NWASNEWS

Volume28 Issue5

Januaryr 2023

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

SAD NEWS

After last month's sad news with the passing of long term member John Arthurs I have received some more devastating news today.

Bob Johnston, one of our founding members, and many of you will also remember as our long standing treasurer until very recently.

This has hit me for six.

I am sure you will all want to pass on your condolences to his family. I have no more details about his passing other than it was quite sudden to his family.

With this in mind and other notification of absence from other members including the no treasurer I had a quick conversation with committee quorum and have decided to make tonight's meeting an online Zoom meeting, details below.

This was already booked with Zoom so our speaker could give his talk from Las Palma so we can all join in. Just allow a little time for Mike and I to set up then we will start the talk at 8:00pm.

Zoom meeting.

Topic: Wiltshire AS January 23 Zoom Meeting

Mike Alexander La Paalma Volcano and more.

Time: Jan 3, 2023 07:30 PM London

Join Zoom Meeting

https://us02web.zoom.us/j/81898671836?pwd=b2lDcWlWaEV5b0pYVVJsNzJlWTJwUT09

Meeting ID: 818 9867 1836

Passcode: 136120

Meeting ID: 818 9867 1836

Passcode: 136120

Find your local number: https://us02web.zoom.us/u/ki1QDLDnr

Clear Skies

Andy

When you try to take a daytime shot of Jupiter, and not only does the Moon photobomb the shot but a pigeon wants to fly between them…

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

Our speaker tonight is Mike Alexander (and many of you remember Layla, his hearing dog. And it is great to see her relaxing in the sun too.

But the Canary of La Palma has had its fun since Mike arrived.

The observatories on the north of the island have been refitted, then along comes a volcano to make things even hotter. Even now it has not fully cooled and it steams every time it rains.

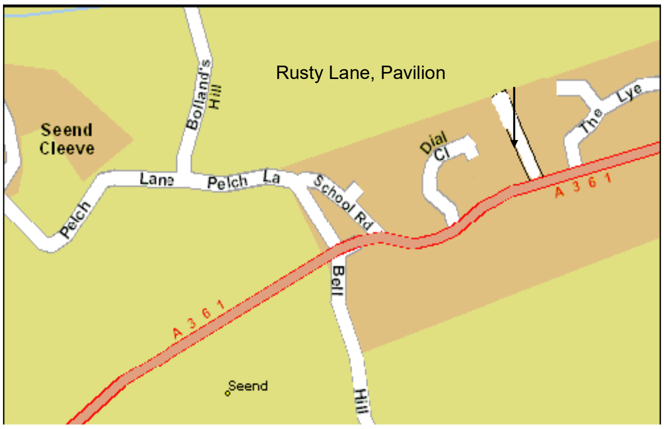
Then just before Christmas a large bolide was seen rushing east to west above north Africa, steering inexorably to La Palma. A huge meteorite crashing into the 8000feet deep sea just to the east of the island.

Membership Meeting nights £1.00 for members £3 for visitors

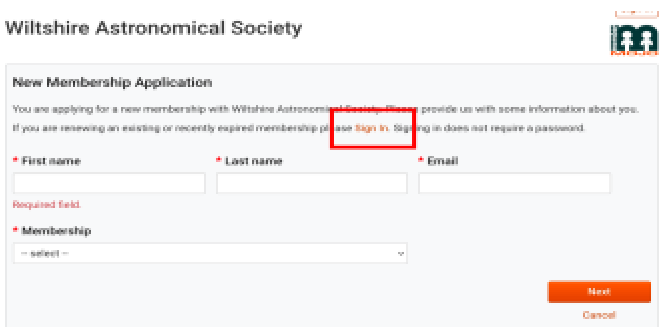
Members can renew or new members sign up online via https://wasnet.org.uk/membership/ and also remind them they can pay in cash too on the door.

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



Wiltshire Astronomical Society

New Membership Application

You are applying for a new membership with Wiltshire Astronomical Society. Please provide us with some information about you.
If you are renewing an existing or recently expired membership please Sign in. Signing in does not require a password.

* First name | * Last name | * Email

Required field.

* Membership

-- select --

Next

Cancel

Swindon Stargazers

Swindon's own astronomy group

Physical meetings continuing!

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

Friday, 20 January - Bernard Henin

Imaging Our Solar System: The Evolution of Space Mission Cameras & Instruments

Bernard studied applied science in biotechnology, and after working in the pharmaceutical industry, he decided to go on a quest to find other life aspirations.
He decided to share his passion for space science with the general public. In doing so, he writes books for Springer International and gets to spend months researching a chosen topic and interviewing leading scientists at space agencies and universities worldwide. His talk is on the story of imaging instruments in space, detailing some of the technological missteps and marvels that have allowed us to view planetary bodies like never before.

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

Meeting Dates For 2023

Friday, 20 January 19.30 onwards

Programme: Bernard Henin: Imaging Our Solar System. The Evolution of Space Mission Cameras & Instruments

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

Friday, 17 March 19.30

Programme: AGM + A Walk Through Astrophotography by Damian Ohara

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 Mizon 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
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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

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) and are of 90 minutes duration or so.

Next Meetings:
Wednesday, 25th January 2023
Talk by **Dr David Tsang** on Neutron Stars

Wednesday, 22nd February
Member's Night – a collection of small talks by Bath Astronomers members

More information and news is available via:
https://bathastronomers.org.uk

https://www.youtube.com/@bathastronomers

On Social Media (Facebook, Twitter, Instagram) as @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. The February half-term, 13th to 17th Feb, will include nightly opportunities to discover the night sky.

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. The Coordination Team of Annie, Camilla, Jade, Jonathan, Meyrick, Mike, Prim and Simon will be happy to help you.

All the best

Simon

SPACE NEWS TO JANUARY 23

.China is Considering Where to Build a Lunar Research Station

The second Moon race is in full swing, with the world's two big superpowers angling to score a new set of firsts on the lunar surface. NASA's Artemis program recently clocked up its first success with the splashdown of Orion, but China is looking to take the lead when it comes to setting up a fully-fledged lunar research station. One of the first steps in that process – figuring out where to put it. That is what a new paper attempts to quantify, and it comes up with a practical solution – the south pole.

There are plenty of advantages to the lunar south pole. It also checks many of the boxes that the Chinese scientists were looking for when they developed their criteria for potential landing sites.

They broke those criteria into two categories- scientific and engineering constraints. Engineering constraints included considerations like the illumination a site receives, its general slope, and the ease with which explorers could access other parts of the moonscape. Scientific constraints, which this particular paper focuses on, include considerations such as water ice exposure, hydrogen abundance, and temperature.

UT Editor Fraser talks about China's exploration plans.

The south pole, therefore, seems ideal, given its relative flatness and relatively constant temperature in the permanently shaded regions of some of its craters. Those craters also most likely hold the largest amount of frozen water deposits on the Moon, making access to them an extremely high priority for any permanent base.

It also has access to one of the oldest basins on the Moon – the South Pole – Aitken (SPA) basin. Plenty of questions about the early formation of the Moon itself and the solar system could be answered more generally by looking at the soil in the basin.

To further explore the region, China plans to send a set of additional robotic explorers to continue the Chang'e program that has brought back the most recent lunar sample. The next, Chang'e 6, plans to bring back a lunar sample from the south pole specifically, and its insights might provide a better understanding of any future site.

Will China or the US make it back to the Moon first? That's still up for debate.

As the program progresses, Chang'e 7 will provide a comprehensive survey of the south polar region, while Chang'e 8 will serve as a technology validation mission for some of the technologies that will be vital in constructing a base there. At the end of the program, the China National Space Agency might have enough information to implement its plan to launch an international, cooperative lunar research base. Hopefully, with that information, China will be able to bring some benefits from the Moon back to Earth.

Want to Build Structures on the Moon? Just Blast the Regolith With Microwaves

Microwaves are useful for more than just heating up leftovers. They can also make landing pads on other worlds – at least according to research released by a consortium of scientists at the University of Central Florida, Arizona State University, and Cislune, a private company. Their research shows how a combination of sorting the lunar soil and then blasting it with microwaves can create a landing pad for future rockets on the Moon – and save any surrounding buildings from being blasted by 10,000 kph dust particles.

This system works in large part because certain minerals on the lunar surface are magnetic, and those same minerals are also very susceptible to being heated up by microwaves. In particular, a type of glassy mineral called ilmenite, which makes up about 1-2% of the Moon's surface, is highly magnetic.

Ilmenite forms when the Moon is blasted by small meteors and forms material called agglutinates. For older lunar soils (i.e., those that haven't been recently blasted by a meteor), up to 60% of the soil is made up of these agglutinates, whereas only about 20% of "younger" lunar soils are. So concentrations are high enough in some places that contain significant amounts of older regolith.

Understanding regolith will be key to setting up any kind of Moon base, according to this UT interview.

So if future explorers wanted to make a landing pad, they could zap this older soil with strong microwaves to sinter it together and create a durable enough surface that would allow a rocket to land on it without sandblasting everything around. That sandblasting would be particularly wicked as there is no air to slow the dust particles down, as it would on Earth.

The solution seems simple enough – blast the soil with microwaves to sinter it together. However, systems can always be improved, and this microwave sintering process is no exception. The researchers found that, by subjecting the regolith to a process known as beneficiation, they could increase the amount of microwaves it absorbed and, therefore, the effectiveness of the heating process.

Beneficiation, in this case, involves sifting the soil and hitting it with a magnetic field, causing the more magnetic soil to move toward the magnet, whereas the non-magnetic soil would simply fall back to the ground. Dr. Phil Metzger, one of the lead authors of the study, compares the process to what recyclers do here on Earth – they sort material by its magnetic strength, allowing magnetic material, such as regular steel, to be separated from the more valuable stainless steel, which is not magnetic.

In this UT video we describe why in-situ resource utilization is useful for all kinds of things.

On the Moon, when the magnet is powered down, the magnetic soil would rest on top of the non-magnetic type. And since the magnetic soil is also much more susceptible to microwaves, the beneficiation process could increase the amount of energy the material absorbs by 60-80%.

That is an absurd improvement and one that could dramatically decrease the necessary size of the microwave power supply needed for such a mission. Given the weight of some microwave power supplies, any reduction in its heft could dramatically decrease the cost of the overall program.

The paper also looks at other potential landing pad creation methodologies, including polymer-based by paver-based pads. However, the cost-effectiveness of using in-situ resources, such as those in the microwave sintering project, is the most effective at the current price point of getting equipment into orbit.

While that price might fall significantly in the coming decades, this technique seems like one of the best for the Artemis mission planners that are hoping to land a reusable rocket on the Moon sometime again this decade. For now, the next research steps would include testing the microwave power source and doing similar tests on the soil in a simulated lunar environment, including in a vacuum. If some microwaved meals are anything to go by, it might not be the best idea to smell the resulting material though.

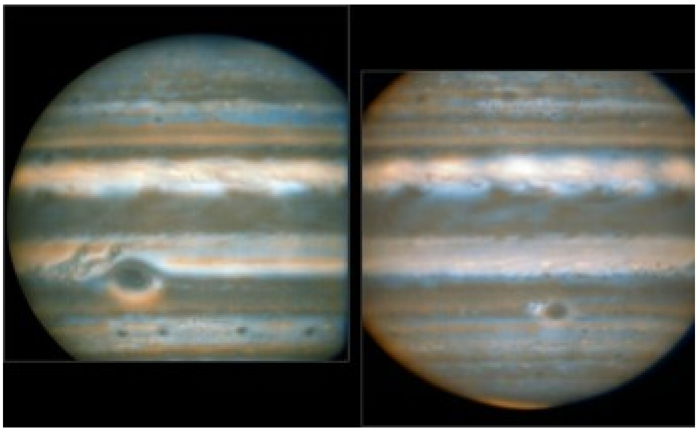
An Ongoing Study of Jupiter's Cloudtops Has Been Going on for 40 Years

Some of the most useful discoveries about distant objects take time to complete. For example, several generations of planetary scientists have been studying the clouds of Jupiter since the late 1970s. Their observations focused on the planet's upper troposphere. The results show unexpected patterns in how the temperatures of Jupiter's belts and zones change over time. Those temperatures rise and fall in cycles not tied to the seasons. That's unusual since scientists didn't expect to find such regular variations. It could be due to Jupiter's very slight tilt on its axis. The four decades of observations also found a connection between temperature shifts in regions several thousand kilometers apart. As temperatures rose at specific latitudes in parts of the Jovian northern hemisphere, they fell at the same latitudes in the southern hemisphere. Is there a connection?

"That was the most surprising of all," said Glenn Orton, a senior research scientist at NASA's Jet Propulsion Laboratory and lead author of a study based on the observations. "We found a connection between how the temperatures varied at very distant latitudes. It's similar to a phenomenon we see on Earth, where weather and climate patterns in one region can have a noticeable influence on weather elsewhere, with the patterns of variability seemingly 'teleconnected' across vast distances through the atmosphere."

Observing Jupiter's Clouds

Jupiter, as we all know, is covered with thick clouds. It has the largest and most complex planetary atmosphere in the solar system and is a natural laboratory where scientists can study interactions between the belts and zones, the creation and evolution of giant whirling windstorms, and other atmospheric activity. It's also a natural laboratory for understanding the atmospheres of other giant planets. Surprisingly, its troposphere (the lowest region of the atmosphere, which sits atop the "surface" of Jupiter's liquid interior) is pretty similar to Earth's. That's because the troposphere on both planets is where clouds form and where storms whirl.



These infrared images of Jupiter with color added were obtained by the European Southern Observatory's Very Large Telescope in 2016 and contributed to the new study. The colors represent temperatures and cloudiness: The darker areas are cold and cloudy, and the brighter areas are warmer and cloud-free.
Credit: ESO / L.N. Fletcher

To understand the tropospheric weather, scientists needed more data about the winds, atmospheric pressure, humidity, and temperatures. They have known since the Pioneer missions that Jupiter's lighter and whiter bands (known as zones) are generally colder. The darker brown-red bands (known as belts) are where temperatures are warmer. But, planetary scientists needed long-term measurements to understand how the weather changes over time.

So, Orton's team used observatories in Chile and Hawai'i to take the temperatures of cloud zones and bands of Jupiter. Starting in 1978, they studied the bright infrared glow that rises from warmer regions on Jupiter. That allowed them to directly measure the temperature of the troposphere. They collected their data during three of Jupiter's 12-year orbits around the Sun. After several decades, they began to combine the data from the observations into a coherent "picture" of Jupiter's tropospheric weather.

An Atmospheric Scientist's Work is Never Done

This time-domain study of Jupiter's lower atmosphere is a good start on understanding what causes the cyclical and apparently synchronized changes it undergoes. But, of course, more work needs to be done. "We've solved one part of the puzzle now, which is that the atmosphere shows these natural cycles," said study co-author Leigh Fletcher of the University of Leicester in England. "To understand what's driving these patterns and why they occur on these particular timescales, we need to explore both above and below the cloudy layers."

Perhaps changes in the stratosphere influence changes in the troposphere and vice versa. But, what mechanism explains the linkage between temperature changes across wide areas of the planet? Further observations should help find a link if there is one. In the meantime, scientists think that the results of this 40-year study could help them predict Jupiter's weather even as they seek to understand the observed changes.

The next step will be to create improved climate models for the giant planet. The data will feed computer simulations of the temperature cycles Orton and the team have measured. Then, they could use that information to predict how the variations affect weather. The information could help with similar predictions at Saturn, Uranus, and Neptune.

The Solar Wind is Creating Water on the Surface of the Moon

Water on the Moon has been a hot topic in the research world lately. Since its first unambiguous discovery back in 2008. Since then, findings of it have ramped up, with relatively high concentration levels being discovered, especially near the polar regions, particularly in areas constantly shrouded in shadow. Chang'e 5, China's recent sample return mission, didn't land in one of those permanently shadowed areas. Still, it did return soil samples that were at a much higher latitude than any that had been previously collected. Now, a new study shows that those soil samples contain water and that the Sun's solar wind directly impacted that water.

The amount of water on the lunar surface varies widely both based on the time of the lunar day and the latitude it is located at. There is so much variability that the water content of the lunar soil can be 200 ppm higher or lower at different times of the day. With that much variability, it seems clear that the Sun plays a significant role in the hydrological cycle there is on the Moon.

Part of that role is controlling the type of hydrogen embedded into the lunar soil. Since the Moon has almost no atmosphere to speak of, the charged hydrogen particles that make up the solar wind can directly interact with the top regolith layer on the lunar surface. When they do so, they leave behind a distinct sign that they do – a large amount of hydrogen atoms with very little deuterium.

UT video on the importance of water at the lunar poles.

Deuterium is a heavier form of hydrogen with an extra neutron in its nucleus. It is relatively rare on the solar wind, given that the neutron gives the extra mass, making it less likely to be caught up in the forces that create the wind. As such, hydrogen and whatever water it eventually forms from the solar wind would be distinctly lacking in water molecules that integrate deuterium.

That is exactly what researchers at the Chinese Academy of Sciences found on some of the soil samples returned by Chang'e 5. They had a high (~1000-2500 ppm) concentration of hydrogen but a relatively low concentration of deuterium. Importantly, this result was the case for the first 100 nm of soil collected, showing that the solar wind effect appears on the topmost layer of the regolith, as expected.

Also, the overall water concentration in the Chang'e 5 sample was estimated to be around 46 ppm, right around what was found using remote sensing prior to the lander touching down. Location also mattered a lot to this study, as the researchers attempted to use the concentration findings and feed them into a model that tracks the outgassing that was evidenced by lunar water at other latitudes. At the higher latitudes of Chang'e 5, there wasn't as much variability as was found at lower latitudes by missions such as Apollo and Luna.

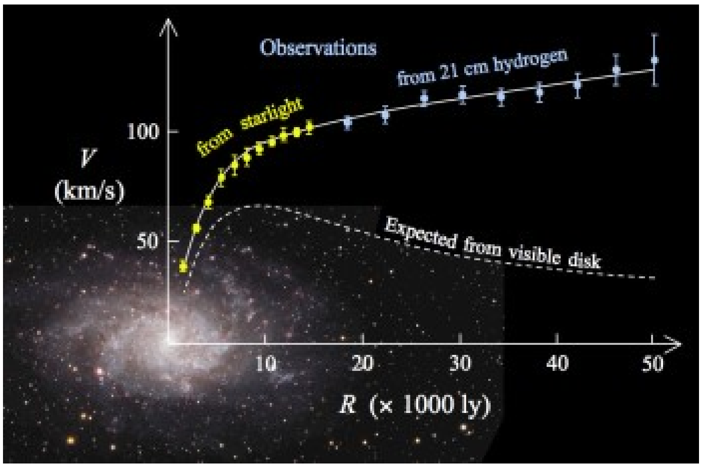
The search for lunar water continues in this UT video.

More importantly, the model also suggests that even higher latitudes, reaching up toward the poles, would have an even greater abundance of hydrogen. That lends credence to the theory that the lunar poles are one of the most likely places to find large amounts of water on the lunar surface. And it also feeds into the interest that the polar regions have garnered as the potential site of the first lunar research base. While that is still a long way off, the results from this study are an important step toward understanding this all-important feature of lunar hydrology.

New Measurements of Galaxy Rotation Lean Towards Modified Gravity as an Explanation for Dark Matter

Although dark matter is a central part of the standard cosmological model, it's not without its issues. There continue to be nagging mysteries about the stuff, not the least of which is the fact that scientists have found no direct particle evidence of it. Despite numerous searches, we have yet to detect dark matter particles. So some astronomers favor an alternative, such as Modified Newtonian Dynamics (MoND) or modified gravity model. And a new study of galactic rotation seems to support them.

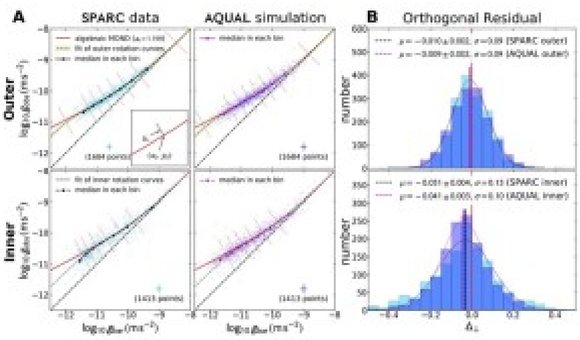
The idea of MoND was inspired by galactic rotation. Most of the visible matter in a galaxy is clustered in the middle, so you'd expect that stars closer to the center would have faster orbital speeds than stars farther away, similar to the planets of our solar system. What we observe is that stars in a galaxy all rotate at about the same speed. The rotation curve is essentially flat rather than dropping off. The dark matter solution is that galaxies are surrounded by a halo of invisible matter, but in 1983 Mordehai Milgrom argued that our gravitational model must be wrong.



Rotation curve of the typical spiral galaxy M 33 (yellow and blue points with errorbars) and the predicted one from distribution of the visible matter (white line). The discrepancy between the two curves is accounted for by adding a dark matter halo surrounding the galaxy. Credit: Public domain / Wikipedia

At interstellar distances, the gravitational attraction between stars is essentially Newtonian. So rather than modifying general relativity, Milgrom proposed modifying Newton's Universal Law of Gravity. He argued that rather than the force of attraction is a pure inverse square relation, gravity has a small remnant pull regardless of distance. This remnant is only about 10 trillionths of a gee, but it's enough to explain galactic rotation curves.

Of course, just adding a small term to Newton's gravity means that you also have to modify Einstein's equations as well. So MoND has been generalized in various ways, such as AQUAL, which stands for A Quadradic Lagrangian. Both AQUAL and the standard LCDM model can explain observed galactic rotation curves, but there are some subtle differences.



Measured shift between inner and outer stellar motions. Credit: Kyu-Hyun Chae

This is where a recent study comes in. One difference between AQUAL and LCDM is in the rotation speeds of inner orbit stars vs outer orbit stars. For LCDM, both should be governed by the distribution of matter, so the curve should be smooth. AQUAL predicts a tiny kink in the curve due to the dynamics of the theory. It's too small to measure in a single galaxy, but statistically, there should be a small shift between the inner and outer velocity distributions. So the author of this paper looked at high-resolution velocity curves of 152 galaxies as observed in the Spitzer Photometry and Accurate Rotation Curves (SPARC) database. He found a shift in agreement with AQUAL. The data seems to support modified gravity over standard dark matter cosmology.

The result is exciting, but it doesn't conclusively overturn dark matter. The AQUAL model has its own issues, such as its disagreement with observed gravitational lensing by galaxies. But it is a win for the underdog theory, which has some astronomers cheering "Vive le MoND!"

Power on the Moon. What Will it Take to Survive the Lunar Night?

With the help of international and commercial partners, NASA is sending astronauts back to the Moon for the first time in over fifty years. In addition to sending crewed missions to the lunar surface, the long-term objective of the Artemis Program is to create the necessary infrastructure for a program of "sustained lunar exploration and development." But unlike the Apollo missions that sent astronauts to the equatorial region of the Moon, the Artemis Program will send astronauts to the Moon's South Pole-Aitken Basin, culminating in the creation of a habitat (the Artemis Basecamp). This region contains many permanently-shadowed craters and experiences a night cycle that lasts fourteen days (a "Lunar Night"). Since solar energy will be limited in these conditions, the Artemis astronauts, spacecraft, rovers, and other surface elements will require additional power sources that can operate in cratered regions and during the long lunar nights. Looking for potential solutions, the Ohio Aerospace Institute (OAI) and the NASA Glenn Research Center recently hosted two space nuclear technologies workshops designed to foster solutions for long-duration missions away from Earth.

