AOH Newsletter

Autumn 2023

News and Notes

In July, we finally got to observe from Kneeland (after six consecutive cancellations due to cloudiness); a group of girl scouts and their families joined us. Meanwhile we did an outreach program at the Cal Poly Natural History Museum Day Camp, and made two visits to Albee Creek Campground in Humboldt Redwoods State Park. August's meeting was canceled because of smoke from fires near Hoopa, and in September we met at Kneeland Observatory because Cal Fire was still using the Airport parking area for their support vehicles.

Thanks to Barry, Catrina, Don, Grace, Rick, Susan, and Yoon for Newsletter help. —*Ken*

Russ explaining telescopes and Ken explaining the Solar System at the Cal Poly Natural History Museum Day Camp.

Mark W giving the kids hands-on telescope experience with a couple of Galileoscopes.

Planet masks are always a big hit.

Photos at far left and top right are by Ken; photos at near left and bottom right are by Grace.

At Kneeland Airport in July 2023. Top left: Ann and Grace looking at the hydrogen-alpha Sun and Grace aligning on the stars. Bottom left and top right: part of the crowd. Bottom right: girl scouts (and Mom) waiting for their turn and Russ setting up at dusk. Photos by Don, except for the two in the dark taken by Ken

Still at Kneeland in July.

Left, Barry setting up his Unistellar. Below, Eagle, Trifid, and Lagoon Nebulas, and Galaxy M101 with Supernova 2023ix.

We also saw "unprocessed" photons from the supernova through Peyton and Jill's 18-inch Dob.

At Albee Creek Campground in Humboldt Redwoods State Park in July.

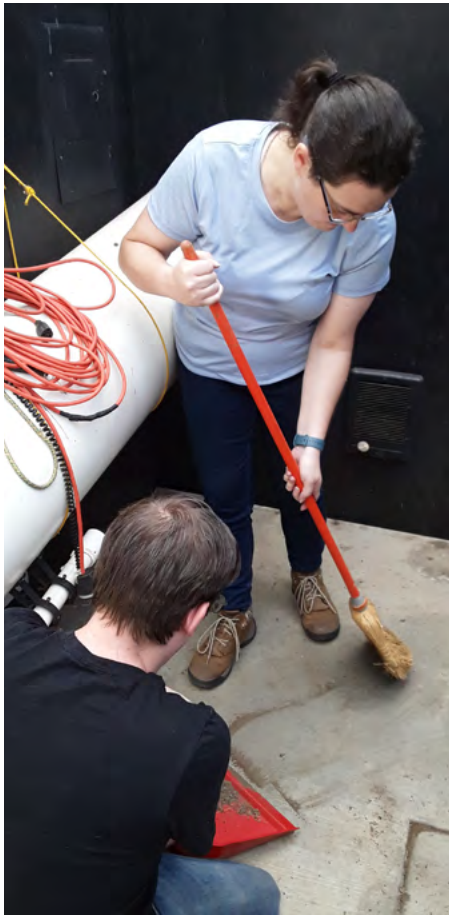
Top: watching wildlife (inset) while waiting for the sky to darken.

Bottom: Visitors looking at the daytime Moon.

Photos by Catrina.

We went back to Albee Creek in August. Top: Mary K welcoming some of the 200+ visitors who showed up. Photo by Catrina. Below: AOH volunteers Susan, Mark W, Ken, Catrina, Brent, Mary, and Don. Photo by Grace.

In September we organized a work party to clean up at the observatory.



After the cleanup effort, we rewarded ourselves with a picnic dinner and some solar-prominence viewing. Many of us stayed until after dark for some viewing of the Milky Way and some northern galaxies.

Astrophotographs

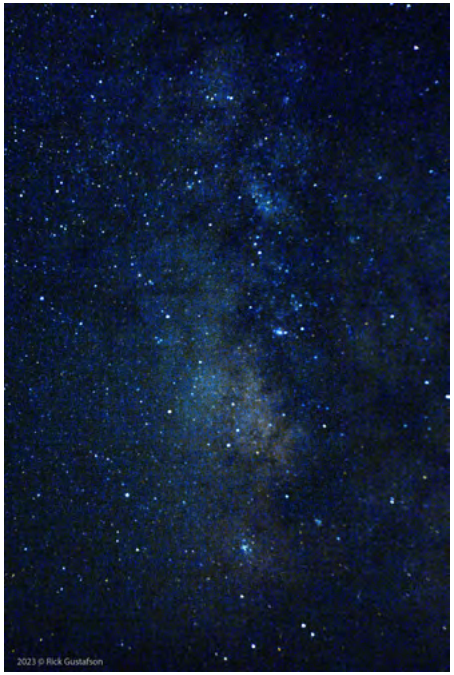
From Barry Evans (right)

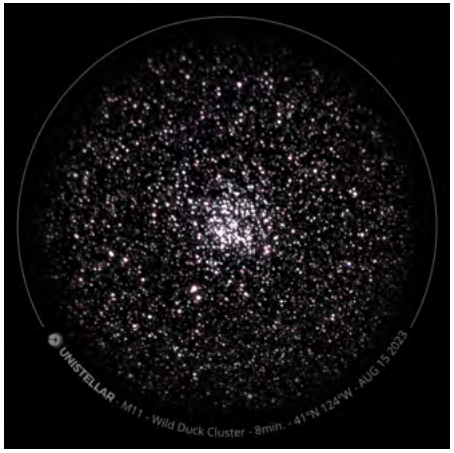
We were at Big Lagoon in August (saw ONE Perseid before it completely clouded over), but got these. I'm wondering what the streak in the M94 pic was.

Ed. note: After further discussion we decided it was most likely a satellite.

From Rick Gustafson (below)

The last best night of 2023 for taking pictures of our galaxy was September 9. I decided to go up to the Kneeland area in Humboldt County to capture a very small part of the Milky Way.



