking into the eyepiece of their telescopes. If we still relied on those efforts, we'd likely never even see a TDE. Automated sky surveys are becoming more and more prevalent, covering larger swaths of the sky than astronomers can, and doing it more diligently. They never get tired, get sick, or take holidays.

But facilities like them generate an enormous amount of data, which Andreoni alluded to. The Vera Rubin Observatory is expected to take 200,000 pictures each year of its ten-year run. That means that it'll generate 1.2 petabytes of data each year, far more data than astronomers will be able to handle. It'll be up to AI and machine learning to deal with all that data.

The Zwicky Transient Facility served as a prototype for the Vera Rubin. But while the ZTF found 78 TDEs since its inception, the Vera Rubin will dwarf those results. Nobody's certain how many TDEs it'll find, but the observatory is expected to generate hundreds of alerts per second, and each one will be a transient of some sort.

Some of those will be TDEs, and as more detections roll in, astronomers will do follow-up observations with other facilities.

"We expect many more of these TDEs in the future," said Lucchini. "Then we might be able to say, finally, how exactly black holes launch these extremely powerful jets."

Tiny Cubesat Will Shine an Infrared 'Flashlight' Into the Moon's Shadowed Craters, Searching for Water Ice

A tiny spacecraft is ready to head out for a big job: shining a light on water ice at the Moon's south pole.

Lunar Flashlight is a cubesat about the size of a briefcase, set to launch on December 1 on a SpaceX Falcon 9 rocket, sharing a ride with the Hakuto-R Mission to the Moon.

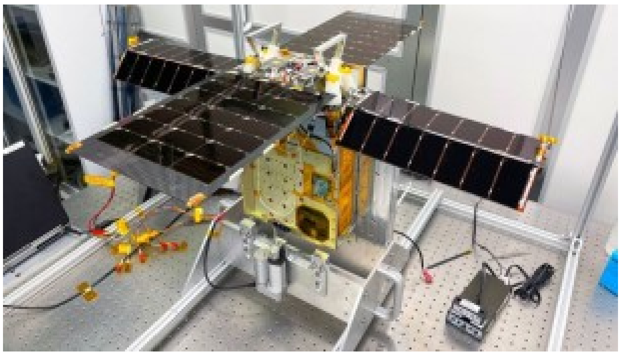
The tiny 14 kg (30 lb) spacecraft will use near-infrared lasers and an onboard spectrometer to map the permanently shadowed regions near the Moon's south pole, where there could be reservoirs of water ice.

"If we are going to have humans on the Moon," said Barbara Cohen, Lunar Flashlight principal investigator, "they will need water for drinking, breathing, and rocket fuel. But it's much cheaper to live off the land than to bring all that water with you."

This illustration shows NASA's Lunar Flashlight over the Moon. The SmallSat mission will have a very elongated orbit, taking it within 9 miles (15 kilometers) above the lunar South Pole to search for water ice in the Moon's darkest craters. Credit: NASA

Several previous missions have found evidence of water ice at the Moon's poles, including Lunar Prospector, the Lunar Crater Observation and Sensing Satellite (LCROSS) and the Lunar Reconnaissance Orbiter. Additionally, other observations have provided many lines of evidence for deep water ice deposits the permanently shadowed regions across both lunar poles.

Cohen told Universe Today that Lunar Flashlight will be looking for "operationally useful" quantities of ice, meaning enough water ice within the craters or embedded in the regolith that could be easily extracted by future rovers or lunar explorers.



The Lunar Flashlight spacecraft underwent pre-launch tests at a Georgia Tech clean room. Credit: NASA/JPL/Caltech.

Lunar Flashlight has just one instrument, a four-laser reflectometer that uses a low-power infrared beam to illuminate the permanently shadowed regions in polar craters. The spectrometer can distinguish between dry regolith and water ice, as the light reflected back from the lunar surface will allow the spacecraft to detect water ice absorption bands in the near infrared.

"Infrared wavelengths are absorbed by water," Cohen explained, "so if water ice there, we'll get fewer photons back than we what we sent."

By repeating these measurements over multiple points and across multiple orbits, the Lunar Flashlight team will be able to create a map of surficial ice concentration. This method could allow NASA to not only find reservoirs of ice but potentially figure out how large they are, since more absorption could indicate more water. Cohen said the data they get can be correlated with data from previous missions to help guide future rovers and humans where to find the water ice.

That's a big task for such a small spacecraft, and Cohen said having such a small footprint to work with was a challenge in constructing the spacecraft.

"Having a 14-kilogram spacecraft means you have to shrink a lot of things down," Cohen said. "But it also means you must get innovative about what you're including and what you're not. That means we could only have one instrument, as we didn't have room for more. But it's a great instrument and it's the first time that active laser spectroscopy will be done at the Moon."

They also had to make their spacecraft require very low power, as there isn't room for a lot of batteries.

"Our lasers have the intensity similar to that of a laser pointer," Cohen explained. "Such low power means we need to be very close to the lunar surface, about 15-20 kilometers away."

Even a full size satellite with a lot of fuel would have a hard time maintaining a that low of an orbit, so Lunar Flashlight will use an innovative orbit called a near rectilinear halo orbit. This is the same orbit currently being used by the microwave-oven-sized CAPSTONE (Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment), which is conduct tests to make sure this unique lunar orbit is actually stable. The same orbit has been proposed for the NASA's future Lunar Gateway. This near-rectilinear halo orbit will take it 70,000 km (42,000 miles) from the Moon at its most distant point and, at its closest approach, the satellite will graze the surface of the Moon, coming within 15 km (9 miles) above the lunar South Pole.

"This orbit enables us to come very, very close to the surface when we want to make the measurements and then go very far away as an energy saving measure for the rest of the orbit," Cohen said, adding that her team is definitely keeping an eye on how things are going for CAPSTONE.

For the primary mission, Lunar Flashlight will get approximately 10 passes of the Moon, depending on how much fuel they have.

"We have an eight-month primary mission, but it depends on fuel," Cohen said. Roughly 50 minutes after launch, Lunar Flashlight will eject from the second stage of the Falcon 9 rocket. "When we are ejected, the spacecraft will tumble and we need to use fuel to get into the right orbit. With such a small fuel tank, we don't have a huge amount of margin."

Lunar Flashlight is considered a technology demonstration mission, as it is testing out several technological firsts, including the first use of the laser reflectometer to look for water ice and the first planetary CubeSat mission to use "green" propulsion – a propellant that is less toxic and safer than hydrazine, a common propellant used by spacecraft.

Another unique aspect is that the “mission control” for the spacecraft is housed at Georgia Tech and will be staffed by a group of 14 operators — eight graduate students and six undergraduates.

“These students helped put this spacecraft together, they wrote all the scripts, they’ll be doing the uplink and downlink – they’re the ones actually in control of the spacecraft. It’s been really gratifying to see such a really meaningful level of student involvement, and they’re going to know the ins and out of operating a spacecraft. You just know those students are going to go on to have amazing careers.”

There have been a few delays leading up to the launch of Lunar Flashlight and Japan’s Hakuto-R Mission, but the launch time is now set for Thursday, December 1 at 3:37 a.m. ET from Cape Canaveral Space Force Station in Florida.

For more details on the mission, see the Georgia Tech website and this article from JPL.

Astronomers Directly Image Debris Disk and find a Jupiter-Sized Planet Orbiting a Sunlike Star

According to the most widely-accepted theory, planetary systems form from large clouds of dust and gas that form disks around young stars. Over time, these disks accrete to create planets of varying size, composition, and distance from their parent star. In the past few decades, observations in the mid- and far-infrared wavelengths have led to the discovery of debris disks around young stars (less than 100 million years old). This has allowed astronomers to study planetary systems in their early history, providing new insight into how systems form and evolve.

This includes the SpHere INfrared survey for Exoplanets (SHINE) consortium, an international team of astronomers dedicated to studying star systems in formation. Using the ESO’s Very Large Telescope (VLT), the SHINE collaboration recently directly imaged and characterized the debris disk of a nearby star (HD 114082) in visible and infrared wavelengths. Combined with data from NASA’s Transiting Exoplanet Space Satellite (TESS), they were able to detect a gas giant many times the size of Jupiter (a “Super-Jupiter”) embedded within the disk.

The SHINE team was led by Dr. Natalia Engler of the Institute for Particle Physics and Astrophysics (IPA) at ETH Zurich. She was joined by astronomers from the European Southern Observatory (ESO), the Space Telescope Science Institute (STScI), the Max-Planck-Institute for Astronomy, the Academia Sinica Institute of Astronomy and Astrophysics, and multiple observatories and universities. The paper that describes their findings recently appeared in the journal *Astronomy & Astrophysics*.

The SPHERE instrument shortly after it was installed on ESO’s VLT Unit Telescope 3. Credit: ESO/J. Girard

As they state in their paper, the team relied on the Spectro-Polarimetric High-contrast Exoplanet REsearch (SPHERE) instrument on the VLT to take optical and near-IR images of HD 114082, an F-type star (a yellow-white dwarf) located in the Scorpius–Centaurus association – a stellar cluster located about 310 light-years from Earth. Like the 500 stars surveyed by the SHINE team, HD 114082 is a young star surrounded by a protoplanetary debris disk (from which planets form). Observations of these disks in recent decades have shown that they are an integral part of planetary systems:

As Dr. Engler told Universe Today via email, these surveys date back to 1983 and the discovery of the first disk around Vega. Since then, dozens of surveys have been performed in infrared wavelengths and scattered light using space-based telescopes like the *Herschel Space Observatory* and the venerable *Hubble* and ground-based telescopes like the Atacama Large Millimeter-submillimeter Array (ALMA), the Gemini Planet Imager (GMI), and SPHERE/VLT. As she explained:

“These studies provided valuable information about the formation and evolution of planetary systems since planets are formed from, reside in, and interact with the dust material. Young debris disks (in the first hundred million years) trace the processes of terrestrial planet formation, and thus studying them helps us to understand the dynamical interaction and evolution of terrestrial planets, in particular the Earth, in the young Solar system.”

Using Sphere, Engler and her team observed HD 114082 in the optical and near-infrared using the angular differential imaging (ADI) and polarimetric differential imaging (PDI) techniques. The former consists of acquiring high-contrast images from an altitude-azimuth telescope while the instrument rotator is off, allowing the instrument and telescope optics to remain aligned and the field of view to rotate relative to the instrument. The latter involves combining different incident polarizations of light and measuring the specific polarization components transmitted or scattered by the object.

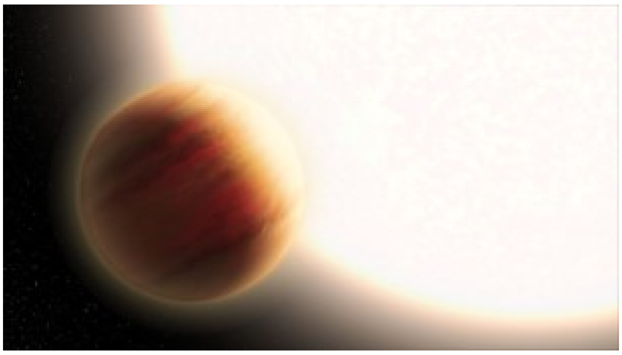
Artist’s impression of circumstellar disk of debris around a distant star. Credit: NASA/JPL

Both techniques have been used extensively in the study of circumstellar debris disks and (according to Engler) revealed some interesting things about HD 114082:

“Our images revealed a bright planetesimal belt at a distance of 35 AU from the host star, very similar to the Kuiper belt in the Solar system. The debris belt is inclined at 83° and has a wide inner cavity. The dust particles, which we trace in this observation, have sizes around 5 microns and a relatively high scattering albedo of 0.65; this means they scatter nearly two-thirds of incoming stellar radiation and absorb only one third of it. The scattered light has a relatively low degree of linear polarization with a maximum of 17% which, however, is comparable with the polarization values for cometary dust in the Solar system.”

The team also consulted data from TESS to confirm the presence of a super-Jupiter companion, which was first detected by the observatory in 2021 using transit photometry (aka. the Transit Method). Consistent with this data, Engler and her colleagues confirmed that the planet orbits its parent star at approximately 0.7 AU – about the same distance between Venus and the Sun. Recent observations based on radial velocity measurements confirmed this planet and produced mass estimates about eight times that of Jupiter.

HD 114082 provides an example for young planetary systems, where the presence of planetary companions to the host star has been inferred from the discovery of a debris disk," Engler added. "This confirms the theoretical considerations of debris systems as signposts for young planets. Studying this and other similar planetary systems will allow [astronomers] to establish a link between the properties of extrasolar Kuiper belts and planets residing within them."



Artist's impression of the super-hot Super-Jupiter WASP-79b located 780 light-years away in the constellation Eridanus. Credit: NASA

The implications of this study go beyond the study of young stars and planetary systems that are still in formation. They are also significant for studying our Solar System, which has some interesting parallels to these protoplanetary environments. Said Engler:

"The direct imaging studies of the last decade show that the circumstellar material in many debris disks is confined to ring-like structures, similar to two debris belts in the Solar system: the Edgeworth-Kuiper belt and the main asteroid belt. The cavities inside the extrasolar Kuiper belts are curved by unseen planets, which leave their imprints in the debris dust distribution, such as warps, clumps and belt eccentricities."

Lastly, this study demonstrates the growing use and effectiveness of direct imaging studies, which are possible thanks to improved instruments, imaging capability, and data-sharing methods. In the near future, next-generation instruments will allow for even more accurate and detailed direct imagining studies. These include space-based observatories like the *JWST* and the *Nancy Grace Roman Space Telescope* and ground-based telescopes like the Extremely Large Telescope (ELT), the Giant Magellan Telescope, and the Thirty Meter Telescope (TMT).

By studying the geometry and asymmetric features in debris disks, astronomers can predict the location and masses of planets that are not yet detectable with current instruments. "Direct imaging makes it possible to study the scattering properties of dust particles around distant stars," Engler added. "These properties contain information about particle composition, shape, and size, and thus we can gain insights into the composition of the building blocks of exoplanets."

Further Reading: arXiv

BlueWalker 3 is a Cellphone Tower in Space and One of the Brightest Objects Ever Launched. Astronomers Aren't Happy.

It seems our nighttime skies are hosting another new communications network. In recent years, we've seen Starlink trains of satellites moving against the backdrop of stars, and more OneWeb satellites will soon be heading to orbit. Now, it's BlueWalker 3, a prototype test satellite for a new communications constellation aimed at cell phones. Think of it as the first of many "cell towers in space" providing communications access for people around the globe.

While all of these satellites can affect astronomy, BlueWalker 3 recently caught the astronomy community's attention because it's big and bright. In fact, it can get as bright as a visual magnitude of 1 (about as bright as Altair or Spica). It also emits a specific set of radio frequencies. Because of this, the International Astronomical Union released a statement about its effect on research.

The company launching this prototype test satellite, AST SpaceMobile, says it has been in contact with the IAU and the astronomy community to mitigate the system's effects on astronomy. Other companies are working with astronomers, too, to mitigate their system's effects on observations. At stake are the conflicting needs of communications companies to make their product available stacked against the needs of the astronomy community to continue its discoveries among the stars.

The IAU and BlueWalker 3

The IAU is the global gathering of astronomers. It advocates for the promotion and safeguarding of all aspects of astronomy and science education. In its release, the organization pointed out its concerns about BlueWalker 3's visibility, saying, "This low Earth orbiting satellite is now one of the brightest objects in the night sky, outshining all but the brightest stars. In addition, the satellite's use of terrestrial radio frequencies poses a new challenge to radio astronomy."

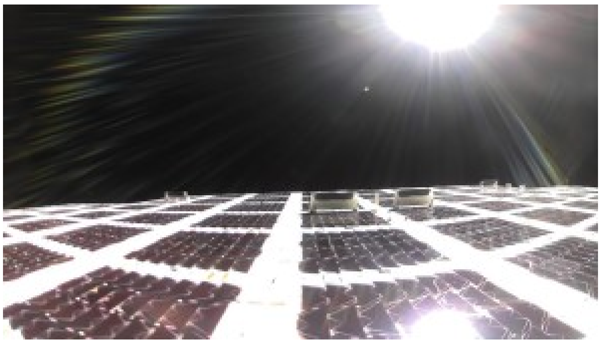
Radio astronomy observatory personnel raised the alarm about the effects on their work. Ground-based observatories are concerned, too. These include NSF's NoIRLab, and the Square Kilometer Array Observatory (SKAO).