NASA's Glenn is the home of NASA's power systems research, where engineers and technicians work to develop advanced power generation, energy conversion, and storage methods – with applications ranging from solar, thermal, and batteries to radioisotopes, fission, and regenerative fuel cells. The Clevand-based OAI is a non-profit research group dedicated to fostering partnerships between government and industry to further aerospace research. The OAI has a long history of collaborating and contracting with NASA and the DoD.

These workshops were the latest step in NASA and the DOE's collaborative development of nuclear technologies for crewed space exploration programs. In terms of propulsion, these efforts have aimed to advance proposals for nuclear-thermal and nuclear-electric propulsion systems (NTP/NEP). In the former case, a nuclear reactor is used to heat propellants like liquid hydrogen (LH_2); in the latter, the reactor generates electricity for a magnetic engine that ionizes an inert gas like xenon (aka. Ion Propulsion).

In 2021, NASA and the DoE selected three reactor design proposals for a nuclear thermal system that could send cargo and crews to Mars and science missions to the outer Solar System. The contracts, valued at around $5 million apiece, were awarded through the DOE's Idaho National Laboratory (INL). In June 2022, they followed up by selecting three design concept proposals for a Fission Surface Power (FSB) system that would expand on NASA's Kilopower project and could be sent to the Moon as a technology demonstration for the Artemis Program.

The nuclear technologies workshops saw over 100 engineers, managers, and experts in power systems from across government, industry, and academia come together to discuss topics ranging from Fission Surface Power to space nuclear propulsion systems. The event featured speakers and panelists from NASA, the U.S. Department of Energy (DoE), the Department of Defense (DoD), and the commercial sector to share knowledge, results, and lessons learned from past efforts to develop nuclear technology. Todd Tofil, NASA's Fission Surface Power project manager, explained in a NASA press release:

"Reliable energy is essential for exploration of the Moon and Mars, and nuclear technology can provide robust, reliable power in any environment or location regardless of available sunlight. As we move forward with projects like Fission Surface Power and nuclear propulsion, it makes sense to look at work that's been done in the past at NASA and other agencies to see what we can learn."

The first workshop (in November) included discussions on mission requirements that call for nuclear power, such as long-duration missions beyond Earth where solar power isn't always an option. This includes the Moon's southern polar region but also on Mars, where the increased distance and periodic dust storms can also limit solar energy. The workshop also included discussions about test hardware from previous programs that could be relevant to today's projects. Things concluded with a tour of the seven Glenn facilities engaged in nuclear research. Said Lee Mason, associate chief of Glenn's Power Division:

"The workshop provided an excellent opportunity to discuss technology advancements and provide the new industry teams an opportunity to learn from the past and build on the foundation that's been established. Strong industry-government collaboration and knowledge sharing will help us be successful with Artemis and missions beyond."

The second workshop took place in early December and saw over 500 people from 28 countries meeting (in-person and virtually) to discuss how to address the extreme challenges of operating in the Lunar Night. During the three-day workshop, attendees learned about relevant developments in the field from power and thermal technology experts from NASA and other organizations. These included those funded by NASA's Space Technology Mission Directorate (STMD) and Exploration System Development Mission Directorate (ESDMD).

Status updates were also provided by several commercial entities that are partnered with NASA through the Commercial Lunar Payload Services (CLPS) initiative, which will begin delivering experiments and technology demonstrations to the lunar surface in early 2023. Most of these missions rely on solar panels or batteries and will face power and thermal challenges as they land in the South-Pole Aitken Basin. Since these systems need to remain in operation longer than a Lunar Day (also 14 days), CLPS providers will also benefit from advanced power systems.

Artist's impression of astronauts on the lunar surface, as part of the Artemis Program. Credit: NASA

As Tibor Kremic, chief of the Space Science Project Office at NASA Glenn, summarized:

"The Moon is rife with extreme conditions, especially during the lunar night, that we must prepare for. We do that by bringing together leading experts from NASA, commercial partners, academia, and other government entities to share insights, review technical capabilities, and discuss the challenges and solutions ahead. The workshop was a learning experience for all of us, helping better prepare our CLPS providers and increase our understanding of the various technical capabilities and constraints as we continue to prepare for ever more ambitious payload deliveries to some of the toughest places in the solar system."

These workshops also build on NASA's Lunar Surface Innovation Initiative, which is dedicated to fostering partnerships that will lead to technologies needed to live and explore on the surface of the Moon. The Initiative is particularly focused on technologies that allow for in-situ resource utilization (ISRU), power generation, mitigating lunar dust, excavating and constructing on the Moon's surface, exploring the lunar environment, and other methods that will ensure a sustainable human presence on the Moon for decades to come.

Another long-term objective of the Artemis Program is to establish the infrastructure and expertise that will allow for crewed missions to Mars in the early 2030s. This presents even greater challenges, ranging from logistics and transportation (transit times of up to nine months) to power systems for surface operations. Here too, nuclear propulsion (which could reduce transit times to 100 days) and nuclear reactors that can power surface habitats and vehicles for long-duration missions are in high demand.

This is yet another example of how this age of renewed space exploration (Space Age 2.0) is spurring the development of technologies that have been dreamt of for decades!

Is Mining in Space Socially Acceptable?

Traditional mining has been subject to a negative stigma for some time. People, especially in developed countries, have a relatively negative view of this necessary economic activity. Primarily that is due to its environmental impacts – greenhouse gas emissions and habitat destruction are some of the effects that give the industry its negative image. Mining in space is an entirely different proposition – any greenhouse gases emitted on the Moon or asteroids are inconsequential, and there is no habitat to speak of on these barren rocks. So what is the general public's opinion on mining in space? A paper from a group of researchers in Australia, one of the countries most impacted by the effects of terrestrial mining, now gives us an answer.

Strangely, as the paper points out, no one had previously studied this particular aspect of space resources. Despite the general media interest in ventures such as Planetary Resources and the success of missions such as Hayabusa-2, no one had attempted to understand how the general public felt about space mining.

It was not a foregone conclusion, as there are some potentially negative environmental factors to mining in space. While it might not cause any immediate harm to ecosystems as it does here on Earth, it does destroy "pristine" environments that have arguably been around since the dawn of the solar system, at least in the case of the asteroids. As excellently portrayed in the Mars Trilogy by Kim Stanley Robinson, there will always be a part of humanity that will want to leave space as it is.

UT video on asteroid mining.

Another confounding factor is that the resources mined in space could, ostensibly at least, be used for products back on Earth. They could therefore end up in landfills, causing a longer-term environmental problem than if we simply recycled the material we already have in these large deposits of everything that humanity has created. So there was still an outstanding question of whether these potential downsides outweighed the risk in the eyes of the public.

Simply put, the public in a variety of countries broadly supports space mining, especially on asteroids. To get these results, the researchers performed two different studies, one involving almost 5,000 people in 27 (mostly rich) countries and another involving around 600 people in the US.

In the first study, the researchers asked a series of questions that focused on the participant's attitudes towards mining – specifically four different kinds: in the Antarctic, on the ocean floor, on the Moon, or on asteroids. In particular, the researchers were interested in the positive and negative reactions that mining in each area elicited in their subjects.

UT interviews Dr. Phil Metzger, one of the world's leaders in ISRU technology.

The results were unambiguous – people generally had negative feelings toward mining on the ocean floor, especially in

the Antarctic, and they generally had positive feelings towards mining on the Moon, especially on asteroids. People across all 27 countries had reasonably similar responses, no matter what their income level or the environment they inhabited.
However, results from the first study were relatively shallow and did not delve too deeply into factors such as the participant's political affiliation or individual morals. These are known to profoundly impact an individual's stance toward terrestrial mining and its potential environmental impacts. Still, it was unclear what, if any, effect it would have on a person's views of space mining.
Similar in structure to the first study, the second looked at people's responses to questions about how they felt about mining in several different locations – this time including "tundra" instead of the Antarctic. However, it also delved into the individual inclinations of the person responding to the questions, including their political orientation, which is currently one of the more polarizing aspects of American life.
Isaac Arthur is also keen on asteroid mining, as he describes in this video.
Credit – Isaac Arthur YouTube Channel
Neither a person's political persuasion nor their moral foundations were found to be clear indicators of whether or not that person would support mining in space. However, there was a negative correlation with support for lunar mining, specifically by those that scored higher on a test that assessed their interest in environmental sustainability. Assumedly that is because they think of the Moon as a pristine "environment" and view mining activities as potentially harmful to it.
Overall these studies seem like a glowing endorsement of public support for asteroid mining. However, there are some other confounding factors, including, as the authors point out, that both lunar and asteroid mining are, at this point, highly abstract concepts, the real impact of which may be hard to grok for many study participants. But studies such as this have to start somewhere, and waiting until after there is already a fully-fledged mining mission on the Moon to see if it has public support might be a little late. For now, at least, those interested in moving forward with this aspect of the economic development of space have the public on their side.

Astronomy 2023: Top Sky Watching Highlights for the Coming Year

Astronomy 2023 highlights include two fine solar eclipses, the Sun heading towards solar maximum, a series of spectacular lunar occultations and much more.
Been out enjoying the sky in 2022? The past year saw two fine total lunar eclipses, a surprise meteor outburst from the Tau Herculids, a fine occultation of Mars by the Moon and more. Astronomy 2023 promises more of the same, plus much more. We've been doing this yearly roundup of things to look for in the sky now for well over a decade in one form or another, and the cosmos never disappoints. So, without further fanfare, here are the very best of the best events for astronomy 2023, coming to a sky near you:

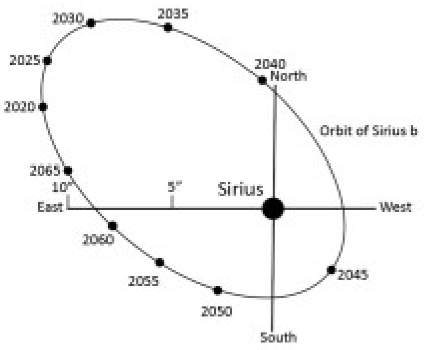
Top events in 2023

First, up let's distill things down to the very 'best of the best…' If I had to choose a 'top ten' list of events for the coming year, here are our picks for astronomy 2023:
-Mars is fine early just off opposition in late 2022 into early 2023
-Comet 96P Machholz reaches perihelion on January 31st
-A rare hybrid solar eclipse
-A fine annular eclipse
-A good year for the Perseids and Geminids
-The Moon resumes occulting Antares
-Moon occults Mars and Jupiter (on separate dates) for North America
-Solar Cycle 25 ramps up
-Venus vs. Jupiter on March 1st, just 30' apart
-A possible outburst from the Andromedid meteors in early December

Comet 96P/Machholz, imaged by NASA's STEREO spacecraft.

2023: An Astronomical Primer

As with any year, there's what is known… and unknown. Eclipses, Moon phases, and conjunctions are always sure to happen in a clockwork Universe… what's less known are how intense the solar cycle or a given meteor shower will be, or when the next great 'Comet of the Century' will turn up. Even less certain are when we can expect the next naked eye nova (we get about a dozen per century) or when the next galactic supernovae will grace our skies. We haven't seen such a spectacle since Kepler's supernova in 1604, though we did see one in our nearby satellite galaxy the Large Magellanic Cloud in 1987. You could say we're due…
Still, we can expect our host star to put on a good show in 2023 as we head towards the peak of the 11-year solar cycle in 2025. This is solar cycle Number 25 since we've started keeping records in 1755. Expect lots of sunspots, solar flares and prominences, and aurora.
2023 kicks off with all five naked eye planets visible at dusk in one visual sweep, a spectacle broken up once Mercury leaves the evening scene on January 5th.
Looking father afield in the solar system, 2023 is a 'miss' year for Jupiter's outermost moon Callisto, the only major Galilean moon that can pass above or below Jove from our perspective. The moons move back towards edge-on in 2026, when a season of mutual transits and eclipses resume.
Saturn's rings were also widest in 2017 from our perspective, and in 2023, narrow from 10 to 6 degrees wide and head towards edge-on once again in 2025.
In 2023, the very best dates to complete a 'Messier Marathon' and see all of the classic deep sky objects from the classic catalog in one night are the weekends of March 18th (primary) and March 25th (Secondary).
The white dwarf star Sirius B also reaches its maximum apparent separation 11.3" from its brilliant primary in 2023, offering a good opportunity to check the elusive companion off of your life-list.



The orbit of Sirius B. Credit: Dave Dickinson.

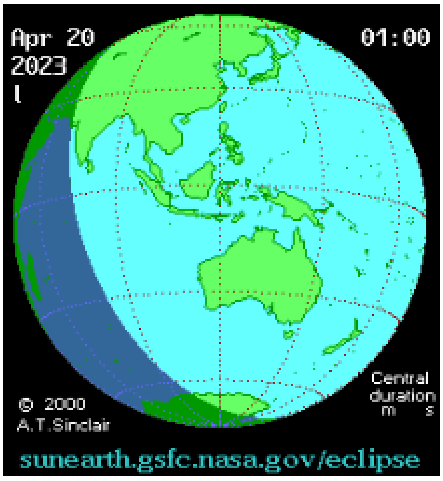
Eclipses in 2023

Eclipses occur when the Moon either passes between the Sun and Earth (a solar eclipse), or the Moon passes into the Earth's shadow (a lunar eclipse). The Moon's orbit is inclined 5 degrees relative to the ecliptic plane, assuring that 2-3 eclipse seasons occur per year.

There are four eclipses in 2023: two solar and two lunar. This is the minimum that can occur in a given year. These span two eclipse seasons, to include:

-A hybrid annular solar eclipse for southeast Asia and Indonesia on April 20th

-A penumbral lunar eclipse for Australia and East Asia on May 5th



The path of the 2024 hybrid solar eclipse. Credit: NASA/ GSFC/A.T. Sinclair.

-An annular solar eclipse for the US southwest and Central/South America on October 14th

-A 12% partial lunar eclipse for Africa, Asia and Europe on October 28th

The path of the October annular eclipse. Credit: Michael Zeiler.

The Sun, Moon and Seasons in 2023

In 2023, the astronomical seasons and phenomena for the Earth unfold as follows:

Earth at perihelion: January 4th at 0.98 AU distant

Northward Equinox: March 20th

Northward Solstice: June 21st

Earth at aphelion: July 6th at 1.02 AU distant

Southward Equinox: September 23rd

Southward Solstice: December21st

In 2023, the Moon orbit versus the ecliptic is 'hilly' as we head towards Major Lunar Standstill in March 2025. This cycle of shallow versus steep follows an 18.6-year span. Expect higher tide fluctuations, as the Full Moon rides high in the sky for northern hemisphere observers in the winter, and low to the south in the summer. This culminates with the 'Long Night's Moon' nearest the December southward solstice. In 2023, this high-riding Full Moon falls on December 26th, the day after Christmas.

The May 19th New Moon is also a 'Black Moon' in the old timey sense of the third in an astronomical season with four, and the August 31st Full Moon is 'blue' in the modern definition of the second full Moon in a calendar month.

Lunar Occultations in 2023

Lunar occultations occur when the Moon passes in front of a planet or bright star. These can be especially dramatic when the Moon is waxing, and the dark limb of our natural satellite leads the way.

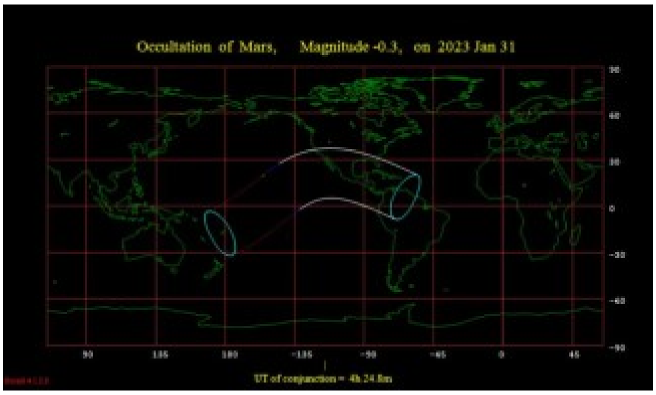
There are 10 occultations of naked eye planets by the Moon in 2023:

-Venus (March 24th) for SE Asia, by a 9% illuminated, waxing crescent Moon

-Venus (November 9th) for Greenland, by a -15% illuminated, waning crescent Moon

-Mars (January 3rd) for southern Africa, by a +92% illuminated, waxing gibbous Moon

–Mars (January 31st) for the southern U.S. and Mexico, by a +74% illuminated, waxing gibbous Moon



Mars occultation footprint for January 31st. Credit: Occult 4.2

-Mars (February 28) for Iceland and northern Scandinavia, by a +59% illuminated, waxing gibbous Moon

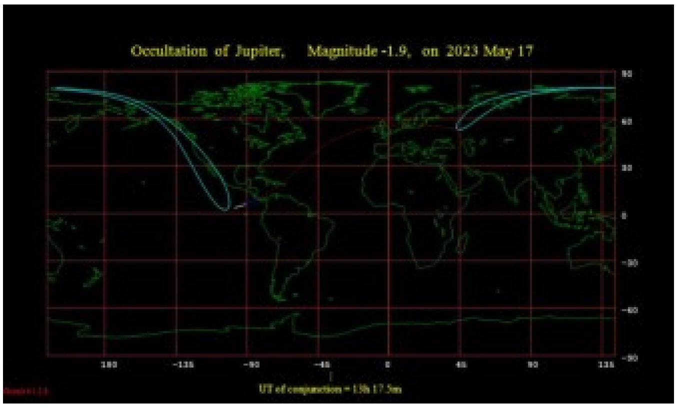
-Mars (September 16) for northeastern South America (North America in the daytime) by a +3% illuminated, waxing crescent Moon

-Mars (October 15) for Antarctica, by a slim +1% illuminated Moon near New

-Jupiter (February 22) for the southern tip of South America, by a +10% illuminated, waxing crescent Moon

-Jupiter (March 22) for the eastern Caribbean, by a +2% illuminated, waxing crescent Moon

-Jupiter (May 17th) for North America, by a +5% illuminated, waxing crescent Moon



Jupiter occultation footprint for May 17th. Credit: Occult 4.2

In the current era, the Moon can also occult four bright +1st magnitude stars (Antares, Spica, Regulus and Aldebaran). The good news is, the Moon starts a series of occultations of Antares (Alpha Scorpii) this year, and blots out the star 5 times in 2023:

-August 25th for North America by a +58% illuminated, waxing gibbous Moon

-September 21st for the western Pacific, by a +35% illuminated, waxing crescent Moon

-October 18th for the Middle East by a +15% illuminated, waxing crescent Moon

-November 14th for eastern North America by a +3% illuminated, waxing crescent Moon

-December 12th for southeast Asia (in the daytime) by a slim -1% illuminated Moon near new

This cycle runs out until one last final occultation of Antares on August 27th, 2028.

Other stars brighter than +3rd magnitude in the synodic path of the Moon in 2023 include Gamma Virginis, Alpha Librae, Sigma Scorpii and Delta Scorpii.

Best Asteroid Occultation for 2023: Rarer still is to see an asteroid pass in front of a distant bright star. Steve Preston maintains a list for the very best asteroid occultation events for the year. Our top pick for 2023 is the occultation of the naked eye star Betelgeuse by asteroid 319 Leona across southern Europe and the southern tip of Florida on December 12th.

Astronomy 2023: The Planets

The planets continue their celestial clockwork dance in 2023 as well. The very best time to observe the inner planets (Mercury and Venus) is when they're near greatest elongation and farthest from the Sun in the dawn or dusk sky, while outer planets are best near opposition, when they rise in the east as the Sun sets in the west, dominating the sky for the entire night.

NASA's solar observing SOHO spacecraft also spies the planetary action as planets transit the field of view of its LASCO C3 and C2 imager. Hopefully, the list of 2023 events and transits will go live here soon.

Astronomy 2023: The Inner Planets

-Mercury reaches greatest elongation 6 times in 2023:

-January 30th, 25 degrees west of the Sun at dawn

-April 11th, 19 degrees east of the Sun at dusk

-May 29th, 25 degrees west of the Sun at dawn

-August 9th, 27 degrees east of the Sun at dusk

-September 22nd, 18 degrees west of the Sun at dawn

-December 4th, 21 degrees east of the Sun at dusk

-Venus reaches greatest (dusk) elongation 45 degrees east of the Sun on June 4th, crosses solar conjunction on August 13th at 5 degrees south of the Sun, then heads back into the dawn sky and reaches greatest elongation 46 degrees west of the Sun again on October 24th.

Astronomy 2023: The Outer Planets

Opposition rollcall for planets in 2023 is as follows:

-Jupiter (November 3rd)

-Saturn (August 27th)

-Uranus (November 13th)

-Neptune (September 19th)

-Pluto (July 22nd)

Astronomy 2023: Conjunctions

Conjunctions occur when the Moon, a star or planets appear near each other in the sky from our Earthly point of view. In keeping with our 'best-of-the-best' doctrine,' here are the closest (less than one degree, or two Full Moon widths apart) conjunctions for 2023:

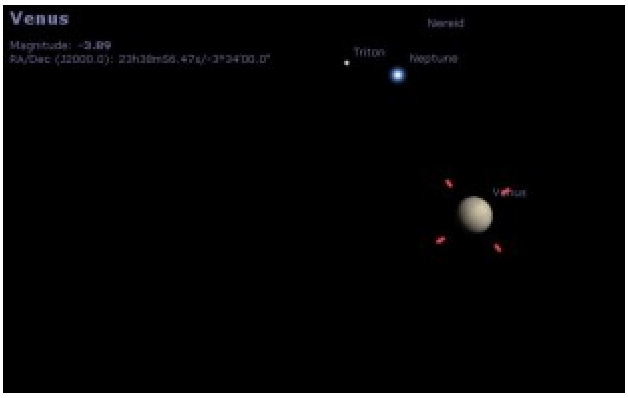
-Best (naked eye) planet vs. planet: Venus-Saturn (January 22nd) 20' apart, 22 degrees east of the Sun.

-Closest planet versus bright star: Mercury-Regulus (July 29th) 6' apart, 25 degrees east of the Sun

Other close conjunctions of planets and bright stars in 2023 include:

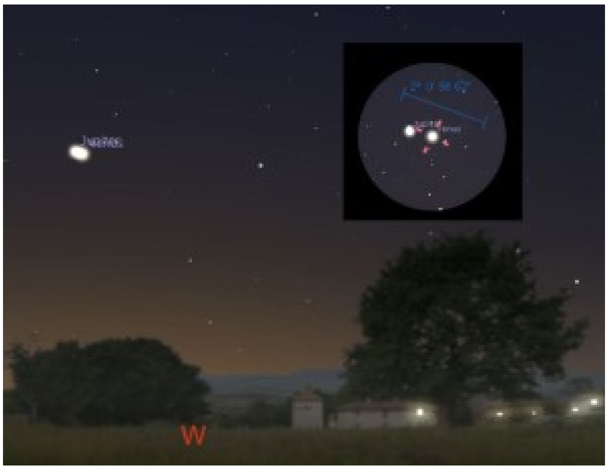
January 22nd: Venus 18' from Saturn (22 degrees east of the Sun).

