SkyWAAtch

The Newsletter of Westchester Amateur Astronomers

February 2025

2021 APEX® Awards for Publication Excellence
2022 APEX® Awards for Publication Excellence
2023 APEX® Awards for Publication Excellence
2024 APEX® Awards for Publication Excellence

Mars Occultation Egress by Jordan Webber

WAA President Jordan Webber used a 102-mm Maksutov and ASI224MC planetary camera to capture Mars emerging from behind the Moon at 10:37:36 p.m. on January 13th. Best 25% of 310 frames, stacked and sharpened with Autosakkert!3. The Moon was just 5 hours past full, so the terminator began to show on the Moon's eastern limb, providing some lovely terrain detail. Mars is emerging above Mare Marginus. The well-defined crater in the foreground is Langrenus, at the eastern edge of the Mare Fecundatis. See also page 24.

Our club meetings are held at the David Pecker Conference Room, Willcox Hall, Pace University, Pleasantville, NY, or on-line via Zoom (the link is on our web site, www.westchesterastronomers.org).

WAA February Meeting

Friday, February 14 at 7:30 pm

Exotic Sandy Clouds in the Atmospheres of Extrasolar Worlds

Genaro Suarez, PhD
American Museum of Natural History

Exoplanets and brown dwarfs are sufficiently cool to form clouds made of sand. It is crucial to understand these clouds to learn about the nature of extrasolar worlds. Dr. Suarez will present recent results about the physics and chemistry of sandy clouds and their effects on extrasolar atmospheres. The data provide a clearer picture of the diversity of exoplanets and brown dwarfs. He will also show exclusive observations from the James Webb Space Telescope that are helping us to decipher the phenomena that occur in the atmospheres of exoplanets.

WAA Members: Contribute to the Newsletter!
Send articles, photos, or observations to
waa-newsletter@westchesterastronomers.org

Also In This Issue

WAA March Meeting

Friday, March 14 at 7:30 pm

The Role of Robotics in NASA's Commercial Crew Program

Carol Higgins
NASA/JPL Solar System Ambassador

Starway to Heaven

Ward Pound Ridge Reservation, Cross River, NY

Star parties resume in March.

New Members

Molly Chidester	Elkton
John Gale	Bronx
Steven Oshry	Tarrytown
Tara Tamny-Young	Briarcliff Manor

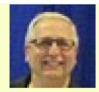
Renewing Members

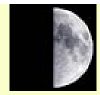
Richard Bronstein	Bedford
Cathy Carapella	Eastchester
Tom & Lisa Cohn	Bedford Corners
Derek Davis	Bronx
Larry and Elyse Faltz	Larchmont
Jonathan Gold	Newcastle
Patrick Guidera	Dobbs Ferry
Suzanne Kavic	Ossining
Scott Levine	Croton On Hudson
Richard Link	Ardsley
Lucian Lipinsky de Orlov	Goldens Bridge
John Markowitz	Ossining
Kevin Mathisson	Millwood
Bob Quigley	Eastchester
David & Lisa Sadowsky	Bedford

Call: **1-877-456-5778** (toll free) for announcements, weather cancellations, or questions. Also, don't forget to visit the WAA website.