"Astronomers build radio telescopes as far away as possible from human activity, looking for places on the planet where there is limited or no cell phone coverage. Frequencies allocated to cell phones are already challenging to observe even in radio-quiet zones we have created for our facilities. New satellites such as BlueWalker 3 have the potential to worsen this situation and compromise our ability to do science if not properly mitigated," said SKAO Director-General Philip Diamond. "This is a key reason why the SKAO is deeply involved in the IAU CPS and promoting the equitable and sustainable use of space."

Trail left by BlueWalker 3 over McMath-Pierce Solar Telescope at Kitt Peak National Observatory, a Program of NSF's NOIRLab.

About BlueWalker 3

The BlueWalker 3 platform is a product of AST SpaceMobile, based in Midland, Texas. The aim of the their satellite constellation is to solve a problem that faces billions of people around the globe: a lack of connectivity. The prototype satellite is the largest-ever commercial communications array deployed in low Earth orbit. It will be accessible by cellular devices via 3GPP standard frequencies at 5G speeds. The platform should have a field of view of over 300,000 square miles on the surface of the Earth.



The BlueWalker 3 array is fully deployed. Courtesy: AST SpaceMobile.

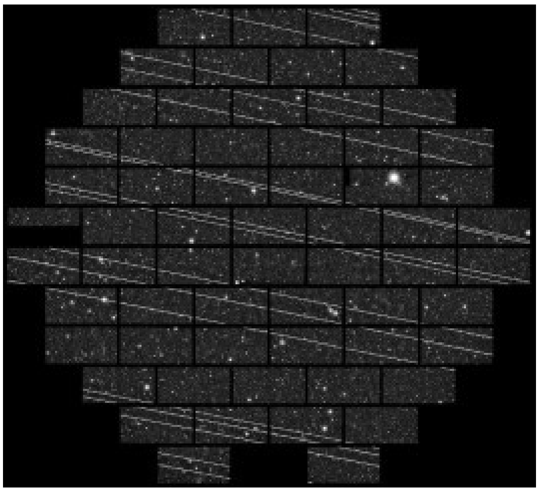
This is a first-of-its-kind space-based cellular network that can reach areas that aren't being served by current networks. The design of the system requires not more than 168 satellites—orders of magnitude fewer than other networks have or are planning to put into orbit.

An AST SpaceMobile spokesman shared that the company has been working with the IAU and other astronomy groups on ways to reduce the system's effects. "We are eager to use the newest technologies and strategies to mitigate possible impacts to astronomy," they said. "We are actively working with industry experts on the latest innovations, including next-generation anti-reflective materials. We are also engaged with NASA and certain working groups within the astronomy community to participate in advanced industry solutions, including potential operational interventions.

"As part of this work, AST SpaceMobile is committed to avoiding broadcasts inside or adjacent to the National Radio Quiet Zone (NRQZ) in the US and additional radioastronomy locations that are not officially recognized, as required or needed. We also plan to place gateway antennas far away from the NRQZ and other radio-quiet zones that are important to astronomy."

Finding Common Space for Both Needs

The conflict between astronomers and communication satellite operators will ultimately come down to technological solutions. Both sides are already working together to find ways to have global communications AND explore the cosmos. The concerns are very real, in particular for the Vera Rubin Observatory in Chile. It is an all-sky survey facility set to begin operation in 2024. In a statement released this past summer, the Rubin Observatory offered a detailed analysis of the challenge. It pointed out that ultimately as many as 30 percent of all its images will contain at least one satellite streak. Very bright satellites could completely saturate its survey camera's CCDs.



This sequence of Starlink streaks was obtained on the night of 12-13 November using the Cerro Tololo Inter-American Observatory (in Chile) all-sky camera. The Vera Rubin Observatory could face similar intrusions on observations from satellite constellations. Courtesy NOIRLab.

Astronomers and Industry Meet to Solve the Challenge

To understand the effects on astronomy of the increasing number of satellites in low-Earth orbit, the American Astronomical Society convened a series of workshops under the name SatCon 1 and SatCon 2. They produced recommendations for reducing the effects of satellites on astronomical observations. Among them is the idea of collaboration between satellite operators and observatories to predict the positions of satellites so that observations can be programmed to avoid most (if not all) passages.

Another idea is to change the reflectivity of the satellites. Certainly, dark coatings on their surfaces do reduce their brightnesses. For example, SpaceX experimented with something called "DarkSat" and astronomers reported a marked change in satellite brightness. The company also deployed a type of sunshade dubbed "VisorSat" to reduce Starlink satellite reflectivity. These haven't completely solved the problems, but mark a step in the right direction. AST SpaceMobile is also looking at these technologies for their next-generation satellites. This test flight for BlueWalker 3, along with input from NASA and IAU working groups should help the company refine its satellite design, as well.

Astronomers are also looking at ways to mitigate the effect of satellites on observations at Vera Rubin by reprogramming its scheduling algorithms. With a reasonably accurate satellite orbit forecast, the observatory could avoid "seeing" some satellites during its operations. This is still a work in progress but requires much more information about the orbits, the surface brightnesses of the satellites, and other systematic errors that could creep into the forecasts.

Charting Satellites in the Sky

To help astronomers and companies like Starlink and AST SpaceMobile understand the effects of these new satellites, the IAU's Center for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (CPS) office invited observations of BlueWalker 3, Starlink, and other satellites. Observers can submit visual and telescopic information about what they see to SatHub.

The CPS recognizes that these new satellite constellations are responding to a global need for improved communications. That means future versions of the satellites should be much more compatible with the needs of the astronomy community.

For More Information

IAU CPS Statement on BlueWalker 3

SatCon1 Report from AAS

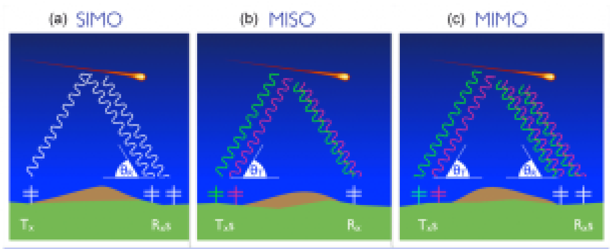
AST SpaceMobile Deploys Largest-Ever Commercial Communications Array in Low Earth Orbit

The Technique for Detecting Meteors Could be Used to Find Dark Matter Particles Entering the Atmosphere

Researchers from Ohio State University have come up with a novel method to detect dark matter, based on existing meteor-detecting technology. By using ground-based radar to search for ionization trails, similar to those produced by meteors as they streak through the air, they hope to use the Earth's atmosphere as a super-sized particle detector. The results of experiments using this technique would help researchers to narrow down the range of possible characteristics of dark matter particles.

The existence of dark matter is pretty well accepted by mainstream physicists. Ever since Lord Kelvin calculated that the mass of all the stars in the Milky Way galaxy was much less than the mass of the galaxy itself, we've known that much of the matter in the Universe is not visible to us. As technology has improved, we've learned how to detect things that were hidden from visible-light telescopes, but we still can't account for all the missing matter. We call this missing material "dark matter", and current estimates say that a full 85% of the mass of the universe is made from dark matter. Most physicists now believe that dark matter is made of an as-yet undiscovered particle.

Dr John Beacom of Ohio State University has proposed an experiment to determine the characteristics of this particle. He wants to adapt the radar technology used to detect and measure meteors as they streak through the atmosphere, using it to look for similar streaks that could indicate a dark matter particle colliding with air molecules. This technique uses radar stations on the ground to detect and measure trails of ionization through the upper atmosphere.



A diagram of different radar systems that can be used to detect ion trails, such as those produced by meteors. SIMO, (a single transmitter and an interferometric receiver), MISO (multiple transmitters and a single receiver) and MIMO (multiple transmitters and receivers). Image source: Novel specular meteor radar systems using coherent MIMO techniques to study the mesosphere and lower thermosphere.

When a meteoroid enters the Earth's atmosphere, it rams through the air faster than the air itself can move out of the way. This causes the air in front of the meteor to compress and become so hot that it ionizes – individual air molecules collide with each other so hard that they lose electrons. Ionized air not only glows, but it is opaque to radio waves. This causes radar signals to reflect back to earth, allowing meteors to be detected even during the day.

Theoretical physicists have calculated the physical characteristics that dark matter particles could possibly have. Unfortunately, since most of what we know about these particles is that they interact weakly with normal matter (we have so far only detected it at all by it's gravitational influence), this leaves a wide range of possibilities. Dr Beacom points out that if dark matter particles fall within the larger, heavier end of the range of possibilities, then they would interact with "normal" matter more easily, although these interactions would still be rare.

"One of the reasons dark matter is so hard to detect could be because the particles are so massive," Beacom said. "If the dark-matter mass is small, then the particles are common, but if the mass is large, the particles are rare."

If these particles are large, then traditional detectors on the ground might never see them, because the particles are being absorbed by Earth's atmosphere. But if this happens, then they should have enough energy to produce an ionization trail, similar to what we see with meteors. Meteor-detecting radar installations could therefore be adapted to also search for dark matter particles — essentially turning the entire Earth's atmosphere into one giant particle detector.

The existence of dark matter was first predicted in 1884 by Lord Kelvin. He had calculated the mass of the Milky Way galaxy, based on the speed at which it rotates, and found that it must be significantly heavier than the combined visible stars. He theorized that most of the galaxy's mass must be made of "dark" material – things which could not be seen with the telescopes of the time. However, most scientists assumed this meant that there would be a lot of cold gas, dust, exoplanets, and other objects that do not shine with their own light. The phrase "dark matter" was first used to describe these things in a French paper in 1906.

Hubble Space Telescope offers a cosmic cobweb of galaxies and invisible dark matter in the cluster Abell 611. Credit: ESA/Hubble, NASA, P. Kelly, M. Postman, J. Richard, S. Allen

Many other lines of evidence have appeared since then: Fritz Zwicky noticed in the 1930s that galaxies in the Coma cluster move as if the entire cluster was 400 times heavier than the total mass of all its visible members. Early radio astronomers in the 1960s saw that spiral galaxies spin way too fast around their edges – they should simply fly apart, unless there was an additional source of gravity to hold them together. Vera Rubin, Kent Ford, and Ken Freeman made the same discovery shortly after, using newly improved spectrographs to measure the rotational curve of galaxies in visible light. And a series of deep cosmological observations in the 1980s detected gravitational lensing and anisotropies in the Cosmic Microwave Background Radiation (CMBR), adding to the evidence for the existence of dark matter.

It's worth noting that nobody yet knows whether dark matter particles will actually produce these ionization trails. Detectors built using this technique may never see anything at all. But either result, detections or no detections, would be a good thing. One way or another, an experiment using this detection technique will answer the question: "Are dark matter particles large heavy, and rare? Or are they small, light, and numerous?"

To learn more about this technique, read the original research paper at https://news.osu.edu/astronomers-create-new-technique-to-assist-in-search-for-dark-matter/

OK, Artemis. Now You're Just Showing Off. A Stunning View of the Moon Eclipsing Earth From the Orion Spacecraft

Have you ever seen a lunar eclipse of the Earth from the far side of the Moon? Now we have.

On Monday (November 28, 2022) NASA's Orion spacecraft streamed back live video showing the Earth and Moon right next to each other, followed by a stunning view of the Moon eclipsing the Earth.

What a time to be alive! Image editor Kevin Gill might have said it best:

The video came from one of the cameras mounted on the tip of the one of the solar arrays on Orion's European Service Module, as it traveled about 64,000 km (39,767 miles) beyond the Moon, or roughly 431,300 km (268,000 miles) away from Earth. The spacecraft is cruising at 1,750 miles per hour.

At the time when the Moon slipped completely in front of Earth, the signal from Orion was lost on the video feed.

The Earth and Moon as see from the Orion spacecraft, close to 44,000 km (270,000) miles from Earth. Credit: NASA livestream.

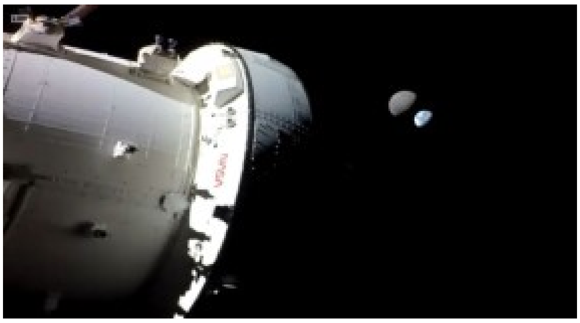
Our David Dickinson put together a video of the event:

The cameras are basically souped-up Go-Pro cameras, made hardy enough for space travel.

"Each of Orion's four solar array wings has a commercial off-the-shelf camera mounted at the tip that has been highly modified for use in space, providing a view of the spacecraft exterior," said David Melendrez, imagery integration lead for the Orion Program at NASA's Johnson Space Center in Houston.

Melendrez said the arrays can adjust their position relative to the rest of the spacecraft, which will optimize the collection of sunlight converted into electricity to power Orion. This also allows flight controllers in the Mission Control Center at NASA Johnson to point the cameras at different parts of the spacecraft for inspections and to document its surroundings in space, including the Earth and Moon.

On Saturday Nov. 26, NASA said the Orion spacecraft broke the record for the farthest distance traveled from Earth of a human-rated spacecraft. The record was previously held by Apollo 13 at 248,655 statute miles from Earth.



Earth and Moon close together prior to the eclipse, as seen from the Orion capsule. Credit: NASA livestream.

However, that doesn't take into account the Apollo 10 lunar module, nicknamed Snoopy (the Command Module was Charlie Brown), which might be still traveling in space. After carrying out a successful lunar orbit and docking procedure, Snoopy was jettisoned and sent into an orbit around the Sun. After 53 years, it's believed to still be in a heliocentric orbit. A team of UK and international astronomers have been working to try and find it, but so far they haven't had any luck.

The Apollo 10 lunar module about to dock with the command module in 1969. Image Credit: NASA

Meanwhile, Orion continues on its uncrewed mission, a shakeout flight to test the spacecraft and ground systems. It launched on the Space Launch System rocket on November 16, and is the first mission in 50 years where a human capable spacecraft is at the Moon. Orion is slated to return to Earth about 25 days after launch, with splashdown currently set for December 11. Using the same exterior cameras as the ones giving us these stunning views today, engineers have been able to assess the exterior or Orion and have deemed it to be in great shape. Therefore, Orion has already been cleared for re-entry.

Astronomers Spotted a Tiny Asteroid A Few Hours Before it Impacted the Earth, and Predicted Exactly Where and When it Would Crash

Humanity is getting better a planetary defense. At least from external threats from outer space. As long as they're just dumb rocks that follow the laws of physics. And a group of extraordinary humans proved it last week when the planetary defense community jumped into action to accurately track and predict exactly where a relatively small meteor would fall on November 19th.

That meteor, now known as 2022 WJ1, was first noticed by the Catalina Sky Survey at around midnight EST on the 19th (the time zone in which it ended up landing). Catalina is one of the most prolific discoverers of asteroids and is a crucial link in the planetary defense chain. A NASA press release details the steps that come afterward that result in a successful landing prediction.

2022 WJ1 was pretty small – only about 1 m wide, and posed no actual threat to anyone or anything on the ground. But the planetary defense network is designed to catch much bigger potential threats. The fact that it reacted with such speed shows that it is becoming more and more capable and will be much more likely to find any potentially devastating events, such as the Chelyabinsk meteor in 2013, which caused 1400 injuries and around $33 million in property damage.

Door cam of 2022 WJ1 streaking across the sky at 3:27 AM on November 19th.
Credit – Jim Geary YouTube Channel

The Chelyabinsk meteor was 20 times the size of 2022 WJ1 and, therefore, would have been much easier to see if astronomers had the same resources in place as they do now. Walking through how 2022 WJ1 was tracked helps illuminate how much planetary detection has improved.