February 15th: Venus less than 1' (!) from Neptune (28 degrees east of the Sun)



Venus vs. Neptune. Credit: Stellarium.

March 1st: Venus 30' from Jupiter (31 degrees east of the Sun)



Jupiter meets Venus on March 1st at dusk. Credit: Stellarium.

March 2nd: Mercury 54' from Saturn (13 degrees west of the Sun)

July 10th: Mars 36' from Regulus (42 degrees east of the Sun)

July 29th: Mercury 6' from Regulus (25 degrees east of the Sun)

October 29th: Mercury 18' from Mars (6 degrees east of the Sun)

Astronomy 2023: Meteor Showers

There are about a dozen major dependable meteor showers per year, with dozens more minor ones… Of course, the Moon's phase always plays a role, as a near-Full Moon will obscure fainter meteors. From this perspective, favorable showers in 2023 include:

-The Lyrids (April 23rd) Zenithal Hourly Rate (ZHR) ~18 (variable up to 90) with the Moon a +16% illuminated, waxing crescent.

-The Perseids (August 13th) ZHR ~100 with the Moon a -16% illuminated, waning crescent.

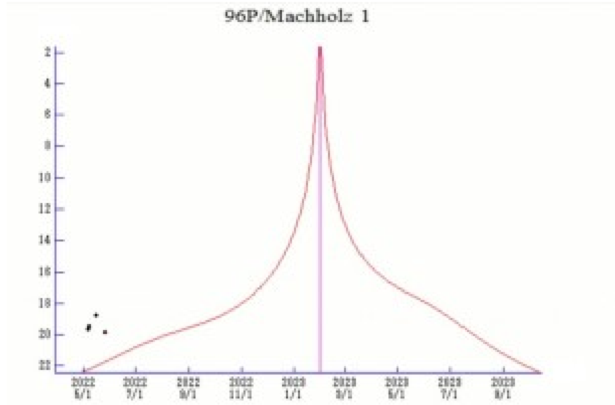
-The Taurids (October 10th) ZHR ~5-15 with the Moon a -15% illuminated, waning crescent. Note that 2023 is also a perihelion year for source comet 2/P Encke.

-The Orionids (October 22nd) ZHR ~20, with the Moon a

+56% illuminated, waxing gibbous.
-The Leonids (November 18^{th}) ZHR 10-15, with the Moon a +31% illuminated, waxing crescent.
-The Geminids (December 14^{th}) ZHR 150, with the Moon a +4% illuminated, waxing crescent.
-Could an Andromedid meteor outburst be on tap for early December 2023? This normally defunct shower was the source of several great meteor outbursts in the 19^{th} century. Fast-forward to the early 21^{st} century, and this shower seems to be making a comeback. Astronomers predict that 2023 may be a storm year for the enigmatic Andromedids. Also, Earth 'may' encounter a debris stream from periodic comet 46P/Wirtanen around December 10th-12th radiating from two possible radiants: one in the southern constellation of Sculptor, and another in the northern constellation of Pegasus.

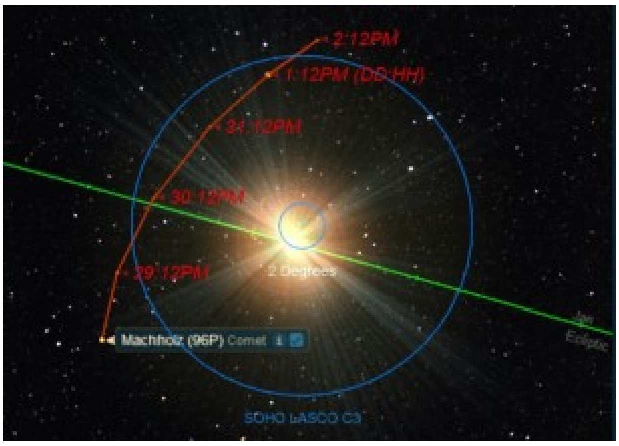
Astronomy 2023: Comets to Watch For

As noted previously, comets come and go. What makes our 'is interesting' radar when it comes to comets is an expected peak magnitude of +10 or brighter. Under this rule, a handful of interesting comets have cropped up in 2023:
-C/2022 E3 ZTF (named after the Zwicky Transient Facility) may reach +5th magnitude in early February 1^{st} as it glides through Camelopardalis into Auriga.
-Comet C/2017 K2 PanSTARRS comes off of perihelion in December 2022, and may still shine at magnitude +8 in the southern constellation of Pavo the Peacock.



The projected 2023 light curve for comet 96P Machholz. Credit: Sechii Yoshida's *Weekly Information About Bright Comets.*

–96P Machholz 1 may top out at $+2^{nd}$ magnitude in February 2023. The comet reaches perihelion on January 31st. Unfortunately, the comet will also pass very close to the Sun at its brightest, and will be visible low to the dawn afterwards.



Comet 96P's path through SOHO's LASCO C3 viewer. Credit: Starry Night

-Comet 263P/Gibbs reaches perihelion on February 2^{nd} in the constellation Capricornus, and may reach +8 magnitude.
-Comet 237P/LINEAR reaches perihelion on May 15^{th} in the constellation Sagittarius, and may reach $+9^{th}$ magnitude.
-Comet T4 (Lemmon) reaches perihelion on July 31^{st}, in the constellation Cetus passing into Telescopium and may reach $+6^{th}$ magnitude.
-Comet 103P/Hartley reaches perihelion on October 12^{th} in the constellation Gemini, and may reach $+8^{th}$ magnitude.
-Comet 2P/Encke reaches perihelion on October 23^{rd} in the constellation Virgo, and may reach $+6^{th}$ magnitude.
-Comet 62P/Tsuchinshan reaches perihelion on December 25^{th} in the constellation Leo, and may reach $+7^{th}$ magnitude.
-Finally, Comet C/2021 S3 PanSTARRS may reach $+8^{th}$ magnitude by year's end going in to 2024, crossing northern Centaurus during this apparition.
And waaaay out in the outer depths of the solar system out past the orbit of planet Neptune, famous Comet 1/P Halley reaches aphelion on December 9th, 2023, at 35.14 AU distant… it's all downhill from there, as the comet begins its plunge towards the inner solar system for perihelion in the summer of 2061. Let's see, by then I'll be…
And of course, we have the next Great North American Total Eclipse to look forward to on April 8^{th}, 2024, as the shadow of the Moon sweeps across Mexico, the U.S. and the Canadian Maritimes.
Isn't it great that we get to share the sky together in 2023? Watch this space, as we expand on these fine celestial events and more in the coming year.
-Thanks to John Flannery for weighing in on his list of the best astronomical events for 2023, and congrats on the first Irish Astronomy Week, coming right up on March 19th, 2023

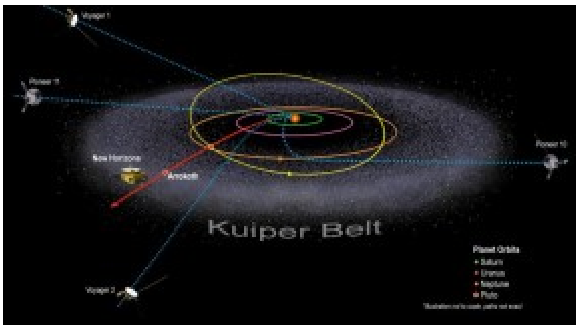
The Universe is Brighter Than we Thought

Over seven years ago, the *New Horizons* mission made history when it became the first spacecraft to conduct a flyby of Pluto. In the leadup to this encounter, the spacecraft provided updated data and images of many objects in the inner and outer Solar System. Once beyond the orbit of Pluto and its moons, it embarked on a new mission: to make the first encounter with a Kuiper Belt Object (KBO). This historic flyby occurred about four years ago (Dec. 31st, 2015) when New Horizons zipped past Arrokoth (aka. 2014 MU69).
Now that it is passing through the Kuiper Belt, away from the light pollution of the inner Solar System, it has another lucrative mission: measuring the brightness of the Universe. These measurements will allow astronomers to make more accurate estimates of how many galaxies there are, which is still the subject of debate. According to new measurements by *New Horizons*, the light coming from stars beyond the Milky Way is two to three times brighter than the light from known populations of galaxies – meaning that there are even more out there than we thought!
The study was led by a team from the Center for Detectors (CfD), an academic research group at the Rochester Institute of Technology (RIT). They were joined by researchers from NASA's Jet Propulsion Laboratory, the Space Exploration Sector (SES) at the Johns Hopkins University Applied Physics Laboratory (JHUAPL), the University of California Irvine, and the Space Sciences Laboratory (SSL) at UC Berkeley. The paper that describes their findings recently appeared online and has been accepted for publication in *The Astrophysical Journal*.
The overall brightness of the Universe is known as the Cosmic Optical Background (COB), which includes the diffuse light given off by all the stars and galaxies in the Universe combined. Like the Cosmic Microwave Background (CMB), the relic radiation left over from the Big Bang, this value is important to astronomers because it allows them to take an inventory of all the normal matter (aka. "luminous matter") in the Universe. This is a challenge here on Earth because of interference caused by sunlight and the way it's reflected by ice particles throughout the Solar System (known as Zodiacal Light).
Space-based telescopes that orbit close to Earth are also subject to interference because of dust between planets that creates foreground light. But any interfering light in the foreground is minimal for a mission like New Horizons, now deep

into the Kuiper Belt and on its way out of the Solar System. To calculate the COB, the team analyzed hundreds of images of background light taken by the New Horizon's Long-Range Reconnaissance Imager (LORRI). Teresa Symons, a postdoctoral researcher at the University of California Irvine, led the study as part of her dissertation while studying for her Ph.D. at the Rochester Institute of Technology (RIT). As she explained in a recent RIT press release:

"We see more light than we should see based on the populations of galaxies that we understand to exist and how much light we estimate they should produce. Determining what is producing that light could change our fundamental understanding of how the universe formed over time."

Previous measurements made in 2021 by researchers from the Space Telescope Science Institute (STScI) revealed that the COB was brighter than expected. This was followed by an independent team of scientists earlier this year that found that the COB was twice as large as originally believed. These latest results validate these previous studies using a much broader set of LORRI observations and hint that there must be additional light sources in the cosmos we have not yet accounted for.



Currently exploring the Kuiper Belt, New Horizons is just one of five spacecraft to reach beyond 50 AUs, on its way out of the Solar System and, eventually, into interstellar space. Credit: NASA/Johns Hopkins APL/SwRI

The New Horizons mission is currently more than 55.85 Astronomical Units (AU) from Earth (or 8.35 billion km; 5.19 billion mi) – almost 56 times the distance between the Earth and the Sun. At this distance, where the foreground light is minimal, astronomers have a much clearer view of the cosmic background and can make more accurate inferences about its galactic population. Symons and her colleagues hope that these observations will pave the way for future missions and instruments that can help explore this discrepancy further.

These include Caltech's Cosmic Infrared Background ExpeRiment-2 (CIBER-2) and NASA's Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx), which will conduct spectrophotometric fluctuations of the cosmic background to learn more about galaxy formation and cosmic evolution since the Big Bang. Co-author Michael Zemcov, a researcher at NASA JPL and a research professor at the RIT's CfD and School of Physics and Astronomy, will play a major role in the SPHEREx mission and its data pipeline.

"This has gotten to the point where it's an actual mystery that needs to be solved," he said. "I hope that some of the experiments we're involved in here at RIT, including CIBER-2 and SPHEREx can help us resolve the discrepancy."

Further Reading: Rochester Institute of Technology, arXiv

Is the Milky Way… Normal?

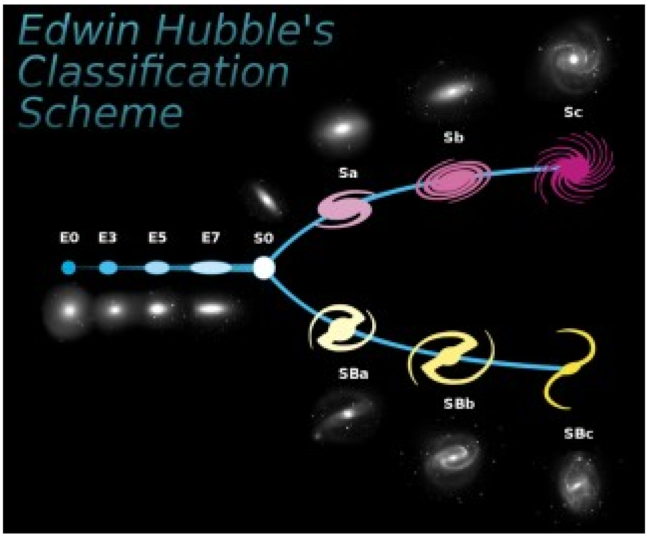
Studying the large-scale structure of our galaxy isn't easy. We don't have a clear view of the Milky Way's shape and features like we do of other galaxies, largely because we live within it. But we do have some advantages. From within, we're able to carry out close-up surveys of the Milky Way's stellar population and its chemical compositions. That gives researchers the tools they need to compare our own galaxy to the many millions of others in the Universe.

This week, an international team of researchers from the USA, UK, and Chile released a paper that does just that. They dug through a catalogue of ten thousand galaxies produced by the Sloan Digital Sky Survey, searching for galaxies with similar attributes to our own.

They discovered that the Milky Way has twins – many of them – but just as many that are only superficially similar, with fundamental differences buried in the data. What they discovered has implications for the future evolution of our own galaxy.

Digging through the Data

To begin their search, the researchers narrowed their sample size by selecting only those galaxies that matched what we know about the Milky Way in three broad categories. First, they filtered for galaxies with a similar total mass to that of the Milky Way. Second, they ruled out galaxies with a vastly different 'bulge-to-total ratio' (the size of the galaxy compared to its bright central core). Finally, they only picked galaxies with a similar 'Hubble Type': a classification system that groups galaxies based on their shape. Some galaxies, like our own, are spiral-shaped, while others, usually older ones, are shaped more like fuzzy blobs, and are known as elliptical galaxies. There are other refinements possible within the Hubble classification system, including bar-shaped centres to some spirals, for example, but the idea was to use the classifications to find rough approximations of the Milky Way from which to begin the more detailed work.



A simple representation of Hubble Classifications, with spiral galaxies on the right (barred galaxies on the lower branch) and elliptical galaxies on the left. Image Credit: Cosmogoblin (Wikimedia Commons).

At the end of this process, the team was left with 138 galaxies superficially similar to our own. From there, they could dig into the details to see just how close our galactic cousins really are to ourselves.

They plugged the data into a model that predicts star formation, taking into account how stellar winds blow excess gas away from star systems, which can be pulled in towards the centre of galaxies. The model also accounted for the chemical composition and metallicity of materials within different regions of the galaxies.

So, what did they find?

It turns out that there are indeed galaxies out there that look a lot like ours. 56 of the 138 galaxies in the sample ended up being a close match to home.

What characterizes these Milky Way-like galaxies is that they have a long timescale in which star formation occurs in their outer regions, steadily birthing new stars in a leisurely fashion. The inner region, on the other hand, experiences a dramatic period of intense star formation early in the galaxy's history, spurred on by a flow of gas being pulled inward towards the centre from the outer region. Later, a much slower period of star formation in the core occurred, relying on recycled gas blown off of older stars in the outer region. These new stars, made of recycled material, have a higher level of metallicity, with heavier elements grafted into them that were lacking in the initial generation of stars. We see this pattern here at home in our own galaxy too.

But this isn't true for all 138 galaxies studied. A significant fraction of the galaxies which at first glance appeared similar to the Milky Way ended up looking very different on closer inspection. These fall into two categories.

The first category (consisting of 55 of the 138 galaxies) are galaxies that appear to have no differentiation at all between their inner and outer regions. These galaxies are experiencing star formation uniformly, in a long slow extended process without the wild burst in the core. In these galaxies, stars in both the inner and outer regions appear identical.

The second category, meanwhile, consists of what are known as 'centrally-quenched' galaxies (27 of 138), and these are perhaps the strangest of the bunch. These outliers seem to lack any significant period of recent star formation from recycled material in their cores, meaning that the radial inflow of gas from the outer regions that we see in the Milky Way isn't occurring in these galaxies.

One consistent feature of these centrally-quenched galaxies is that they appear, as a rule, to have completed most of their star formation in the past, hinting that perhaps they might be older than the Milky Way.

If that's true, perhaps we are looking at the Milky Way's own future. Our galaxy may someday also end up with a quenched centre, and these galaxies therefore represent a preview of the next stage of galactic evolution.

"Perhaps these galaxies are the evolutionary successors of the Milky Way, which are further along in their lives," write the authors.

They also pose some other possible explanations, such as an overly active galactic nucleus that might subdue star formation in the inner regions of the galaxies.

There's still much to learn, but this study offers a lot of new possibilities to chew on when it comes to galactic evolution. Fundamentally, it shows that we are not entirely unique. There is an enormous variety of galaxy types in the Universe, but at least some of them play by the same rules as the Milky Way, and many are at the same life stage. Studying these look-alikes can help us learn more about our own home, giving us the next best thing to holding our galaxy up to a mirror and showing us our reflection.

The paper is available in preprint format on ArXiv: Shuang Zhou, Alfonso Aragón-Salamanca, Michael Merrifield, Brett H. Andrews, Niv Drory, Richard R. Lane. "Are Milky-Way-like galaxies like the Milky Way? A view from SDSS-IV/MaNGA."

Webb's New Image Reveals a Galaxy Awash in Star Formation

When a spiral galaxy presents itself just right, observations reveal more detail. That's the case with NGC 7469, a spiral galaxy about 220 million light-years away. It's face-on towards us, and the James Webb Space Telescope captured its revealing scientific portrait.

NGC 7469 is scientifically interesting for a number of reasons and is the subject of several recent papers based on James Webb Space Telescope (JWST) observations.

It's a luminous infrared galaxy (LIRG) with an active galactic nucleus (AGN.) It's a Seyfert galaxy, which are some of the most intensely studied objects in the Universe. They're similar to quasars but closer and less luminous. Astrophysicists think they're powered by the same source as quasars, but they're easier to observe. NGC 7469 has a bright nucleus and is one of the most studied galaxies of its type. It also has a starburst ring embedded in its circumnuclear region. To top all that off, it's part of a pair of interacting galaxies, the other being the much smaller IC 5283. (The pair is also known as Arp 298 in the *Atlas of Peculiar Galaxies*.)

This striking image from the NASA/ESA Hubble Space Telescope showcases Arp 298, a stunning pair of interacting galaxies. Arp 298 — which comprises the two galaxies NGC 7469 and IC 5283 — lies roughly 200 million light-years from Earth in the constellation Pegasus. Image Credit: ESA/Hubble & NASA, A. Evans, R. Chandar

Because of all of its intriguing characteristics and because it appears face-on from our vantage point, astronomers have studied NGC 7469 intently. It only makes sense that once the JWST became operational, it would also cast its keen infrared eyes on the galaxy.

A recent observing program called GOALS (Great Observatories All-sky LIRG Survey) included the galaxy in its observations. GOALS combines observations of galaxies from multiple sources: Spitzer, Hubble, Chandra, GALEX, and now, the JWST.

The GOALS website says, "Galaxies evolve through a combination of secular processes, such as cold gas accretion, and non-secular processes, such as galactic mergers, which can trigger massive starbursts and powerful AGN. JWST will transform our understanding of galactic evolution, providing a detailed look at the physics of star formation and black hole growth in nearby and distant galaxies."

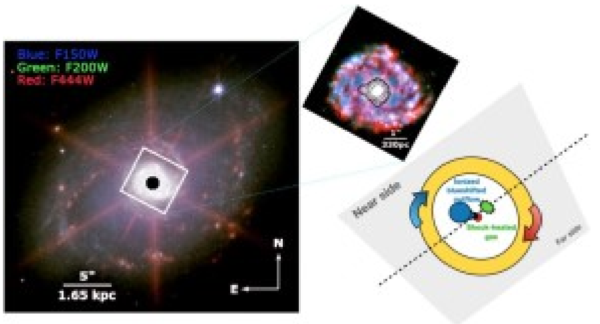
While NGC 7469 is well-studied, its compact nature and its dust are both obstacles to understanding it. But the JWST's power and sensitivity are overcoming those obstacles. The telescope is bringing new understanding to the relationships between the galaxy's central AGN, the starburst ring, and all of the gas and dust.

The newly-released papers show how the JWST is transforming our understanding of galactic evolution. Its instruments—MIRI, NIRCam and NIRspec—have revealed new details hidden from the JWST's predecessors. The GOALS team found very young star-forming clusters never seen before, as well as pockets of very warm, turbulent molecular gas. They also found direct evidence for the destruction of small dust grains within a few hundred light-years of the nucleus — proving that the AGN is impacting the surrounding interstellar medium.

The Webb also revealed more detail in the outflow of molecular gas coming from the galaxy. The gas is ionized and highly diffuse and leaves the galaxy at about 6.4 million kph (4 million mph.)

While the JWST has given us gorgeous images that inspire our spirit of wonder, the images in these studies are more scientific. You won't see them on calendars, but they will appeal to your curious, inner astrophysicist.

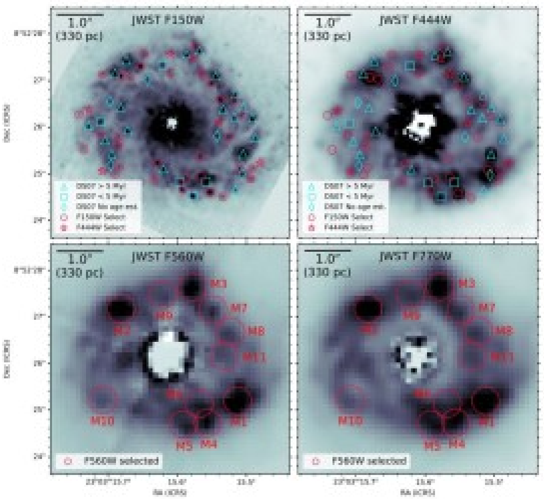
The first of the papers is "GOALS-JWST: Resolving the Circumnuclear Gas Dynamics in NGC 7469 in the Mid-infrared." It's published in the Astrophysical Journal Letters, and the lead author is Vivian U, an Assistant Research Astronomer at the University of California Irvine. This is the first time that mid-infrared gas dynamics in the central region of a LIRG nucleus have been seen so clearly. It's another example of how the JWST's power is pushing our understanding of galaxy evolution forward. The images clearly show how the AGN is depositing energy into the dense interstellar gas via shocks. It's an example of AGN feedback, a subject of great interest to astrophysicists as they try to understand how that feedback shapes the growth and evolution of galaxies.