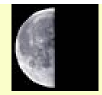
ALMANAC For February 2025

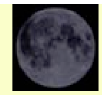
Bob Kelly, WAA VP of Field Events


Bob Kelly


1Q Feb 5


Full Feb 12

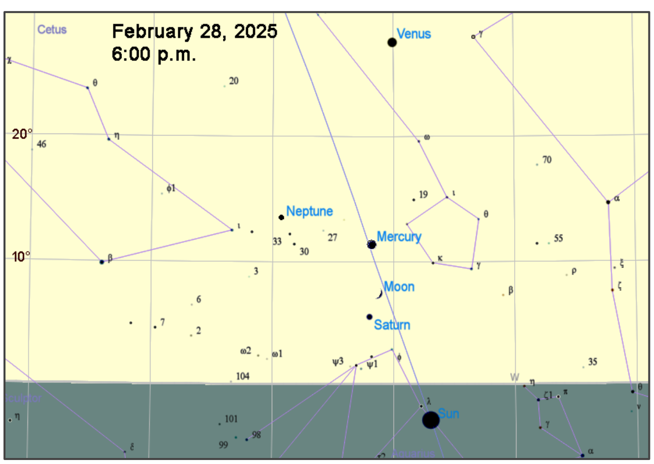

3Q Feb 20


New Feb 27

The great planetary parade spanning the evening sky continues in February, with a new member! Several of the planets are in the western sky after sunset and line up almost directly above where the Sun sets, making them easy to find. Catch Saturn before it sinks too low in the west to be seen. Otherwise, we have Mercury joining Venus, Jupiter and Mars in the evening sky. You can catch Uranus and Neptune out after sunset as well.

Venus' brightness tops out at magnitude -4.6 on the 14th. The combination of increasing size and decreasing phase results in the planet's greatest illuminated extent on that date. It's worth using filters or high magnification to see its crescent shape. Otherwise, I just see a blazing blob because of its extreme brightness. I've got to try viewing Venus through the 8-inch dob with sunglasses! See page 23 for more on Venus.

Mercury comes out of superior conjunction on the 9th to show up low in the western sky after sunset by the last week in February. This will be a good time to find the innermost planet, as it is bright at magnitude -1. Mercury and an extremely thin, 1% illuminated Moon are near each other, very low in the sky and just above Saturn, on the 28th. The Sun sets at 5:45 p.m. Use binoculars starting around 6:00 p.m.



Saturn lines up with Mercury on the 24th. The ringed planet soon bids farewell from our viewing until it pops up in the morning sky in early April. Saturn sets by the end of evening twilight on the 18th.

As if the thin crescent Moon and blazing Venus aren't enough of a wonderful sight on the 1st, the 2.4 arcsecond, 8th-magnitude disc of Neptune appears to their left. Saturn will be below this happy coupling of Venus and the Moon, its rings barely visible.

If brightness is any indication, Mars is moving away from Earth like crazy. Mars' post-opposition brightness falls off one magnitude from -1 at the beginning of this month to 0, and its disc shrinks from 13.6" to 10.9". It'll be easy to imagine Mars as the heart of a set of conjoined twins (in Gemini), but as the month goes on, Mars fades, looking like the twins need CPR. Despite the dimming, it's still a good planet to observe. It's up almost all night, setting near the start of morning twilight. Its distinctive ruddy glow makes it stand out even as it dims. The Moon adds its brightness to the scene on the 9th.

Jupiter, with its four bright moons, continues to be well placed high in the sky this month. It spends February hung up on the upper horn of Taurus the Bull. There are four evening shadow transits with Jupiter above 30° for the entire transit:

Date	Moon	Ingress	Egress
Feb 1	Io	19:51	22:04
Feb 7	Europa	21:52	00:09 (2/8)
Feb 8	Io	21:46	00:00 (2/9)
Feb 24	Io	20:07	22:20