After Catalina first detected the meteor, it immediately sent a notice to the Minor Planet Center, a central data hub for small bodies surrounding the Earth. From there, the entry was picked up by automatically Scout, a program from the Center for Near Earth Object Studies, which attempted to assess the likelihood that 2022 WJ1 would impact the Earth.

Its original assessment, posted 7 minutes after the asteroid was initially discovered, showed a 25% chance of hitting the Earth. That's where the rest of the planetary defense community came in.

UT video on how we track asteroids

Catalina continued tracking the asteroid throughout the night, but several other astronomers, including a group of amateurs from the Farpoint Observatory in Eskridge, Kansas, a little southwest of Topeka. Over 600 asteroids have been discovered there, so this is another feather in their cap.

As the data continued streaming in, there were a total of 46 observations made of the 2022 WJ1 in the three hours following its initial discovery. The University of Hawai'i made the last observation about a half hour before its predicted impact.

At the predicted time – 3:27 AM, and at the predicted place – southern Ontario, Canada, a fireball lit up the sky and was captured on myriad door cams and other recording devices, resulting in some pretty impressive videos. After the fact, plenty of other astronomers spent time analyzing the asteroid's trajectory, even going so far as to come up with models that showed how the Earth's actual gravitational pull caused 2022 WJ1 to fall to its firey doom – or join the larger Earth's biosphere, depending on how you look at it.

Fraser discusses tracking of 2022 WJ1.

As it didn't cause any harm, and there were no safety implications, this was an excellent exercise in the search for potentially dangerous asteroids, and we do seem to be getting better at it. This sixth detection comes fourteen years after the first detection of 2008 TC3 but less than a year after the last detection of 2022 EB5 over the Nubian desert earlier this year. That last event dropped plenty of meteorites across the desert, and there are likely some from 2022 WJ1 scattered around southern Ontario. Now it's up to the meteorite hunters to find them, as the planetary defense community gave them an excellent head start.

What Happened to those CubeSats that were Launched with Artemis I?

NASA made history on November 16th when the Artemis I mission took off from Launch Complex 39B at Cape Canaveral, Florida, on its way to the Moon. This uncrewed mission is testing the capabilities of the Space Launch System (SLS) and Orion spacecraft in preparation for the long-awaited return to the Moon in 2025 (the Artemis III mission). Rather than astronauts, this mission carries a group of mannequins with sensors and has a primary payload consisting of the Callisto technology demonstrator (a human-machine video interface system).

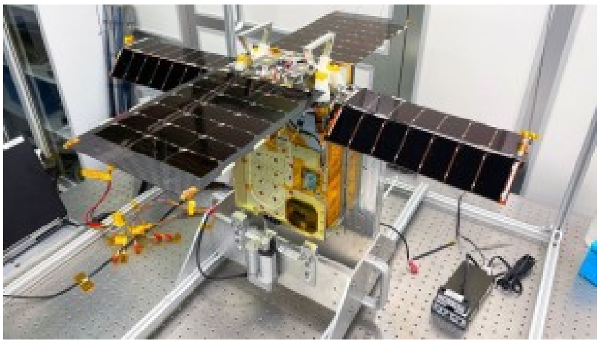
As a secondary payload, Artemis I also brought ten 6U CubeSats beyond Low Earth Orbit (LEO), three of which were NASA missions designed to perform experiments. The rest were built by partner space agencies, commercial space entities, research institutes, and universities to carry out a variety of unique deep-space science experiments. While all these satellites managed to deploy successfully, six have not made contact with controllers on the ground or since experienced problems, and their whereabouts remain unknown.

The three NASA missions include the **BioSentinel**, which was designed, built, and tested by engineers at NASA's Ames and will measure the effects of deep-space radiation on DNA using yeast organisms. The second is the **IceCube**, a technology demonstrator developed by Morehead State University in partnership with NASA's Goddard and space propulsion specialist the Busek Company. Its purpose is to look for surface water ice in the permanently-shadowed regions near the lunar south pole and test out new spacecraft technologies.

The third is the **NEA Scout** mission developed by the NASA Marshal Space Flight Center in partnership with NASA JPL, with support from NASA Goddard, the Johnson Space Center, and the Langley Research Center. The purpose of the mission is twofold: one, to demonstrate solar sail deployment; and two, to demonstrate solar sail navigation by rendezvousing (and characterizing) the near-earth asteroid (NEA) 2020 GE. The other missions include the following:

ArgoMoon: Contributed by the European Space Agency (ESA) and ArgoTec, an Italian aerospace company. This CubeSat aims to observe the SLS interim cryogenic propulsion stage with advanced optics and software imaging systems.
CuSP: Contributed by the Southwest Research Institute (SwRI), this satellite is a "space weather" mission that will measure solar particles and magnetic fields.
EQUULEUS: This satellite was developed by the Japan Aerospace Exploration Agency (JAXA) and the University of Tokyo to image Earth's plasmasphere and study Earth's radiation environment from the Earth-Moon L2 point.
LunaH-Map: This satellite, contributed by Arizona State University, will use neutron spectrometers to create higher-fidelity maps of near-surface hydrogen in permanently-shadowed craters and other regions near the lunar South Pole.
Linux: Developed by Lockheed Martin, this mission will conduct advanced infrared imaging of the lunar surface.
OMOTENASHI: Developed by JAXA, this lunar lander (the smallest ever deployed) will study the lunar environment.
Team Miles: Developed by Florida-based aerospace company Miles Space, this demonstrator will test plasma

thrusters and compete in NASA's Deep Space Derby Centennial Challenge (formerly the Cube Quest Challenge).



NASA's Lunar Flashlight CubeSat undergoing tests at a Georgia Tech clean room. Credit: NASA/JPL-Caltech.

All ten CubeSats successfully deployed from the Interim Cryogenic Propulsion Stage (ICPS), an adapter attached to the SLS's upper stage. On November 18th, NASA officials confirmed that ArgoMoon, Biosentinel, Equuleus, LunaH-Map, and OMOTENASHI were all operational, though OMOTENASHI began experiencing problems since then. On November 24th, NASA reported that the NEA Scout mission still hadn't made contact. This prompted the mission controllers to deploy the CubeSat's sail ahead of schedule, hoping it will be visible to ground-based telescopes.

In short, only four satellites were deployed and successfully established communications with their controllers back on Earth. The teams behind the remaining six missions are currently troubleshooting various solutions and are waiting to learn more. But as time has taught us, such is the nature of CubeSat missions, which are inherently high-risk and high-reward. And it may be premature at this point to count out all the missions that have experienced problems.

As you can see, the new instrument shows the galaxy in incredible detail. NGC 1097 is located 45 million light-years away from Earth, in the constellation Fornax. ERIS's view shows a clearer picture of the gas and dusty ring that lies at the center of the galaxy, with a crisper view of the the bright spots in the surrounding ring, which are stellar nurseries.

First light for ERIS, *the Very Large Telescope's newest infrared instrument. This image has been taken through four different filters by ERIS's state-of-the-art infrared imager, the Near Infrared Camera System — or NIX. The filters have been represented here by blue, green, red and magenta, where the last one highlights the compact regions in the ring. To put NIX's resolution in perspective, this image shows, in detail, a portion of the sky less than 0.03% the size of the full Moon.* ***Credit:****ESO/ERIS team*

The ERIS instrument combines a state-of-the-art infrared imager, the Near Infrared Camera System — or NIX imager (NIX) and an integral-field spectrograph (SPIFFIER – SPectrometer for Infrared Faint Field Imaging), both of which use a laser-assisted adaptive optics system to enhance the imaging performance. The adaptive optics corrects for the blurring effects of Earth's atmosphere in real time. ESO says ERIS will be active for at least ten years and is expected to make significant contributions to a myriad of topics in astronomy, ranging from distant galaxies and black holes through to exoplanets and dwarf planets within our own Solar System.

"We expect not only that ERIS will fulfil its main scientific objectives," said Harald Kuntschner, ESO's project scientist for ERIS, in a press release, "but that due to its versatility it will also be used for a wide variety of other science cases, hopefully leading to new and unexpected results."

ERIS is mounted on the VLT's Unit Telescope 4 and officials say the upgrade provides some essential improvements to the facility for the coming decade.

"ERIS breathes new life into the fundamental adaptive optics imaging and spectroscopy capability of the VLT," says Ric Davies, the Principal Investigator of the ERIS consortium and researcher at the Max Planck Institute for Extraterrestrial Physics. "Thanks to the efforts of all those involved in the project over the years, many science projects are now able to benefit from the exquisite resolution and sensitivity the instrument can achieve."

Volcanoes are the worst. They've caused extinctions on Earth, and probably killed Venus

Is there anything good about volcanoes? They can be violent, dangerous, and unpredictable. For modern humans, volcanoes are mostly an inconvenience, sometimes an intriguing visual display, and occasionally deadly.

But when there's enough of them, and when they're powerful and prolonged, they can kill the planet that hosts them.

Modern-day Venus is a blistering hellscape. The temperature rises above 464 C (850 F, 737 K), which is, as Universe Today readers know, hot enough to melt lead (and spacecraft). It's why, out of all the missions Russia sent to the planet's surface, only four managed to transmit pictures before quickly succumbing to Venus' extreme conditions.

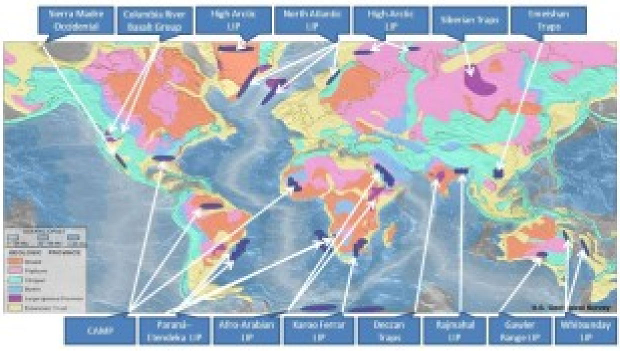
But modern-day Venus might be dramatically different from ancient Venus. Some research shows that ancient Venus had an atmosphere similar to ancient Earth's. The planet may also have had substantial quantities of water on its surface. It's possible that simple life existed on Venus at one time, but there's not enough evidence yet to prove or disprove that.

A new study shows that massive volcanic eruptions over an extended period of time may be responsible for changing the planet into what it is today. If there was simple life on ancient Venus, volcanism was its doom. The study also shows how powerful volcanic activity has played a role in shaping Earth's habitability and how Earth only narrowly avoided the same fate as Venus.

The study is titled "Large-scale Volcanism and the Heat Death of Terrestrial Worlds," and it's published in The Planetary Journal. Dr. Michael J. Way of NASA's Goddard Institute is the lead author. Way has been researching Venus for years and is the author and co-author of several papers on the planet, especially its ancient habitability. "By understanding the record of large igneous provinces on Earth and Venus, we can determine if these events may have caused Venus' present condition," Way said in a press release announcing the study.

Venus's thick clouds mean that only radar imaging and ultraviolet observations can reveal its details. Image Credit: NASA/JPL-Caltech

Earth has experienced prolonged periods of sustained volcanic eruptions in its history. Large Igneous Provinces (LIPs) are the evidence for the periods, which can last hundreds of thousands of years—maybe even millions of years. LIPs can deposit more than 100,000 cubic miles of rock on the surface. That's enough to bury Texas a half-mile deep. On Earth, we know of many LIPs, and we know that in the last 500 million years, they coincide with periods of climate change and with mass extinctions.

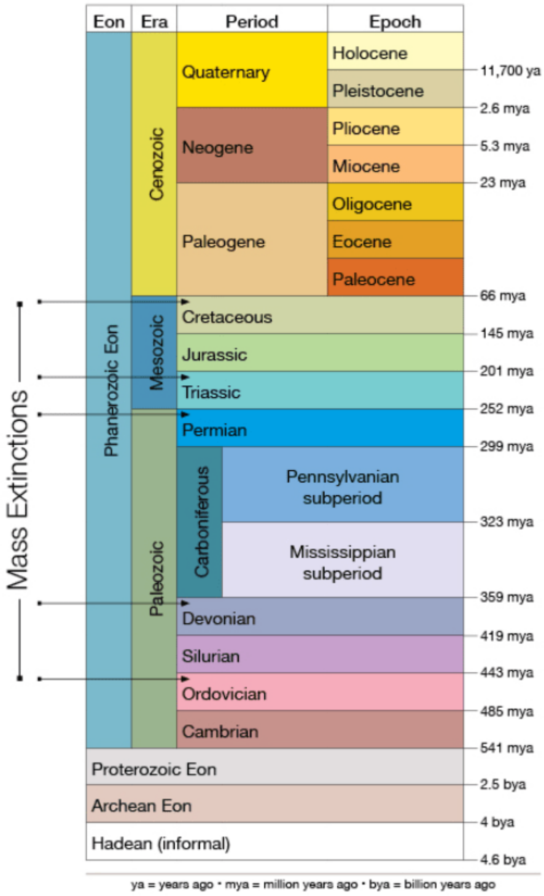


This map shows the Earth's crustal geologic provinces, of which LIPs are one type. The Siberian Traps and the Deccan Traps are well-studied LIPs that are chronologically associated with extinctions. Image Credit: By Williamborg – Own work – based on the markup of the USGS map. Source: https://earthquake.usgs.gov/research/structure/crust/maps.php; CC BY-SA 3.0

The study suggests that Venus underwent massive volcanic outbursts of its own that created Venus' modern atmosphere, with its extreme temperatures and pressures. More specifically, it says that intense outbursts in a period as short as one million years created a runaway greenhouse effect. The runaway greenhouse effect is when an atmosphere prevents a planet's heat from radiating into space. With no way to cool, the temperature rises to extreme levels, like a greenhouse with all its vents closed.

Venus's greenhouse effect is exacerbated by its apparent lack of plate tectonics. Earth's plate tectonics allows heat from the planet's interior to reach the surface by periodically opening the mantle blanket. It also takes carbon dioxide out of the atmosphere and into rock via weathering and subduction.

Our planet's experienced five mass extinctions, and all of them are associated with increased volcanic activity, according to this work. (Some researchers point to a sixth mass extinction that is just beginning, as human activity causes increased species loss.) The Chicxulub impact event was the prime driver of the Permian-Triassic extinction that wiped out the dinosaurs, but volcanic activity also played a role. While the Chicxulub dinosaur extinction is well-known and popularized dramatically, volcanic activity has been the principal driver of extinctions on Earth.



A timeline of Earth's 5 mass extinctions, which all coincide with increased volcanic activity. A sixth one is occurring currently, according to some scientists. It's the only one unrelated to volcanic activity. Image Credit: University of Kansas.

Life on Earth suffered mightily from powerful and sustained volcanic activity. But it always recovered, and the volcanoes never caused a runaway greenhouse effect, while Venus suffers to this day from the effect. What's the difference?

The scale of eruptions had something to do with it. Venus's surface is 80% covered with solidified volcanic rock. The sulphur in the atmosphere is also evidence of pronounced volcanic activity. And Venus' surface has fewer craters than expected, indicating abundant volcanic activity in the last few hundred million years.

But the study should make anyone uncomfortable. Though Earth has avoided the runaway greenhouse effect, it may only have narrowly avoided it.

Untangling the history of volcanism, impacts, and extinctions in Earth's history is challenging because craters get erased. There are scientific efforts to understand the conditions in Earth's mantle that lead to LIPs, but that's also a difficult task.