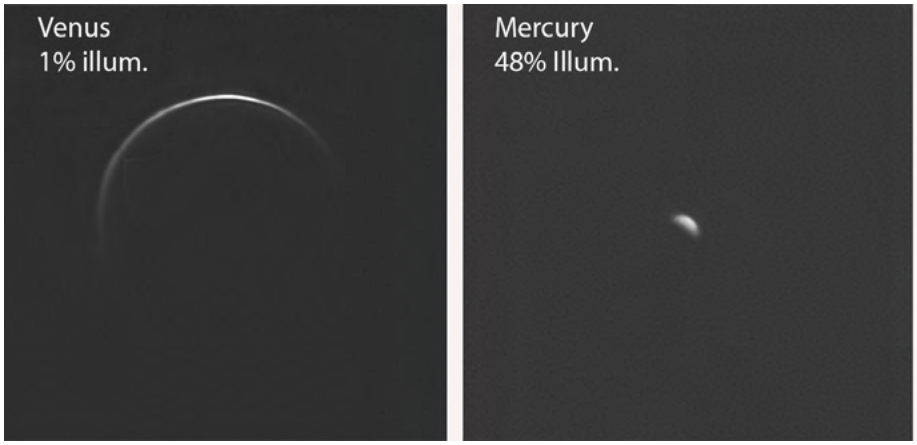


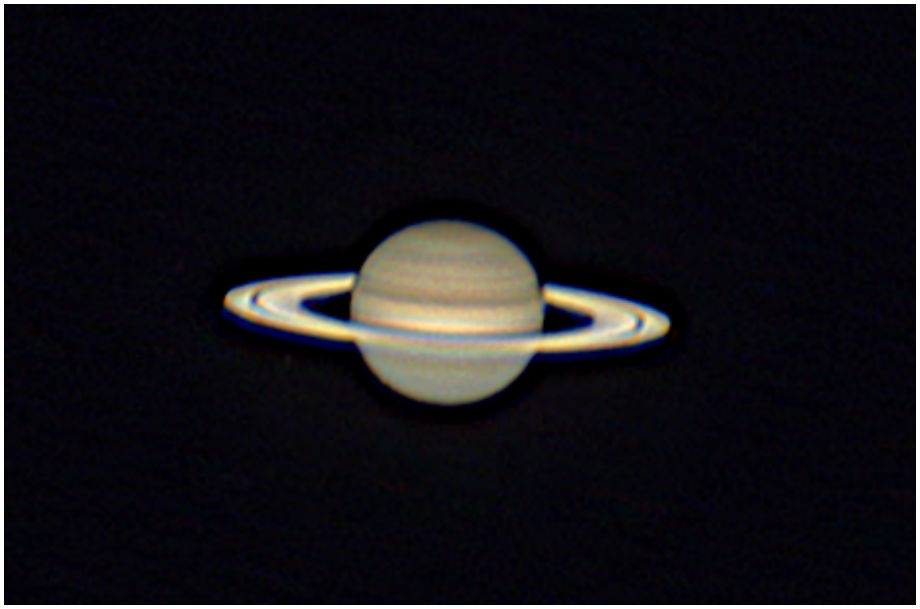
From Grace Wheeler

On August 10th, Venus was 1% illuminated as its orbit placed it between the Earth and the Sun (near inferior solar conjunction).

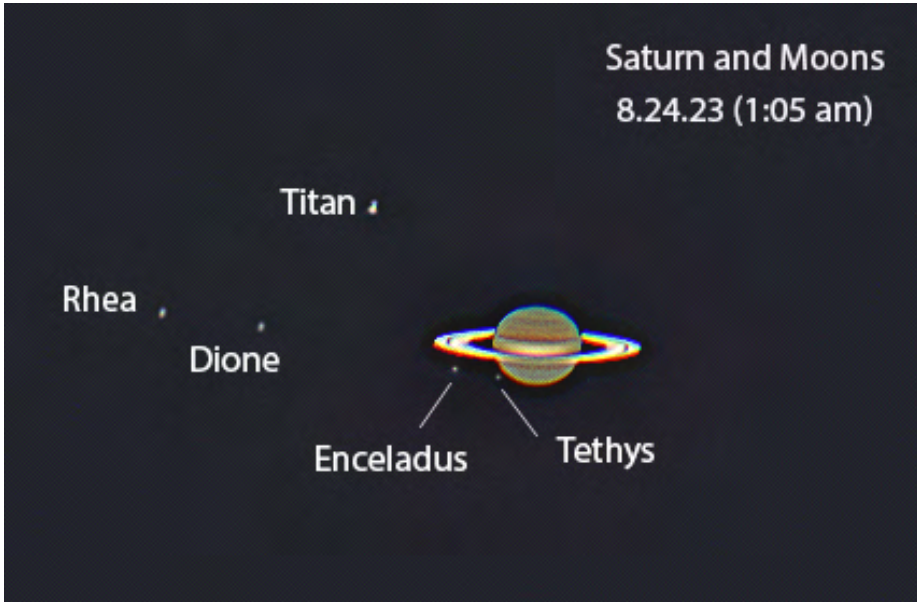
And on August 10th, Mercury reached its greatest eastern elongation, i.e., the greatest angular distance from the Sun. The disk was 48% illuminated. Mercury is usually hard to see because of its small size and close proximity to the Sun. The best time to observe Mercury is at elongation when the planet is at its brightest and, because it is farther from the sun, is not lost in the haze.

Images of Venus and Mercury were captured with an 8-inch SCT on an Ioptron equatorial mount. A Zwo 294MM planetary camera was used to record videos of the planets. The frames were stacked in Autostakkert and sharpened in Registax.

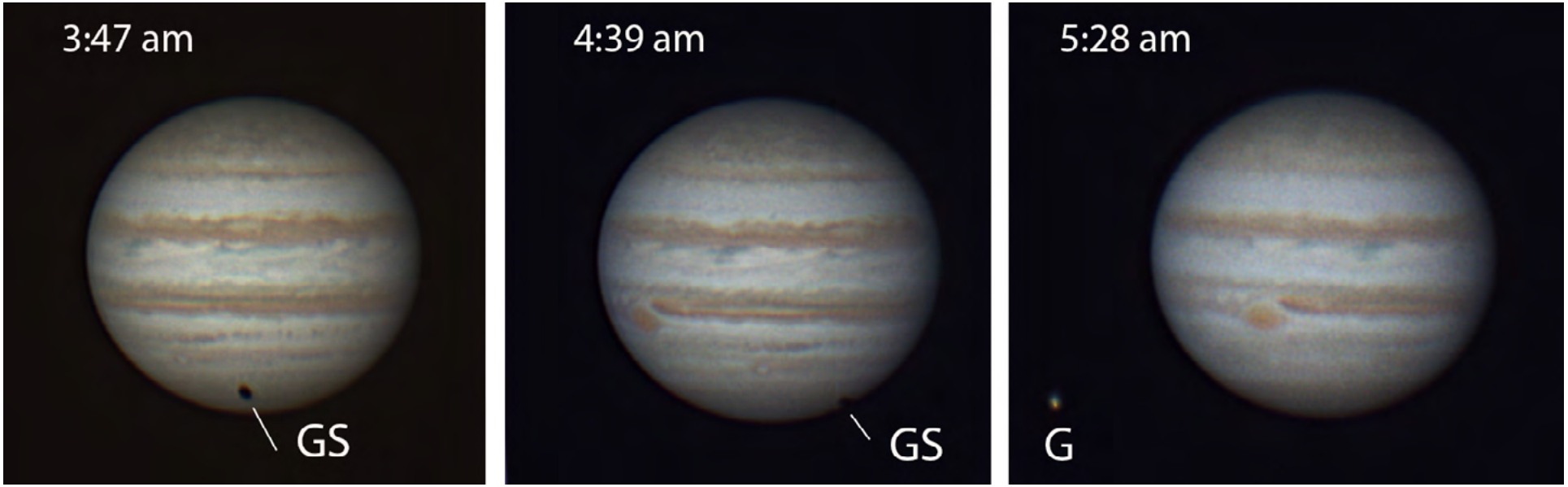




Saturn was imaged on August 24th about two days before opposition. This is one of my better efforts at imaging Saturn, and the banding pattern on the planet and the Cassini Division on the rings were particularly pronounced. Video of Saturn was captured using a 2.5x Barlow lens with a Zwo planetary camera, stacked in Autostakkert, and sharpened in Registax. The final processing was done with Photoshop.



To visualize the moons, a second image of Saturn was stacked and processed. This Saturn image was taken without the Barlow lens; this not only let in more light, but also widened the field of view. The "camera raw filter" in Photoshop was used to selectively increase the exposure of the background; this method made Enceladus and Tethys visible in the image. (Disclosure: I still had to use the dodge tool for these two moons.)



In the predawn hours of September 14th, there was a transit of the shadow of the moon Ganymede in the polar region of Jupiter. As a bonus, a transit of the Great Red Spot was also seen. The shadow transit started at 2:44 a.m. and ended at 4:44 a.m. I was able to capture the mid-point (3:47) and end of the shadow transit (4:44). The transit of Ganymede itself on the disk would not start for another three hours (7:46 a.m.) and was not visible because it occurred after sunrise. The lag between the transit of the Jovian moon and its respective shadow is most pronounced at the time interval before and after opposition (Jupiter opposition is on November 2nd). Before opposition, the moon trails behind the shadow. The reverse is true after opposition when the shadow lags behind the moon. In the period close to opposition, the moon and shadow transits occur in tandem. In the image above, Ganymede's shadow (GS) and Ganymede (G) are labeled.