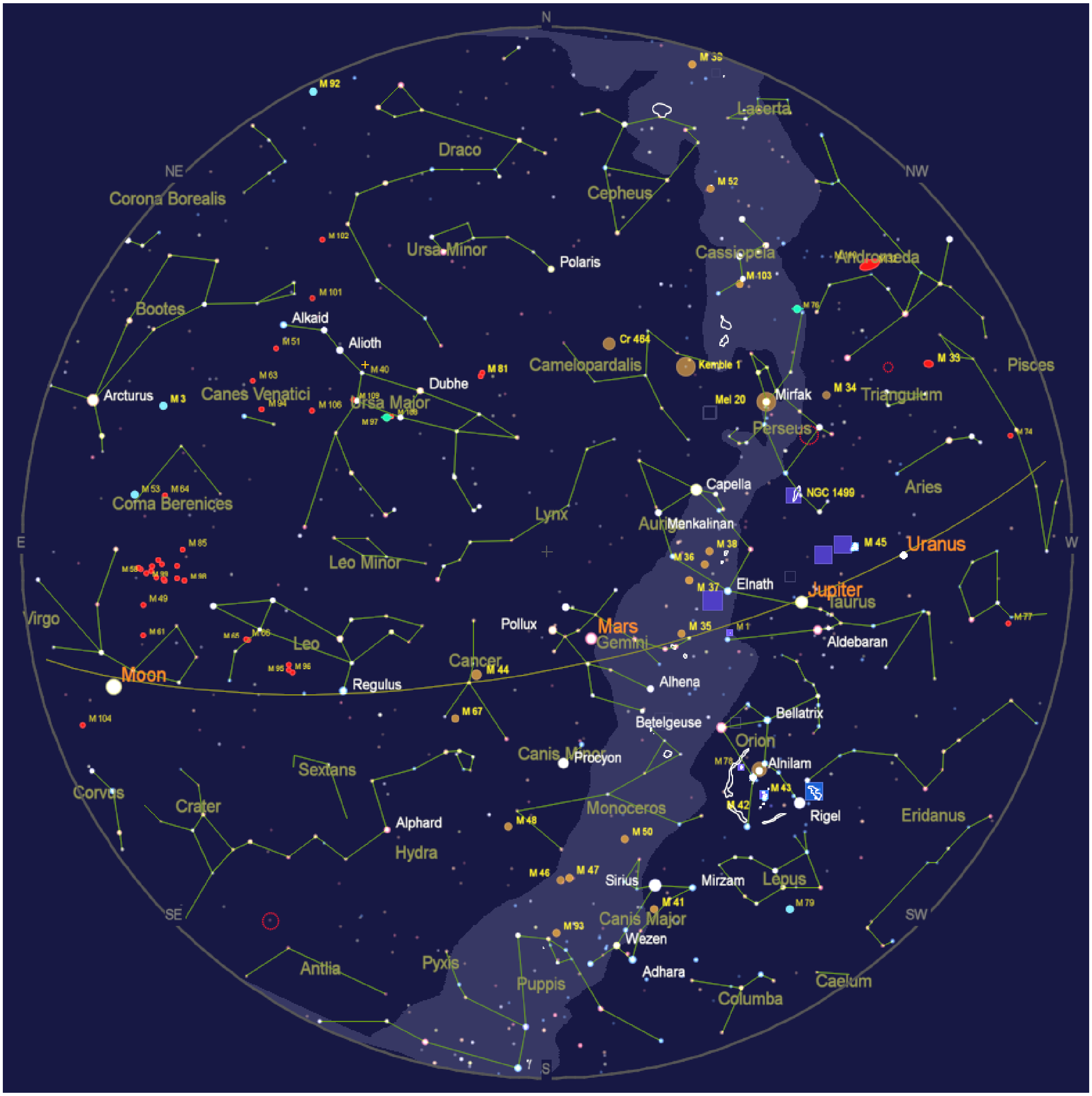
Uranus is in the evening sky in Aries at magnitude +5.7. Its disc is only 3.5 arcseconds across.

As for our friendly constellations, the dog, the hunter and the bull take center stage in the southern sky after darkness arrives. A lion roars up into the eastern sky. The Big Dipper (okay, an asterism, not a constellation), does its trick of standing on its handle as it gains altitude after appearing to scoop up water low in the northern sky this winter.

The International Space Station appears once in the evening sky on the 2nd. Then it soars over us in the morning sky for the rest of the month starting on the 11th. Tiangong appears in the morning sky though the 8th and the evening sky starting on the 16th.

Be on the lookout for aurora alerts, as the Sun continues its active phase. ■

Sky Map for February



The map above shows the night sky from Westchester at 10 p.m. on February 15. Solar system objects will be in similar positions, except for the location of the Moon, at 10:45 p.m. on February 1 and 9 p.m. on February 28.

Join the WAA Discord Server

Discord is an app (iOS, Android, Windows) that will vastly enhance communication within the club and increase the value of your membership. It's free.