This image shows NGC 7469's spiral structure with its nucleus blocked out. The white square in the main image is expanded in the upper right image. Since this paper is focused on gas dynamics, the upper right image shows the star-forming ring around the central nucleus. The white-contoured region shows blue-shifted gas travelling toward us from the AGN. The cartoon schematic shows a nearly face-on outflow that appears one-sided and mostly in blueshift (blue cone). The shock-heated gas is the result of outflow striking the galaxy's interstellar medium, an example of AGN feedback. The cartoon isn't to scale; it's just to show one plausible interpretation of the observations. Image Credit: Vivian U *et al.* 2022 *ApJL* **940** L5

The second paper is "GOALS-JWST: NIRCam and MIRI Imaging of the Circumnuclear Starburst Ring in NGC 7469." It's been submitted to Astrophysical Journal Letters but is available at arxiv.org. The lead author is Thomas Bohn, from the Hiroshima Astrophysical Science Center, Hiroshima University, Japan.

This study identified 66 star-forming regions in NGC 7469's starburst ring, 37 of which were not identified in previous Hubble Space Telescope observations. These are likely young stellar populations no older than 5 million years. This shows the JWST's power to see through obscuring dust. "Thanks to JWST, we find a significant number of young dusty sources that were previously unseen due to dust extinction," the authors write. "These results illustrate the effectiveness of JWST in identifying and characterizing previously hidden star formation in the densest star-forming environments around AGN."



These images from the study show the star-forming regions in four separate filters, with the AGN masked out in each one. The cyan and red markers show the star-forming regions according to how they were found. DS07 refers to a previous study of the galaxy with the Hubble (D'iaz-Santos et al. 2007.) The bottom panels show star forming regions from brightest (M1) to faintest (M11.) Image Credit: Bohn *et al.* 2022.

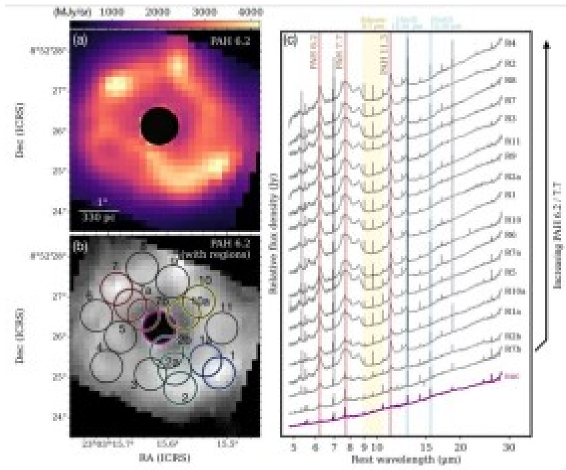
The newly identified regions in this study tend to be the reddest and faintest, according to the authors. That makes sense since the JWST excels at identifying those types of objects. The study results indicate that "… with JWST, we are discovering a large number of heavily obscured sources previously missed by HST." That, in a nutshell, sums up the JWST's purpose.

"In total, we detect 66 star-forming regions in NIRCam," the authors explain."This more than doubles the 30 sources previously identified by HST."

The third study is "GOALS-JWST: Tracing AGN Feedback on the Star-Forming ISM in NGC 7469." It's available at arxiv.org. The lead author is Thomas S.-Y. Lai from IPAC, California Institute of Technology.

AGN feedback is a hot topic in astronomy. It explores how outflow gas from active galactic nuclei deposits energy and momentum into the interstellar medium (ISM.) AGN feedback plays a key role in the evolution of galaxies by redistributing gas. Somehow, SMBHs and their host galaxies co-evolve, and AGN is connected.

This study is focused on Polycyclic Aromatic Hydrocarbons (PAHs). PAHs are a large class of organic chemicals that all contain carbon atoms. They're considered building blocks of life, but they also help astronomers in another way. They glow in star-forming regions and allow astronomers to trace the outlines of the clouds of gas that birth stars. PAHs can also indicate the star-formation rate.



This figure shows extractions of the JWST/MIRI spectra in this study. In (a), the NGC 7469 starburst ring is resolved and bright in PAH emission. (b) shows 17 spectral regions, and they're significant because they sample different surface brightnesses out of the image in (a.) (c) shows the extracted spectra from each region in (b.) While not terribly interesting in a strictly visual sense, it shows how the JWST is propelling our understanding of everything we point it at. Image Credit: Lai *et al.* 2022.

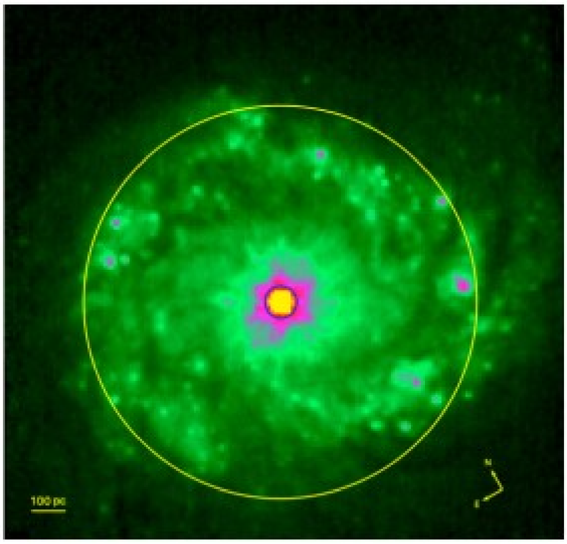
The characteristics of the PAHs in different star-forming regions shed light on AGN feedback in NGC 7469. The authors explain that "… the central AGN <has> only a moderate impact on the dust and gas properties throughout much of the starburst ring." Their study also shows that there's "… no clear sign of shocks from the outflowing wind heating the molecular gas."

What does it all add up to? This data is too preliminary to arrive at any grand conclusions about AGN feedback. But it's a piece of the puzzle that will help guide future observations. "Future observations with JWST will undoubtedly shed great light on the importance of feedback from AGN on star formation in galaxies," the authors write.

The fourth paper is "GOALS-JWST: Mid-Infrared Spectroscopy of the Nucleus of NGC 7469," and it's been submitted to Astrophysical Journal Letters. It's also available at arxiv.org. The lead author is Lee Armus from IPAC, California Institute of Technology. It focuses on the outflow from NGC 7469's Active Galactic Nuclei.

The authors point out how critical LIRGs are in understanding black hole growth. Massive bursts of star formation power most of LIRGs luminosity, but the AGNs also contribute. AGN contributions to the galaxies' luminosity vary widely, and that's something astrophysicists want to understand better.

Previous infrared observatories like the Spitzer Space Telescope were helpful, but Spitzer was limited by its small mirror. Once again, the JWST is pushing the boundaries of infrared observations. Its larger mirror and higher sensitivity are paying dividends. "… we are now poised to greatly extend our understanding of dusty star-forming regions, nascent AGN, galactic outflows, and all variety of active galaxies over an extremely large stretch of cosmic time," the authors write.



This image is another view of NGC 7469's active galactic nucleus and starburst ring. The ring is resolved into dozens of star-forming knots, interspersed with dust lanes and emission regions. This paper focuses on the spectrum from the AGN. Image Credit: Armus *et al.* 2022.

The region around AGNs is complex and multilayered. The authors of this paper call it a "… multi-phase interstellar media surrounding actively accreting supermassive black holes," and they mention how these MIRI images, though early, highlight the JWST's powerful ability to explore the region.

Compared to earlier IR observatories, the JWST's "… greatly increased resolving power allows the shapes of the midinfrared lines and hence the dynamics of the atomic and warm molecular gas, to be analyzed in detail for the first time." One of their findings is that gas in the AGN's nuclear wind is blue-shifted and moving much faster than thought. Perhaps counterintuitively, the mostly blue-shifted gas suggests that NGC 7469's AGN-driven outflow is decelerating. That shows how complex the region is and why detailed observations with the JWST are the best way forward in understanding galaxies, star formation, and black hole growth.

While the Webb's gorgeous images of structures like the Cosmic Cliffs create headlines and fuel our imaginations, these studies show how its resolving power and sensitivity are driving science forward.

The leading image of NGC 7469 is the Webb's picture of the month for good reason. The galaxy's spiral arms, its bright nucleus, and even the diffraction spike from the telescope itself are all important ingredients in a tasty image. But as these four early paper show, the JWST is delivering a wealth of data alongside its more accessible images. With a $10 billion+ price tag, that's really what the telescope is all about.

Perseverance Places its First Sample on the Surface of Mars. One Day This Will be in the Hands of Scientists on Earth

In the not-too-distant future, a planetary scientist will open up a tube of rocks that came from Mars. Thanks to the Perseverance rover, there are at least 17 of these rock and regolith samples, just waiting for analysis on Earth. To get them, the rover has covered about 13 kilometers on its Mars geology field trip.

The rover has been drilling and scooping since shortly after landing, squirreling away rocks and sand into special tubes for transport. It dropped its first load near a place called "Three Forks" this week. That tube contains bits of igneous rock it found in January of this year.

It wasn't just a "drop and run". Mission engineers had to make sure the tube landed safely. So, they did it slowly. First, Perseverance pulled the container out of its belly. Then it looked everything over with a camera before dropping the tube down 90 centimeters onto the surface. Then another image showed mission engineers the sample was safely in position on its side for easy pickup.

Eventually, all the containers Perseverance has filled will make their way to labs on Earth. Scientists will analyze them to understand the chemical and mineral properties of the samples. From there, they can construct a more accurate geological and atmospheric history of the Red Planet.

"Choosing the first depot on Mars makes this exploration campaign very real and tangible," said David Parker, ESA's director of Human and Robotic Exploration. "Now we have a place to revisit with samples waiting for us there."

What Will We Learn from the Perseverance Mars Rock Samples?

Mars is an enigma of a planet. Its history is complex. Volcanoes exist there. How long ago were they active? Canyons split the landscape. What caused those tectonic actions? Craters scar the planet, digging up material from deep beneath the surface. And, places on Mars clearly show evidence of flowing liquid water. Yet, no water flows there now. It's all locked up in subsurface ice or at the poles. So, how do we find out more about the geological history of the planet?

An igneous rock called Rochette that Perseverance sampled for return to Earth. Courtesy NASA/JPL/Perseverance mission.

The most direct way is to look at rock samples. Mars has igneous rock, as well as sandstones, mudstones, and clays. And, of course, there's dust and sand nearly everywhere. All of those can tell something about the time on Mars when lava flowed, lakes and oceans existed, and when it all happened. Detailed technical analysis of igneous rocks will tell how long ago the volcanoes were active. Chemical and mineralogical clues in Mars rocks will help planetary scientists understand if they were in contact with water. Finally, all of that information should help scientists figure out if and when Mars could have supported life.

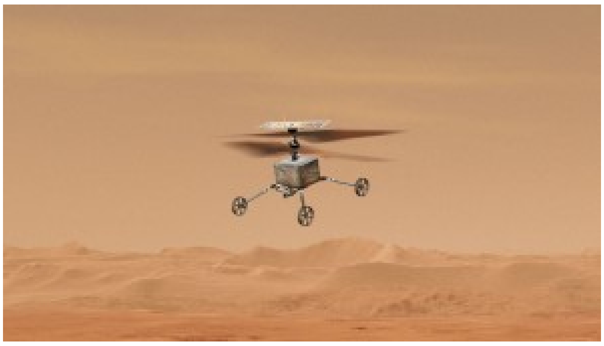
The rock samples that Perseverance gathers come from different rock "regimes" in Jezero Crater. Orbital images show that this region was once an ancient delta that was flooded with water. It appears to be rich in clay minerals and carbonates, which form only in the presence of water. Those same carbonates contain a record of Mars's ancient climate. Yet, here's another interesting thing about them: on Earth, living organisms can also produce carbonates. It's not clear if those on Mars have the same life-friendly origin, but it does make Jezero Crater a tantalizing place to sample.

Establishing a Rock Pipeline from Mars to Earth

The sample-gathering expedition using the tubes has been part of the program from the beginning. The original idea was to have the rover gather and deliver them to the NASA Sample Return Lander (SRL). That mission is being planned and built by NASA and the European Space Agency for launch later this decade. It should land in Jezero Crater near Perseverance to make for easy delivery of the tubes. The lander is equipped with a sample transfer arm built by ESA for the job.

The planned sample-retrieval mission that will gather up rocks Perseverance has collected for return to Earth. Courtesy: NASA/JPL.

Of course, scientists don't want to leave anything to chance. So, the mission also has a backup plan in case Perseverance can't deliver. Mission scientists will send a couple of small helicopters out to gather the samples. We know that could work because the Ingenuity chopper has been cranking away in overtime, showing scientists just what a Mars chopper can do.



A proposed sample recovery helicopter based on the Ingenuity design. If Perseverance can't bring the samples to the lander, then these will gather them up. Courtesy: NASA/JPL

Once the rocks are onboard the SRL, they'll get loaded into a small rocket that will take off from the surface. Once in space, it will deliver them to an ESA-built spacecraft orbiting Mars for eventual return to Earth. If all goes well, the rocks are expected to be in labs for more detailed study sometime in 2033.

Webb Stares Deeply Into the Universe, Showing How Galaxies Assemble

The James Webb Space Telescope is delivering a deluge of images and data to eager scientists and other hungry-minded people. So far, the telescope has shown us the iconic Pillars of Creation like we've never seen them before, the details of very young stars as they grow inside their dense cloaks of gas, and a Deep Field that's taken over from the Hubble's ground-breaking Deep Field and Ultra Deep Field images. And it's only getting started.

True to its main science objectives, the JWST has peered back in time to the Universe's earliest galaxies looking for clues to how they assemble and evolve.

PEARLS, the Prime Extragalactic Areas for Reionization and Lensing Science, is one of the Webb Telescope's observing programs. In a new paper in the Astronomical Journal, a team of researchers behind PEARLS explained the program and presented their first findings. The paper is "JWST PEARLS. Prime Extragalactic Areas for Reionization and Lensing Science: Project Overview and First Results."

The name 'Prime Extragalactic Areas for Reionization and Lensing Science' is an unwieldy mouthful of words, but we can break it down to figure out how it's relevant.

There's only one way to understand the Universe and what led up to us, and everything else we can observe in the Universe. We have to somehow wind the clock back to long before the Earth, the Sun, our Solar System, or even the Milky Way existed in its present form. Fortunately, the Universe hasn't expanded so much yet that all the other galaxies have disappeared over the observational horizon.

"The main goal of PEARLS is to study the epoch of galaxy assembly, active galactic nucleus (AGN) growth, and First Light."

From the paper "JWST PEARLS. Prime Extragalactic Areas for Reionization and Lensing Science: Project Overview and First Results."

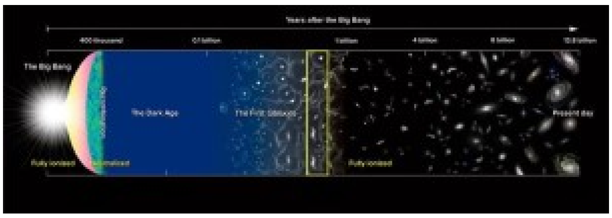
Instead, we can see billions of galaxies in the sky, and some of the light from ancient galaxies and the Universe's early days is only now reaching us after its 13+ billion-year journey. Scientists know this, and they knew the only way to examine that light in great detail and unearth clues to our origins was to build a powerful, discerning telescope that can look back in time and see the faintest, most red-shifted galaxies. So they built the James Webb Space Telescope with its powerful capabilities to observe in the infrared.

So far, the JWST has lived up to expectations and even exceeded them.

"Webb's images are truly phenomenal, really beyond my wildest dreams."

Rogier Windhorst, lead author, JWST PEARLS.

The PEARLS program was born of the need to look back in time to the earliest days of the Universe. The term Extragalactic in PEARLS means the program is looking at fields of galaxies rather than individual galaxies. Reionization refers to the formation of the earliest stars and galaxies energetic enough to reionize the Universe and make it transparent. That signalled the end of the Universe's Dark Ages and the appearance of the Universe's first light. Lensing refers to gravitational lensing, which is how the gravity from massive structures like galaxy clusters can act as a lens, amplifying the light from objects behind the cluster. It allows astronomers to study objects at even more extreme distances.



Milestones in the history of the Universe (not to scale). The intergalactic gas was in a neutral state from about 300,000 years after the Big Bang until the light from the first generation of stars and galaxies began to ionize it. That brought an end to the Universe's Dark Age. The gas was completely ionized after 1 billion years. Image Credit: NAOJ.

Add it all up, and you get PEARLS. "The main goal of

PEARLS is to study the epoch of galaxy assembly, active galactic nucleus (AGN) growth, and First Light," the authors explain in their paper. "PEARLS' main science goals address JWST's first two themes: First Light and Reionization, and Assembly of Galaxies, including supermassive black hole (SMBH) growth."

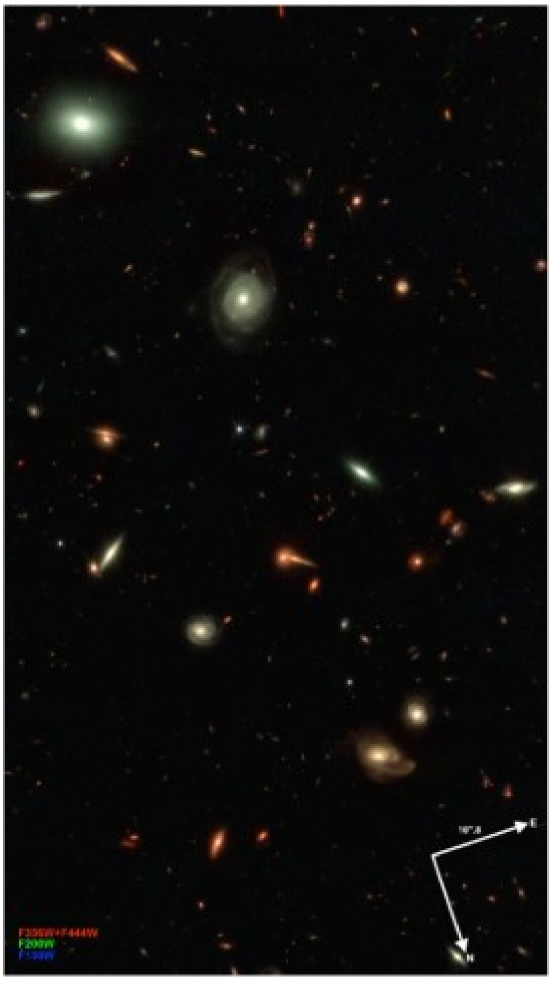
"The stunning image quality of Webb is truly out of this world," said Anton Koekemoer, a research astronomer at STScI who assembled the PEARLS images into very large mosaics. "To catch a glimpse of very rare galaxies at the dawn of cosmic time, we need deep imaging over a large area, which this PEARLS field provides."

PEARLS has captured one of the first medium-deep wide-field images of the cosmos. It features the North Ecliptic Pole region of the sky. The images show how the gravitational lensing from galaxy clusters in the foreground brings more distant objects into view. Some of the distant objects are ancient galaxies interacting with each other. Some of them are Active Galactic Nuclei, extremely luminous regions at the center of galaxies, where black holes superheat material that falls toward them. The AGN images should provide clues to how supermassive black holes (SMBHs) grow so large, an extremely active area of research.

PEARLS has captured one of the first medium-deep wide-field images of the cosmos. This image is only one-quarter the size of the final image and features interacting galaxies with active nuclei. Click the image for a much larger, zoomable version of the image. It's filled with red-shifted objects that date from the Universe's early days. Image Credit: SCIENCE: NASA, ESA, CSA, Rolf A. Jansen (ASU), Jake Summers (ASU), Rosalia O'Brien (ASU), Rogier Windhorst (ASU), Aaron Robotham (UWA), Anton M. Koekemoer (STScI), Christopher Willmer (University of Arizona), JWST PEARLS Team
IMAGE PROCESSING: Rolf A. Jansen (ASU), Alyssa Pagan (STScI)

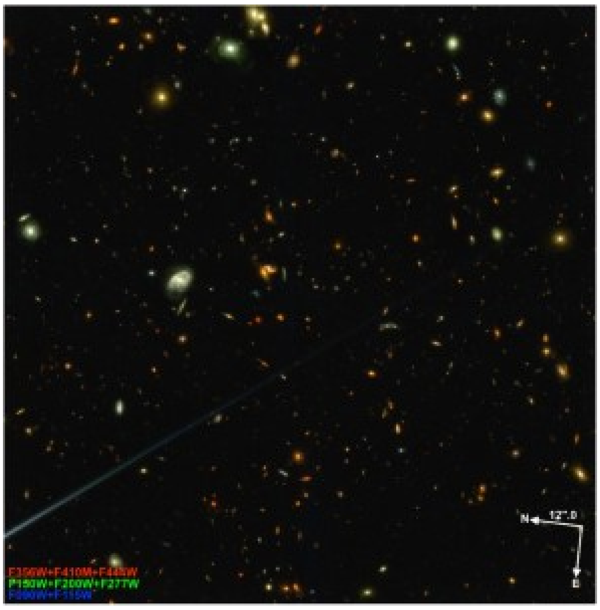
Research Scientist Rolf Jansen is one of the paper's co-authors. He studies how the earliest galaxies formed and how they evolved into the forms they take today. "I was blown away by the first PEARLS images," Jansen said. "Little did I know, when I selected this field near the North Ecliptic Pole, that it would yield such a treasure trove of distant galaxies and that we would get direct clues about the processes by which galaxies assemble and grow — I can see streams, tails, shells and halos of stars in their outskirts, the leftovers of their building blocks."

PEARLS will observe the same regions of the sky four times, making it an important time domain survey.



This image is the PEARLS NIRCam image of the IRAC Dark Field (JWIDF) Epoch-1 at the north Ecliptic pole. The IRAC Dark Field is one of two fields PEARLS will observe, and it's considered a blank field that's suited to time domain surveys. PEARLS will observe this field and its other targets up to four times in one year. Image Credit: STScI/Windhorst *et al.* 2023.

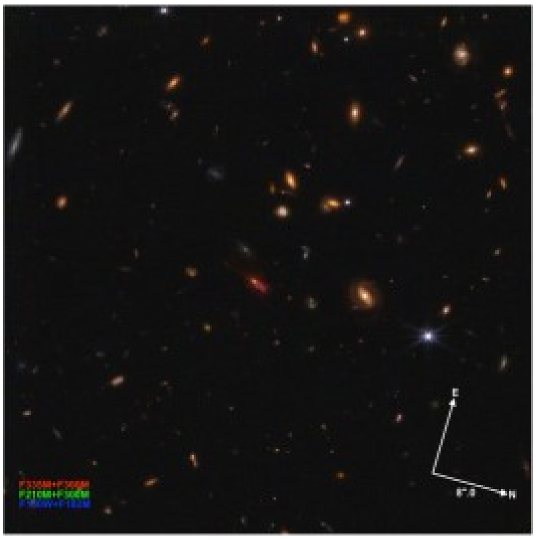
The authors explain how PEARLS will image "… several rich galaxy clusters that boost the signal of faint, high-redshift objects via strong gravitational lensing." PEARLS observed six galaxy clusters for their gravitational-lensing characteristics. "All of our selected clusters show gravitationally lensed arcs," the authors explain.



This image is of the El Gordo cluster, a cluster of galaxies chosen for its enormous mass. This image doesn't show the center of the cluster, but it has a "rich collection of distant lensed source candidates," according to the authors. STScI/ Windhorst *et al.* 2023.