The magmatic events that create LIPs are typically short-lived in geological time scale, less than 5 million years in duration. They can also be a series of pulses over a few tens of millions of years. Though they push a lot of rock onto the surface, the chemicals they emit into the atmosphere are what drive extinctions. Massive quantities of CO^2 heated

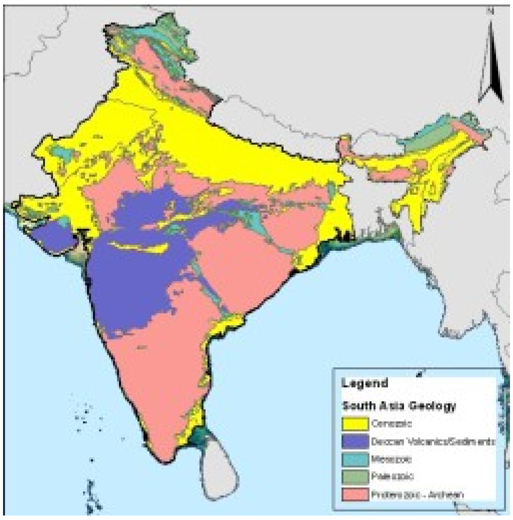
Earth's atmosphere dramatically, and sulphur dioxide ($S0^2$) compounded the warming. Toxic compounds like hydrogen sulphide (H_2S) and carbon monoxide (CO) also come from eruptions, but only in tiny amounts.

Earth's volcanic activity is similar to Venus' because the planets are "sister planets." They're very close in size and are both rocky planets in the inner Solar System. But the critical thing they share when it comes to volcanism is their bulk composition. Since they formed in the same region of the Solar System, they have very similar compositions.

Venus' lowlands are dominated by lava flows. Image Credit: NASA

In their study, the authors recreated Earth's volcanic history in random simulations based on what's known about Earth's volcanic activity and LIPs. "In one approach, we make a conservative estimate of the rate at which sets of near-simultaneous LIPs (pairs, triplets, and quartets) occur in a random history statistically the same as Earth's," the authors write. "We find that LIPs closer in time than 0.1–1 million yr are likely; significantly, this is less than the time over which terrestrial LIP environmental effects are known to persist."

That means that LIP events overlap one another, and before the planet can remove the CO^2 released into its atmosphere from one event, another is busy releasing more. String enough of those together, and you get the runaway greenhouse effect. Separate LIPs on different parts of the globe, even under the oceans, exacerbate the effect.



The blue area indicates the Deccan Traps, a massive remnant of immense volcanic eruptions at the end of the Cretaceous period that may have contributed to the terminal Cretaceous extinction. Credit: CamArchGrad, English Wikipedia Project.

A key part of their study concerns variability. Are LIPs related to one another causally? That matters because if the LIP rate is variable, then that increases the likelihood of overlapping or simultaneous events, which would contribute to a runaway greenhouse effect.

"How would variability in the LIP rate over time affect the chances for simultaneous events?" the authors write. "During times of increased rate, the probability of simultaneous events is enhanced over that for the average rate. On the other hand, during times of decreased rate, this probability is diminished relative to the average. It is not obvious which of these effects predominates."

An interesting point in all of this concerns Earth's longest-lasting LIPs. The longer one lasts, the more likelihood there is of it overlapping with another. "… we find that the probability of the largest LIP in recorded Earth history overlapping with a similar-sized (in area) event is approximately 30%. Multiple simultaneous LIPs may be important drivers of the transition from a serene habitable surface to a hothouse state for terrestrial worlds, assuming they have Earth-like geochemistries and mantle convection dynamics," the paper states.

There's a point where all of this diverges. While we have fairly complete and reliable data on Earth's LIPs, we don't have anywhere near that for Venus. But the research shows that, even with our lack of detailed data, it's likely that Venus suffered overlapping LIPs that led to its doom.

Fortunately, upcoming missions to Venus will open this inquiry up with better data.

The Venus VERITAS (Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy) mission is an orbiter being developed by NASA. Its launch date isn't yet scheduled, but it'll be a three-year mission to image Venus' surface in high resolution using radar and near-infrared spectroscopy. It'll provide detailed information on the planet's impact history, volcanism, geochemistry, and more.

An artist's illustration of NASA's VERITAS mission orbiting Venus. It's scheduled for launch later this decade. Image Credit: NASA/JPL

The DAVINCI (Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging) mission is also a NASA mission, but it'll have an atmospheric probe along with an orbiter. Once scientists have more detailed information on Venus' atmosphere and its surface, they can start untangling the planet's past. "A primary goal of DAVINCI is to narrow down the history of water on Venus and when it may have disappeared, providing more insight into how Venus' climate has changed over time," Way said.

An artist's illustration of the VERITAS's descent probe at rest on Venus' surface. Image Credit: NASA/GSFC.

Both DAVINCI and VERITAS will launch in the late 2020s, with DAVINCI launching first.

The ESA is planning an orbiter mission to Venus, too. It's called EnVision and should launch in the early 2030s. EnVision will also study Venus's atmosphere, but it'll dig deeper, using its instrument package to investigate the planet's internal structure.

These results will also play a role in understanding exoplanets. Exoplanets are a burgeoning area of research, and the James Webb Space Telescope is beginning to deliver better data on exoplanet atmospheres. But it'll be difficult for scientists to interpret the JWST's findings without better overall models, and a more detailed understanding of our sister planet's history will definitely refine our models for planetary atmospheres.

For some reason, Earth has remained habitable for billions of years, and Venus is much worse off. If Venus ever hosted ancient, simple life, it's long gone now. (Apologies to people who think life might live on in Venus' clouds.) While we may never have a complete understanding of all the factors that made Earth and Venus so different from one another, volcanic activity clearly played a role. Once VERITAS, DAVINCI, and EnVision do their thing, we should understand Venus' divergent path in more detail.

Hubble Sees a Dense Cloud of Gas and Dust That's About to Become a Star

The process of star birth begins in a shroud of gas and dust. Hubble Space Telescope (HST) excels in showing detailed views of these stellar crêches because there's still a lot to learn about them. Its latest image shows an object called a "dense core", where a stellar embryo could already exist.

In HST's view, we see the outside of the crêche—a region called CB130-3. This dense core lives up to its name; it's so thick that we can't see into the center. But, it's giving us a glimpse into the complexities of star-making machinery.

This cloud of gas and dust and its hidden stellar embryo lie in a filament of gas and dust located in the direction of the constellation Serpens. It's in an area called the Aquila Rift region and lies about 650 light-years away from us. This site and other places in the galaxy where nebulae are forming stars are of great interest to astronomers seeking to understand all aspects of star birth. It has previously been observed in radio and infrared wavelengths, as well as optical observations.

CB130-3 lies in a filament of the great rift stretching through Aquila and Serpens. In this image, it's to the right of center in the thick dust clouds that create the rift. Courtesy NASA.

Dense Cores Form Baby Stars

So, what happens during star formation, and what role does the dense core play? Star birth is lengthy and these cores are only one part of the process. The first part starts long before cores show up on the scene. First, we need a cloud of gas and dust called a "nebula". Then, it needs some outside influences. Maybe a passing star roils up the nebula. Or, a nearby supermassive star dies in a supernova explosion. Both processes send shock waves through the cloud. Whatever the impetus, those shocks fragment the cloud into smaller clumps and push on them to make the dense cores.

Inside a dense core, material swirls around and falls into the center. It's basically piling up gas and dust in a concentrated area. As that happens, pressures and temperatures rise. When enough material gathers, a protostar forms. That happens perhaps a thousand years or more later, depending on the mass of the material. The protostar continues to accrete more gas and dust for another several hundred thousand years.

The whole protostar phase can last for about a half-billion years or so (depending on the mass of the eventual star). Eventually, the temperatures and pressures get so high that the core of the protostar ignites nuclear fusion. Again, depending on the final mass of the newborn star, it could take up to ten million years before that happens. But, when that nuclear fusion begins, that's the moment the star is born. What began as a "seed" inside a dense core of gas and dust is now a full-fledged star.

Hubble's View of the Gas and Dust Cloud

CB130-3 is one of many of these dense cores that astronomers observe to understand the fine details of star formation. Although it's hidden by the thick birth cloud, this dense core already has an embryonic star inside. It won't be long (in cosmic time) before that hot young object erupts as a newborn star like the Sun.

Objects like this one have interesting chemical properties. They are what's called a "carbon-chain-rich" dense core. The molecules it contains are particularly useful to trace the chemistry of thick clouds of gas and dust where stars form. Astronomers see them as important tracers of reactive organic materials in star-forming regions. They also use them to trace chemical elements in protoplanetary disks, particularly complex organics that could eventually influence the eventual formation of life.

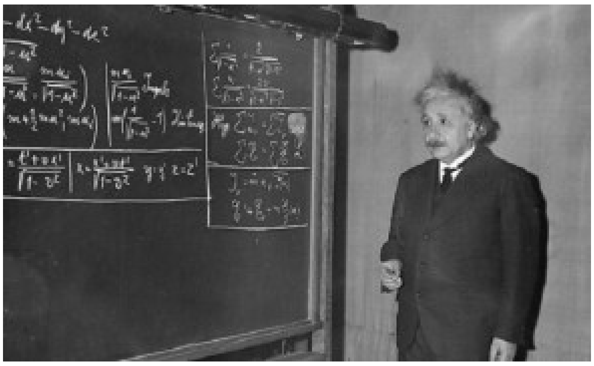
To study CB130-3, astronomers used HST's Wide Field Camera 3 to inspect the cloud surrounding the dense core. It varies in thickness, ranging from a diaphanous veil on the outskirts of the object to an almost impervious shroud of gas and dust in the center. Light from stars in the background appears reddened as it passes through the cloud. That color shift helps astronomers understand the density of different parts of the cloud that will unleash new stars into the galaxy.

Einstein's Predictions for Gravity Have Been Tested at the Largest Possible Scale

According to the Standard Model of Particle Physics, the Universe is governed by four fundamental forces: electromagnetism, the weak nuclear force, the strong nuclear force, and gravity. Whereas the first three are described by Quantum Mechanics, gravity is described by Einstein's Theory of General Relativity. Surprisingly, gravity is the one that presents the biggest challenges to physicists. While the theory accurately describes how gravity works for planets, stars, galaxies, and clusters, it does not apply perfectly at all scales.

While General Relativity has been validated repeatedly over the past century (starting with the Eddington Eclipse Experiment in 1919), gaps still appear when scientists try to apply it at the quantum scale and to the Universe as a whole. According to a new study led by Simon Fraser University, an international team of researchers tested General Relativity on the largest of scales and concluded that it might need a tweak or two. This method could help scientists to resolve some of the biggest mysteries facing astrophysicists and cosmologists today.

The team included researchers from Simon Fraser, the Institute of Cosmology and Gravitation at the University of Portsmouth, the Center for Particle Cosmology at the University of Pennsylvania, the Osservatorio Astronomico di Roma, the UAM-CSIC Institute of Theoretical Physics, Leiden University's Institute Lorentz, and the Chinese Academy of Sciences (CAS). Their results appeared in a paper titled "Imprints of cosmological tensions in reconstructed gravity," recently published in *Nature Astronomy.*



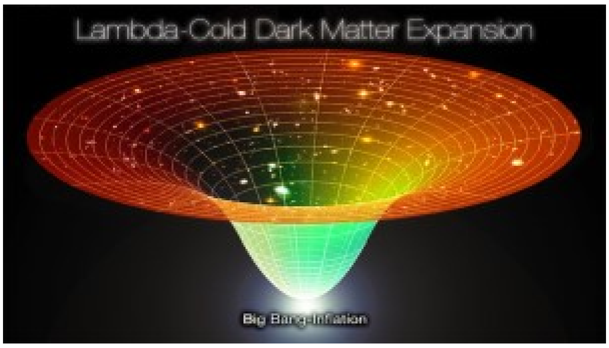
Prof. Albert Einstein delivering the 11th Josiah Willard Gibbs lecture at the Carnegie Institute of Technology on Dec. 28, 1934. Credit: AP Photo

According to Einstein's field equations for GR, the Universe was not static and had to be in a state of expansion (otherwise, the force of gravity would cause it to contract). While Einstein resisted this idea initially and tried to propose a mysterious force that held the Universe in equilibrium (his "Cosmological Constant"), the observations of Edwin Hubble in the 1920s showed that the Universe is expanding. Quantum theory also predicts that the vacuum of space is filled with energy that goes unnoticed because conventional methods can only measure changes in energy (rather than its total amount).

By the 1990s, new observatories like the *Hubble Space Telescope* (HST) pushed the boundaries of astronomy and cosmology. Thanks to surveys like the Hubble Deep Fields (HDF), astronomers could see objects as they appeared over 13 billion light-years (or less than a billion years after the Big Bang). To their surprise, they discovered that for the past 4 billion years, the rate of expansion has been accelerating. This led to what is known as "the old cosmological constant problem," where gravity is weaker on cosmological scales, or a mysterious force is driving cosmic expansion.

Lead-author Levon Pogosian (Professor of Physics, Simon Fraser University) and co-author Kazuya Koyama (Professor of Cosmology, University of Portsmouth) summarized the issue in a recent article via *The Conversation*. As they explained it, the cosmological constant problem comes down to a single question with drastic implications:

"[W]hether the vacuum energy actually gravitates – exerting a gravitational force and changing the expansion of the universe. If yes, then why is its gravity so much weaker than predicted? If the vacuum does not gravitate at all, what is causing the cosmic acceleration? We don't know what dark energy is, but we need to assume it exists in order to explain the universe's expansion. Similarly, we also need to assume there is a type of invisible matter presence, dubbed dark matter, to explain how galaxies and clusters evolved to be the way we observe them today."



The LCDM cosmological model incorporates Dark Energy (L) with the "cold" theories of Dark Matter. Credit: Alex Mittelmann/Wikimedia

The existence of Dark Energy is part of the standard cosmological theory known as the Lambda Cold Dark Matter (LCDM) model – where Lambda represents the Cosmological Constant/Dark Energy. According to this model, the mass-energy density of the Universe consists of 70% Dark Energy, 25% Dark Matter, and 5% normal (visible or "luminous") matter. While this model has successfully matched observations gathered by cosmologists over the past 20 years, it assumes that most of the Universe is made up of undetectable forces.

Hence why some physicists have ventured that GR may need some modifications to account to explain the Universe as a whole. Moreover, a few years ago, astronomers noted that measuring the rate of cosmic expansion in different ways produced different values. This problem, explained Pogosian and Koyama, is known as the Hubble tension:

"The disagreement, or tension, is between two values of the Hubble Constant. One is the number predicted by the LCDM cosmological model, which has been developed to match the light left over from the Big Bang (the Cosmic Microwave Background radiation). The other is the expansion rate measured by observing exploding stars known as supernovas in distant galaxies."

Many theoretical ideas have been proposed for modifying the LCDM model to explain the Hubble Tension. Among them are alternative gravity theories, such as Modified Newtonian Dynamics (MOND), a modified take on Newton's Law of Universal Gravitation that does away with the existence of Dark Matter. For over a century, astronomers have tested GR by observing how the curvature of spacetime is altered in the presence of gravitational fields. These tests have become particularly extreme in recent decades, which include how Supermassive Black Holes (SMBHs) affect orbiting stars or how gravitational lenses amplify and alter the passage of light.

An illustration of cosmic expansion. Credit: NASA's GSFC Conceptual Image Lab

For the sake of their study, Pogosian and his colleagues used a statistic model known as Bayesian inference, which is used to calculate the probability of a theorem as more data is introduced. From there, the team simulated cosmic expansion based on three parameters: the CMB data from the ESA's Planck satellite, supernova and galaxy catalogs like the Sloan Digital Sky Survey (SDSS) and Dark Energy Survey (DES), and the predictions of the LCDM model.

"Together with a team of cosmologists, we put the basic laws of general relativity to test," said Pogosian and Koyama. "We also explored whether modifying Einstein's theory could help resolve some of the open problems of cosmology, such as the Hubble tension. To determine if GR is correct on the largest of scales, we set out, for the first time, to simultaneously investigate three aspects of it. These were the expansion of the Universe, the effects of gravity on light, and the effects of gravity on matter."

Their results showed a few inconsistencies with Einstein's predictions, though they had a rather low statistical significance. They also found that resolving the Hubble tension problem was difficult simply by modifying the theory of gravity, suggesting that an additional force may be required or that there are errors in the data. If the former is true, said Pogosian and Koyama, then it is possible this force was present during the early Universe (ca. 370,000 years after the Big Bang) when protons and electrons first combined to create hydrogen.