For more information, go to this link: https://is.gd/WAADisc

Another Movie Telescope: The Losers

You've seen this formulaic, cartoonish movie before, perhaps more than once. A team of well-muscled special ops commandos with incredible martial arts and military skills are on the run, fighting a power-mad bad guy, once their superior, to prevent him from getting and using a new super-weapon. There is a small band of good guys, a good guy who turns out to be a bad guy, a bad guy who turn out to be a good guy (actually Zoe Saldana), innumerable bad guy minions who are dispatched by the good guys, and a mastermind super bad guy, a CIA turncoat, who is defeated with a particularly gruesome death as the good guys save the world. The good guys almost never get hit by bullets, win every hand-to-hand fight, and never miss with whatever weapon they are using, of which they have lots.

We caught this movie on TV one lazy night, but in truth we spent most of the time looking at our phones.

The movie was made in 2010 and filmed primarily in Puerto Rico. The then-functioning Arecibo Radio Telescope is the location of a scene in which the top bad guy meets with a lackey. He demonstrates his superiority with this wonderfully absurd dialogue:

Radio voice: We're all set, sir. Code?
Super-Arrogant Chief Bad Guy: [into radio] Pulsar.
Lackey: What's pulsar?
Super-Arrogant Chief Bad Guy: [Obnoxiously] What do *you* know about deep space tachyons?
Lackey: Nothing.
Super-Arrogant Chief Bad Guy: [sneeringly] Base particle string theory?
Lackey: [shrugs]
Super-Arrogant Chief Bad Guy: [even more sneeringly] Singularity events?
Lackey: [shrugs again]
Super-Arrogant Chief Bad Guy: [dismissively] I think we should move on, then.

Deep Sky Object of the Month: Messier 48

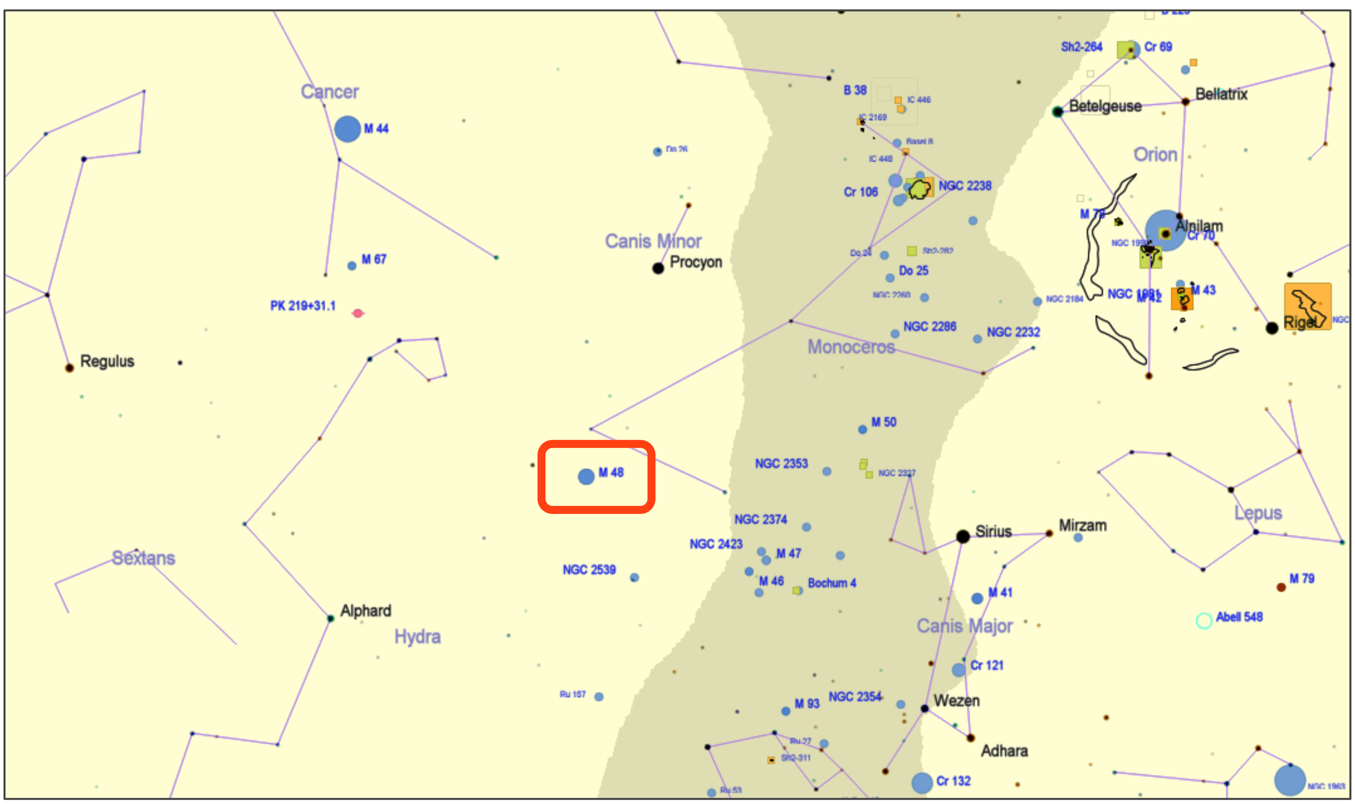
Messier 48	
Constellation	Hydra
Object type	Open Cluster
Right Ascension J2000	08h 13m 43.0s
Declination J2000	−05° 45′ 00″
Magnitude	5.8
Size	30 arcminutes
Distance	2,500 light years
NGC designation	2548
Discovery	Messier, 1771