Library Telescope Update

As we have previously reported, AOH has made two telescopes available to the Humboldt County Library for the use of Library patrons. The program has been very popular; there is a long wait list for patrons who want to reserve a scope.

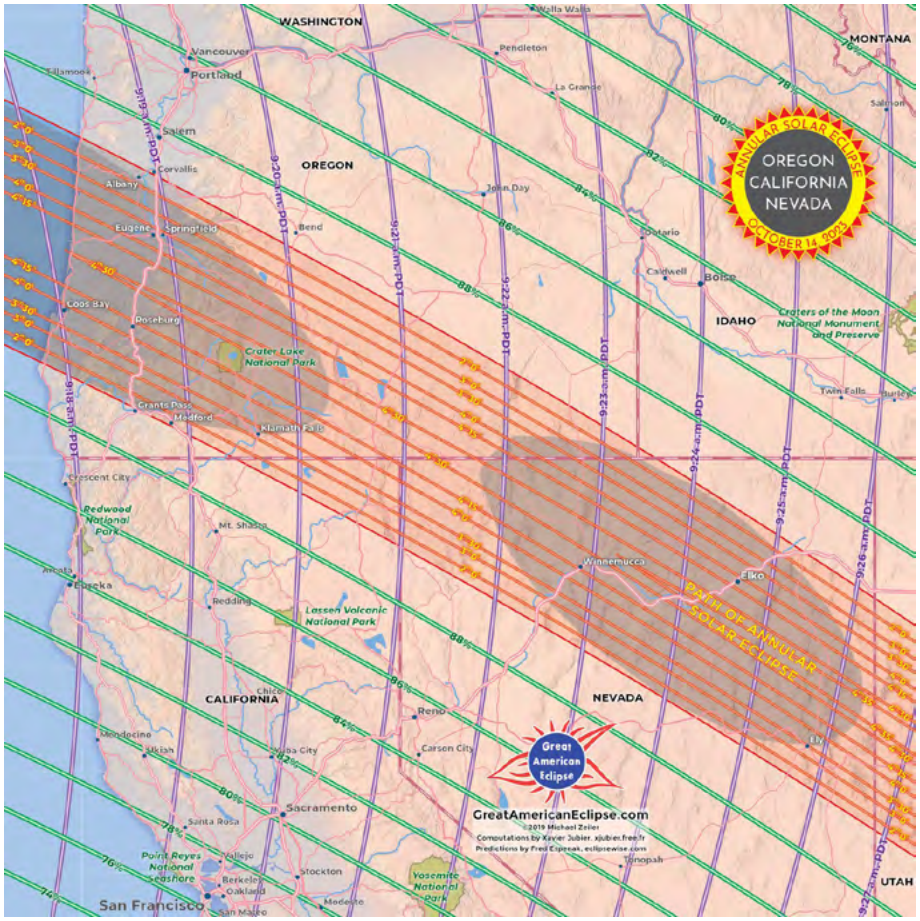
We have been recently informed that AOH has been chosen to receive a third telescope in a drawing by the Astronomical League to add to the Library's collection. We are eagerly awaiting delivery, and will get it put to use as soon as we can.

General Membership Meeting and Election of Members of the Board of Directors

The Club's annual general membership meeting and election of the Board of Directors will be held sometime in November. Information will be announced as soon as details are available, Check your inbox for updates.

Solar Eclipse: October 14, 2023

Viewers along a path from Coos Bay, across Crater Lake, the Northeastern tip of California, through Winnemucca and Elko, and down through Utah, New Mexico, and Texas will experience an annular, or "ring of fire" eclipse of the Sun. Those outside the path of annularity, but within a few hundred miles of it, will get a partial eclipse. Here in Humboldt County those who stay home will see 89% of the Sun's diameter, or 83.8% of the Sun's surface, blotted out by the Moon.



Viewers along the path of annularity see the "ring of fire" eclipse. Elsewhere viewers see a "crescent of fire"; in Eureka the solar obscuration will be 83.8%. Graphic from https://www.greatamericaneclipse.com/california-2023-eclipse.

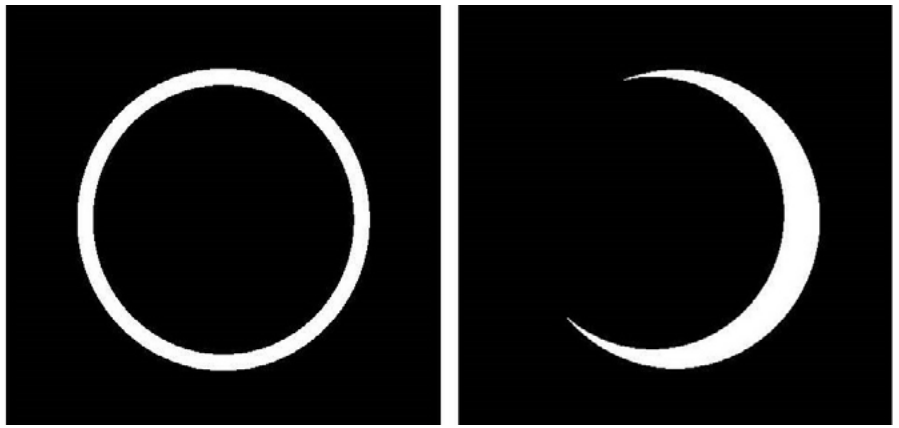
	Time (PDT)	Sun's Altitude (degrees)	Sun's Azimuth (degrees)
Eclipse Begins	**8:04:33.8**	**6.1**	**106.4**
Maximum Eclipse	**9:17:51.7**	**18.9**	**119.6**
Eclipse Ends	**10:39:08.4**	**30.9**	**137.5**

Duration	**2h 34m 34.6s**
Magnitude	**0.890**
Obscuration	**83.8%**

Data is from the US Naval Observatory, computed for Eureka, California.
https://aa.usno.navy.mil/data/Eclipse2023

However, regardless of whether you are looking at an annular or a partial eclipse, some sort of safe viewing procedure is needed. If you are looking through a telescope or binoculars, you must have a certified solar filter mounted *in front of* the device (*not* behind the eyepiece). Or you may wear certified solar eclipse glasses (*not* ordinary sunglasses); number 14 welder's glass also makes a safe filter. Or you can project an image of the sun by making a small hole in a piece of stiff paper and letting the sun shine through the hole onto a plain flat surface. The eclipse happens in the morning, so an east-facing wall is ideal for this purpose.

Choose your viewing location before the eclipse. Check at the appropriate time a few days before the event to see if the Sun is clear of trees or buildings.



Left, computed view of the Sun at mid-eclipse from the midline of the eclipse. Right, view of the Sun at mid-eclipse from Eureka.