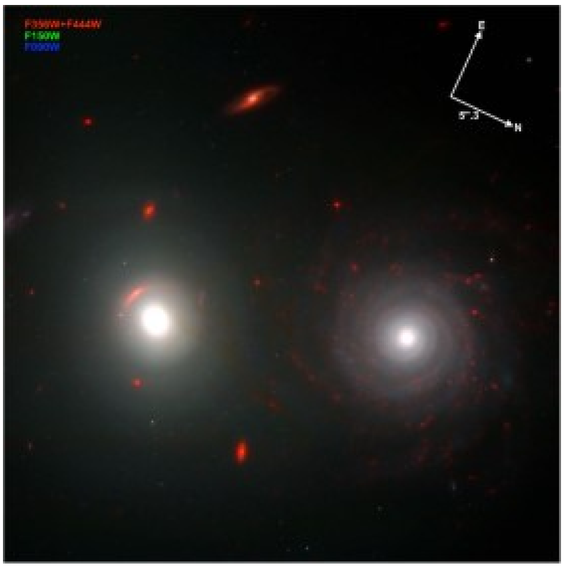
Research assistant Jake Summers is one of the paper's co-authors. "The JWST images far exceed what we expected from my simulations prior to the first science observations," Summers said. "Analyzing these JWST images, I was most surprised by their exquisite resolution."

Galaxy clusters are the second-largest type of gravitationally bound structures in the Universe, second only to galaxy filaments. PEARLS will observe two young protoclusters from the Universe's early age. One of them is the embryonic cluster named TNJ1338-1942. It's the most distant known protocluster and is only about 1.5 billion years old.



This image shows the TNJ1338-1942 protocluster, the most distant known protocluster. It contains a luminous, steep-spectrum radio source. The radio source is an active galactic nucleus, and a future JWST observing program will study it in more detail. The radio source is the irregular orange object in the center. Image Credit: STScI/Windhorst et al. 2023.

PEARLS also imaged the VV 191 pair of galaxies. They're so faint and red that when the Hubble looked at this region, they were invisible. That's a testament to the JWST's capabilities. VV 191 features an elliptical galaxy (VV 191a) on the left and a spiral galaxy (VV 191b) on the right. The orange arc south of VV 191a is a distant galaxy that's gravitationally lensed by VV 191a.



The PEARLS NIRCam image of the VV 191 system. VV 191a on the left is gravitationally lensing the red galaxy at 10 o'clock and stretching its light into a curve. Image Credit: STScI/Windhorst et al. 2023.

"For over two decades, I've worked with a large international team of scientists to prepare our Webb science program," lead author Windhorst said. "Webb's images are truly phenomenal, really beyond my wildest dreams. They allow us to measure the number density of galaxies shining to very faint infrared limits and the total amount of light they produce. This light is much dimmer than the very dark infrared sky measured between those galaxies."

Galaxies that were invisible to the Hubble appear in large numbers in JWST images. These first PEARL images show objects as faint as 10 fireflies as far away as the Moon. That's an incredible achievement. It means the faintest red objects in the images date back to only a few hundred million years after the Big Bang.

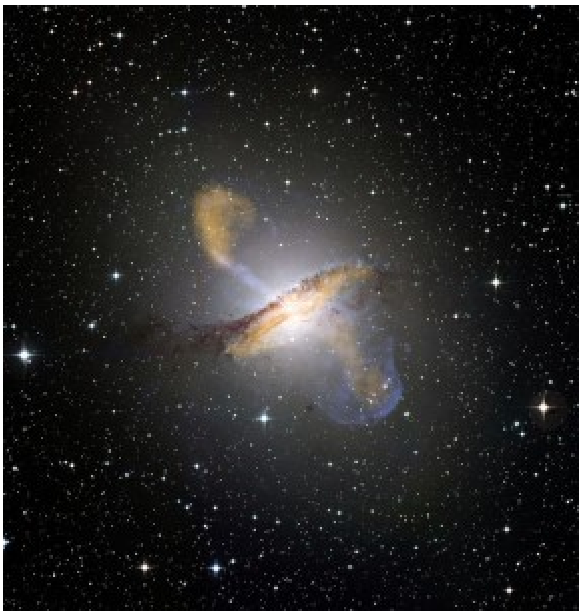
The faint light in between stars and galaxies is also an object of interest to astronomers. Scientists cannot abide by unexplained light in the Universe. When astronomers work with images and remove all the light from known sources, like stars and galaxies, a tiny bit of light remains. They call it "ghost light," and its source is still being investigated. Some astronomers call it the sky's surface brightness, and it might be related to missing faint galaxies. If they're there, the powerful JWST should find them.

Third-year astrophysics graduate student Rosalia O'Brien is one of the paper's co-authors. She designed algorithms to measure faint light between the galaxies and stars that first catch our eye.

"The diffuse light that I measured in between stars and galaxies has cosmological significance, encoding the history of the universe," O'Brien said. "I feel fortunate to start my career right now — JWST data is like nothing we have ever seen, and I'm excited about the opportunities and challenges it offers."

The fields that PEARL is imaging will likely be monitored throughout JWST's mission. PEARL will be a time-domain study of the region as it images it four times in one year. But after that, others may study the same region due to its accessibility and desirability as a target.

"I expect that this field will be monitored throughout the JWST mission to reveal objects that move, vary in brightness or briefly flare up, like distant exploding supernovae or accreting gas around black holes in active galaxies," Jansen said.



This is Centaurus A, the nearest galaxy with an active nucleus. The active nucleus is where a supermassive black hole (SMBH) resides. One of the questions in astrophysics is how SMBHs grow so large, and the JWST should help answer that question by looking at more ancient active nuclei. Image Credit: By ESO/WFI (Optical); MPIfR/ESO/APEX/A.Weiss et al. (Submillimetre); NASA/CXC/CfA/R.Kraft et al. (X-ray) – http://www.eso.org/public/images/eso0903a/, CC BY 4.0,

https://commons.wikimedia.org/w/index.php?curid=5821706
"This unique field is designed to be observable with Webb 365 days per year, so its time-domain legacy, area covered, and depth reached can only get better with time," said lead author Windhorst.
This is just a taste of what the JWST has in store for scientists. In their paper's conclusion, the authors spell out how the new space telescope will advance our understanding of the early Universe.

The galaxy cluster SMACS 0723 as seen by NIRCam on JWST (Not part of PEARL.) Its gravitational lensing properties (from its mass and from the mass of dark matter) are helping astronomers identify 88 distant galaxies in this field of view for further study. These distant galaxies are the most ancient and are critical to understanding how the Universe takes the shape it does today. JWST images like this also show evidence of dark matter, another question waiting for an answer. Courtesy NASA, ESA, CSA, STScI
"With the enormous new range in both flux and wavelength that the JWST images provide, the community will now have the resources to expand and deepen the study of the morphology, SED (spectral energy distribution), star formation rates, masses, dust content, and extinction at redshifts extending to the epoch of first light, as well as better constrain how much diffuse light may be present in the infrared."
Young scientists just beginning their careers as the JWST begins its mission aren't the only fortunate ones. For those of us who grew up on Hubble images, the James Webb is also a source of excitement and discovery. It'll be fun watching as researchers working with Webb continue to make progress on some long-standing questions.

What Kind of an Impact did DART Have on Dimorphos? The Science Results are Here

On September 26th, NASA's Double Asteroid Redirection Test (DART) spacecraft collided with Dimorphos, the small moonlet that orbits the larger Near-Earth Asteroid (NEA) Didymos. The purpose was to test a planetary defense technique known as the kinetic impact method, where a spacecraft intentionally collides with a Potentially Hazardous Asteroid (PHAs) to alter its course. Based on a post-collision analysis, NASA determined that DART's impact altered Dimorphos' orbital period by 33 minutes and caused tons of rock to be ejected from its surface.
Since the collision, NASA has also been monitoring the cloud of ejecta produced by the impact to see how it has since evolved. The purpose of this is to better understand what the DART spacecraft achieved at the impact site, how much of it was delivered by the spacecraft, and how much was due to the recoil produced by the ejection. On December 15th, during the Fall Meeting of the American Geophysical Union (AGU) in Chicago, members of the DART team provided the preliminary analysis of their findings.

Artist's impression of the DART mission impacting the moonlet Dimorphos. Credit: ESA
Tom Statler, the program scientist for DART, was one of the presenters at the briefing. As he related in a recent NASA press statement:
"What we can learn from the DART mission is all part of a NASA's overarching work to understand asteroids and other small bodies in our Solar System. Impacting the asteroid was just the start. Now we use the observations to study what these bodies are made of and how they were formed – as well as how to defend our planet should there ever be an asteroid headed our way."
The team's report consists of a detailed analysis of all the science and engineering data that focused on measuring the momentum transfer imparted by the DART spacecraft – which was traveling at roughly 22,530 km/h (14,000 mph) when it struck. Being able to predict momentum transfer accurately is vital to planning future kinetic impact missions in the event that an asteroid is likely to impact Earth. This includes determining the impactor's size and estimating the lead time needed to push an asteroid off its path.
Based on observations before and after, the team learned that Dimorphos and Didymos have very similar compositions. Both are composed of chondrite, rocky material that formed from dust and small grains in the early Solar System, the same material found in the most common type of meteorite to impact Earth. These measurements also incorporated telescope images of the ejecta, which accounted for the majority of reflected sunlight by the double-asteroid in the days following the impact. These showed how solar radiation pressure stretched the ejecta stream into a twin tail (similar to what comets form) that measures about 10,000 km (6,200 mi).

The last complete image of asteroid moonlet Dimorphos, taken by the DRACO imager on NASA's DART mission 2 seconds before impact. Credits: NASA/Johns Hopkins APL
Scientists also estimate that DART's impact displaced over a thousand metric tons (two million lbs) of chondrite rock into

space – about the same weight as a cargo ship. This data was combined with new information on the moonlet's composition and the ejecta's characteristics. They also consulted telescope observations and images taken by DART's ride-along CubeSat companion – the Light Italian CubseSat Imaging of Asteroids (LICIACube) – contributed by the Italian Space Agency (ASI).

Based on all this data and assuming that Didymos and Dimorphos have the same densities, the team calculated the momentum transferred by the DART impact compared to the recoil generated by the ejected mass. Ultimately, they found that the total momentum transfer from the impact and ejecta was roughly 3.6 times greater than if the asteroid had absorbed the spacecraft and produced no ejecta at all. As Andy Cheng, the DART investigation team lead from Johns Hopkins Applied Physics Laboratory (JHUAPL), explained:

"Momentum transfer is one of the most important things we can measure, because it is information we would need to develop an impactor mission to divert a threatening asteroid. Understanding how a spacecraft impact will change an asteroid's momentum is key to designing a mitigation strategy for a planetary defense scenario."

The DART test proved that the kinetic impact technique has the potential to divert an asteroid on approach to Earth. The task now is to apply this knowledge so that future asteroid defense spacecraft can be built and the technique tested further. The success of these tests could mean the difference between the continued safety of all life on Earth (and our civilization) and a massive impact that causes mass extinction someday.

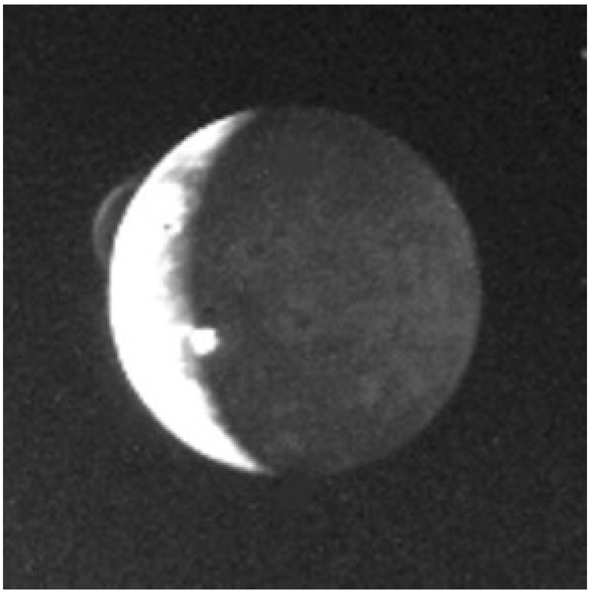
Juno's has Been Touring Jupiter's Moons on its Extended Mission. Next Stop: Volcanic Io

For a tiny moon orbiting a giant planet, Io sure packs a giant wallop. It's the most volcanic world in the solar system. Due to that extreme volcanism, scientists with the Juno mission are now focusing the spacecraft's instruments and cameras on Io. They want to know more about its eruptions and how its constant stream of material into space interacts with Jupiter's magnetosphere.

Over the next year and a half, the Juno spacecraft will make nine close flybys of Io. At least one loop will bring it within 1500 kilometers of the surface, giving an up-close and personal look at the volcanic action. "The team is really excited to have Juno's extended mission include the study of Jupiter's moons. With each close flyby, we have been able to obtain a wealth of new information," said Juno Principal Investigator Scott Bolton of the Southwest Research Institute in San Antonio. "Juno sensors are designed to study Jupiter, but we've been thrilled at how well they can perform double duty by observing Jupiter's moons."

Io Bubbles with Volcanoes

Io is a rocky moon that orbits Jupiter at a close distance of only 422,000 kilometers. Galileo Galilei discovered this moon in 1610. In 1979, Voyager navigation team astronomer Linda Morabito noticed a plume in a Voyager 1 image. That discovery confirmed predictions of volcanic activity due to Io's unique position in the Jovian system.



The discovery image from Voyager 1 of Io's volcanic plume. Courtesy NASA/JPL.

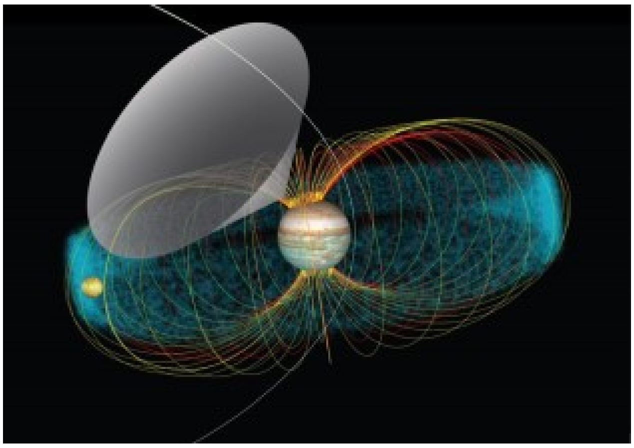
The volcanic activity on Io gives it a mottled, pizza-like appearance. There are hundreds of vents and calderas on the surface and these create a huge variety of interesting features. Volcanic plumes and lava flows across the surface show up in a palette of colors, from red and yellow to orange and black. Some of the lava "rivers" stretch for hundreds of kilometers.

Why is Io volcanic? Look at where it is. Jupiter on one side and two outer moons on the other. The planet's huge gravity pulls on Io while Europa and Ganymede tug on it from their direction. That tug-of-war actually deforms Io, basically stretching and squeezing it. The friction of that action heats the interior, in a process called "tidal heating." That causes the surface to bulge up and down as much as 100 meters. The result of the heating, heaving, and pulling, is a surface dotted with volcanic features.

Io constantly "repaves itself" with lava. That volcanism also feeds a thin atmosphere made mostly of sulfur dioxide. It also sends particles into the magnetosphere, where they create a huge donut-shaped "torus" of plasma surrounding Jupiter. The moon itself travels inside Jupiter's much stronger and more extensive magnetosphere and the magnetic field lines trap particles from the torus. They spiral into the Jovian poles and create glowing auroral displays.

What Will Juno Learn Here?

The Juno spacecraft is on a two-year extended mission, focusing on the Jovian moons. It recently flew past Ganymede and Europa, gathering data about those two icy moons. It extended our view of Ganymede under the surface. At Io, it will speed through the extended torus of ions several times to get more information about the radiation environment. This is useful information for the upcoming JUICE and Europa Clipper missions.



Artist's concept of the Jupiter-Io system and their interaction. The blue region is the Io plasma torus made from particles ejected from Io volcanoes. The magnetic field lines emanate from Jupiter; radio waves are generated by activity in the magnetosphere (grey cone), which Juno can detect when it's in the right position. Courtesy: NASA/GSFC/Jay Friedlander

The 9 flybys of Io will provide Junocam and other instruments ample opportunity to get high-resolution images of the rugged Io surface and provide plenty of other data about this tiny moon. It has already made one infrared image showing the glowing hotspots of its eternally active volcanoes.

As it loops the moons, Juno also will continue to study Jupiter, focusing on its internal structure, magnetic field, atmosphere, and magnetosphere. As its orbit slowly evolves over the next two years, it will focus on studies of the Io and Europa torus regions. In addition, Juno will continue its study of the dusty faint rings of Jupiter. All the images and data should give a much fuller understanding of the activities on Jupiter, its moons, and how they are interconnected.

The Oort Cloud Could Have More Rock Than Previously Believed

The Oort Cloud is a collection of icy objects in the furthest reaches of the Solar System. It contains the most distant objects in the Solar System, and instead of orbiting on a plane like the planets or forming a ring like the Kuiper Belt, it's a vast spherical cloud centred on the Sun. It's where comets originate, and beyond it is interstellar space.

At least that's what scientists think; nobody's ever seen it.

A new study shows that the Oort Cloud is not exclusively the domain of frozen objects. There's more rock there than we thought. And if there's more rock there than we thought, it changes our understanding of how the Solar System formed. The study is based on a meteoroid that burned up in the sky over Alberta in 2021.

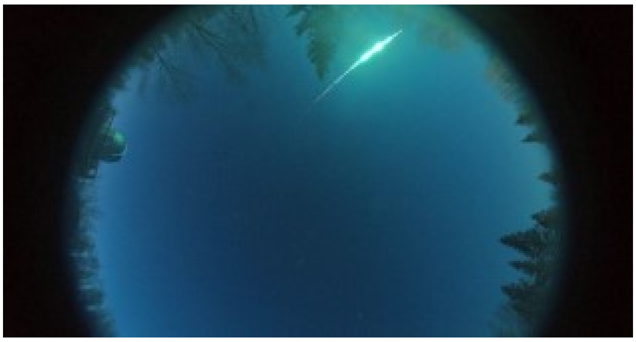
"This discovery supports an entirely different model of the formation of the Solar System."

Denis Vida, study lead author, Western University.

The study is "Direct measurement of decimetre-sized rocky material in the Oort cloud," published in Nature Astronomy. The lead author is Denis Vida, a meteor physics postdoctoral researcher at Western University in London, Ontario, Canada.

"This discovery supports an entirely different model of the formation of the Solar System, one which backs the idea that significant amounts of rocky material co-exist with icy objects within the Oort cloud," said Vida. "This result is not explained by the currently favoured Solar System formation models. It's a complete game changer."

Door camera videos of the fireball created a stir when the meteoroid burned up over Alberta in February 2021. Scientific cameras with the Global Fireball Observatory (GFO) program also captured the fireball. The GFO is a global collaboration including institutions like NASA Ames Research Center, the Lunar and Planetary Institute, Western University, and many others. The GFO takes pictures of fireballs so scientists can recover the ones that reach Earth.



This image of the fireball is from the Global Fireball Observatory camera at Miquelon Lake Provincial Park, Alberta. Image Credit: University of Alberta.

The researchers in this study used tools from another collaboration, the Global Meteor Network (GMN), to calculate its origins. The GMN is a citizen-science project, a network of cameras on homes worldwide aimed at the sky. There are over 500 of them in 31 countries, and they log data each night and send it to a central repository. Scientists use it to determine the orbits of meteors.

A specialized satellite provided data for the study, too. It's called the Geostationary Lightning Mapper (GLM.)

Bright flashes from fireballs can over-saturate some cameras, but the GLM excels at spotting them because it's designed to map lightning. The GLM takes 500 images per second, enough data to reveal the detail in a meteoroid's path through the atmosphere. When the researchers combined GLM observations with the coverage from ground-based cameras, the data set increased in breadth and depth.

With all these ground-based and satellite-based data, Vida and his colleagues understood they were dealing with something unusual.

"In 70 years of regular fireball observations, this is one of the most peculiar ever recorded."

Hadrien Devillepoix, Curtin University, Australia, principal investigator of the GFO

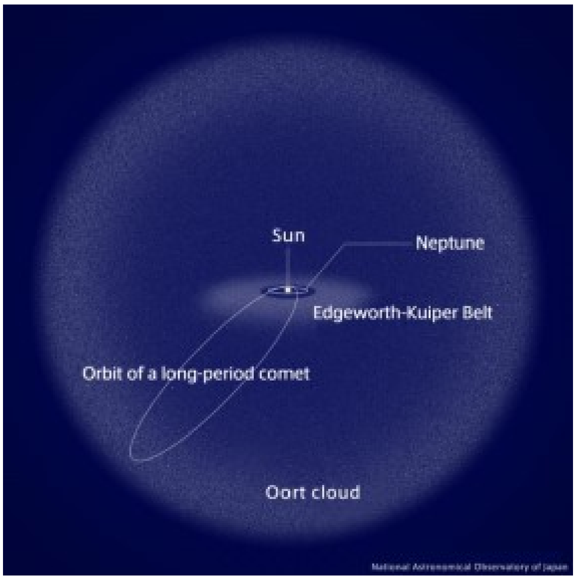
Objects on similar orbits as this one typically burn up in the atmosphere's upper reaches more quickly because they're icy and less dense. But this one took much longer to burn up and travelled more deeply into the atmosphere. That told researchers that the Alberta fireball had to be a rocky object. The research team says it was a 2kg chunk of rock the size of a grapefruit. And this rock came from much further away than previous rocky fireballs.

"In 70 years of regular fireball observations, this is one of the most peculiar ever recorded. It validates the strategy of the GFO established five years ago, which widened the 'fishing net' to ~5 million square kilometres of skies and brought together scientific experts from around the globe," said Hadrien Devillepoix, research associate at Curtin University, Australia, and the principal investigator of the GFO. "It not only allows us to find and study precious meteorites, but it is the only way to have a chance of catching these rarer events that are essential to understanding our Solar System."

These images show the fireball as seen from the two GFO stations. It was observed for a total of 2.4 seconds with a path length of 148.5 km. Top: Miquelon Lake. Bottom: Vermilion (the Big Dipper can be seen on the left side). The fireball is moving left to right, and the periodic breaks in the fireball are used to encode the absolute time to an accuracy of 1 ms. Image Credit: GFO/Vida *et al*. 2022

The rocky object travelled at a velocity of 62.1 km s^{-1} and penetrated down to a height of 46.5 km, just inside the stratosphere. An icy object should never have made it that close to Earth.

The chunk of rock is undoubtedly rare, or at least its pathway to Earth is. It follows a Long Period Comet (LPC) orbit, and LPCs come from the Oort Cloud. LPCs have orbits longer than 200 years and are highly inclined compared to the ecliptic, the orbital plane of the planets around the Sun. Its orbit is also retrograde, meaning it's reversed compared to the planets.