Messier included a cluster at the right ascension of M48 but the declination he cites was 5 degrees off, so maybe he was seeing something else. In this unlikely circumstance, credit might be given to Caroline Herschel, who logged it in 1783. About 450 million years old, it has low metallicity compared to both the older Hyades (650 million years) and younger Pleiades (115 million years).

The decidedly asymmetric cluster has at least 438 members and a total mass of 2,366 $M_\odot$, meaning there are a good number of large stars within it. There appear to be three "cores" of stars within the cluster, each having a distinct proper motion.

Visibility for Messier 48			
22:00 EST	2/1	2/15	2/18
Altitude	39° 34′	42° 36′	42° 30′
Azimuth	154° 08′	171° 56′	189° 16′

The cluster is just above the galactic plane, and has been partially disrupted by gravitational forces, accounting for disparate proper motion of the cores. See https://arxiv.org/pdf/1606.06044 for more information.



On the Tail of Comet C/2023 A3 (Tsuchinshan-ATLAS) Robin Stuart

We have been fortunate to have had our skies graced by two bright Oort Cloud visitors in relatively quick succession—Comets C/2022 E3 (ZTF) in 2023 and C/2023 A3 (Tsuchinshan-ATLAS) in 2024. The first of these sported a rare anti-tail, seen pointing toward the Sun, which led me to investigate how such features were formed. My conclusions were written up in the May 2023 SkyWAAtch, page 11. That article also examined the future prospects for the then-recently discovered comet C/2023 A3 (Tsuchinshan-ATLAS) for which it was concluded that "from a geometrical perspective the chances of an anti-tail appearing seem very good." As shown spectacularly in Steve Bellavia's image on page 20 of the November 2024 SkyWAAtch, C/2023 A3 (Tsuchinshan-ATLAS)'s anti-tail did not disappoint.

To Earth-bound observers, C/2023 A3 (Tsuchinshan-ATLAS) appeared like a single brush stroke on the sky but this impression belies the vast and intricate 3D structure of the dust tail as a whole. The purpose of this article is to review the forces that influence the form of the dust tail and the circumstances that affect our view of it.