Book Review: Guy Ottewell's *Astronomical Calendar 2024*

by Ken Yanosko

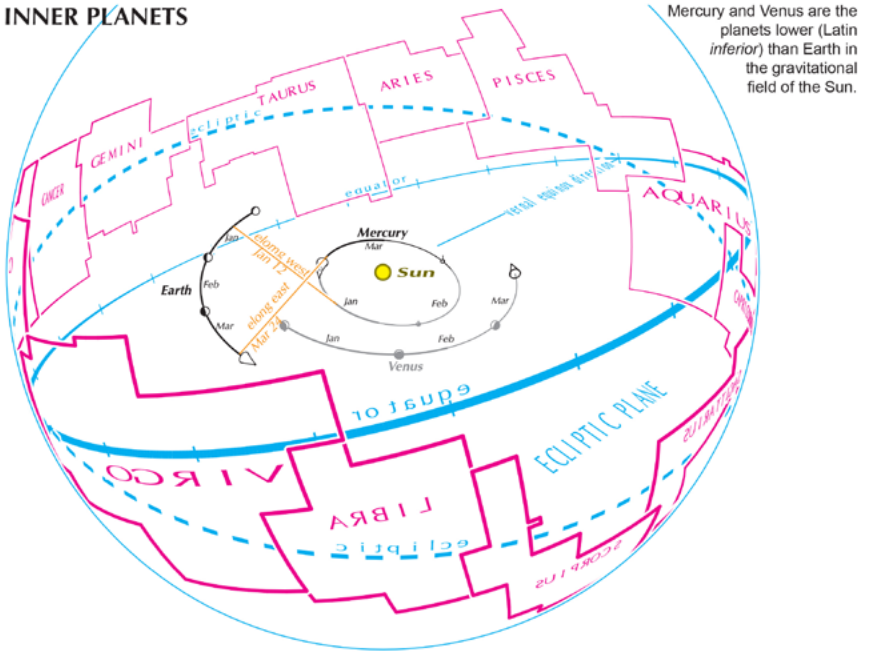
Veteran armchair astronomers recall eagerly awaiting the publication each year of Guy Ottewell's Astronomical Calendar. The 1974 through 2016 editions were paper copies only. From 2017 through 2022 it was an online-only text. But beginning last year it is available both as an on-paper book and as a downloadable pdf document. The 2024 downloadable version has just become available; the paper version will be available soon. Go to the author's website at https://www.universalworkshop.com/astronomical-calendar-2024/ to download the e-copy ($12) or get updated about the paper copy ($22).

This isn't a typical page-a-month calendar (If that's what you want download our AOH Calendar—the 2024 edition is coming soon.) but is 141 pages of astronomical delight. Data is presented in several formats: tables, three-dimensional diagrams, and all-sky and partial-sky astronomical charts. There is a full explanation of the main features; there

The 2024 cover picture story is the myth of Danae, who gave birth to Perseus after Zeus descended on her in the form of a shower. The picture was painted by the author and the text has a two-full-page recounting of this story and its possible relationship to the Perseid meteor shower.

JD 245-				UT	JANUARY
0310.5	Jan	1	Mon		Gregorian calendar Jan 1 = Julian calendar 2023 Dec 19
0311.141	Jan	1	Mon	15	Moon at apogee; distance 63.48 Earth-radii
0311.626	Jan	2	Tue	3	Mercury stationary in longitude; resumes direct motion
0311.656	Jan	2	Tue	4	Mercury stationary in right ascension; resumes direct motion
0312.468	Jan	2	Tue	23	**Earth at perihelion**; 0.9833 AU from the Sun
0313.5	Jan	4	Thu	0	**Quadrantic meteors**; ZHR 80; near Last Quarter Moon
0313.647	Jan	4	Thu	3:32	**Last quarter Moon**
0314.286	Jan	4	Thu	19	Moon at descending node; longitude 200.9°
0314.583	Jan	5	Fri	2	**Moon 1.78° NE of Spica;** 80° from Sun in morning sky; magnitudes -9.7 and 1.0
0314.807	Jan	5	Fri	7:22	Latest sunrise, at latitude 40° north
0316.381	Jan	6	SAT	21	Mars at southernmost declination, -24.03°
0316.813	Jan	7	SUN	8	Venus 6.3° N of Antares; 36° and 37° from Sun in morning sky; magnitudes -4.0 and 1.0

A sample of tabulated data for the first week of January. Dates and hours are in Universal Time; you have to subtract 8 hours to get Pacific Standard Time, or 7 hours to get Pacific Daylight Time.



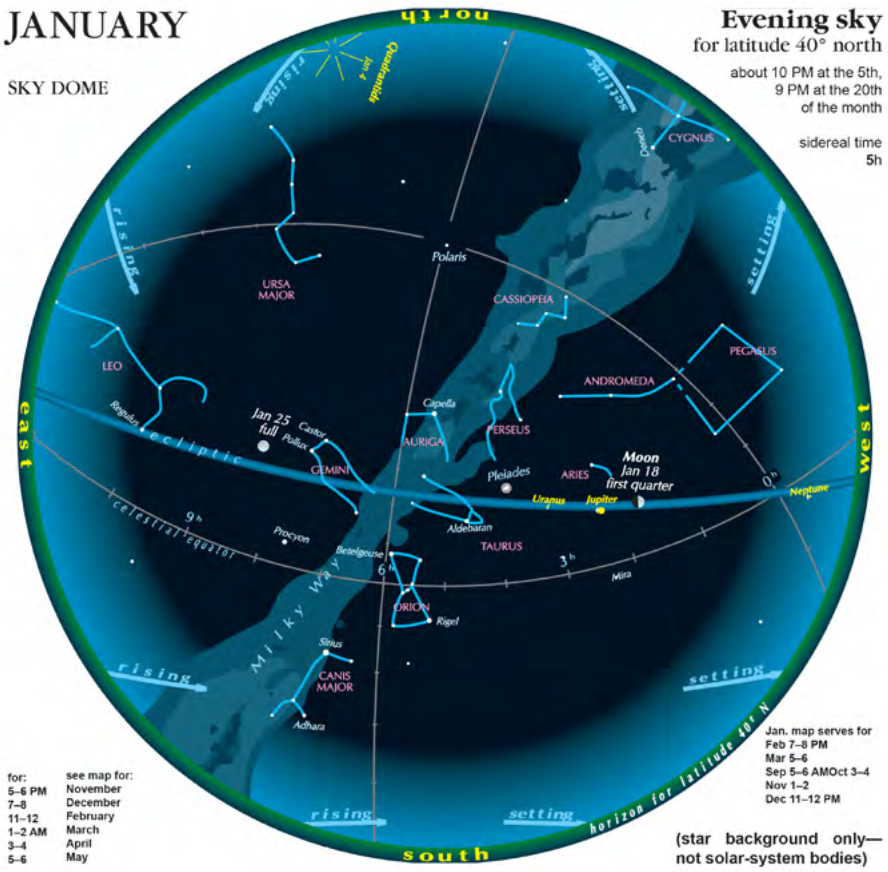
Here is a reduced-size version of a typical three-dimensional "space map". In the e-book you can zoom in on any picture and get full resolution.

are predictions of meteor showers, occultations, and conjunctions; and there is a glossary of terms.

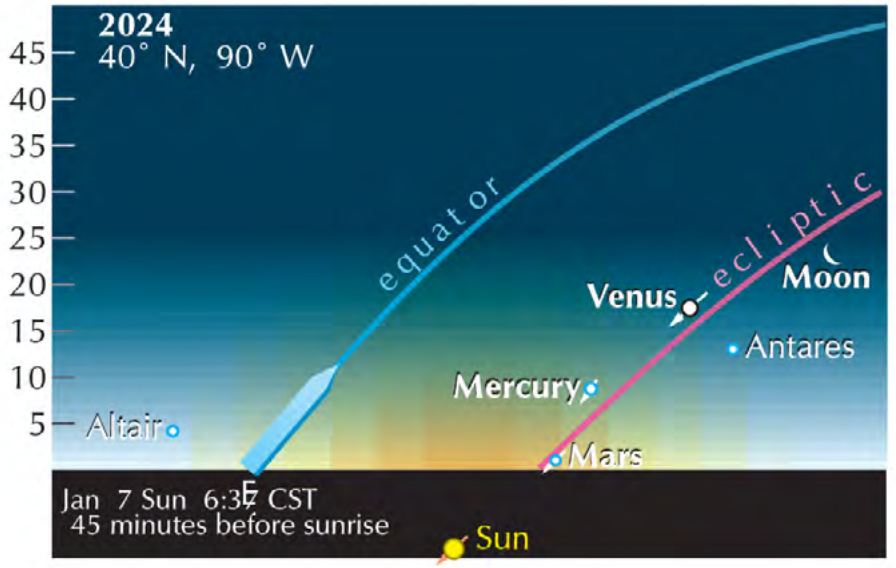
Happily, for us, the northern-hemisphere diagrams are for 40 degrees north latitude (southern-hemisphere readers are accommodated too).