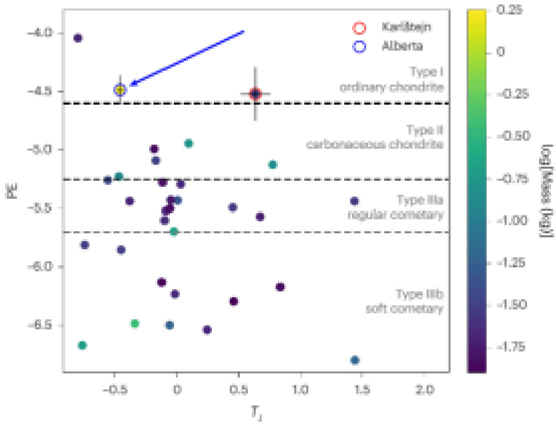
This image shows the orbit of a long-period comet. Since these comets come from the distant Oort Cloud, a spherical region on the Solar System's edges, their orbits are highly inclined. Image Credit: NAOJ.

The question this study poses is, "How did this chunk of rock originate in the Oort Cloud?" Finding an answer to that will shed more light on our Solar System's formation because the existence of the icy bodies that make up the Oort Cloud is a fundamental part of our understanding.

"We want to explain how this rocky meteoroid ended up so far away because we want to understand our own origins. The better we understand the conditions in which the Solar System was formed, the better we understand what was necessary to spark life," said Vida. "We want to paint a picture, as accurately as possible, of these early moments of the Solar System that were so critical for everything that happened after."

The meteoroid behaved like most meteoroids, most of which come from asteroids. "During its flight, it fragmented at dynamic pressures similar to fireballs dropping ordinary chondrite meteorites," the paper states. "A numerical ablation model fit produces bulk density and ablation properties also consistent with asteroidal meteoroids."

Monitoring meteoroids and how far they penetrate the atmosphere is its own scientific endeavour. Scientists use the PE (Penetrate Earth) factor in describing a meteor's structural strength, resistance to ablation, and how far it penetrates Earth's atmosphere. It's an imperfect measurement, but it's still helpful in comparing meteoroids.



This figure from the study shows how the Alberta meteoroid's PE compares to others in the Meteor Observation and Recovery Project dataset. The Alberta meteoroid is in a different region of the graph than softer cometary objects. It also shows how another noteworthy fireball called the Karlštejn event compares. Image Credit: Vida *et al*. 2022.

In their study, the researchers expand on the significance of the rocky object originating in the Oort Cloud. It won't be the only one, and the study shows that the Cloud contains significant amounts of rocky material. But the rocky material didn't form there. The ancient migration of planets in the Solar System drove the material into the Oort Cloud's icy reaches.

"Our result gives support to migration-based dynamical models of the formation of the Solar System, which predict that significant rocky material is implanted in the Oort cloud, a result not explained by traditional Solar System formation models," the authors write in their paper.

The authors say the data rules out an icy object. "The fireball fragmented under dynamic pressures similar to those observed for rocky meteoroids," they explain. This points out the need for a new model to explain how these rocky objects got into the Oort Cloud.

While a new model for the Solar System is beyond the scope of this paper, the researchers mention a couple of things.

They calculate the ratio of icy objects to lithic (rocky) objects in the Oort cloud. They constrain the ratio "… of icy/rocky objects to between 130:1 and 5:1 for masses >10 g." The rocky objects can't have formed there, so a Solar System model needs to have an ejection mechanism, even if the objects never even originated in our Solar System. "Even in a scenario where most of the Oort cloud objects are captured from other star systems, an ejection mechanism still needs to be present to explain the radial mixing of material," they write.

The authors say that the rocky objects were implanted in the Oort Cloud during the formation of the Solar System and that the icy/rocky ratio is an intrinsic parameter of the Cloud.

When it comes to the Alberta fireball, they think that object was likely not an intact primordial object. "The interstellar-medium erosion model predicts that all primordial objects smaller than a few metres should have been eroded away, indicating that the Alberta fireball possibly originated from a larger parent asteroid," they write.

The researchers conclude that the rocky objects embedded in the Oort Cloud came from a proto-asteroid belt. They point to previous research showing that only the Grand Tack Hypothesis can explain how material from a proto-asteroid belt became embedded in the Oort Cloud. They also say that the pebble accretion theory, which describes how particles in a protoplanetary disk combine over time to form planetesimals, can't explain their results.

It all adds up to a big challenge for our scientific models of how the Solar System formed.

"These findings challenge Solar System formation models based on pebble accretion alone, which currently cannot

explain the high observed abundance of rocky material in the Oort cloud as derived from fireball measurements and telescopic reflectance spectra data," they write in their conclusion.
This study shows how much we still have to learn about our Solar System. For decades, the widespread understanding was that the Oort Cloud was an icy enclave of primordial objects and that an occasional perturbation would send one of them into the inner Solar System as a comet. The Cloud is named after Danish astronomer Jan Oort, who proposed its existence back in 1950.

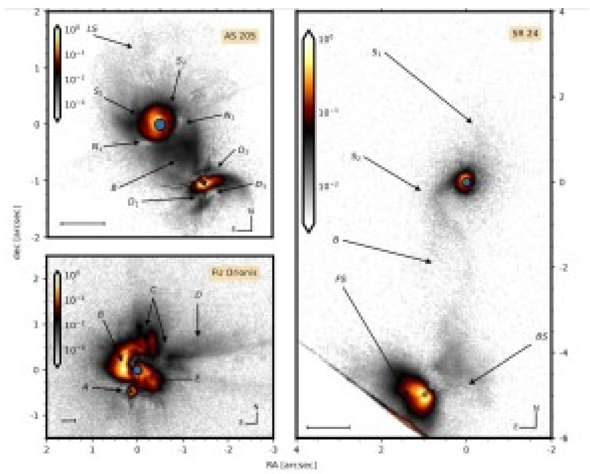

From a score of well-observed original orbits it is shown that the "new" long-period comets generally come from regions between about [illegible] and [illegible] A.U. distance. The sun must be surrounded by a general cloud of comets with a radius of this order, containing about 10^{11} comets of observable size; the total mass of the cloud is estimated to be of the order of 1/10 to 1/100 of that of the earth. Through the action of the stars fresh comets are continually being carried from this cloud into the vicinity of the sun.

This image shows part of the abstract from Jan Oort's 1950 paper "The structure of the cloud of comets surrounding the Solar System and a hypothesis concerning its origin." Image Credit: Oort, 1950/Bulletin of the Astronomical Institutes of the Netherlands.
But the Alberta fireball shows there's more to the Cloud than we thought.

Astronomers Spot Three Interacting Systems with Twin Discs

According to the most widely-accepted theory about star formation (Nebular Hypothesis), stars and planets form from huge clouds of dust and gas. These clouds undergo gravitational collapse at their center, leading to the birth of new stars, while the rest of the material forms disks around it. Over time, these disks become ring structures that accrete to form systems of planets, planetoids, asteroid belts, and Kuiper belts. For some time, astronomers have questioned how interactions between early stellar environments may affect their formation and evolution.
For instance, it has been theorized that gravitational interactions with a passing star or shock waves from a supernova might have triggered the core collapse that led to our Sun. To investigate this possibility, an international team of astronomers observed three interacting twin disc systems using the Spectro-Polarimetric High-contrast Exoplanet REsearch (SPHERE) on the ESO's Very Large Telescope (VLT). Their findings show that due to their dense stellar environments, gravitational encounters between early-stage star systems play a significant role in their evolution.
The research team consisted of astronomers from the European Southern Observatory (ESO), the Space Telescope Science Institute (STScI), the Millennium Nucleus on Young Exoplanets and their Moons (YEMS), the Center for Interdisciplinary Research in Astrophysics and Space Exploration (CIRAS), the Institute for Particle Physics and Astrophysics at ETH Zurich, the Max-Planck-Institute for Astronomy (MPIA), the Mullard Space Science Laboratory, the Kavli Institute for Astrophysics and Space Research, and multiple universities.

The classical idea of star formation states that stars form individually from a spherically-symmetric and isolated prestellar core. This has come into question in recent years as astronomers have made more observations that don't fit with this model. For one, astronomers have observed newborn stars embedded in thin filaments within molecular clouds, suggesting that large-scale processes are at work in these dynamical environments. In addition, surveys of star-forming regions have found that a statistically-significant fraction of prestellar cores leads to the formation of multiple systems rather than just one.
This is believed to have been the case with our Sun, which formed from the same nebula as several "solar siblings" that were then dispersed throughout the Milky Way. These lines of evidence all point toward interactions between early systems, and the effect this has on their evolution is not yet well-constrained. But by examining early star systems and the protoplanetary disks that orbit them, astronomers can observe the gravitational perturbations these interactions would cause. As they indicate in their paper, stellar interaction may occur in three ways.
These include non-recurring, hyperbolic, or parabolic passages (aka. "fly-bys"), through the co-evolution of binary stars, or through one star capturing another (aka. binary capture). To test their predictions, the team analyzed three interacting twin-disc systems (AS 205, EM* SR 24, and FU Orionis) using the Infra-Red Dual Imaging and Spectrograph (IRDIS) on the VLT's SPHERE instrument. This cryogenic camera allows SPHERE to conduct dual polarized light observations of AS 205, EM* SR 24, and FU Orionis in the 0.95 – 2.32 ?m near-infrared (NIR) band.
All were previously observed by instruments like the Atacama Large Millimeter-submillimeter Array (ALMA) and the VLT's NaCo Nasmyth Adaptive Optics System Near-Infrared Imager and Spectrograph (NAOS-CONICA, or NACO) instrument. These observations confirmed that these binary stars are twin disk systems, where both the primary and companion stars have confirmed protoplanetary disks. They also compared their polarized light observations with similar-resolution data sets (ALMA and gas emission data) to place tighter constraints on the geometry and content of each system.



SPHERE/IRDIS observations of three twin disc systems: AS 205, SR 24, and FU Orionis. Credit: P. Weber et al.

By examining how light from these stars was scattered by their disks, the team discerned spiral patterns that were likely caused by gravitational interaction and connecting filaments between the stars. From this, they were able to predict what types of interactions have taken place between the binary companions and their respective disks. As they stated:
"The overall structure observed in AS 205 is consistent with a hyperbolic stellar fly-by as [the] dynamical origin. The clockwise direction of the spirals S_1 and S_2 around AS 205N suggests a counter-clockwise fly-by and that the periastron of the orbit (location of closest approach) has already been crossed."
"The northern disc constitutes a circumbinary disc around the components SR 24Na and SR 24Nb. Also, the northern disc displays [a] strong asymmetrical structure with the presence of extended scattering north-west of the stars (?1), tracing a spiral arm that opens in [a] counter-clockwise direction and is opposed by a spiral arm to the south-west of SR 24N (?2). The southern spiral arm smoothly merges into the bridge towards SR 24S."
"The scattered light [of FU Orionis] shows strongly disturbed structures such as the bright extended arm east of the northern source, possibly linked to gravitational interaction and a subsequent stellar outburst. The kinematics of the arm (?) link it to both the systematic velocity of the northern and southern source, further promoting the idea that it results from a recent close stellar encounter."
The authors also acknowledge that possible dynamical scenarios could explain the spiral perturbations they observed, such as "coupled binary formation from a common molecular

cloud of high angular momentum." They also note that there are uncertainties in their analysis as it does not take systemic error into account and that their results should not be considered definitive. However, this presents an opportunity for follow-up observations and future surveys to further constrain the geometry of these systems and test these results.

These surveys will benefit from next-generation instruments like the *James Webb Space Telescope* (JWST) that are optimized for studying objects in the near- and mid-infrared spectrum. Ground-based observatories like the Extremely Large Telescope (ELT) will be able to directly image these systems using a combination of coronographs, spectrometers, and adaptive optics. These surveys will reveal a great deal about young star systems and the formation and evolution of planetary systems.

Further Reading: arXiv

Asteroids Didn't Create the Moon's Largest Craters. Left-Over Planetesimals Did

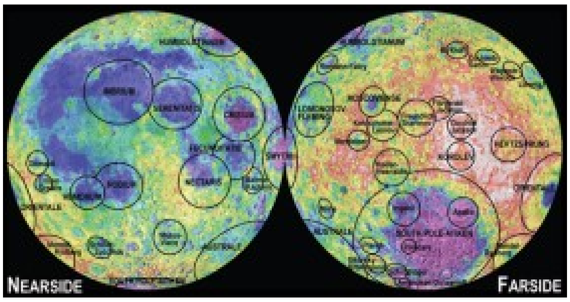
The Moon's pock-marked surface tells the story of its history. It's marked by over 9,000 impact craters, according to the International Astronomical Union (IAU.) The largest ones are called impact basins, not craters. According to a new study, asteroids didn't create the basins; leftover planetesimals did.

The Giant Impact Hypothesis shows that the Moon was created when a Mars-sized protoplanet slammed into Earth about 4.5 billion years ago. The collision sent molten material into orbit around Earth. Some of that material fell to Earth, and some coalesced to become the Moon.

As the molten rock coalesced, the Moon experienced a phase called the Lunar Magma Ocean (LMO.) The Moon's entire surface was molten during the LMO, and while astronomers do not doubt that massive objects collided with the Moon during that episode, there's no record of them. Only once the Moon solidified could impacts leave a lasting mark.

This illustration shows the Lunar Magma Ocean and the first rocky crust on the Moon. Image Credit: NASA/Goddard Space Flight Center

Researchers try to understand the Moon by piecing together the history of lunar impacts, and the solidification of the LMO marks hour zero for the Moon's impact record. Since the Moon is geologically inactive, every impactor that struck the Moon since hour zero left a mark that's still there to this day. Some of the Moon's craters are so vast that they're called impact basins, not craters. Basins are not only larger than craters, but they're also more complex and tend to have a central peak ring rather than a single central peak. Features larger than 300 km are called lunar impact basins, and there are about 50 of them. The Moon's largest impact basin is the South-Pole Aitken (SPA) basin, and it's 2,494.5 kilometres (1,550 miles) in diameter. Texas could fit inside it.

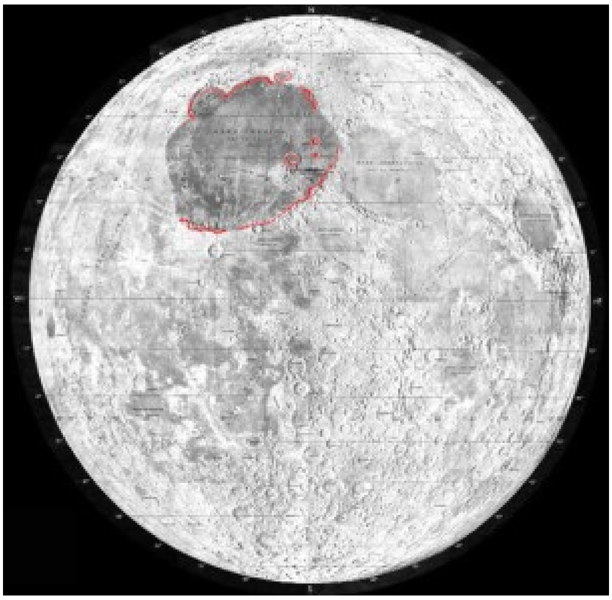


This image shows the main impact basins on the Moon. The left shows the lunar near side, and the right shows the far side. Image Credit: *LPI (Paul Spudis and David Kring)*

A new study says the leftover terrestrial planetesimals formed these basins when they slammed into the Moon. The study is "Formation of Lunar Basins from Impacts of Leftover Planetesimals," published in The Astrophysical Journal Letters. The lead author is David Nesvorný from the Southwest Research Institute (SwRI.)

The impactors that created the basins played a huge role in the Moon's history and controlled much of its geology. When they struck, they removed existing crust material from the innermost peak ring and thickened the crust between the inner peak ring and the outer rim crest. The Moon's mare basalts, which the Apollo missions sampled, are mostly confined to the topographic depressions in the middle of the basins. The impacts also created faulting and other deformations over large regions of the lunar surface and excavated mantle material. This exposed mantle material holds clues to fundamental planetary formation and evolution processes.

Some impact basins are still referred to as lunar mares because of their appearance. Ancient humans thought the dark regions inside the basins were oceans. The basins became filled with basaltic lava not when they were initially formed but when other impactors struck the opposite side of the Moon from the basins and triggered volcanic activity. Mares cover about 16% of the lunar surface.



Mare Imbrium, or the Sea of Showers, is easily seen from Earth and is highlighted in this map of the Moon. It's called a lunar mare because the Imbrium impact basin was covered in basaltic lava sometime in the past. The other large, dark spots are also basins created from asteroid impacts. Credit: NASA

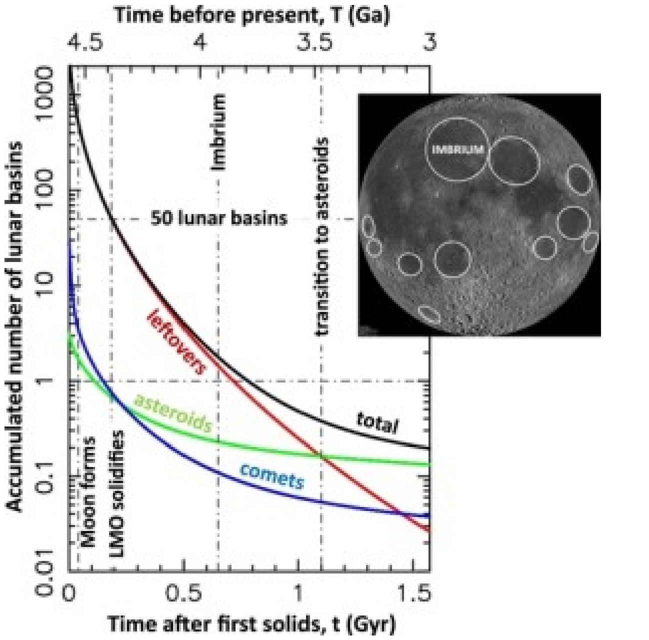
When these basins form, the impact spreads ejecta far and wide, which helps researchers piece together the Moon's history. A crater on top of the ejecta must be younger than the impact basin, and if a basin partially buries a crater, then the crater is older.

Previous research showed that asteroids from the main belt are responsible for these impact basins. "The basin-forming impactors were suspected to be asteroids released from an inner extension of the main belt (1.8–2.0 au)," the authors write. But in their paper, the authors say that most impactors were planetesimals. "Here, we show that most impactors were instead rocky planetesimals left behind at ~0.5–1.5 au after the terrestrial planet accretion."

The Schrodinger impact basin is on the lunar far side. It's a strong example of a peak-ring basin with a central peak ring rather than a single central peak. Schrodinger is an ancient basin formed around 3.8 to 3.9 billion years ago. Image Credit: *NASA Scientific Visualization Studio (NASA SVS).*

More planetesimals collided with the Moon than show up in the record because planetesimals were more plentiful earlier in the Solar System's history, and some would have struck during the Moon's LMO phase. "… the first ~200 Myr of impacts are not recorded on the lunar surface," the researchers explain.

The researchers created models to determine planetesimals' role in forming the lunar basins. They based their models on previous research into terrestrial planet accretion that shows how planetesimals changed over time due to collisions with other objects. This is called collisional grinding, which eventually results in a uniform size distribution of planetesimals. They also relied on the dynamical modelling of asteroids and comets to see what role they played in lunar impacts.



This figure from the study shows early impacts of diameter *d* > 20 km planetesimals on the Moon. In the first billion years after the LMO solidified, leftover terrestrial planetesimals accounted for most impact basins. Over time, they were depleted from the Solar System, leaving only asteroids and comets as lunar impactors. Image Credit: David Nesvorný *et al* 2022 *ApJL* **941** L9

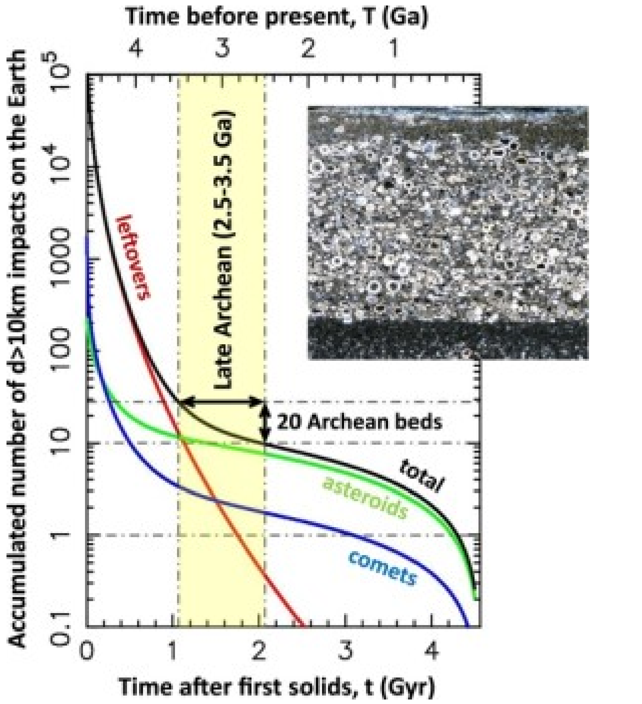
The authors' work shows that asteroid impacts created the most impacts in the last 3.5 billion years. But before that, planetesimals did most of the damage. "The integrated history of lunar impacts shows that leftover planetesimals dominated the early impact flux (*t* < 1.1 Gyr or *T* > 3.5 Ga; *T* is measured looking backward from today)." Comets created some impact craters in the Solar System, but not many, compared to asteroids and planetesimals.

Their results also show that about 500 20km diameter planetesimals struck the Moon during its LMO phase. But those impacts left no lasting mark.

The prominent Imbrium basin is a bit of an outlier, according to this work. In their model, the planetesimal that created the Imbrium basin "occurs with a 15%–35% probability", was greater than or equal to about 100 km in diameter, and struck about 3.92 billion years ago. The authors say it must have formed late because it only has two smaller basins overlying it.

The results are supported by impacts on Earth, too. But without impact craters to study, researchers rely on spherule beds. When impactors strike Earth, they create a plume of vaporized rock. The rock condenses into tiny sphere-shaped rocks called spherules that shower back onto the Earth. They form spherule beds embedded in rock. "Our model predicts ~20 *d* > 10 km impacts on the Earth for *T* = 2.5–3.5 Ga.," the study says. "This is similar to the number of known spherule beds in the late Archean."

In this time interval, both main-belt asteroids and leftover planetesimals struck Earth. But, they write, "Whereas the asteroid impacts were more uniformly spread over the late Archean, nearly all planetesimal impacts should have happened before 3 Ga."



This figure from the study shows the number of 10km diameter or larger impactors that struck Earth. Leftover planetesimals accounted for most of the impacts for the first billion years following Earth's magma ocean phase. The number of spherule beds on the Earth agrees with their model, according to the authors. The inset picture is the Monteville spherule layer in South Africa. Image Credit: David Nesvorný *et al* 2022 *ApJL* **941** L9. Inset Image Credit: Reimold & Koeberl 2014

Researchers are still studying the Moon's craters and piecing together the Solar System's history. While the IAU officially recognizes 9,137 craters, of which 1,675 have been dated, these numbers are likely to change. New research based on data from China's Chang'E lunar orbiter puts the number of craters closer to 130,000. Other research puts the number even higher: two million craters larger than 1-2 km.

Whatever the eventual number, each crater is like a fossil. Earth lacks this fossil record, and piecing together the impact fossil record on the Moon not only reveals the Moon's history; it reveals Earth's.