Several possibilities have been advanced in recent years, ranging from a special form of Dark Matter, an early type of Dark Energy, or primordial magnetic fields. In any case, this latest study indicates that there is future research to be done that may lead to a revision of the most widely-accepted cosmological model. Said Pogosian and Koyama:

"[O]ur study has demonstrated that it is possible to test the validity of general relativity over cosmological distances using observational data. While we haven't yet solved the Hubble problem, we will have a lot more data from new probes in a few years. This means that we will be able to use these statistical methods to continue tweaking general relativity, exploring the limits of modifications, to pave the way to resolving some of the open challenges in cosmology."

Perseverance has Found a Nice Patch of Sandstone on Mars

NASA's rolling geology robot shared a great image of sandstone that it found on Mars in Jezero Crater. It's in a region called "Yori Pass", which is part of an ancient river delta. Perseverance will take rock samples there for the upcoming Sample Return Mission. They should tell more about what happened with water in this region. And maybe they'll show evidence of life.

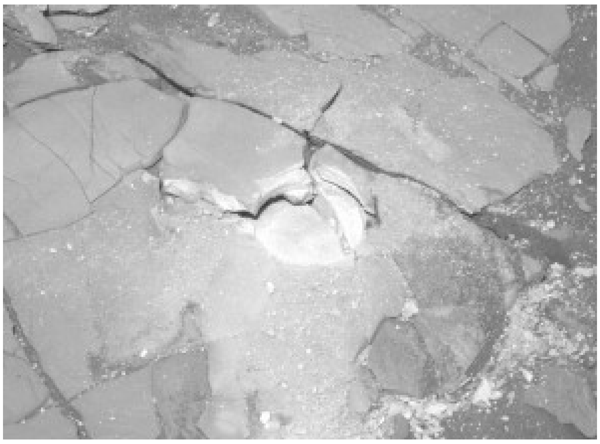
What's So Important about Sandstone?

Most of us have run across sandstone at one time or another here on Earth. It's a rock formed when water carries sand from one place to another and deposits it. This could be in a lake or ocean environment, on an ancient beach, or along the edges of rivers. Some sandstones are also created when the wind blows sand into dunes. Over time, all these sand layers harden into solid rock. That rock tells a chemical and physical story about the conditions at the time it was laid down.

A sandstone formation on Earth found in the Valley of Fire Nevada State Park. This area was once covered by an inland sea that receded and left behind sand deposits. Winds deposited more sand in the area, and the layers hardened into rock. Courtesy United States Geological Survey.

On Mars, both types of sandstone exist. However, in this particular area of Jezero Crater, flowing water deposited sand and small pebbles. Here on Earth, that kind of action also included organic materials such as plants and animals. While we haven't yet found evidence for that on Mars, it does raise interesting questions about the possibilities for life.

"We often prioritize the study of fine-grained sedimentary rocks like this one in our search for organics and potential biosignatures," said Katie Stack Morgan, Perseverance deputy project scientist at NASA's Jet Propulsion Laboratory in Southern California. "What's especially interesting about the Yori Pass outcrop is that it is laterally equivalent to 'Hogwallow Flats,' where we found very fine-grained sedimentary rocks. That means that the rock bed is located at the same elevation as Hogwallow, and has a large, traceable footprint visible on the surface."



Sandstone in Hogwallow Flats, where Perseverance visited earlier in 2022. The rocks are very fine-grained sandstone. Courtesy NASA/JPL-Caltech/ASU

Hogwallow Flats is a region where Perseverance also studied sandstones. As mentioned above, when water deposits sand and other rocks, it carries along other stuff. It all becomes part of the rock record, too. In particular, Martian clay and mudstones interest planetary scientists. That's because clays can "bind" organic molecules to themselves and protect them from environmental degradation. So, the study of Martian sandstones remains a top priority as mission scientists put together a clearer picture of the planet's ancient past.

Water and the Hunt for Life

Perseverance, along with the other Mars probes on the surface, continues its search for evidence of flowing water. That's not surprising, since a major background theme of the mission is to follow the water. Rocks that come into contact with water always give physical and chemical evidence of that encounter. If there was any life in that watery environment, scientists hope that Perseverance will gather biosignatures that they can study. Or, failing to find life signs, the rover may find organic molecules that indicate the possibility of life.

Organic molecules are compounds of mostly carbon and usually include hydrogen and oxygen atoms. They may also have nitrogen, phosphorus, and sulfur. A wide variety of processes can produce organic molecules—they aren't always due to life. But, they are all chemical building blocks of life. So, if they show up in a chemical analysis of rocks, then they could be biosignatures. They can also be signs of some other process that occurred on the planet in the past.

A view from Curiosity of sandstone and other types of rocks in Gale Crater. This image is from a place where the rover stopped called "the Kimberley". Courtesy: NASA/JPL-Caltech

Now, the Curiosity rover in Gale Crater has found these chemical building blocks of life in its searches. So, if the organic molecules were there, then perhaps they also existed at Jezero Crater where Perseverance is rolling along in its ongoing mission. That also includes the in-depth study of rocks, collecting samples, and gathering information that Mars explorers can use when they get to the Red Planet.

What Would Asteroid Mining do to the World's Economy?

About a decade ago, the prospect of "asteroid mining" saw a massive surge in interest. This was due largely to the rise of the commercial space sector and the belief that harvesting resources from space would soon become a reality. What had been the stuff of science fiction and futurist predictions was now being talked about seriously in the business sector, with many claiming that the future of resource exploitation and manufacturing lay in space. Since then, there's been a bit of a cooling off as these hopes failed to materialize in the expected timeframe.

Nevertheless, there is little doubt that a human presence in space will entail harvesting resources from Near Earth Asteroids (NEAs) and beyond. In a recent paper, a team of researchers from the University of Nottingham in Ningbo, China, examined the potential impact of asteroid mining on the global economy. Based on their detailed assessment that includes market forces, environmental impact, asteroid and mineral type, and the scale of mining, they show how asteroid mining can be done in a way that is consistent with the Outer Space Treaty (i.e., for the benefit of all humanity).

The research was conducted by He Sun, Junfeng Zhu, and Yipeng Xu, three researchers from the Department of Computer Science at the University of Nottingham. They are part of a research group known as GemAI (Group for Equity Modeling with AI) that explores the intersection between mathematical modeling, artificial intelligence, and the social sciences (largely focused on equity issues). The paper describing their findings is currently being reviewed for publication in the *Annual Review of Sociology*.

Simply put, the prospect of asteroid mining comes down to resources and the continued growth of human civilization. There are many reasons cited for this, from ensuring the survival of humanity and life on Earth (having a "backup location" or becoming "multiplanetary") to fulfilling a basic and ancestral need to explore and "wander." Then there's the idea of preventing ecological collapse here on Earth through mining and manufacturing or ushering in a "post-scarcity" society by relocating all of our resource extraction and manufacturing to near-Earth space, Cislunar space, and beyond.

Carl Sagan, the late and great physicist, author, and science communicator, summarized these beautifully and related how the two might be intertwined at the intuitive level. As he put it:

"The open road still softly calls, like a nearly forgotten song of childhood. We invest far-off places with a certain romance. The appeal, I suspect, has been meticulously crafted by natural selection as an essential element in our survival. Long summers, mild winters, rich harvests, plentiful game—none of them lasts forever. Your own life, or your band's, or even your species' might be owed to a restless few—drawn, by a craving they can hardly articulate or understand, to undiscovered lands and new worlds."

From a material perspective, the rationale is that human growth is an exponential phenomenon that has been taking place ever since Upper Paleolithic Era (ca. 50,000 to 12,000 years ago). The period that has since followed – the Holocene – has seen the rapid proliferation of human societies and the growth of their impact on environmental systems worldwide. The trend has become so acute that by the mid-20th century, geologists began referring to the current epoch as the Anthropocene, where humanity is the single-greatest driver of environmental changes on the planet.

The belief that humanity's future lies in space commands a large following today, thanks in no small part to the rise of the commercial space (aka. NewSpace) industry. Another factor is the continued pressure to ensure that there are enough resources to see to the needs of a growing population, coupled with the effects of climate change. As we approach the mid-21st century, the greatest challenge will be providing for an estimated 10 billion people worldwide amid the impacts of climate change. The argument goes that if our future is to be assured, then off-world resources must be harnessed.

Mining asteroids might be necessary for humanity to expand into the Solar System. But what effect would asteroid mining have on the world's economy? Credit: ESA.

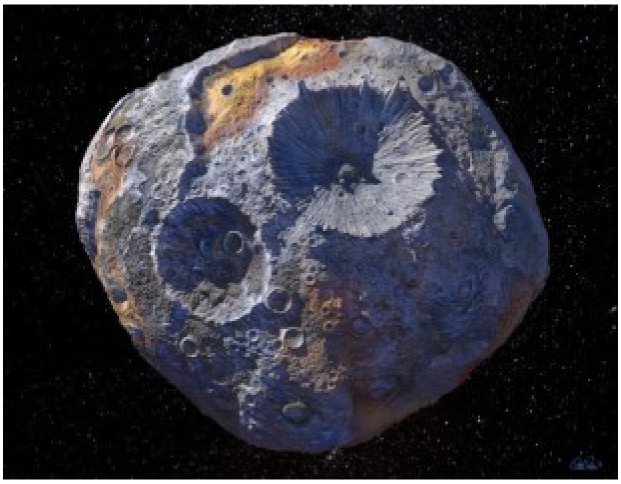
The demand for minerals, He Sun explained to Universe Today via email, is a major factor in ensuring resource abundance:

"Due to the fact that the total amount of minerals on the planet is finite, continuous advances in resource recovery technology cannot fundamentally solve the problem of mineral depletion. In this context, the significance of asteroid mining is becoming more apparent. Large asteroid mining companies (including Space X, Blue Origin, and others that already have a presence in this area) could create hostile competition. To prevent the disorderly expansion of capital and related industrial monopoly, it is necessary for the United Nations to establish relevant regulations."

To prevent asteroid mining and the future space economy from becoming a "Wild West"-type situation, there are many calls for laws to be drafted that could prevent cutthroat competition and ensure that mineral wealth is used for the good of all humanity. This is in keeping with the Outer Space Treaty signed in 1967 between the U.S., the Soviet Union, and the U.K., which were the most influential players in space at the time. The Treaty has since been signed and ratified by 112 countries (as of February 2022) and remains the most important piece of space legislation ever passed.

According to NASA, the Outer Space Treaty is the inspiration behind the Artemis Accords, a set of principles and best practices governing international partnerships to advance the Artemis Program. As stated in Section I – Purpose and Scope, the Accords are "intended to increase the safety of operations, reduce uncertainty, and promote the sustainable and beneficial use of space **for all humankind**." The Treaty, says He Sun, also served as a background to the team's analysis:

"On the one hand, it reflects the concern of the United Nations about asteroid mining (the important value of asteroid rare earth metals, the growing space power of companies and national space agencies)," he said. "On the other hand, our paper provides [the UN] with improved programmatic policies to prevent the negative effects on global equity of possible scenarios such as monopolies, resource curses, etc."



NASA's mission to asteroid 16 Psyche has been delayed. Now a review panel is examining the delay. Credit: Maxar/ ASU/P. Rubin/NASA/JPL-Caltech

He Sun and his colleagues began their analysis with an appraisal of the global situation and space exploration capabilities of various countries. They then focused on creating a model that would measure the impact of space mining on global equity and formulating policies that would ensure (as much as possible) that all people would share the benefits. The first step was to calculate a Unified Equity Index (UEI) for each country, which consisted of an analysis of six factors: economic, education, science and technology, health, environment, and social stability.

In short, they considered how a country's UEI would be affected by things like wealth inequality (the Gini coefficient), Gross Domestic Product (GDP), unemployment, the average level of education, the average number of patents and research expenditures, life expectancy and health outcomes, environmental issues, and crime rates. From this, they obtained an Equity Index for the entire world based on the entropy of each country's UEI. This brought them to step two, where the impact of asteroid mining was simulated based on the types of asteroids being mined.

This was based on three broad categories scientists use to classify asteroids: C-type, S-type, and M-type. Whereas C-type (chondrite) asteroids – the most common – contain large amounts of carbon and are composed mainly of clay and silicate rocks, S-type ("stony") asteroids are composed of silicate minerals and metal (nickel-iron), and M-types are mostly metallic. They also considered which entities were involved (private, national, international) and changing mineral values over time. Said He Sun:

"In addition, we define the impact of mining and equity through a gray correlation matrix derived from mineral development data for a typical country (the United States) over the last 50 years with data from these indicators. This gray correlation matrix is used as a bridge to future global equity impacts of asteroid mining. We use these gray correlation coefficients, the scale of future plans for asteroid mining for each entity, and the change in equity for 20 countries over time to predict the impact of asteroid mining on global equity in the coming decades."

Asteroid mining concept. Credit: NASA/Denise Watt

In particular, their model looked at how the value of minerals would change between 2025 and 2085, coinciding with the expected growth of asteroid mining in this century. Ultimately, their model showed that without regulation, the gap between space-competitive entities (countries with space programs, companies with advanced space capability) and other entities would increase profoundly, and equity within nations would become graver. To this end, they made some specific recommendations.

"We suggest the UN add the Mining Information Policy, Mineral Legacy Policy, Mutual Assistance Policy, Antitrust Policy, and Transaction Guidance Policy to the updated version of the Outer Space Treaty," said He Sun. "There are unimaginably tremendous resources in space, and if we do not exploit and distribute them wisely, the consequence will be severe."

Of course, He Sun and his colleagues make these recommendations with the caveat that asteroid mining is still a hypothetical venture, mainly because the associated costs are still prohibitive. A lot of work needs to be done before it can become an industry that promises to relocate resource extraction to space and usher in a "post-scarcity" economy. This includes a further reduction in launch costs, the creation of infrastructure in Low Earth Orbit (LEO) and wherever else we intend to mine, and the ability to process minerals in space cheaply.

Nevertheless, there is little doubt that the prospect of asteroid mining is approaching, and multiple legal, ethical, and economic questions need to be addressed beforehand. Like many aspects of humanity's future in space, these efforts are intended to prevent a "free-for-all" that could turn space into the next scramble for resources, territory, and imperial ventures. If space is to be for all humankind, we need to take the necessary steps to make sure it's not claimed and exploited for the benefit of the few.

Addendum: *Yipeng Xu was the Chinese researcher to name an exoplanet discovered by Chinese astronomers and its host star: "Wangshu" and "Xihe," which mean "moon goddess" and "sun goddess" in Chinese mythology (respectively). Yipeng recently researched weak gravitational lensing and galaxy morphology using deep learning models at the Chinese Academy of Sciences (CAS).*

The Case of the "Missing Exoplanets"

Today, the number of confirmed exoplanets stands at 5,197 in 3,888 planetary systems, with another 8,992 candidates awaiting confirmation. The majority have been particularly massive planets, ranging from Jupiter and Neptune-sized gas giants, which have radii about 2.5 times that of Earth. Another statistically significant population has been rocky planets that measure about 1.4 Earth radii (aka. "Super-Earths"). This presents a mystery to astronomers, especially where the exoplanets discovered by the venerable *Kepler Space Telescope* are concerned.

Of the more than 2,600 planets *Kepler* discovered, there's an apparent rarity of exoplanets with a radius of about 1.8 times that of Earth – which they refer to as the "radius valley." A second mystery, known as "peas in a pod," refers to neighboring planets of similar size found in hundreds of planetary systems with harmonious orbits. In a study led by the Cycles of Life-Essential Volatile Elements in Rocky Planets (CLEVER) project at Rice University, an international team of astrophysicists provide a new model that accounts for the interplay of forces acting on newborn planets that could explain these two mysteries.

The research was led by André Izidoro, a Welch Postdoctoral Fellow at Rice's NASA-funded CLEVER Planets project. He was joined by fellow-CLEVER Planets investigators Rajdeep Dasgupta and Andrea Isella, Hilke Schlichting of the University of California, Los Angeles (UCLA), and Christian Zimmermann and Bertram Bitsch of the Max Planck Institute for Astronomy (MPIA). As they describe in their research paper, which recently appeared in the *Astrophysical Journal Letters*, the team used a supercomputer to run a planetary migration model that simulated the first 50 million years of planetary system development.