Pages are in 8.5 by 11 inch format, so the owner can easily print out or photocopy individual pages as desired. This also facilitates the publisher's print-on-demand system for those who order paper copies.

The text includes a tip on how best to display the e-book on your



For each month there is a full-sky "dome" map of the constellations.



There are after-sunset and before-sunrise horizon maps. These are updated daily, or every few days, since things seem to change rapidly near the horizon.

device. Since it is in pdf format, your computer or e-reader will use its default software for pdf displays (maybe Adobe Reader or maybe a web browser). If you are a Kindle user you can Google "Send to Kindle" to learn how to get it into your Kindle Library; that's what I did. Once installed, the e-book displays beautifully. The figures can all be enlarged using the "magnify" button or by "un-pinching" on a touch-screen. They have been created as "vector" images; this means they can be enlarged to full resolution without pixelation.

The author, Guy Ottewell, is a prolific writer, having turned out not only these annual calendars since 1974 but also a number of books on astronomy (*To Know the Stars*, *The Astronomical Companion*, *The Under-Standing of Eclipses*, and others) and also some fictionalized accounts of historical lore (*Berenice's Hair* and *The Troy-Town Tale*) and some historical and social-science works (*Turkey, A Very Short History*; *Approval Voting in the Balance*; and *Ten-Minute History of the World and Queen Guinevere's Rules*). He has been an adventurer, a cataloger of books in Middle Eastern languages, a teacher, and a human rights activist.

Lizard in the Sky with Diamonds

by Ken Yanosko

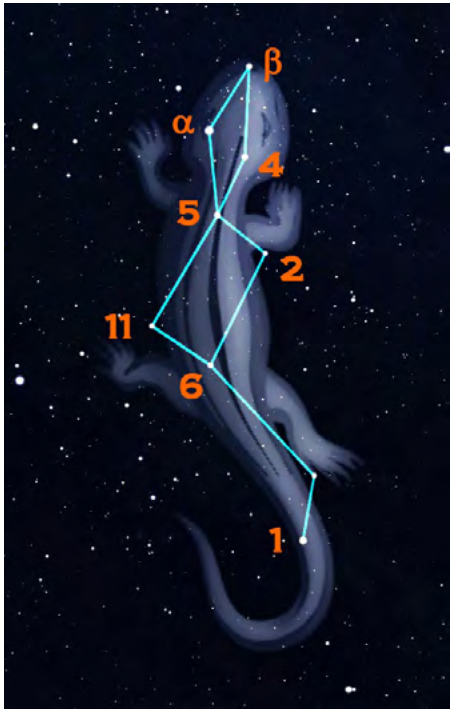
Yes, there's a Lizard in the Sky. It's the constellation Lacerta, and in late summer it passes directly overhead for us 40-degree-north-latitudians. Look south of Cepheus, in between Cygnus and Andromeda.

It's one of those "modern" constellations, made up by the Polish astronomer Jan Heweliusz, better known as Johannes Hevelius, 1611-1687. I've mentioned Hevelius before; he's the guy who couldn't stand the empty spaces between the classical Greek constellations, so made up his own to fill the voids. His atlas, *Prodromus Astronomiae*, published posthumously in 1690, depicts the lizard with the label "Lacerta or Stellio." "Lacerta" is the lizard genus, and "Stellio" ("Stellion" in modern English) is a common name for the "Star Lizard," so called for the line of star-shaped spots running down its back.

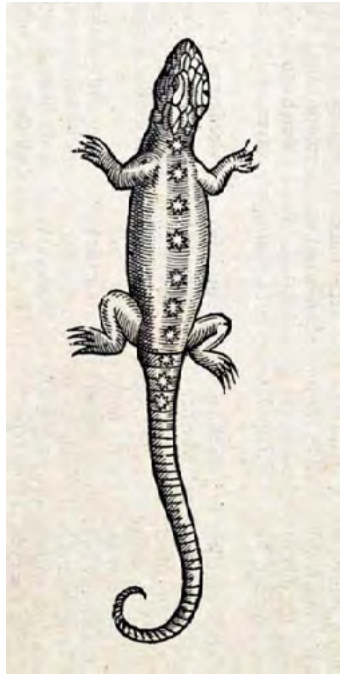
Lacerta in Prodromus Astronimicae *by Johannes Hevelius, 1690.*

Stellions are indigenous to the Eastern Mediterranean, not Poland, so Hevelius probably never saw one; but he was undoubtedly familiar with its picture in a 1658 1100-page treatise *The History of Four-footed Beasts and Serpents* by Edward Topsell. At any rate, the name "Stellio" fell into disuse, and "Lacerta" is now the constellation's official name. (But don't confuse it with "Chamaeleon," a constellation of the far southern skies.)

If you look at the picture from Hevelius's book, you will note that the Lizard consists of a diamond of stars, with appendages at each end representing the head and tail. Above the Lizard's head are two more stars that, in Hevelius's drawing, belong to a tassel on Cepheus's turban. Modern astronomers have moved these two stars to the Lizard (where they are now known as Alpha and Beta Lacertae). So modern drawings depict Lacerta with two diamonds, a broad one for the body and a narrow pointy one for the head (whence the title of this article).

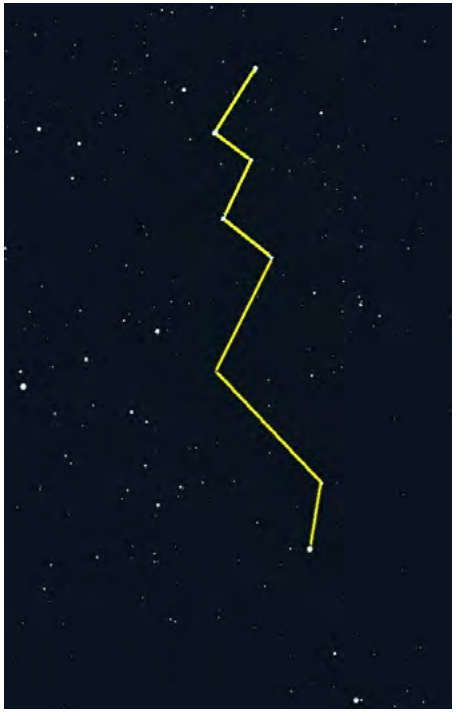


A modern depiction of Lacerta. Note that only the Alpha and Beta stars are bright enough to get Greek-letter designations. From Stellarium.