Meteorites Bathed in Gamma Rays Produce More Amino Acids and Could Have Helped Life get Going on Earth

Our modern telescopes are more powerful than their predecessors, and our research is more focused than ever. We keep discovering new things about the Solar System and finding answers to long-standing questions. But one of the big questions we still don't have an answer for is: 'How did life on Earth begin?'

We won't answer the question of life's origins in one dramatic act. Instead, we're chipping away at it, slowly piecing together an answer over generations. We know life has building blocks, molecules critical to life gaining a foothold here on Earth and, hopefully, elsewhere. Amino acids are some of those building blocks.

Amino acids play a critical role in life on Earth, though we don't know exactly how they fit into a timeline of life's origins. We've found them in space, which has led to speculation that they originated there and then found their way to Earth as biological building blocks.

A new study fills in part of the picture by showing that meteorites bathed in gamma rays produce more amino acids.

There are hundreds of amino acids, but only 22 appear in the genetic code. Glycine is one of the simplest amino acids in the genetic code, and scientists have found glycine in objects in space. They've seen it in comets, interstellar dust clouds, and meteorites that fell to Earth, which led to the idea that meteorites contributed to the appearance of life on Earth.

A new study shows that when meteorites are bathed in gamma rays, they produce more amino acids. The study is "Gamma-Ray-Induced Amino Acid Formation in Aqueous Small Bodies in the Early Solar System," and it was published in ACS Central Science, the journal of the American Chemical Society. The lead author is Yoko Kebukawa, an associate professor in the Department of Chemistry at Yokohama National University.

When Earth formed, the Solar System was a much more chaotic place. Meteorites flew through space, slamming into things like particles in an accelerator. Many of them struck Earth. There are fewer of them now, though they still fall to Earth. When they do, people find some of them, and many have found their way to scientists' labs. Over time, scientists have classified meteorites into different families.

There are three top-level categories of meteorites: stony meteorites, iron meteorites, and stony-iron meteorites which are a combination of both types. There are further classifications based on chemical compositions, isotopes, and mineralogy.

Carbonaceous chondrites (CCs) are a type of stony meteorite and are some of the most primitive. The name is a bit confusing. Scientists thought they contained carbon because of their dark and grey appearance, but they actually contain less carbon than other meteorites. However, CCs contain something more important than carbon: they're known for containing water and other molecules, including amino acids. That, along with their ancient age, makes them important because they hold clues to the early Solar System, back when Earth was settling down, and life was getting started.

There seems little doubt that carbonaceous chondrites contained amino acids back then and that they would've delivered them to the young Earth. But how did the amino acids form?

That's the question behind the new study.

Artist's concept of a meteorite entering Earth's atmosphere. There were more meteorites striking Earth billions of years ago. Could they have delivered building blocks like amino acids to Earth, spurring on the appearance of life? Image Credit: University of Oxford

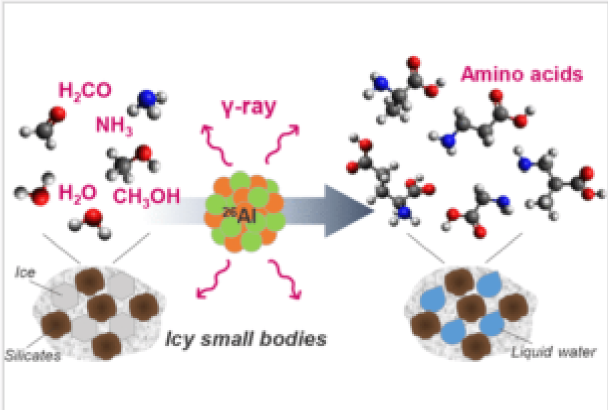
Lead author Kebukawa showed in previous research that reactions between simple molecules such as ammonia and formaldehyde could create macromolecules, including amino acids. But only in the presence of liquid water and only when there's heat to drive reactions. We know carbonaceous chondrites contain water, but where did the heat come from? It could've come from one of the two naturally-occurring isotopes of aluminum: ^{26}Al.

^{26}Al is cosmogenic, meaning it was created when cosmic rays bombarded meteor fragments. It was relatively abundant back when the Solar System was forming but has now decayed.

^{26}Al is unstable and releases gamma rays as it decays. Scientists think the heat from that decay is responsible for the melting and differentiation of some asteroids after they formed in the early Solar System. But the heat could've also driven the production of amino acids in meteors.

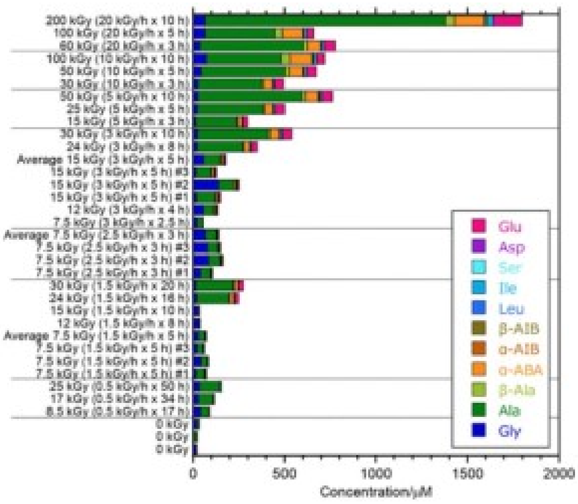
Kebukawa and her colleagues tested this idea in their laboratory. They combined compounds like formaldehyde and ammonia, both common chemicals in space, and exposed them to gamma rays. Not gamma rays from ^{26}Al but from more readily available ^{60}Co (cobalt-60). ^{60}Co is a synthetic radioisotope produced in nuclear reactors. It's used in radiation therapy, sterilizing medical instruments, and other things.

Since it produces gamma rays as it decays, the researchers used ^{60}Co as a proxy for primordial ^{26}Al.



The experiment showed that the rays melted ice in carbonaceous chondrites when ^{26}Al decayed and released gamma rays. In the presence of liquid water and the energy from the ^{26}Al, simple chemicals like ammonia (NH_3) and methanol (CH_3OH) formed amino acids. Image Credit: Kebukawa et al. 2022.

The researchers found that the gamma rays increased the production of some amino acids as the gamma-ray exposure increased.

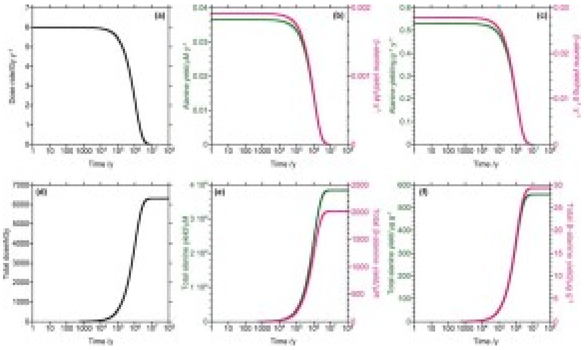


This figure from the study shows how gamma rays produced different amino acids. Gamma rays are measured in kGy, kilo-Grays (*1 kGy. = 1,000 J/kg*). The zero kGy rows on the bottom are the control group. The colour-coded legend explains how much of each amino acid was produced. Glycine, the simplest and most common amino acid, is shown in blue at the bottom of the legend. Image Credit: Kebukawa et al. 2022.

Amino acids are divided into four categories: alpha, beta, gamma, and delta. Alpha amino acids are the most essential amino acids because they're used to synthesize proteins. Glycine (Gly), Alanine (Ala), Leucine (Leu), Serine (Ser), Asparagine (Asp), Isoleucine (Ile), and Glutamine (Glu) are all alpha amino acids produced in the experiment. The quantities of these essential amino acids rose in the irradiation solutions as the total gamma-ray dose increased.

What do these laboratory results mean in the real world? The researchers took their results and calculated a plausible level of amino acid production in meteorites. They focused on a specific family of meteorites called CM chondrites, the most commonly recovered carbonaceous chondrite type. The M stands for the Mighei meteorite, and their calculations are for the parent body of all CM chondrites. Their analyses also take into account the decay of amino acids over time.

The team calculated the production of alpha-alanine and beta-alanine, a component of things like vitamin B_5. They calculated the yields of amino acids in the liquid phase and the whole rock. Their work shows that it would've taken between 1,000 and 100,000 years to produce the amount of alanine and ?-alanine found in the Murchison meteorite, the most well-studied Mighei meteorite.



This figure from the study shows the calculated yields of alpha-alanine (green) and beta-alanine (pink) in the CM parent body. The top row shows (a) the Gamma-ray dose rate expected in the parent bodies of CM chondrites and calculated yields of alanine and beta-alanine per year (b) in the liquid phase, and (c) in the whole rock. The bottom row shows (d) the Total gamma-ray dose expected in the parent bodies of CM chondrites and calculated total yields of alanine and beta -alanine (e) in the liquid phase and (f) in the whole rock. Image Credit: Kebukawa et al. 2022.

In the paper's conclusion, the researchers explain their results. "Our findings point to the possibility of gamma-ray-induced amino acid formation from ubiquitous, simple molecules such as formaldehyde and ammonia in the presence of water inside small bodies during the early stages of the formation of the Solar System." Note the prudent use of the word "possibility."

"The gamma-ray-induced production of amino acids could be a novel prebiotic amino acid formation pathway that could have contributed to the origins of life on early Earth, as building blocks of life were delivered through the fall of meteorites."

The idea that meteorites could've brought amino acids to the Earth and helped spur on life is not new. But this study strengthens that idea and is another piece of the intricate puzzle that is life on Earth.

E Mails Viewings Logs and Images from Members.

Viewing Log for 14th of December

As there was a clear sky and temperatures of around zero, I thought I would miss my weekly game of Chess and do some viewing instead. I went out to my greenhouse to put on the heater for the night and was surprised to see the thermometer reading – 1.7 ° C and that was inside the greenhouse! Might be a bit colder than I expected for the evening?

I arrived at my usual viewing place near Uffcott just off of the A4361 and had my Meade LX90 set up and ready by 19:17, as usual I would be using my Pentax WX 14 mm eye piece. The starting temperature would be – 3 °C with a slight wind and some snow on the ground for company, might get cold later on. To the south of me was a large cloud bank which should slowly go south, if you believe the forecast for the evening.

As Saturn was just above this cloud bank, I started with this planet. I could not make out any detail as this planet was well past it best for viewing but I could see the moon Titan out to the west of the planet. Jupiter was still blazing away (mag – 2.6) in the southern sky, so that was my next port of call. I could make out the two usual weather belts and thought I could make out the Great Red Spot (looking at the programme Jupiter 2 later on) confirmed this. Ganymede and Europa were to the east of Jupiter and Io and Calisto to the west. Now on to a hard object for me and Neptune, I think I found this planet via the finder scope? Uranus was found in the finder scope but no detail could be made out on this planet. Mars was blazing (mag – 1.9) in the eastern horizon, could make out some markings on the surface. While viewing Mars I noticed a Geminids meteor at about mag 1 in Capella?

For a change I thought I would use the programme 'Tonight's Best' from the hand controller and see what it would take me too. Mars and Jupiter were the first objects which I already had done. Then it went off to Messier (M) 42 in Orion which was just clearing the hedgerow, could not make out the trapezium stars at all, the dust lines could be seen but not very well? Next was the star Mira which shines between mag 3 to 9, I thought it was around 5 to 6 at the time, this star is a red giant. The Double Cluster or Caldwell (C) 14 was the next target and it was wonderful to look at, the open clusters (OC) of NGC 869 and 884 make up this object. Back to a star and Vega, this blue/white star at mag 0.0 is the fifth brightest star in the sky. On to M 45, the Pleiades which is best seen with the finderscope as with the eye piece we are look thru the OC. Now on to stars and Betelgeuse in Orion, shining at mag 0.5 and a red super giant followed by Albireo a lovely double star (yellow and blue) spilt by 34.7 arc seconds in Cygnus, Aldebaran in Taurus shining at mag 0.8 and the 13th brightest star in the sky which is not part of the Hyades OC but a foreground star. Noticed another Geminids meteor nearby which was around mag 2? Final star for the time was Castor, a tight double with 2.0 arc seconds between them, actually this star system is made up of 6 stars! On to the Hyades C 41, this OC is best seen with your own eyes as it is too large even for my finderscope! Enif is the nose of Pegasus, a red star. Back to deep sky objects and M 37 in Capella, a very large and dense OC with no bright stars, next was M 38 nearby, a large and not as dense OC as M 37. For some reason we went off to M 34 next, I thought we would have done M 36, anyway this OC was sparse and small to look at. M 36 was our next target, a large and sparse OC. Back to Pegasus and M 15, this globular cluster (GC) had a bright core but did not show up any stars as it was getting low in the western sky. Back in the other direction and M 35, a large and loose OC. Back to the western sky again and M 27, the Dumbbell nebula which looked like a large grey blob, did not help being just above the hedge line! M 2 which normally is a good GC to look at was dim being only 10 ° above the horizon did not help. Higher in the sky was Deneb a blue/white star which makes up part of the 'Summer Triangle' of stars. By now I was having trouble writing the information on my notebook, the pages were freezing up, so I knew I would not have much time left before I called it a night? Next was M 92, a GC in the hedge (line of sight) which I could just make out, being only 12 ° above the horizon does not help? One of the better galaxies to view on Messier's list IMO is M 82, a long and thin spiral galaxy. Back to the hedge again and M 57, the Ring nebula, this planetary nebula was very dim I could make it out as there was a small gap in the hedge, if the hedge had leaves on I would not be able to make this object out? Final object on this list was M 31, the Andromeda galaxy, this object has a bright core. With the Tonight's best out of the way I had one final look at M 42 which by now had totally cleared the hedge line, could make out the trapezium stars very clearly now and the view generally was better.

The time was 21:15 and I had been out for just under two hours and the equipment used was covered in a nice layer of ice (see picture in the magazine) which would need to be dried overnight before storing the equipment. Finishing temperature was – 6 °C, I have never done a viewing session with temperatures this low in this country before, my feet and toes were cold at times. Good thing about this session, not one car went past me, who in the right mind would go out on a night like this, answers on a postcard please!

One thing I could not work out with the programme 'Tonight's Best' is why it would slew across the sky when an object nearby would be looked very soon?

Clear skies.

Peter Chappell

WAS viewing session viewing log for 29th of December

During the afternoon I had been playing a round of golf with strong winds and at times rain for company, I did not think there would be much chance of a viewing session in the evening at Lacock? After having one at the 19th hole and starting to go home to dry out a bit the skies had started to clear and noticed Venus very low down in the western sky, first time I have seen this planet since its superior conjunction a few months ago. After I had got home and sorted out the wet golf gear and clubs I caught up with my e mails and noticed the session was going ahead.

After having some tea and loading the car with grab and go equipment only (there was a chance of rain coming in by around 21:00, by having grab and go I can put the gear in the car quickly) I headed off to Lacock to meet up with Chris

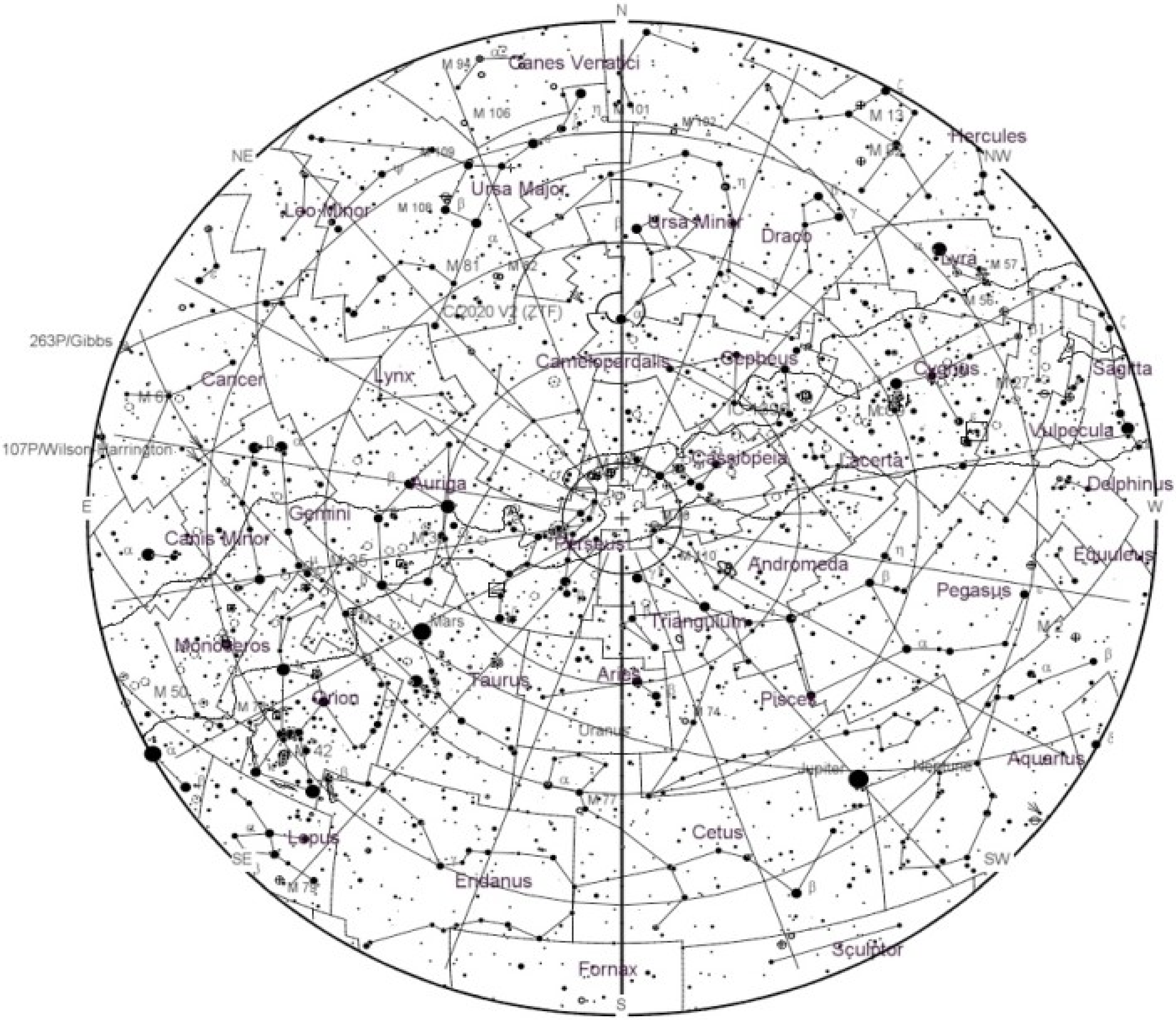
and anyone else who was there. Once I arrived at the car park behind the Red Lion pub I noticed the building work had been completed and gone away leaving access to the playing fields, our normal viewing area. After walking around the area I found the picnic area with Chris Brookes and Andy Burns already set up and had company with them. So I returned to my car and returned to set up my William Optic's 80 mm refractor on my new Skywatcher AZ4 mount with a Televue Ethos 13 mm eye piece. The time was now 19:58 and the wind had died down to nearly nothing, the temperature was 4 °C, so it might get chilly later on? With me arriving late, Saturn had already set behind the toilet block. So my first target was Jupiter, I saw three of the moons quickly out to the east (Ganymede, Io and Calisto), I thought the fourth (Europa) was hiding behind the planet but after having a longer look I found it very close to the edge of Jupiter. Europa was actually doing a shadow transit at the time but I neither Chris nor me spotted it, the Great Red Spot was on the other side of the planet at the time. A first for me was finding Messier (M) 29 in Cygnus by star hoping, I could only find the six main stars of this open cluster (OC) that makes up a slightly crushed rectangle. It was fairly small and dim to look at, using this set up the magnification was only around 35 when using my Meade telescope with a 14 mm eye piece I would be getting around 143, so lot larger to look at. Next target was M 45, the Pleiades OC, instead of viewing it with the finder scope I could use the eye piece, it filled the eye piece and looked wonderful. Uranus and Neptune would be no good for me as I had no clues to where they were, so I went on to Mars instead shining brightly in Taurus. The red showed up well but I could not make out any detail on the surface of the planet. By now Orion had cleared the trees to the south east, so I had a look at M 42 and M 43 next door. Could make out the two main dust lanes very clearly but had trouble with the trapezium stars could see three but the fourth has hard to find. Andy had heard me saying I was having trouble with the 'trap' so he brought across a 4 mm Televue radian eye piece for me to try, yes the fourth star appeared. After giving Andy the eye piece back I had a go at finding M 81 and M 82 in Ursa Major, I found what I thought was a fuzzy blob which Chris agreed with but we could not find the other galaxy? Moving the scope slightly I came across the other galaxy hiding just off the edge. Out of the two I think M 81 was the brighter (by over 1 magnitude). Tried for M 1, the only Supernova Remnant on Messier's list but could not find it, think the Moon was washing part of the sky out plus the small size of it made it a challenge for me? By now the battery in my red dot finder (RDF) had given up the ghost and for some reason I did not have a spare battery in the bag, so I would be limited to what I could find from now on! Hoped to get M 41 close to Sirius but this was a no go for me, saw it in Chris's telescope instead. Final object for me was the waxing gibbous Moon which was 6.46 days old or 48.2 % lit and 376,427 kms away. The terminator (day/night line on surface of the Moon) was good as usual, Mere Serenitatis had just cleared the terminator, crater Aristoteles and Eudoxus had good peaks in the centre of their craters. For a while I had been having trouble with my eye piece, it kept dewing up! Andy also said he was having trouble so at 21:29 we decided to call it a night and go to white light so we could pack up. Think when I arrived there was four people who came along for the experience, once they had left another group turned up and stayed with us for around 20 minutes looking at M 42, the Moon or Jupiter (main highlights in the sky currently).
Once home and the gear used had been dried out overnight I put a new CR2032 battery in the RDF, should keep me going for several years with this equipment. The temperature had not dropped below 4 °C during the night, yet the following day strong wind had returned with a good supply of the wet stuff, I think we were lucky for the viewing session?

Clear skies for 2023.

Peter Chappell

PS I could not do any deep sky objects about 45 ° or higher in the sky as I would have trouble finding them with my RDF, getting down to view them would require a knee on the wet grass and I was not prepared for that, did try several times to find objects with no luck. As this was the first use for my new tripod for evening sessions I forgot about the extension piece that comes with it, turns out I had left it in the box that the tripod had arrived in and was currently in the roof space, doh! The tripod is set up with my Solarscope for viewing the sun and currently is not that high in the sky! I have since recovered the extension piece from the roof space and is now beside the tripod in case I use grab and go kit in the near future.

WHATS UP, JANUARY 2023



January 3, 4 - **Quadrantids Meteor Shower.** The Quadrantids is an above average shower, with up to 40 meteors per hour at its peak. It is thought to be produced by dust grains left behind by an extinct comet known as 2003 EH1, which was discovered in 2003. The shower runs annually from January 1-5. It peaks this year on the night of the 3rd and morning of the 4th. This year the nearly full moon will block out most of the fainter meteors. But if you are patient you may still be able to catch a few good ones. Best viewing will be from a dark location after midnight. Meteors will radiate from the constellation Bootes, but can appear anywhere in the sky.

January 6 - **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 23:09 UTC. This full moon was known by early Native American tribes as the Wolf Moon because this was the time of year when hungry wolf packs howled outside their camps. This moon has also been know as the Old Moon and the Moon After Yule.