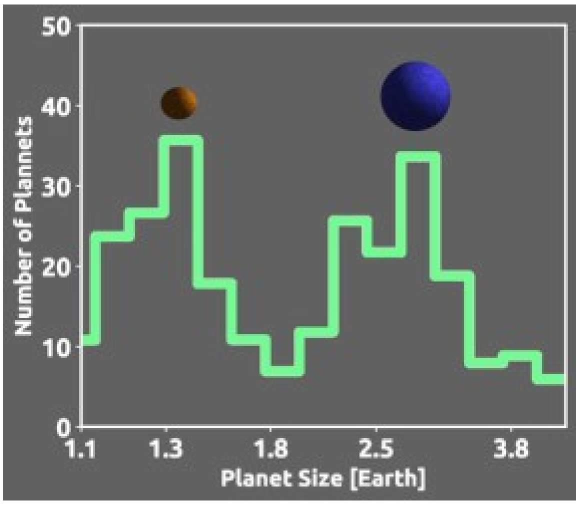
In their model, protoplanetary disks of gas and dust also interact with migrating planets, pulling them closer to their parent stars and locking them in resonant orbital chains. Within a few million years, the protoplanetary disk disappears, breaking the chains and causing orbital instabilities that cause two or more planets to collide. While planetary migration models have been used to study planetary systems that retained orbital resonances, these findings represent a first for astronomers. As Izidoro said in a Rice University statement:

"I believe we are the first to explain the radius valley using a model of planet formation and dynamical evolution that self-consistently accounts for multiple constraints of observations. We're also able to show that a planet-formation model incorporating giant impacts is consistent with the peas-in-a-pod feature of exoplanets."

This work builds on previous work by Izidoro and the CLEVER Planets project. Last year, they used a migration model to calculate the maximum disruption to TRAPPIST -1's seven-planet system. In a paper that appeared on Nov. 21st, 2021, in *Nature Astronomy*, they used N-body simulation to show how this "peas in a pod" system could have retained its harmonious orbital structure despite collisions caused by planetary migration. This allowed them to place constraints on the upper limit of collisions and the mass of the objects involved.

Their results indicate that collisions in the TRAPPIST-1 system were comparable to the impact that created the Earth-Moon system. Said Izidoro:

"The migration of young planets towards their host stars creates overcrowding and frequently results in cataclysmic collisions that strip planets of their hydrogen-rich atmospheres. That means giant impacts, like the one that formed our moon, are probably a generic outcome of planet formation."



An illustration depicting the scarcity of exoplanets about 1.8 times the size of Earth observed by NASA's Kepler spacecraft. Credit: A. Izidoro et al./Rice University

This latest research suggests that planets come in two variants, consisting of dry and rocky planets that are 50% larger than Earth (super-Earths) and planets that are rich in water ice about 2.5 times the size of Earth (mini-Neptunes). In addition, they suggest that a fraction of planets twice the size of Earth will retain their primordial hydrogen-rich atmosphere *and* be rich in water. According to Izidoro, these results are consistent with new observations that suggest that super-Earths and mini-Neptunes are not exclusively dry and rocky planets.

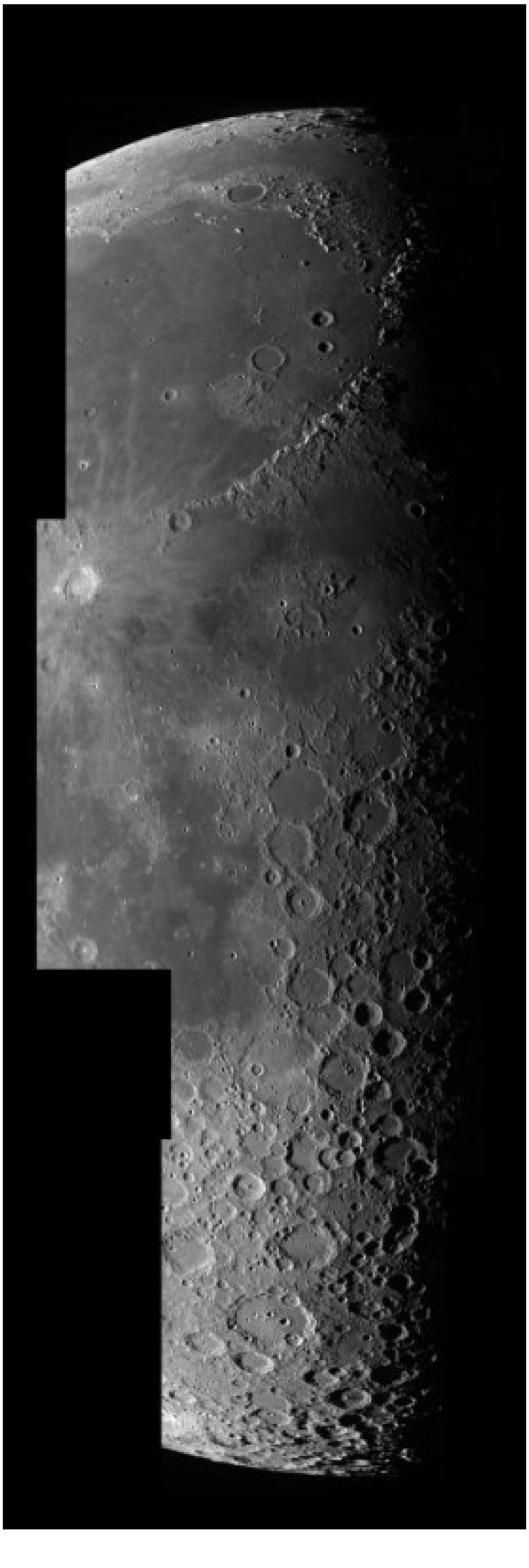
These findings present opportunities for exoplanet researchers, who will rely on the *James Webb Space Telescope* to conduct detailed observations of exoplanet systems. Using its advanced suite of optics, infrared imaging, coronographs, and spectrometers, *Webb* and other next-generation telescopes will characterize the atmospheres and surfaces of exoplanets like never before.

Want a Sneak Peek From NASA's Lucy Mission? Here are Some Photos it Took of the Moon During its Flyby

We reported a few weeks ago about an Earth gravity assist flyby for the Lucy mission. Around the same as the spacecraft took a dip closer to Earth than the ISS, it took some fantastic pictures of our nearest neighbor – the Moon. After some processing, those pictures are available for inspection or gawking, as the case may be.

Lucy took three separate pictures, ranging from 6.5 hours to about 8 hours after it flew past the Earth. Each was taken with the Lucy LOng Range Reconnaissance Imager, also called L'LORRI. And they are absolutely breathtaking.

The first covers an area of the Moon known as the Lunar Central Highlands, which is most likely well-known to most lunar observers. Located near the "center of the last quarter of the moon," according to a NASA press release, there are some prominent craters in the 1200 sq km image, including Arzachel, with its characteristic sub-impacts, near the center of the picture.



"Terminator Mosaic" image captured by Lucy.
Credit – NASA/Goddard/SwRI/JHU-APL/Tod R. Lauer (NOIRLab)

L'LORRI next turned its camera to take a composite shot of the whole Moon from top to bottom. Called a "terminator mosaic" in the press release, it shows a combination of the other two main images Lucy took on its journey past. Some craters clearly stand out, such as Copernicus, which shows as much brighter than other craters on the left side of the image.

Finally, Lucy took an image of Mare Imbrium, which includes the Apollo 15 landing site, in the bottom right corner. Other features include the Apennine mountains, named after the famous range in Italy, and Mare Imbrium itself, which is an ancient impact basin. The image covers a total of 1000 sq km.

To create these images, Lucy mission scientists used several compositing techniques, including stitching together multiple images – the terminator image and the Central Highlands image were crafted from five and ten individual images, respectively. The Mare Imbrium image, on the other hand, was captured with only one.

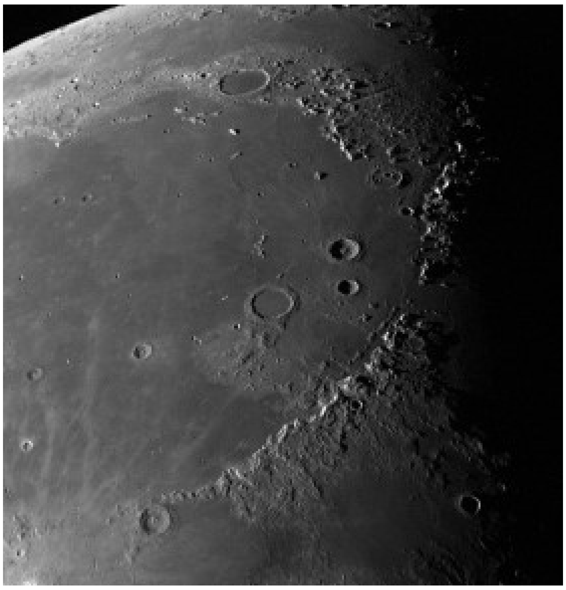


Image of Mare Imbrium on the Moon, as taken by Lucy.
Credit – NASA/Goddard/SwRI/JHU-APL/Tod R. Lauer (NOIRLab)

Scaling is essential to understand in the images as well – each pixel of the image constitutes between 1.1 km and 1.3 km of area. Also, each image was taken while Lucy was between 230,000 to 260,000 km away from the Moon.

These images are a testament both to how close Lucy got to the Moon, the sensitivity of its instruments, and the technical aptitude of its science team. Taking pictures of the Moon isn't Lucy's first priority, but it will still be a few years before it reaches its final destination – the Trojan asteroids on the outer edges of the Jupiter system. In the meantime, we might be able to see even more amazing pictures, either of Earth or the Moon, as Lucy still has two more close encounter gravity assists in its near future.

E Mails Viewings Logs and Images from Members.

John Arthurs

I first came across John at my first meeting of Wiltshire Astronomical Society back in the autumn of 1999 when we had our meetings in the WI hall across the road from our present place, as we both lived in Swindon it made sense to share the driving duties going to the monthly meeting of Wiltshire AS, from this we built up a very good friendship.

John has helped me out many times over the years when I have been asked to do astronomy outreach sessions for people I know, mainly from schools in this area, as I knew there would be quite a few people at these sessions I would need someone to help me out and this is where John has volunteered his time, a true friend! When we car shared to the monthly meetings John loved to ask the guest speaker I had staying with me lots of questions on the way to the talk they were due to give. One of his best stories was about The Crammer Lake in Devizes and how Wiltshire became known as the Moonrakers County, very interesting story and made me laugh.

John had many hobbies, he was a very good painter and we have one of his painting in our lounge, he also made me a wooden plinth for the golf ball when I got a hole in one back in 2010 to sit on. Also John and Val were volunteer's for many years at the Crofton Beam Engine pumping stations near Marlborough.

One of his favourite hobbies with his wife Val was to spend the summer going around the canals of England in their narrow boat called September Pearl, quite often he would miss the June meeting and sometimes the September ones as he was still out enjoying the countryside in his boat.

John's last meeting at Wiltshire was back in February 2020 the month before we went into lockdown, he did not have a computer therefore could not see the Zoom meetings we were having instead. His last meeting he attended in person was with Swindon Stargazers back in September.

Peter Chappell

Thank you for this fitting tribute to our long time member John. All the best for his family. Andy

Viewing Log for 20th of November

After coming back from Barcelona earlier in the day after a week's holiday, the sky was clear and I had the evening free, so it was time to go out and do some viewing at Uffcott. A new member of WAS, Ben Luger said he was interested in going out if anyone had plans, I said I would be going out and would meet him at my usual place if he was interested?

I arrived at my usual layby on the back road to Uffcott and had my Meade LX90 using my trusted Pentax 14 mm eye piece set up and ready by 19:35. With a temperature of 5 ° C and no wind, it should be a good evening viewing? The road was wet, a recent shower had gone thru, and so the skies should be clear of dust? While I was setting up a car pulled up and which turned out to be Ben, we introduced ourselves and carried on setting up our equipment. Ben had brought along an impressive 16 inch Dobsonian with him, views thru that should be great! Ben explained he did not know the night sky very well, one would thought having such a large scope he would know the night sky but talking to Ben he explained that he got it from his late father and been stuck in the garage for several years while his children were small, now that they are older he has some time to go out viewing. I said I could show him some deep sky objects to look at with his monster of a scope, planets were easy to see! I will start with what we saw with my telescope before going over to Ben's.

First object was Saturn (starting to sink in to the western horizon), could make out Titan as usual but no other moons this time, while viewing Saturn we had the only car that past us all evening go by. On to Jupiter, could make out the two main weather belts and three moons, Europa was to the west of Jupiter with Io and Calisto out to the east. Turns out Ganymede was doing a transit and the Great Red Spot was on view but we missed both of these! Thin cloud had now started to roll in, so our viewing time would be limited from now on? Finding Uranus was difficult, the planet was about halfway to the edge of the finderscope had to try various points of light (stars) before I found the planet, Ben had not seen this planet before so that was a plus for him. As for Neptune could not locate it at all! Next was Mars, first time I have looked at this planet this current season. There was some markings on the planet but not sure what they were? By now, there was not much to see as the cloud had covered most of the sky. Quick look at Auriga and Messier (M) 36, 37 & 38, all objects were dim to look at. Orion was starting to climb the eastern horizon but could not see M 42 as it was just below the hedge line. That was it with my telescope.

Apart from the planets with Ben's telescope we had a look at M 31 and 32 in the same field of view, M 31 had a very bright core. On to Caldwell 14, the Double Cluster in Perseus, these two open clusters looked brilliant but with my telescope I would have to do one at a time as the field of view is much smaller. In to Pegasus and M 15 just past the star Enif, this globular cluster had a bright but small core to look at. Only Supernova Remnant on Messier's list is M 1 in

Taurus close to the star Zeta. Even with a large aperture this object was a fuzzy blob to look at, the sky problem! Final object was M 45, the Pleiades open cluster also in Taurus, had some bright stars within the cluster. We tried for M 42 but the clouds beat us so we called it a day at 21:00. Temperature was still 5 °C with some dew on the equipment.

Nice to meet a new member of the club and hopefully Ben will be able to come out later in the season as there are lots of treasures still to see with his scope.

Clear skies.

Peter Chappell

Viewing Log for 22nd of November

Earlier in the day, Hilary Wilkey from Swindon Stargazers said she was interested in going out viewing via the WhatsApp group. I had thought about it and not made a decision until just before 19:00 that I would be going out, so I arrived at my usual viewing place and had this time my Porta Mount II grab and go kit with me as there was a good hint that cloud would roll in later in the evening! I was set up and ready by 19:28 with my 98 mm William Optics refractor (rarely comes out) telescope on the Porta Mount II and the 13 mm Ethos eye piece. With no wind and a temperature of 5 °C it should be a reasonable viewing session, while setting up I noticed a band of cloud out to the west, so time will not be long for this session?