A stellion from The History of Four-footed Beasts and Serpents *by Edward Topsell, 1658.*

Some celestial cartographers ignore the diamonds, however, and

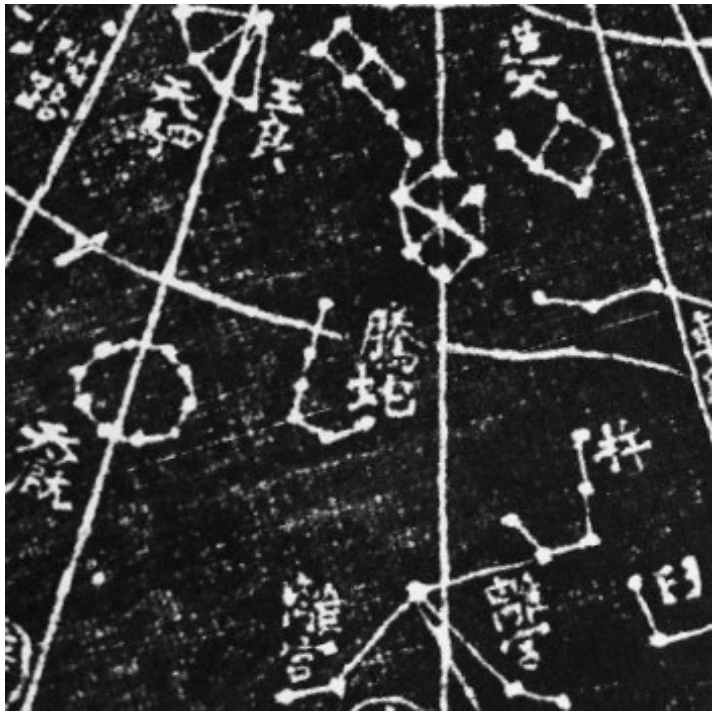


Lacerta, drawn as a zigzag. Note that the top five stars determine four segments that closely resemble a miniature copy of Cassiopeia. From Stellarium..

instead just draw a zigzaggedy line along the lizard's body. The first five stars in this zigzag form a W; for this reason Lacerta has sometimes been called "Little Cassiopeia."

The alpha star has magnitude just under 4, and everything else is over 4, so the Lizard is well camouflaged. And the only deep-sky objects in Lacerta that are brighter than 9th magnitude are the open clusters NGC 7209 and 7243. Look carefully in binoculars or a small

Open clusters in Lacerta. They are both around magnitude 7.5 and appear as concentrations of the background Milky Way stars. The larger Telrad circles are 4 degrees in diameter. From Stellarium..



A part of the Suzhou Star Map from 13th century China. In the center is a backwards-J-shaped asterism labeled with the characters 螣蛇 *("Tengshe" which means "Flying Serpent"). This is a scan of an ink-on-paper rubbing made in the 1990's from the original limestone engraving which was carved in 1247. The rubbing is owned by The History of Chinese Science and Culture Foundation of London, and the original engraving is in the Purple Mountain Observatory of Nanjing, China.*

scope; to the eye they are little more than concentrations of the background Milky Way.

In the Far East, the Chinese astronomers recognized the stars of Lacerta as one of their mini-asterisms. It was indicated on a 13-century engraved star chart known as the "Souzhou Planisphere." In a reptilian coincidence, Lacerta was known to the Chinese as the "Flying Serpent."

So the next time you're out stargazing, add the Lizard to your personal Zodiac. As you view it, make up your own mythology. What heroic deeds earned Lacerta its place in the heavens? What obstacles overcome? What villains vanquished? Modern constellations demand tales of modern superheroes! Wherefore these Diamonds in the Sky?

This article is distributed by the NASA Night Sky Network, a coalition of hundreds of astronomy clubs across the US dedicated to astronomy outreach.

Find an Observing Program for You with the Astronomical League!

Looking for something to jump-start your stargazing? Maybe need a bit of direction? Or possibly you are tired of looking at the same set of objects every time you observe? If so you should definitely check out one of the Astronomical League's observing programs!

The League has run their excellent observing programs for the past 50 years. Since 1967, the Astronomical League's observing programs have awarded over 10,000 observing certificates to skilled amateurs in recognition of their stargazing achievements—along with some great pins, too! These programs have helped amateur astronomers shore up their observing legs as well. Many folks might eventually observe all of the Messier objects, for example; but the League's requirements for their Messier program will make that observer carefully take into consideration the factors around their observation, such as the time and observing conditions present that night, as part of their needed documentation. Some harder to spot objects may even go unnoticed but for the need to complete the observing list—helping to sharpen those eyes and starhopping skills, with a cool pin and certificate as a reward—although the true reward is the boost in confidence and knowledge gleaned from working towards these observations for the participating observers.

The are programs for observers of all levels and interests. Beginners can start with programs like the Binocular Messier or Constellation Hunter programs. The Caldwell Observing Program, Two in the View, or Asteroid Observing programs are great programs for stargazers who have gotten a few observations under their belt and want to further sharpen their skills! Experts can test their mettle and go deep with programs like the Binocular Variable Star Observing Program, Herschel 400, or Master Observing Program. Even stargazers who are surrounded by light pollution in urban areas can participate in programs like the Urban Observers Program or Lunar Observing Program—or help fight light pollution and attain the Dark Sky Advocate award. Fans of astronomy outreach, like many members of Night Sky network clubs, can pursue the Outreach Observing Award—and snag another pin to feature alongside their NSN award pins! You don't even need a telescope to participate in an observing program; there are programs for naked-eye observations and binocular-wielding observers. Participants aren't even necessarily restricted by observing in visible light, as there is even a Radio Astronomy Observing Program.

There are many, many more programs you can find on their program list. Find one today and take up the challenge. Keep it up and one day you too will become a recognized as a master observer!

Go to the Astronomical League Observing Program web page at https://www.astroleague.org/observing-program-division/ for more information.

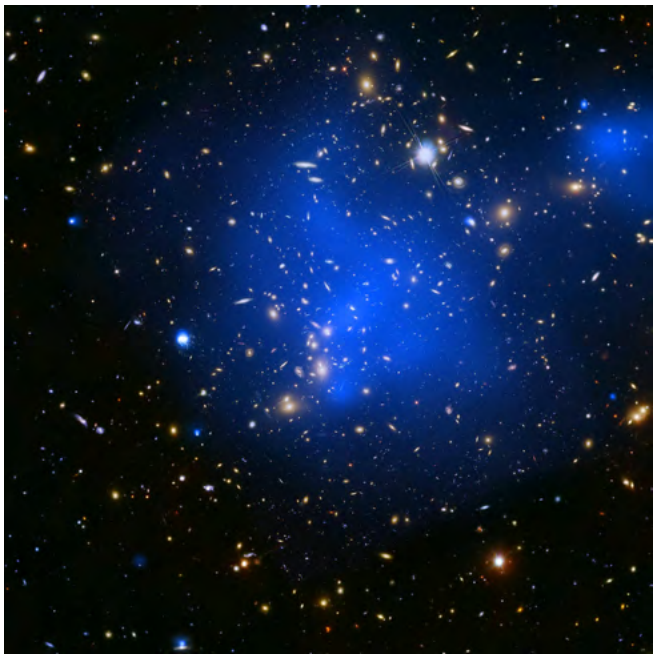
Pins and logos from the Astronomical League's many excellent observing programs—there are even more than seen here!
Image Credit: The Astronomical League

Looking back toward cosmic dawn – astronomers confirm the faintest galaxy ever seen

by Guido Roberts-Borsani

The universe we live in is a transparent one, where light from stars and galaxies shines bright against a clear, dark backdrop. But this wasn't always the case – in its early years, the universe was filled with a fog of hydrogen atoms that obscured light from the earliest stars and galaxies.

The intense ultraviolet light from the first generations of stars and galaxies is thought to have burned through the hydrogen fog, transforming the universe into what we see today. While previous generations of telescopes lacked the ability to study those early cosmic objects, astronomers are now using the James Webb Space Telescope's superior technology to study the stars and galaxies that formed in the immediate aftermath of the Big Bang.



A phenomenon called gravitational lensing can help astronomers observe faint, hard-to-see galaxies. NASA/STScI

I'm an astronomer who studies the farthest galaxies in the universe using the world's foremost ground- and space-based telescopes. Using new observations from the Webb telescope and a phenomenon called gravitational lensing, my team confirmed the existence of the faintest galaxy currently known in the early universe. The galaxy, called JD1, is seen as it was when the universe was only 480 million years old, or 4% of its present age.