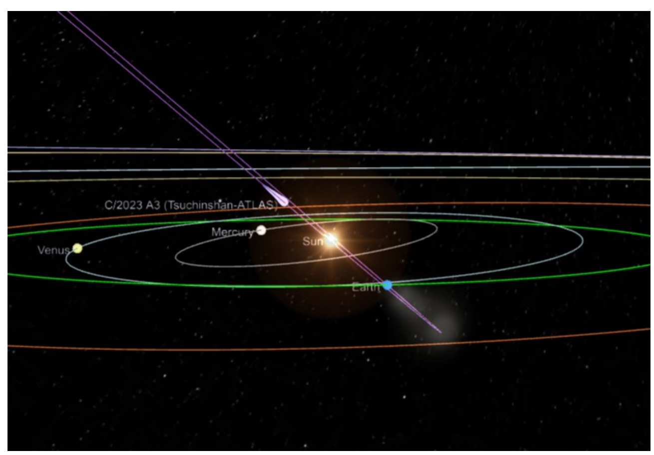
Dust Tail Dynamics Recap

A comet approaching the Sun follows a Keplerian orbital trajectory approximated by an ellipse, parabola or hyperbola. Heating from solar radiation liberates dust and gas into the surrounding space. Dust particles leave the surface at a low velocity relative to the comet itself. Once free they are acted on by the force of gravity, directed toward the Sun, and light pressure exerted by solar radiation, directed outward. The magnitude of the light-pressure force experienced by a dust particle depends on its size and is characterized by a quantity denoted μ, which is the ratio of the light-pressure force acting on the particle to the force of gravity. Smaller dust particles have larger values for μ. A particle with $\mu = 1$ experiences no net force and will follow a straight-line trajectory with speed and direction being that of the comet at the time it was emitted.

Both the forces of gravity and light pressure are inversely proportional to the square of the distance from the Sun but they act in opposite directions. The net effect is that a free dust particle effectively feels a reduction the Sun's gravity and consequently follows its own Keplerian orbit, determined by that reduced inverse square force, as it moves away from the comet.

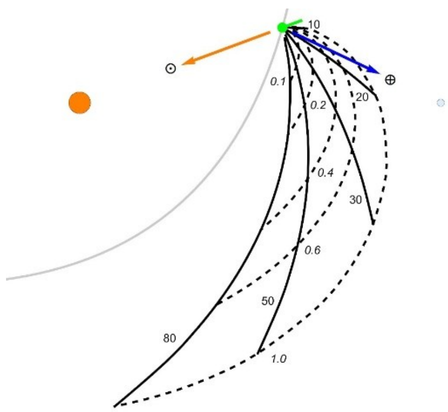
A comet's orbit lies in a plane that contains the Sun. There are no forces acting on a freed dust particle that would cause it to move out of that plane so that in 3 dimensions a comet's tail is a flat fan-like structure lying in the comet's orbital plane. How we perceive it depends on where we get to view it from.

When seen from within the orbital plane, the dust tail appears straight and narrow and, because all the dust particles it contains are concentrated into a relatively small area, the tail's surface brightness is enhanced and fainter diffuse regions are more easily seen. This is the view presented around the time that the Earth passes through the comet's orbital plane. How long this condition lasts depends on how quickly we move through the plane which in turn depends on the inclination of the comet's orbit to the ecliptic, *i*. In the case of C/2022 E3 (ZTF), $i = 109.2°$ which is equivalent to a retrograde orbit of inclined at 70.8°. As this is a steep angle, our passage through the orbital happens quite quickly. For C/2023 A3 (Tsuchinshan-ATLAS), $i = 139.1°$, equivalent to a retrograde orbit inclined at 40.9°, meaning that the edge-on geometry will persist for a longer time.



Inner solar system positions at the time Earth crossed the comet's orbital plane (TheSkyLive)

The Earth passed through C/2023 A3 (Tsuchinshan-ATLAS) orbital plane on October 14, 2024 at 18:36 UT. The diagram below shows the geometry of the tail viewed from far above north pole of the comet's orbital plane. Because of the comet's retrograde motion this is below the invariable plane of the solar system.[1]



In the diagram the gray curve represents the comet's orbital path around the Sun, which the comet moves along in a counter-clockwise direction. The green dot is the comet's head and the green line represents the ion tail, if present, that would be 5° long when viewed from Earth. The directions from the comet to the Earth and the Sun are indicated by the blue and orange arrows respectively. At this time C/2023 A3 was just 0.49 AU from the Earth and 0.60 AU from the Sun making it possible to plot their actual positions as pale blue and orange disks.