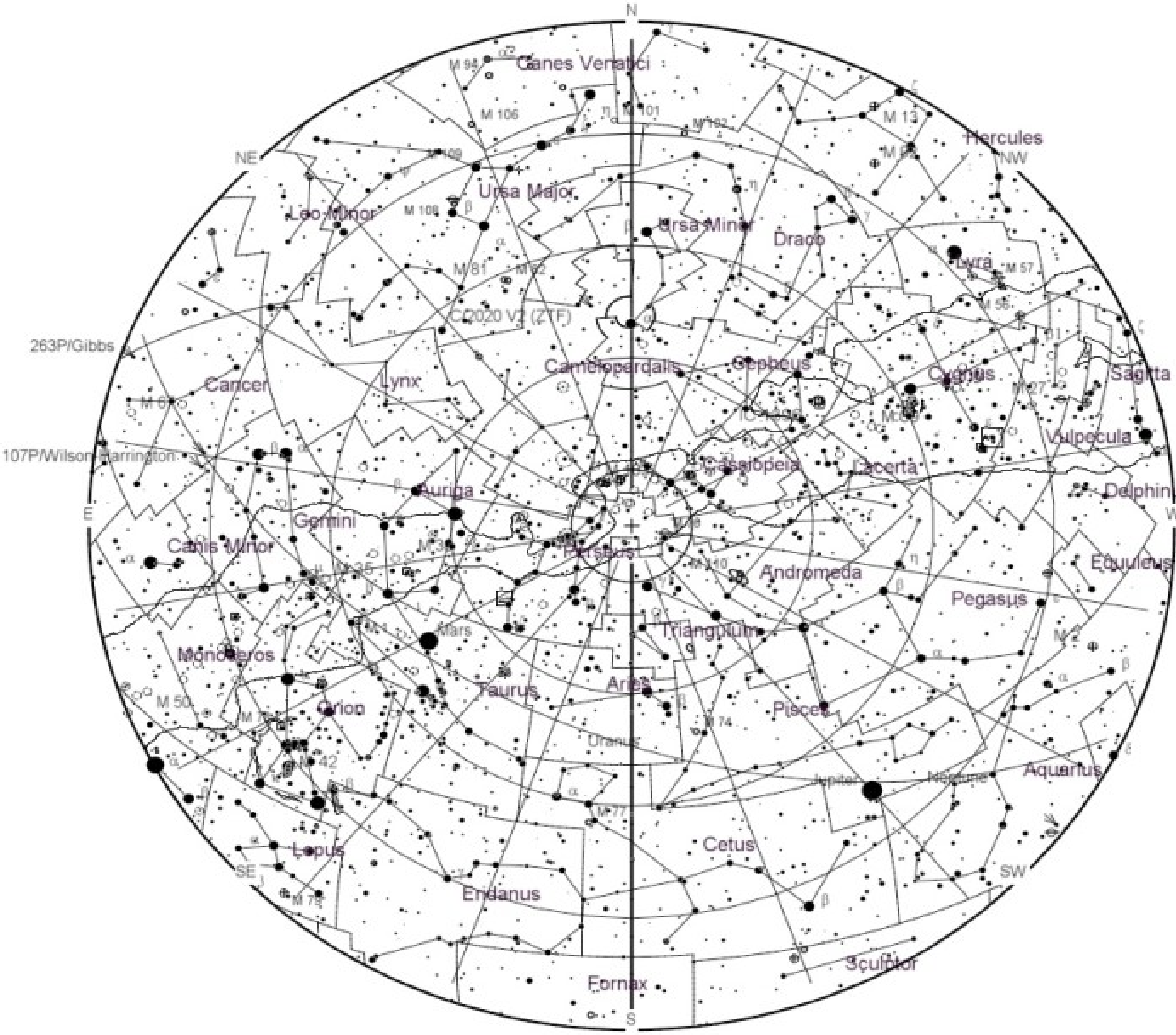
First object was Saturn, could not even make out Titan, cloud had closed that act! On to Jupiter could only make out three moons to start with plus the weather belts. On further inspection the fourth (Io) was very close to the inner most moon which turned out to be Europa, then we had Ganymede with Calisto the outer most. Again, the Great Red Spot was on view but I missed it, eyes are not that great these days unfortunately! Mars was next could make out some detail on the planet but not sure what. Messier (M) 45, the Pleiades looked great, nice to see the whole cluster with an eye piece as my Meade goes straight thru the cluster. By now it was getting hopeless and Hilary joined me, she was surprised at the state of the sky, like me she thought it would come in later? Is it worth me setting up my scope out? I said yes as the skies might clear soon, I was very wrong! ilary Wilke Hilary brought along a 102 mm Skywatcher refractor telescope with 25 mm eye piece on a very good Skywatcher AZ5 Deluxe Alt-AZ mount. This time she brought along her finder scope, every other time she has been out with me the finder scope did not come out with her even when I said it would be much easier to find objects? First job was to align the finder with the main scope, only star on view was Betelgeuse very low down on the eastern horizon (the cloud had not got that far across the sky, yet) I had to show Hilary how to do this as it had been ages since she last did it. So for the next odd 20 minutes we talked about various subjects hoping the skies might clear, then Hilary noticed a bright light in the sky which turned out to be Jupiter, before you knew it, it had gone again behind the clouds. A few times we managed to see Jupiter again thru the clouds, by now Io getting closer to Europa. Cassiopeia had now come into view, so using my Sky & Telescope Pocket Sky Atlas I managed to locate M 36, this was small and dim to look at.

We waited another 10 minutes before decided to pack up as there did not look like to be any breaks in the sky. Time was now 20:38, glad I brought along my grab and go kit, much easier to put away than my usual Meade kit. At least Hilary sorted out her finder scope problems so not a wasted journey. Hopefully next time we will have a better session? When I got home and started to unpack my kit I noticed Jupiter and Mars in the sky, the cloud bank had now gone thru, just typical.

Clear skies.

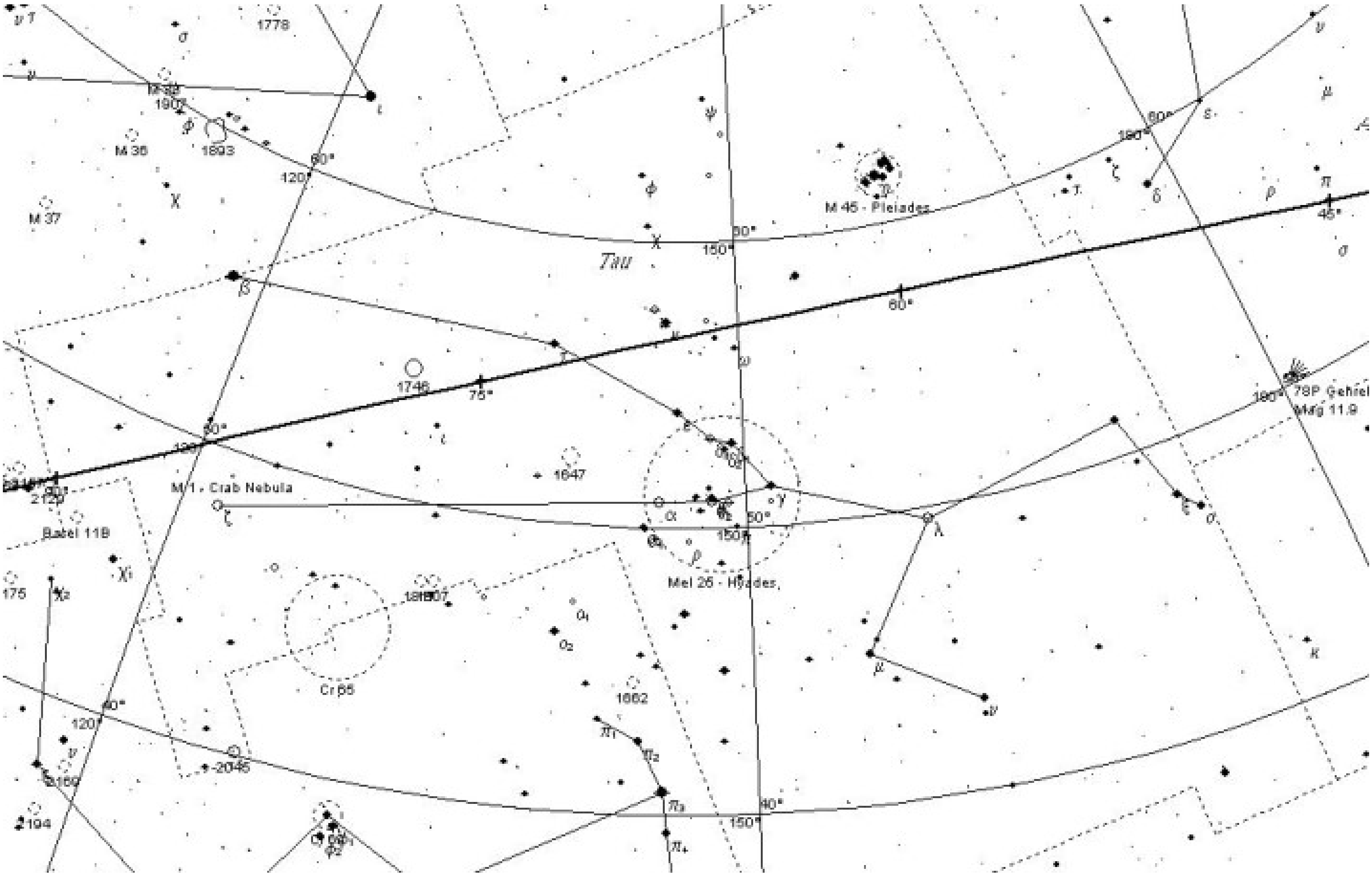
Peter Chappell

PS I am writing this viewing log on the 24th of November, I had planned to go out and do a viewing session this evening but decided against it as the clouds and rain would arrive within an hour of set up? When I looked outside at 19:00, I could see Jupiter and Saturn very clearly but after the last two short sessions I decided I would do a letter and the viewing logs instead. While I have been doing all this writing Jupiter has been clearly seen in the window all the time, it is now 21:46 AND I can still see Jupiter in the sky, wasted viewing evening unfortunately and the Moon is out of the way currently!



December 8 - **Full Moon.** The Moon will be located on the opposite side of the Earth as the Sun and its face will be will be fully illuminated. This phase occurs at 04:09 UTC. This full moon was known by early Native American tribes as the Cold Moon because this is the time of year when the cold winter air settles in and the nights become long and dark. This moon has also been known as the Long Nights Moon and the Moon Before Yule.
December 8 - **Mars at Opposition.** The red planet will be at its closest approach to Earth and its face will be fully illuminated by the Sun. It will be brighter than any other time of the year and will be visible all night long. This is the best time to view and photograph Mars. A medium-sized telescope will allow you to see some of the dark details on the planet's orange surface.
December 13, 14 - **Geminids Meteor Shower.** The Geminids is the king of the meteor showers. It is considered by many to be the best shower in the heavens, producing up to 120 multicolored meteors per hour at its peak. It is produced by debris left behind by an asteroid known as 3200 Phaethon, which was discovered in 1982. The shower runs annually from December 7-17. It peaks this year on the night of the 13th and morning of the 14th. The waning gibbous moon will block many of the fainter meteors this year. But the Geminids are so numerous and bright that this should still be a good show. Best viewing will be from a dark location after midnight. Meteors will radiate from the constellation Gemini, but can appear anywhere in the sky.
December 21 - **December Solstice.** The December solstice occurs at 21:40 UTC. The South Pole of the earth will be tilted toward the Sun, which will have reached its southernmost position in the sky and will be directly over the Tropic of Capricorn at 23.44 degrees south latitude. This is the first day of winter (winter solstice) in the Northern Hemisphere and the first day of summer (summer solstice) in the Southern Hemisphere.
December 21 - **Mercury at Greatest Eastern Elongation.** The planet Mercury reaches greatest eastern elongation of 20.1 degrees from the Sun. This is the best time to view Mercury since it will be at its highest point above the horizon in the evening sky. Look for the planet low in the western sky just after sunset.
December 21, 22 - **Ursids Meteor Shower.** The Ursids is a minor meteor shower producing about 5-10 meteors per hour. It is produced by dust grains left behind by comet Tuttle, which was first discovered in 1790. The shower runs annually from December 17-25. It peaks this year on the the night of the 21st and morning of the 22nd. This year, the nearly new moon will leave dark skies for what should be a really good show. Best viewing will be just after midnight from a dark location far away from city lights. Meteors will radiate from the constellation Ursa Minor, but can appear anywhere in the sky.
December 23 - **New Moon.** The Moon will located on the same side of the Earth as the Sun and will not be visible in the night sky. This phase occurs at 10:17 UTC. This is the best time of the month to observe faint objects such as galaxies and star clusters because there is no moonlight to interfere.

CONSTELLATIONS OF THE MONTH: TAURUS



The ancient zodiacal constellation of Taurus was one of Ptolemy's original 48 constellations and remains today as part of the official 88 modern constellations recognized by the IAU. It is perhaps one of the oldest constellations of all and may have even been recognized prehistorically. Taurus spreads over 797 square degrees of sky and contains 7 main stars in its asterism with 130 Bayer Flamsteed designated stars located within its confines. It is bordered by the constellations of Auriga, Perseus, Aries, Cetus, Eridanus, Orion and Gemini. Taurus is visible to all observers located at latitudes between +90Â° and ? 65Â° and is best seen at culmination during the month of January.

There is one major annual meteor shower associated with the constellation of Taurus, the annual Taurids, which peak on or about November 5 of each year and have a duration period of about 45 days. The maximum fall rate for this meteor shower is about 10 meteors per hour average, with many bright fireballs often occuring when the parent comet – Encke – has passed near perihelion. Look for the radiant, or point of origin, to be near the Pleiades.

Taurus is considered by some to be one of the oldest recognized constellations known, and may have even been depicted with the Pleiades in cave paints dating back to 13,000 BC. According to Greek myth, Taurus was the god Zeus, transformed into a bull in order to woo princess Europa, and perhaps could represent one of the Cretean Bull of Herculean fame. The ancient Egyptians also worshiped a bull-god for which this constellation might represent, just as the Arabs also considered it to be bovine by nature. The Hyades cluster was meant to represent the sisters of Hyas, a great hunter, placed in the sky to honor their mourning for the loss of their brother – just as the Pleiades represent the seven sisters of Greek mythology – as well as many other things in many other cultural beliefs. The Persians called this group of stars "Taura", just as the Arabs referred to it as "Al Thaur". No matter what way you want to look at it, this handsome collection of stars contains many fine deep sky objects to pique your interest!

Let's begin our binocular and telescope tour of Taurus with its brightest star- Alpha – the "a" symbol on our map. Known to the Arabs as Al Dabaran, or "the Follower," Alpha Tauri got its name because it appears to follow the Pleiades across the sky. In Latin it was called Stella Dominatrix, yet the Olde English knew it as Oculus Tauri, or very literally the "eye of Taurus." No matter which source of ancient astronomical lore we explore, there are references to Aldebaran.

As the 13th brightest star in the sky, it almost appears from Earth to be a member of the V-shaped Hyades star cluster, but this association is merely coincidental, since it is about twice as close to us as the cluster is. In reality, Aldebaran is on the small end as far as K5 stars go, and like many other orange giants, it could possibly be a variable. Aldebaran is also known to have five close companions, but they are faint and very difficult to observe with backyard equipment. At a distance of approximately 68 light-years, Alpha is "only" about 40 times larger than our own Sun and approximately 125 times brighter. To try to grasp such a size, think of it as being about the same size as Earth's orbit! Because of its position along the ecliptic, Aldebaran is one of the very few stars of first magnitude that can be occulted by the Moon.

Now, head off to Beta Tauri – the "B" symbol on our chart. Located 131 light years from our solar system, El Nath, or Gamma Aurigae, is a main sequence star about to evolve into a peculiar giant star – one high in manganese content, but low in calcium and magnesium. While you won't find anything else spectacular about El Nath, there is a good reason to remember its position – it, too, get frequently occulted by the Moon. Such occultations occur when the moon's ascending node is near the vernal equinox. Most occultations are visible only in parts of the Southern Hemisphere, because the star lies at the northern edge of the lunar occultation zone and occasionally it may be occulted as far north as southern California.

Now, turn your binoculars or small telescopes towards Omicron – the "o". Omicron is sometimes called Atirsagne, meaning the "Verdant One", but there's nothing green about this 212 light year distant yellow G-type giant star, only that it has a great optical companion! Be sure to take a look at Kappa Tau, too… the "k". Kappa is also a visual double star – but a whole lot more. Located 153 light years from Earth, this Hyades cluster member is dominated by white A-type subgiant star K1 and white A-type main sequence dwarf star, K2. They are 5.8 arcminutes, or at least a quarter light year apart. Between the two bright stars is a binary star made up of two 9th magnitude stars, Kappa Tauri C and Kappa Tauri D, which are 5.3 arcseconds from each other and 183 arcseconds from K1 Tau. Two more 12th magnitude companions fill out the star system, Kappa Tauri E, which is 136 arcseconds from K1 Tau, and Kappa Tauri F, 340 arcseconds away from K2 Tau. Still more? Then have a look at 37 Tauri, an orange giant star with a faint optical companion star… or 10 Tauri! 10 Tauri is only 45 light years away, and while it just slightly larger and brighter than our Sun, its almost the same age. It is believed to be a spectroscopic binary star, but you'll easily see it's optical companion. What's more, thanks to noticing a huge amount of infrared radiation being produced by 10, we know it also has a dusty debris disk surrounding it!