A brief history of the early universe

The first billion years of the universe's life were a crucial period in its evolution. In the first moments after the Big Bang, matter and light were bound to each other in a hot, dense "soup" of fundamental particles.

However, a fraction of a second after the Big Bang, the universe expanded extremely rapidly. This expansion eventually allowed the universe to cool enough for light and matter to separate out of their "soup" and – some 380,000 years later – form hydrogen atoms. The hydrogen atoms appeared as an intergalactic fog, and with no light from stars and galaxies, the universe was dark. This period is known as the cosmic dark ages.

The arrival of the first generations of stars and galaxies several hundred million years after the Big Bang bathed the universe in extremely hot UV light, which burned – or ionized – the hydrogen fog. This process yielded the transparent, complex and beautiful universe we see today.

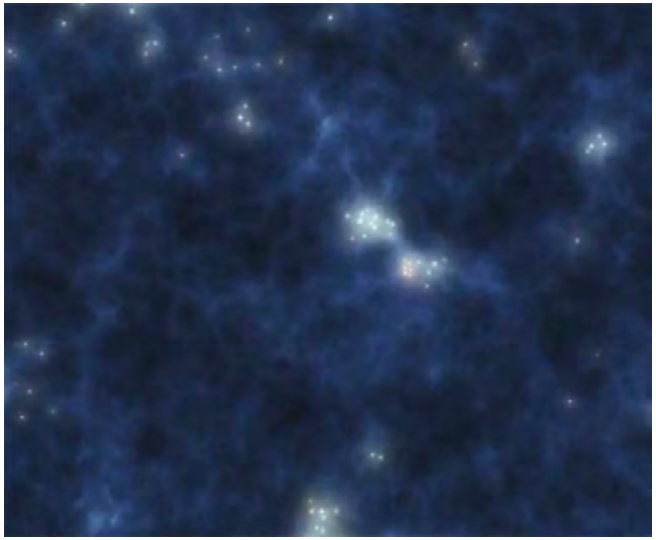
Astronomers like me call the first billion years of the universe – when this hydrogen fog was burning away – the epoch of reionization. To fully understand this time period, we study when the first stars and galaxies formed, what their main properties were and whether they were able to produce enough UV light to burn through all the hydrogen.

The search for faint galaxies in the early universe

The first step toward understanding the epoch of reionization is finding and confirming the distances to galaxies that astronomers think might be responsible for this process. Since light travels at a finite speed, it takes time to arrive to our telescopes, so astronomers see objects as they were in the past.

For example, light from the center of our galaxy, the Milky Way, takes about 27,000 years to reach us on Earth, so we see it as it was 27,000 years in the past. That means that if we want to see back to the very first instants after the Big Bang (the universe is 13.8 billion years old), we have to look for objects at extreme distances.

Because galaxies residing in this time period are so far away, they appear extremely faint and small to our telescopes and emit most of their light in the infrared. This means astronomers need powerful infrared tele-



The early universe was filled with a fog made up of hydrogen atoms until the first stars and galaxies burned it away. NASA/JPL-Caltech, CC BY

scopes like Webb to find them. Prior to Webb, virtually all of the distant galaxies found by astronomers were exceptionally bright and large, simply because our telescopes weren't sensitive enough to see the fainter, smaller galaxies.

However, it's the latter population that are far more numerous, representative and likely to be the main drivers to the reionization process, not the bright ones. So, these faint galaxies are the ones astronomers need to study in greater detail. It's like trying to understand the evolution of humans by studying entire populations rather than a few very tall people. By allowing us to see faint galaxies, Webb is opening a new window into studying the early universe.

A typical early galaxy

JD1 is one such "typical" faint galaxy. It was discovered in 2014 with the Hubble Space Telescope as a suspect distant galaxy. But Hubble didn't have the capabilities or sensitivity to confirm its distance – it could make only an educated guess.

Small and faint nearby galaxies can sometimes be mistaken as distant ones, so astronomers need to be sure of their distances before we can make claims about their properties. Distant galaxies therefore remain "candidates" until they are confirmed. The Webb telescope finally has the capabilities to confirm these, and JD1 was one of the first major confirmations by Webb of an extremely distant galaxy candidate found by Hubble. This confirmation ranks it as the faintest galaxy yet seen in the early universe.

To confirm JD1, an international team of astronomers and I used Webb's near-infrared spectrograph, NIRSpec, to obtain an infrared spectrum of the galaxy. The spectrum allowed us to pinpoint the distance from Earth and determine its age, the number of young stars it formed and the amount of dust and heavy elements that it produced.

Gravitational lensing, nature's magnifying glass

Even for Webb, JD1 would be impossible to see without a helping hand from nature. JD1 is located behind a large cluster of nearby galaxies, called Abell 2744, whose combined gravitational strength bends and amplifies the light from JD1. This effect, known as gravitational lensing, makes JD1 appear larger and 13 times brighter than it ordinarily would.

Without gravitational lensing, astronomers would not have seen JD1, even with Webb. The combination of JD1's gravitational magnification and new images from another one of Webb's near-infrared instruments, NIRCam, made it possible for our team to study the galaxy's structure in unprecedented detail and resolution.

Not only does this mean we as astronomers can study the inner regions of early galaxies, it also means we can start determining whether such early galaxies were small, compact and isolated sources, or if they were merging and interacting with nearby galaxies. By studying these galaxies, we are tracing back to the building blocks that shaped the universe and gave rise to our cosmic home.

A sky full of galaxies and a few stars. JD1, pictured in a zoomed-in box, is the faintest galaxy yet found in the early universe. Guido Roberts-Borsani/UCLA; original images: NASA, ESA, CSA, Swinburne University of Technology, University of Pittsburgh, STScI

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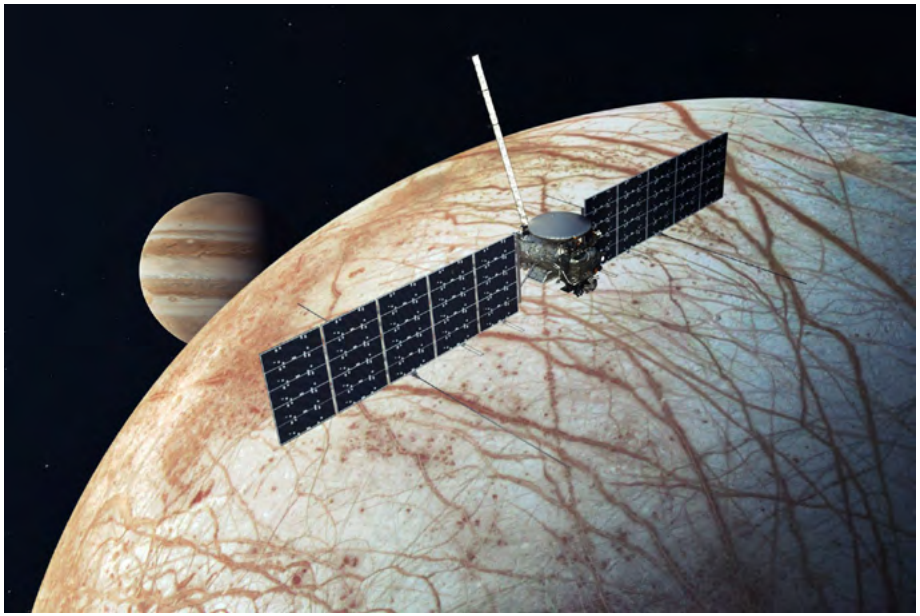
Europa Clipper
Exploring Jupiter's Icy Moon



What is NASA's Europa Clipper spacecraft?