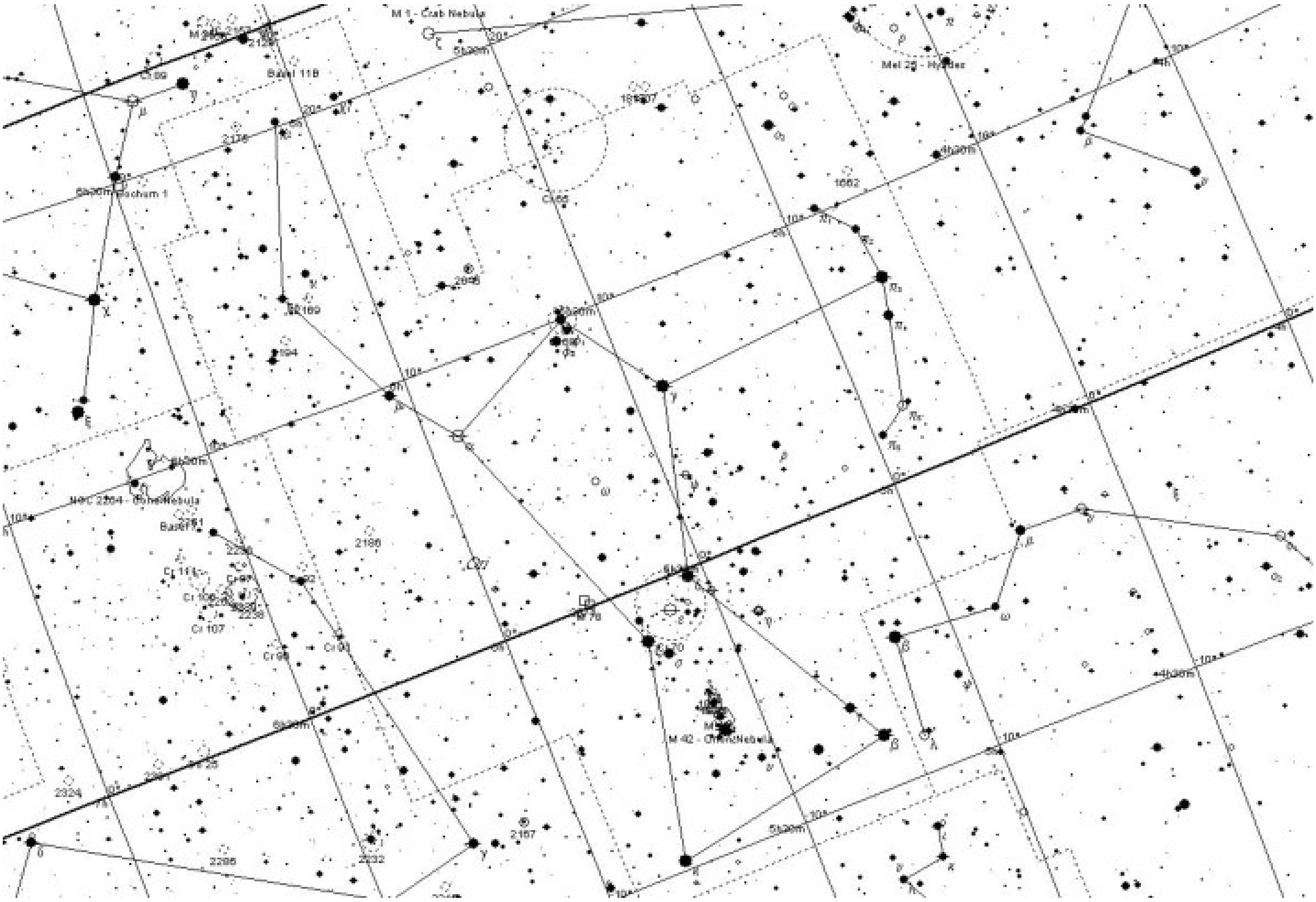
January 21 - **New Moon.** The Moon will located on the same side of the Earth as the Sun and will not be visible in the night sky. This phase occurs at 20:55 UTC. This is the best time of the month to observe faint objects such as galaxies and star clusters because there is no moonlight to interfere.

January 30 - **Mercury at Greatest Western Elongation.** The planet Mercury reaches greatest western elongation of 25 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 morning sky. Look for the planet low in the eastern sky just before sunrise.

All through the month those with clear unobstrusted skies from the southwest horizon to the southeast will be able to witness the planetary line up across the skies from just after sunset. Mercury, Venus, Saturn, Neptune, Jupiter, Uranus, Mars (and don't forget you are stood on the Earth… all eight major planets of our solar system.

Just after sunset to the north west and to the north east after 1am we shall be getting the brightening comet c/2022 e3 ztf. Currently at mag 7.9 it should brighten to 5th magnitude by the end of the month. Look above the semicircle of stars of Corona Borealis between Arcturus and the Keystone of Hercules with binoculars.

CONSTELLATIONS OF THE MONTH: ORION



Orion is the master of the winter skies. He lords over the heavens from late fall to early spring, with his hunting dog Sirius trailing at his feet.

The mythic tales of Orion go as far back as the Hittites, who flourished from the Second Millenium BC to around 1200 BC.

One story from this culture gives an interesting account of Orion's death. Here he is called Aqhat, and was a handsome and famous hunter. The Battle-Goddess Anat fell in love with Aqhat, but when he refused to lend her his bow, she sent another man to steal it. This chap bungled the job, and wound up killing Aqhat and dropping the bow into the sea. This is said to explain the astronomical fact that Orion and the Bow (an older version of the constellation) drops below the horizon for two months every spring.

Like all myths borrowed from several sources over a great length of time, the Greek stories offer many variations. Generally speaking, Orion was known as the "dweller of the mountain", and was famous for his prowess both as a hunter and as a lover. But when he boasted that he would eventually rid the earth of all the wild animals, his doom may have been sealed.

It might have been the Earth Goddess herself who sent the deadly scorpion to Orion. Or possibly Apollo, concerned that Orion had designs on his sister, Artemis. Thus Apollo may have told the Earth Goddess of Orion's boast. In any case, it seems clear that it was the Earth Goddess who sent the scorpion on its mission.

Some stories have the scorpion killing Orion with its sting. However the general consensus is that he engaged the scorpion in battle but quickly realised its armour was impervious to any mortal's attack. Orion then jumped into the sea and swam toward Delos. But Apollo had witnessed Orion's struggle with the scorpion and would not let him escape so easily. He challenged his sister Artemis, who was an excellent shot, if she could hit that small black object far away in the sea, the head -- he told her -- of an infamous and treacherous villan. Artemis struck the object with her first shot. She then swam out to retrieve her victim's corpse, and discovered she had killed Orion. Artemis implored the gods to restore his life, but Zeus objected. So she put Orion's image in the heavens.

In his eternal hunting, Orion is careful to keep well ahead of the scorpion. In fact Orion has disappeared over the horizon by the time Scorpio rises in the east, as it becomes his turn to rule the evening sky.

Finding Orion should be no problem. Its stars are some of the most familiar in all the heavens. Question: can you name the three stars that make up Orion's Belt. (Answer below.)

Above the belt, slightly to the left, is *Betelgeuse, alpha Orionis.*

Betelgeuse, the right arm of Orion (or "armpit" as the name suggests), glows with a dull red. Although labelled *alpha Orionis*, it is less bright than *beta Orionis* (Rigel), in the opposite corner of the constellation, to the southwest. Yet if slightly less bright, it is much larger, estimated at around 250 Suns. If one were to replace our Sun with Betelgeuse, its size would completely engulf the Earth and extend as far as Mars.

As the brightest star in Orion, *Rigel* ranks as the seventh brightest star in all the heavens, just behind Capella. It is a visual binary; its companion is much fainter, but quite visible if you are persistent enough (PA 202º, 9.4").

The other corners of the constellation are formed by *Bellatrix (gamma Orionis)* and *Saiph (kappa Orionis)*. It was once thought that all women born under the sign of Bellatrix would be fortunate and have the gift of speech. The star's name is often translated as Female Warrior or Amazon, and another name sometimes seen is "Amazon Star".

The constellation's main feature is of course the three stars which form the "belt" across the middle of Orion: from west to east *Mintaka, Alnilam,* and *Alnitak*. Even the Bible makes reference to this famous group. God, while pointing out how all-powerful he was, is purported to have asked Job if he (Job) was able to "loose the bands of Orion" (*Job* 38.31).

The last of these stars is also known as *zeta Orionis*, and is a well known triple star system. The primary is a blue-white star, and its companion (165º, 2.3") is a dull red. Close by, just to the south, is the renowned Horsehead Nebula, a so-called dark nebula that is not visible in scopes but quite spectacular in long-exposure photographs.

Binary stars in Orion:

There are many double stars in this constellation visible in small telescopes. Below are several selected from a wide list.

Beta Orionis (Rigel) has a 10.4 visual magnitude companion at 202º and a wide 9.5" separation. This is a fixed system.

Lambda Orionis (between Betelgeuse and Bellatrix) is another fixed binary, with a 5.5 companion at PA 43º and 4.4" away.

Theta[1] is a complex system of fixed stars. The four brightest form The Trapezium, an outstanding multiple system for small telescopes. AB is at a position angle of 32º and separation 8.8", AC: PA 132º, 12.7", and AD: PA 96º, 21.5".

Theta[2] is also a fine binary, a triple system to the southeast of The Trapezium. Component B is a binocular object: 6.4 magnitude at a position angle of 92º and separation 52.5". Component C (8.5) is even wider: PA 98º and separation 128.72".

Sigma Orionis is one of the few orbiting binaries found in Orion. Component B has an orbit of 158 years and is one of the few components that traces a not-quite-perfect circle. That's to say, we see it nearly face on, as a wheel spinning around its hub.

The separation never changes much from its current distance of only 0.2". Its 2000.0 position angle is 132º.

Much easier to resolve is component E, with a visual magnitude of 6.7, this is a binocular object at a position angle of 61º and separtion of 42".

Zeta Orionis (1.9, 4.0) has a very slow orbit of 1509 years, and is currently at 165º and 2.3" separation.

Variable stars in Orion:

A dozen stars in this constellation are visible in small scopes, but most of them are of the EA type of eclipsing binaries, which change very little. These include two stars of the Trapezium (theta 1A and 1B).

EA variables are old stars, nearing the end of their evolutionary process. The companion has grown to the size of a subgiant, perhaps equal in size to its primary. But their luminosities are quite different; thus, as the dimmer companion revolves around its primary, variations in the total brightness occur.

The maximum brightness occurs of course when the two are not eclipsed, with each one adding its luminosity to the total output. Two minima also occur: the principal minimum is when the companion blocks out the primary; while a secondary minimum occurs when the companion is eclipsed by the primary.

The only interesting Mira-type regular variable is *U Orionis*, which usually has a brightness of 4.8 but every 368.3 days it drops down to 13. In 2000 the minimum is scheduled to occur on 5 December.

Deep Sky Objects in Orion:

M42, The Orion Nebula is perhaps the most photographed deep sky object in the heavens, a vast nebula of gas and dust exquisitely lit by surrounding stars.

This is a celestial nursery; soon (that's to say, in several hundred million years) young stars will appear from this wealth of cosmic matter.

Inside the nebula is the fascinating four-star system known as *The Trapezium*: theta 1A, 1B, 1C, and 1D - four stars held together by common gravity (actually at least two other stars are part of this complex system.) They are visible in medium sized telescopes and, with the nebula, form one of the most beautiful binary systems in the heavens.

M43 (NGC 1982) is a detached part of the Orion Nebula, with a ninth magnitude central star. A dark lane of gas separates M43 from M42, although the two are actually part of the same vast cloud.

M78 (NGC 2068) is a faint reflection nebula NE of Alnitak (zeta Ori), that looks best in long-exposure photographs.

The Horsehead Nebula is an intriguing and devilishly difficult dark nebula found just between zeta Orionis and sigma Orionis, visible in medium to large telescopes given the right sky conditions. An H-Beta filter is also helpful.

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

03 Jan	4.8	04:34:25	17°	ENE	04:34:25	17°	ENE	04:35:25	10°	ENE
03 Jan	2.0	06:09:13	46°	WNW	06:10:13	67°	N	06:14:11	10°	E
04 Jan	5.3	04:16:34	12°	ENE	04:16:34	12°	ENE	04:16:50	10°	ENE
04 Jan	1.9	05:51:23	64°	NNW	05:51:37	67°	N	05:55:35	10°	E
04 Jan	2.0	07:26:28	10°	WNW	07:30:27	87°	SSW	07:34:25	10°	ESE
05 Jan	2.3	05:33:30	59°	NE	05:33:30	59°	NE	05:36:59	10°	E
05 Jan	2.0	07:08:19	13°	WNW	07:11:51	85°	SSW	07:15:48	10°	ESE
06 Jan	3.1	05:15:37	41°	ENE	05:15:37	41°	ENE	05:18:22	10°	E
06 Jan	2.0	06:50:25	19°	WNW	06:53:13	83°	SSW	06:57:11	10°	ESE
07 Jan	3.9	04:57:43	28°	ENE	04:57:43	28°	ENE	04:59:44	10°	E
07 Jan	2.0	06:32:31	27°	WNW	06:34:35	81°	SSW	06:38:33	10°	ESE
08 Jan	4.6	04:39:49	20°	E	04:39:49	20°	E	04:41:07	10°	E
08 Jan	1.9	06:14:37	40°	W	06:15:57	78°	SSW	06:19:54	10°	ESE
09 Jan	5.1	04:21:56	14°	E	04:21:56	14°	E	04:22:28	10°	E
09 Jan	1.9	05:56:44	62°	W	05:57:18	76°	SSW	06:01:15	10°	ESE
09 Jan	3.7	07:32:24	10°	W	07:35:32	22°	SW	07:38:39	10°	SSE
10 Jan	2.0	05:38:52	71°	S	05:38:52	71°	S	05:42:36	10°	ESE
10 Jan	3.7	07:13:48	10°	W	07:16:51	21°	SW	07:19:54	10°	S
11 Jan	2.9	05:21:03	45°	SE	05:21:03	45°	SE	05:23:56	10°	ESE
11 Jan	3.7	06:55:51	13°	W	06:58:10	21°	SW	07:01:08	10°	S
12 Jan	3.8	05:03:15	28°	SE	05:03:15	28°	SE	05:05:15	10°	ESE
12 Jan	3.7	06:38:04	16°	WSW	06:39:28	20°	SW	06:42:21	10°	S
13 Jan	4.6	04:45:31	17°	SE	04:45:31	17°	SE	04:46:34	10°	ESE
13 Jan	3.7	06:20:20	18°	SW	06:20:45	19°	SW	06:23:34	10°	S
14 Jan	5.2	04:27:51	10°	ESE	04:27:51	10°	ESE	04:27:52	10°	ESE
14 Jan	3.9	06:02:40	17°	SSW	06:02:40	17°	SSW	06:04:45	10°	S
15 Jan	4.3	05:45:04	13°	SSW	05:45:04	13°	SSW	05:45:56	10°	S
24 Jan	4.1	18:22:15	10°	SSE	18:23:41	12°	SE	18:23:41	12°	SE
24 Jan	4.8	19:58:01	10°	SW	19:58:31	13°	SW	19:58:31	13°	SW
25 Jan	4.0	18:03:15	10°	SSE	18:05:04	13°	SE	18:06:03	12°	ESE
25 Jan	3.9	19:39:13	10°	SW	19:40:52	23°	SW	19:40:52	23°	SW
26 Jan	4.1	17:44:17	10°	SSE	17:46:15	14°	SE	17:48:15	10°	ESE
26 Jan	3.0	19:20:25	10°	SW	19:23:09	39°	SSW	19:23:09	39°	SSW
27 Jan	4.1	17:25:18	10°	SSE	17:27:26	14°	SE	17:29:34	10°	E
27 Jan	2.2	19:01:36	10°	SW	19:05:21	55°	SSE	19:05:21	55°	SSE
27 Jan	5.4	20:40:09	10°	W	20:40:09	10°	W	20:40:09	10°	W
28 Jan	2.1	18:42:47	10°	SW	18:46:36	57°	SSE	18:47:29	44°	ESE
28 Jan	4.8	20:21:22	10°	W	20:22:18	17°	W	20:22:18	17°	W
29 Jan	2.1	18:23:58	10°	SW	18:27:47	59°	SSE	18:29:34	29°	E
29 Jan	4.1	20:02:33	10°	W	20:04:22	26°	W	20:04:22	26°	W
30 Jan	2.1	18:05:08	10°	SW	18:08:58	61°	SSE	18:11:36	19°	ENE
30 Jan	3.2	19:43:45	10°	W	19:46:25	40°	WNW	19:46:25	40°	WNW
31 Jan	2.1	17:46:17	10°	SW	17:50:08	64°	SSE	17:53:37	13°	ENE
31 Jan	2.3	19:24:56	10°	W	19:28:25	61°	NW	19:28:25	61°	NW
01 Feb	2.1	17:27:27	10°	WSW	17:31:19	66°	SSE	17:35:11	10°	ENE
01 Feb	2.0	19:06:07	10°	W	19:10:01	67°	N	19:10:23	62°	NE
01 Feb	5.2	20:44:54	10°	WNW	20:45:11	12°	WNW	20:45:11	12°	WNW

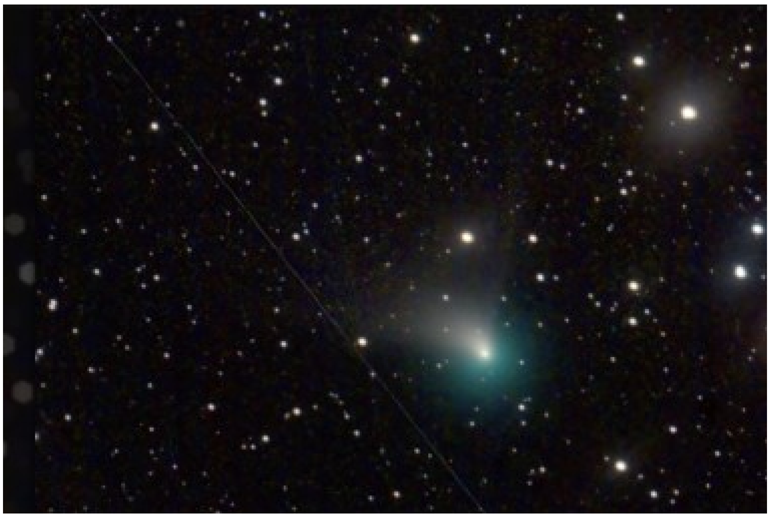
ISS PASSES For JANUARY 2023

from Heavens Above website maintained by Chris Peat.

Date	Brightn	Start	Highest point	End						
	(mag)	Time	Alt.	Az.	Time	Alt.	Az.	Time	Alt.	Az.
03 Jan	-0.7	**04:55:28**	15°	**ESE**	04:55:28	15°	**ESE**	04:56:07	10°	**ESE**
03 Jan	-2.3	06:28:23	22°	WSW	06:29:12	24°	SSW	06:31:59	10°	SSE
04 Jan	-2.1	05:42:09	26°	S	05:42:09	26°	S	05:44:08	10°	SE
05 Jan	-0.5	04:55:57	11°	SE	04:55:57	11°	SE	04:56:06	10°	SE
05 Jan	-1.4	06:28:52	12°	SW	06:28:59	12°	SW	06:30:22	10°	SSW
06 Jan	-1.1	05:42:43	12°	S	05:42:43	12°	S	05:43:13	10°	S
17 Jan	-1.4	18:21:36	10°	SSE	18:22:47	13°	SSE	18:22:47	13°	SSE
18 Jan	-1.7	19:07:42	10°	SW	19:09:14	22°	SSW	19:09:14	22°	SSW
19 Jan	-2.4	18:19:25	10°	SSW	18:22:15	25°	SSE	18:22:42	25°	SE
19 Jan	-0.4	19:55:19	10°	WSW	19:55:35	12°	WSW	19:55:35	12°	WSW
20 Jan	-1.8	17:31:21	10°	S	17:33:42	18°	SE	17:36:05	10°	E
20 Jan	-2.5	19:06:39	10°	WSW	19:08:58	39°	SW	19:08:58	39°	SW
21 Jan	-3.2	18:18:03	10°	SW	18:21:17	46°	SSE	18:22:17	34°	ESE
21 Jan	-0.6	19:54:33	10°	W	19:55:10	15°	W	19:55:10	15°	W
22 Jan	-2.6	17:29:32	10°	SW	17:32:37	33°	SSE	17:35:32	11°	E
22 Jan	-3.0	19:05:46	10°	W	19:08:25	53°	WSW	19:08:25	53°	WSW
23 Jan	-3.8	18:16:59	10°	WSW	18:20:20	74°	SSE	18:21:37	35°	E
23 Jan	-0.7	19:53:42	10°	W	19:54:30	16°	W	19:54:30	16°	W
24 Jan	-3.4	17:28:14	10°	WSW	17:31:33	58°	SSE	17:34:47	10°	E
24 Jan	-3.2	19:04:52	10°	W	19:07:40	59°	W	19:07:40	59°	W
25 Jan	-3.8	18:15:59	10°	W	18:19:22	87°	N	18:20:48	32°	E
25 Jan	-0.8	19:52:45	10°	W	19:53:41	18°	W	19:53:41	18°	W
26 Jan	-3.7	17:27:07	10°	WSW	17:30:28	84°	S	17:33:50	10°	E
26 Jan	-3.5	19:03:51	10°	W	19:06:49	67°	W	19:06:49	67°	W
27 Jan	-3.8	18:14:56	10°	W	18:18:18	86°	N	18:19:57	28°	E
27 Jan	-1.0	19:51:41	10°	W	19:52:50	19°	W	19:52:50	19°	W
28 Jan	-3.8	17:26:00	10°	W	17:29:21	85°	N	17:32:43	10°	E
28 Jan	-3.5	19:02:44	10°	W	19:05:59	61°	SSW	19:05:59	61°	SSW
29 Jan	-3.7	18:13:45	10°	W	18:17:07	76°	SSW	18:19:11	21°	ESE
29 Jan	-1.1	19:50:41	10°	W	19:52:04	19°	WSW	19:52:04	19°	WSW
30 Jan	-2.5	19:01:33	10°	W	19:04:39	36°	SSW	19:05:19	32°	S
31 Jan	-3.0	18:12:29	10°	W	18:15:43	49°	SSW	18:18:40	12°	SE
31 Jan	-0.8	19:50:11	10°	WSW	19:51:34	13°	SW	19:51:34	13°	SW
01 Feb	-1.3	19:00:33	10°	W	19:03:02	19°	SW	19:05:02	12°	S
02 Feb	-1.8	18:11:12	10°	W	18:14:07	27°	SSW	18:17:01	10°	SSE
04 Feb	-0.8	18:10:21	10°	WSW	18:12:15	14°	SW	18:14:11	10°	S

END IMAGES, AND OBSERVING

Just after sunset to the north west and to the north east after 1am we shall be getting the brightening comet **c/2022 e3 ztf.** Currently at mag 7.9 it should brighten to 5th magnitude by the end of the month. Look above the semicircle of stars of Corona Boreal- is between Arcturus and the Keystone of Hercules with binocu- lars.



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	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.