Now, let's have a go at variable stars – starting with Lambda, the upside down "Y" on our map. Al Thaur is in reality a binary star system as well as being an eclipsing variable star. The primary is a blue-white B-type main sequence dwarf star located about 370 light years away. However, located at a distance of 0.1 AU away from it is a white A-type subgiant star, too… and a third player even further away. Watch over a period of 3.95 days as first one, then the other passes in front of the primary star, dimming it by almost a full stellar magnitude! Don't forget to check out HU Tauri, too. It is also an eclipsing binary star that drops by a magnitude every 2.6 days!

Ready to take a look at Messier 45? Visible to the unaided eye, small binoculars and every telescope, the Pleiades bright components will resolve easily to any instrument and is simply stunning. The recognition of the Pleiades dates back to antiquity and they're known by many names in many cultures. The Greeks and Romans referred to them as the "Starry Seven," the "Net of Stars," "The Seven Virgins," "The Daughters of Pleione" and

even "The Children of Atlas." The Egyptians referred to them as "The Stars of Athyr," the Germans as "Siebengestiren" (the Seven Stars), the Russians as "Baba" after Baba Yaga, the witch who flew through the skies on her fiery broom. The Japanese call them "Subaru," Norsemen saw them as packs of dogs and the Tongans as "Matarii" (the Little Eyes). American Indians viewed the Pleiades as seven maidens placed high upon a tower to protect them from the claws of giant bears, and even Tolkien immortalized the star-group in The Hobbit as "Remmirath." The Pleiades have even been mentioned in the Bible! So, you see, no matter where we look in our "starry" history, this cluster of seven bright stars has been part of it.

The date of the Pleiades culmination (its highest point in the sky) has been celebrated through its rich history by being marked with various festivals and ancient rites â€" but there is one particular rite that really fits this occasion! What could be spookier on this date than to imagine a bunch of Druids celebrating the Pleiades' midnight "high" with Black Sabbath? This night of "unholy revelry" is still observed in the modern world as "All Hallows Eve" or more commonly as "Halloween." Although the actual date of the Pleiades' midnight culmination is now on November 21 instead of October 31. Thanks to its nebulous regions M45 looks wonderfully like a "ghost" haunting the starry skies. Binoculars give an incredible view of the entire region, revealing far more stars than are visible with the naked eye. Small telescopes at lowest power will enjoy M45's rich, icy-blue stars and fog-like nebulae. Larger telescopes and higher power reveal many pairs of double stars buried within its silver folds. No matter what you chose, the Pleiades definitely rocks!

Our next most famous Messier catalog object in Taurus is M1 – the “Crab Nebula”. Although M1 was discovered by John Bevis in 1731, it became the first object on Charles Messier’s astronomical list. He rediscovered M1 while searching for the expected return of Halley’s Comet in late August 1758 and these “comet confusions” prompted Messier to start cataloging. It wasn’t until Lord Rosse gathered enough light from M1 in the mid-1840’s that the faint filamentary structure was noted (although he may not have given the Crab Nebula its name). To have a look for yourself, locate Zeta Tauri and look about a fingerwidth northwest. You won’t see the “Crab legs” in small scopes – but there’s much more to learn about this famous “supernova remnant”.

Factually, we know the “Crab Nebula” to be the remains of an exploded star recorded by the Chinese in 1054. We know it to be a rapid expanding cloud of gas moving outward at a rate of 1,000 km per second, just as we understand there is a pulsar in the center. We also know it as first recorded by John Bevis in 1758, and then later cataloged as the beginning Messier object – penned by Charles himself some 27 years later to avoid confusion while searching for comets. We see it revealed beautifully in timed exposure photographs, its glory captured forever through the eye of the camera â€” but have you ever really taken the time to truly study the M1? Then you just may surprise yourselfâ€¦ In a small telescope, the “Crab Nebula” might seem to be a disappointment – but do not just glance at it and move on. There is a very strange quality to the light which reaches your eye, even though at first it may just appear as a vague, misty patch. To small aperture and well-adjusted eyes, the M1 will appear to have “living” qualities – a sense of movement in something that should be motionless. This aroused my curiosity to study and by using a 12.5″ scope, the reasons become very clear to me as the full dimensions of the M1 “came to light”.

The Next Sky Blemish for Profit: Bluewalker 3 communication sail will be making itself seen.

05 Dec	**2.1**	**16:40:57**	**10°**	**W**	**16:44:52**	**67°**	**N**	**16:48:46**	**10°**	**E**
05 Dec	1.8	18:19:46	10°	WNW	18:23:43	88°	S	18:24:00	76°	ESE
05 Dec	5.3	19:58:42	10°	W	19:58:50	11°	W	19:58:50	11°	W
06 Dec	1.9	18:01:23	10°	WNW	18:05:18	86°	SSW	18:06:30	43°	ESE
06 Dec	4.9	19:40:19	10°	W	19:41:20	16°	W	19:41:20	16°	W
07 Dec	1.9	17:42:58	10°	WNW	17:46:55	84°	SSW	17:49:07	25°	ESE
07 Dec	4.3	19:21:57	10°	W	19:23:57	21°	WSW	19:23:57	21°	WSW
08 Dec	2.0	17:24:34	10°	WNW	17:28:30	81°	SSW	17:31:50	14°	ESE
08 Dec	3.9	19:03:35	10°	W	19:06:42	25°	SW	19:06:42	25°	SW
09 Dec	2.1	17:06:09	10°	WNW	17:10:05	79°	SSW	17:13:59	10°	ESE
09 Dec	4.0	18:45:12	10°	W	18:48:21	23°	SW	18:49:37	20°	SSW
10 Dec	2.1	16:47:44	10°	WNW	16:51:40	77°	SSW	16:55:33	10°	ESE
10 Dec	4.2	18:26:49	10°	W	18:29:54	22°	SW	18:32:47	11°	S
11 Dec	4.4	18:08:26	10°	W	18:11:27	21°	SW	18:14:27	10°	S
12 Dec	4.6	17:50:04	10°	W	17:53:00	20°	SW	17:55:54	10°	S
13 Dec	4.8	17:31:41	10°	W	17:34:32	19°	SW	17:37:22	10°	S
14 Dec	4.9	17:13:19	10°	W	17:16:04	18°	SW	17:18:48	10°	S
15 Dec	5.0	16:54:56	10°	W	16:57:35	18°	SW	17:00:14	10°	S
22 Dec	5.6	06:35:28	10°	SE	06:36:15	10°	SE	06:37:02	10°	ESE
23 Dec	5.4	06:16:32	10°	SSE	06:17:44	11°	SE	06:18:55	10°	ESE
24 Dec	5.2	05:57:42	10°	SSE	05:59:12	12°	SE	06:00:41	10°	ESE
25 Dec	5.1	05:38:57	10°	SSE	05:40:40	13°	SE	05:42:24	10°	ESE
25 Dec	3.0	07:14:46	10°	SW	07:18:36	49°	SSE	07:22:27	10°	ENE
26 Dec	4.9	05:20:13	10°	SSE	05:22:08	13°	SE	05:24:03	10°	ESE
26 Dec	2.9	06:56:15	10°	SW	07:00:06	51°	SSE	07:03:58	10°	ENE
27 Dec	4.8	05:02:00	11°	SSE	05:03:36	14°	SE	05:05:42	10°	E
27 Dec	2.7	06:37:43	10°	SW	06:41:35	54°	SSE	06:45:28	10°	ENE
28 Dec	4.7	04:45:04	15°	SE	04:45:04	15°	SE	04:47:18	10°	E
28 Dec	2.6	06:19:56	15°	SW	06:23:04	56°	SSE	06:26:58	10°	ENE
29 Dec	5.0	04:27:53	13°	ESE	04:27:53	13°	ESE	04:28:54	10°	E
29 Dec	2.5	06:02:44	29°	SW	06:04:33	58°	SSE	06:08:27	10°	ENE
30 Dec	2.3	05:45:21	51°	SSW	05:46:02	60°	SSE	05:49:57	10°	ENE
30 Dec	2.0	07:20:46	10°	W	07:24:44	69°	N	07:28:41	10°	ENE
31 Dec	2.4	05:27:51	59°	SE	05:27:51	59°	SE	05:31:26	10°	ENE
31 Dec	2.0	07:02:40	13°	W	07:06:13	68°	N	07:10:10	10°	E
01 Jan	3.3	05:10:14	39°	E	05:10:14	39°	E	05:12:55	10°	ENE
01 Jan	2.0	06:45:03	20°	W	06:47:42	68°	N	06:51:39	10°	E
02 Jan	4.1	04:52:33	26°	E	04:52:33	26°	E	04:54:22	10°	ENE
02 Jan	2.0	06:27:22	30°	WNW	06:29:10	67°	N	06:33:08	10°	E
03 Jan	4.8	04:34:48	17°	ENE	04:34:48	17°	ENE	04:35:50	10°	ENE
03 Jan	2.0	06:09:37	45°	WNW	06:10:39	67°	N	06:14:35	10°	E

ISS PASSES For NOVEMBER/DECEMBER 2022

from Heavens Above website maintained by Chris Peat.

Date	Brightn	Start	Highest point	End						
	(mag)	Time	Alt.	Az.	Time	Alt.	Az.	Time	Alt.	Az.
05 Dec	-2.7	16:50:10	10°	W	16:53:24	48°	SSW	16:56:39	10°	SE
05 Dec	-0.7	18:28:00	10°	WSW	18:29:34	13°	SW	18:31:08	10°	SSW
06 Dec	-1.0	17:39:12	10°	W	17:41:37	19°	SW	17:44:02	10°	S
07 Dec	-1.4	16:50:45	10°	W	16:53:37	26°	SSW	16:56:27	10°	SSE
09 Dec	-0.4	16:51:52	10°	WSW	16:53:34	13°	SW	16:55:15	10°	S
17 Dec	-0.7	07:12:10	10°	S	07:14:35	19°	SE	07:17:02	10°	E
18 Dec	-0.5	06:24:49	10°	SSE	06:26:24	13°	SE	06:27:59	10°	ESE
19 Dec	-2.0	07:11:06	10°	SW	07:14:13	35°	SSE	07:17:19	10°	E
20 Dec	-1.5	06:23:04	10°	SSW	06:25:53	25°	SSE	06:28:44	10°	E
21 Dec	-1.1	05:35:54	13°	S	05:37:36	18°	SE	05:39:57	10°	E
21 Dec	-3.2	07:10:33	10°	WSW	07:13:53	61°	SSE	07:17:13	10°	E
22 Dec	-0.5	04:50:02	12°	SE	04:50:02	12°	SE	04:50:44	10°	ESE
22 Dec	-2.8	06:22:59	16°	SW	06:25:27	46°	SSE	06:28:41	10°	E
23 Dec	-2.4	05:36:51	33°	SSE	05:37:02	33°	SSE	05:40:07	10°	E
23 Dec	-3.7	07:10:12	10°	W	07:13:34	86°	S	07:16:57	10°	E
24 Dec	-0.6	04:50:34	15°	E	04:50:34	15°	E	04:51:25	10°	E
24 Dec	-3.7	06:23:29	29°	WSW	06:25:03	74°	SSE	06:28:25	10°	E
25 Dec	-2.9	05:37:04	50°	ESE	05:37:04	50°	ESE	05:39:50	10°	E
25 Dec	-3.8	07:09:58	11°	W	07:13:14	85°	N	07:16:37	10°	E
26 Dec	-0.6	04:50:33	15°	E	04:50:33	15°	E	04:51:15	10°	E
26 Dec	-3.9	06:23:27	37°	W	06:24:39	87°	N	06:28:01	10°	E
27 Dec	-2.9	05:36:51	49°	E	05:36:51	49°	E	05:39:25	10°	E
27 Dec	-3.8	07:09:45	12°	W	07:12:48	86°	SSW	07:16:10	10°	ESE
28 Dec	-0.6	04:50:12	14°	E	04:50:12	14°	E	04:50:48	10°	E
28 Dec	-3.8	06:23:05	40°	W	06:24:11	87°	N	06:27:34	10°	E
29 Dec	-2.8	05:36:23	47°	E	05:36:23	47°	E	05:38:54	10°	E
29 Dec	-3.4	07:09:17	12°	W	07:12:14	60°	SSW	07:15:33	10°	ESE
30 Dec	-0.5	04:49:40	14°	E	04:49:40	14°	E	04:50:14	10°	E
30 Dec	-3.8	06:22:33	40°	W	06:23:37	75°	SSW	06:26:58	10°	ESE
31 Dec	-2.8	05:35:48	47°	ESE	05:35:48	47°	ESE	05:38:18	10°	E
31 Dec	-2.7	07:08:42	12°	W	07:11:28	35°	SSW	07:14:34	10°	SE
01 Jan	-0.5	04:49:04	14°	E	04:49:04	14°	E	04:49:35	10°	E
01 Jan	-3.2	06:21:57	36°	WSW	06:22:52	48°	SSW	06:26:07	10°	SE
02 Jan	-2.5	05:35:12	39°	SE	05:35:12	39°	SE	05:37:32	10°	ESE
02 Jan	-1.8	07:08:05	10°	W	07:10:29	19°	SW	07:12:54	10°	S
03 Jan	-0.4	04:48:29	13°	ESE	04:48:29	13°	ESE	04:48:50	10°	ESE
03 Jan	-2.4	06:21:22	25°	SW	06:21:55	26°	SSW	06:24:47	10°	SSE
04 Jan	-1.9	05:34:40	25°	SSE	05:34:40	25°	SSE	05:36:24	10°	SE
05 Jan	-1.5	06:20:54	14°	SW	06:20:54	14°	SW	06:22:30	10°	S
06 Jan	-1.0	05:34:17	12°	S	05:34:17	12°	S	05:34:40	10°	SSE

END IMAGES, AND OBSERVING

There are lots of features within Taurus that are overshadowed by the big 3, M1 crab nebula, then the Pleiades cluster M45 and the even close open cluster of the Hyades.
Here are some of the smaller clusters. Ngc1647, ngc1746,, ngc 1807 and ngc 1817 among many and also one or two distant galaxies!
Andy Burns.

Observing Sessions

Proposed Observation Sessions for 2022-2023

Planned observing evenings will be on a Friday night in the Lacock playing fields behind the Red Lion pub at 19:00 or an Hour after sunset depending on the time of year.
With the New Moon being around the beginning of the month and the full moon generally around the middle, the following dates for observing are proposed:

a ad-hoc session for other reasons and at other locations, such as astro-photography, solar observing etc, with other like-minded members then they can do so through the Society Members Facebook Page or through the WAS contact page on the website.

Opportunity	Day	Date	Month	Set-up	Observe
First	Friday	16th	December	18:30	19:00
Second	Friday	23rd	December	18:30	19:00
First	Friday	13th	January	18:30	19:00
Second	Friday	20th	January	18:30	19:00
First	Friday	10th	February	18:30	19:00
Second	Friday	17th	February	19:00	19:30
Third	Friday	24th	February	19:00	19:30
First	Friday	17th	March	19:00	19:30
Second	Friday	24th	March	19:30	20:00
First	Friday	14th	April	20:00	20:30
Second	Friday	21st	April	20:30	21:00
First	Friday	12th	May	20:30	21:00
Second	Friday	19th	May	20:30	21:00

OUTREACH: Stanton St Quinton school TBC

NOTE: Due to building work likely to extend into early 2023 I have been in touch with the National Trust Lacock Estates Office for permission to use the Picnic area just behind the Café and Toilets. News hopefully later this week.