Europa Clipper is a robotic solar-powered spacecraft built to conduct the first detailed investigations of Jupiter's icy moon Europa. The spacecraft will orbit Jupiter and make nearly 50 flybys of Europa to determine whether there are places below Europa's surface that could support life.

With its solar arrays deployed, Europa Clipper spans more than 100 feet (about 30 meters) – about the length of a basketball court. The main body of the spacecraft consists of its avionics vault, radio frequency module, and propulsion module.

At launch, Europa Clipper will weigh approximately 13,000 pounds (6,000 kilograms). Almost half of the weight will be fuel – nearly 6,000 pounds (2,750 kilograms) of propellant.

Europa Clipper will launch in October 2024 on a SpaceX Falcon Heavy rocket from Kennedy Space Center in Florida. The spacecraft will fly by Mars, then back by Earth, using the gravity of each planet to increase its momentum. These so-called "gravity assists" will provide Europa Clipper with the velocity needed to reach Jupiter in 2030.

After it begins orbiting Jupiter, Europa Clipper will spend about a year altering its trajectory to prepare for its first Europa flyby. The spacecraft will then spend about three years soaring past Europa dozens of times and sending data back to Earth. Over the course of the mission, the spacecraft will investigate nearly the entire moon.

What will Europa Clipper do?

Europa Clipper's main science goal is to determine whether there are places below the surface of Jupiter's icy moon, Europa, that could support life.

The mission's three main science objectives are to understand the nature of the ice shell and the ocean beneath it, along with the moon's composition and geology. The mission's detailed exploration of Europa will help scientists better understand the astrobiological potential for habitable worlds beyond our planet.

NASA's Europa Clipper spacecraft will perform dozens of close flybys of Jupiter's moon Europa, gathering detailed measurements to investigate the moon. The spacecraft, in orbit around Jupiter, will make nearly 50 flybys of Europa at closest-approach altitudes as low as 16 miles (25 kilometers) above the surface, soaring over a different location during each flyby to scan nearly the entire moon.

What is the spacecraft's design?

With its massive solar arrays and radar antennas, Europa Clipper

will be the largest spacecraft NASA has ever developed for a planetary mission. The spacecraft needs large solar arrays to collect enough light for its power needs as it operates in the Jupiter system, which is more than five times as far from the Sun as Earth. The spacecraft will be about 16 feet (5 meters) in height. With its arrays deployed, the spacecraft spans more than 100 feet (30.5 meters) and has a dry mass (no propellant in the tanks) of 7,145 pounds (3,241 kg).

Because Europa is bathed in radiation trapped in Jupiter's magnetic field, Europa Clipper's payload and other electronics will be enclosed in a thick-walled vault. This strategy of armoring up to go to Jupiter with a radiation vault was developed and successfully used for the first time by NASA's Juno spacecraft. The vault walls – made of titanium and aluminum – will act as a radiation shield against most of the high-energy atomic particles, dramatically slowing down degradation of the spacecraft's electronics.

What will we learn?

Europa shows strong evidence for an ocean of liquid water beneath its icy crust. Beyond Earth, Europa is considered one of the most promising places where we might find currently habitable environments in our solar system. Europa Clipper will determine whether there are places below Europa's surface that could support life.

The spacecraft's payload will include cameras and spectrometers to produce high-resolution images and composition maps of Europa's surface and thin atmosphere, an ice-penetrating radar to search for subsurface water, and a magnetometer and gravity measurements to unlock clues about its ocean and deep interior. The spacecraft will also carry a thermal instrument to pinpoint locations of warmer ice and perhaps recent eruptions of water, and instruments to measure the composition of tiny particles in the moon's thin atmosphere and surrounding space environment.

How can I participate?

NASA's Message in a Bottle campaign [see https://europa.nasa.gov/message-in-a-bottle/sign-on/] invites people around the world to sign their names to a poem written by the U.S. Poet Laureate Ada Limón. The poem connects the two water worlds — Earth, yearning to reach out and understand what makes a world habitable, and Europa, waiting with secrets yet to be explored. The campaign is a special collaboration, uniting art and science, by NASA, the U.S. Poet Laureate, and the Library of Congress.

The poem is engraved on NASA's robotic Europa Clipper spacecraft, along with participants' names that will be etched onto microchips mounted on the spacecraft. Together, the poem and names will travel 1.8 billion miles on Europa Clipper's voyage to the Jupiter system.

In Praise of Mystery: A Poem for Europa
by Ada Limón, U.S. Poet Laureate

Arching under the night sky inky
with black expansiveness, we point
to the planets we know, we

pin quick wishes on stars. From earth,
we read the sky as if it is an unerring book
of the universe, expert and evident.

Still, there are mysteries below our sky:
the whale song, the songbird singing
its call in the bough of a wind-shaken tree.

We are creatures of constant awe,
curious at beauty, at leaf and blossom,
at grief and pleasure, sun and shadow.

And it is not darkness that unites us,
not the cold distance of space, but
the offering of water, each drop of rain,

each rivulet, each pulse, each vein.
O second moon, we, too, are made
of water, of vast and beckoning seas.

We, too, are made of wonders, of great
and ordinary loves, of small invisible worlds,
of a need to call out through the dark.

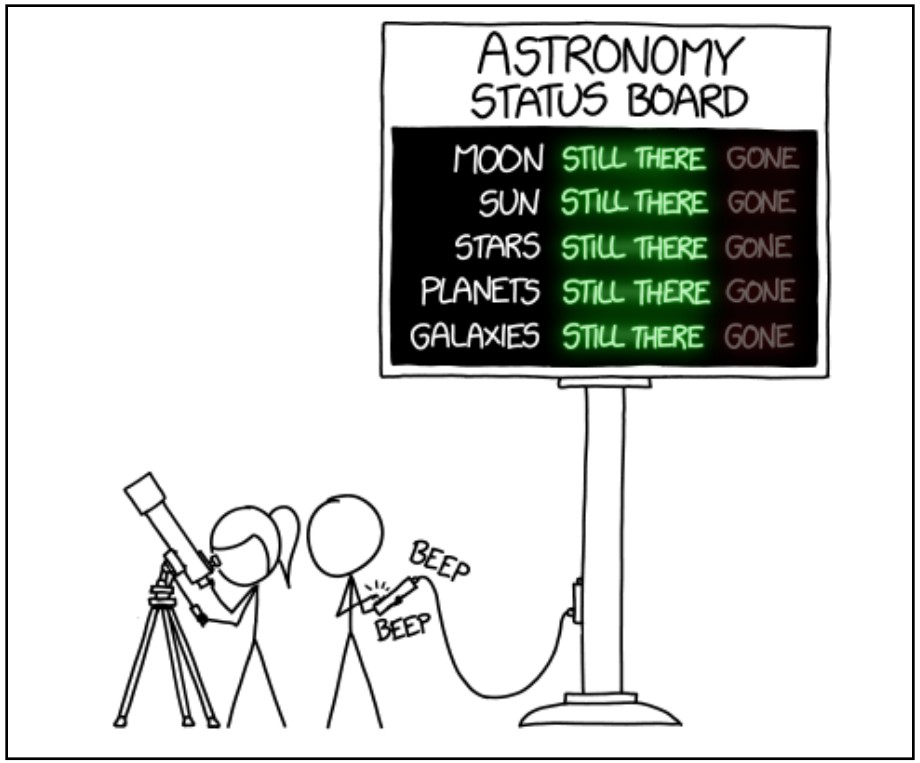
After Words

"People who believe they are ignorant of nothing have neither looked for, nor stumbled upon, the boundary between what is known and unknown in the universe."

Neil deGrasse Tyson
Astrophysics for People in a Hurry, 2017

"I will love the light for it shows me the way, yet I will love the darkness because it shows me the stars."

Og Mandino
The Greatest Salesman in the World, 1968



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