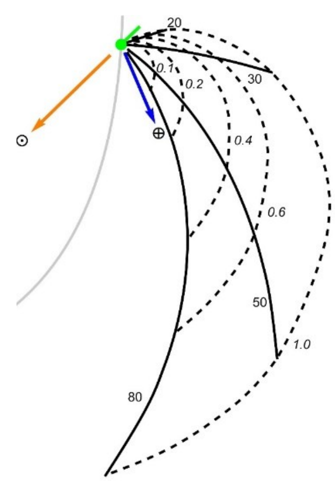
In the diagram the overall shape of the dust tail is shown by the solid and dotted black lines. The dashed curves are *syndynes* which represent streams of particles of the same size emitted at different times in the past. They are labelled in italics with their value of μ. Points on a syndyne that are closer to the nucleus were emitted more recently than those further out. The solid curves are *synchrones* which trace out the positions of particles that were all emitted at the same time in the past. They are labelled with the time since their emission in days. Smaller particles, with larger μ, lie further from the nucleus. Synchrones tend to be straighter than syndynes. Note that each point in the tail is associated with a unique pairing of particle size, as given by μ, and time since emission. Each syndyne and synchrone represents the trajectory of particles emitted from the nucleus with zero initial relative velocity. In the real tail, variations in these initial conditions will lead to some dispersion around the plotted paths.

Notice that the dust tail curves strongly in a direction toward the Earth and continues on so that, from the perspective of an Earth-based observer, much of it appears on the sunward side of the comet's nucleus. This is what is seen as the anti-tail and it shows up spectacularly in Steve Bellavia's image.

Capturing the Comet

My first opportunity to photograph C/2023 A3 (Tsuchinshan-ATLAS) came on October 17th. I imaged it on most evenings until early November using a variety of equipment and techniques. For comparison with the foregoing, I offer a pair of images taken on October 28th at around 7:45pm (pages 9 and 10).

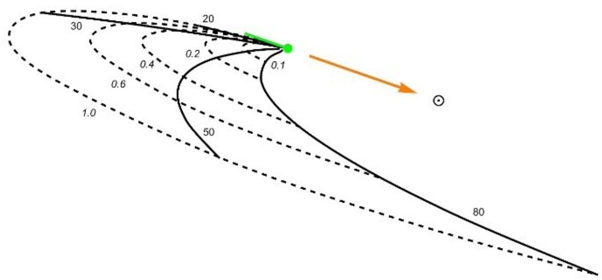
Analogous to the previous diagram, the one below shows the view of the comet's tail looking down from above its orbital north pole. From the perspective of an Earth-based observer, much of the tail still lies to the sunward side of the nucleus. However, the Earth lies below the comet's orbital plane and the dust tail is no longer being viewed edge-on. It appears broadened and particles are seen spread out over a greater area making the anti-tail fainter but still discernible.



The diagram below, sometimes called a Finson-Probstein diagram, shows the corresponding view as seen from the Earth. Once again the green ion tail is 5°

[1] The invariable plane of a planetary system is the plane passing through its barycenter (center of mass) defined by the weighted average of all planetary orbital and rotational planes. In the Solar System, about 98% of this effect is from the mass of the gas giants (Jupiter, Saturn, Uranus, and Neptune). The invariable plane is within 0.5° of the orbital plane of Jupiter.—Ed.

long. Note that in both diagrams, the one side of the tail close to the nucleus the syndynes bunch together, forming a sharp boundary.



The image below is a stack of 25 × 90 second subframes for a total exposure of 37½ minutes using a ZWO ASI2600MC camera attached to a Rokinon 135-mm telephoto lens at f/2. Processing was done in PixInsight. The images were aligned separately on the stars and the comet before applying the StarNet2 plugin. Stars and comet were then processed independently before being recombined.

The image is 6.68° × 5.01°.

As predicted by the Finson-Probstein diagram, the upper edge of the comet's tail is sharply defined and the sky above it is dark. No tail dust particles occupy this region. By contrast, the lower edge of the tail fades out gradually and the background sky is brightened by the diffuse glow of tail material. The anti-tail has become faint but is still evident a full 14 days since the plane crossing. From a spike at the time of plane crossing, it has been transformed into a fan-like structure.

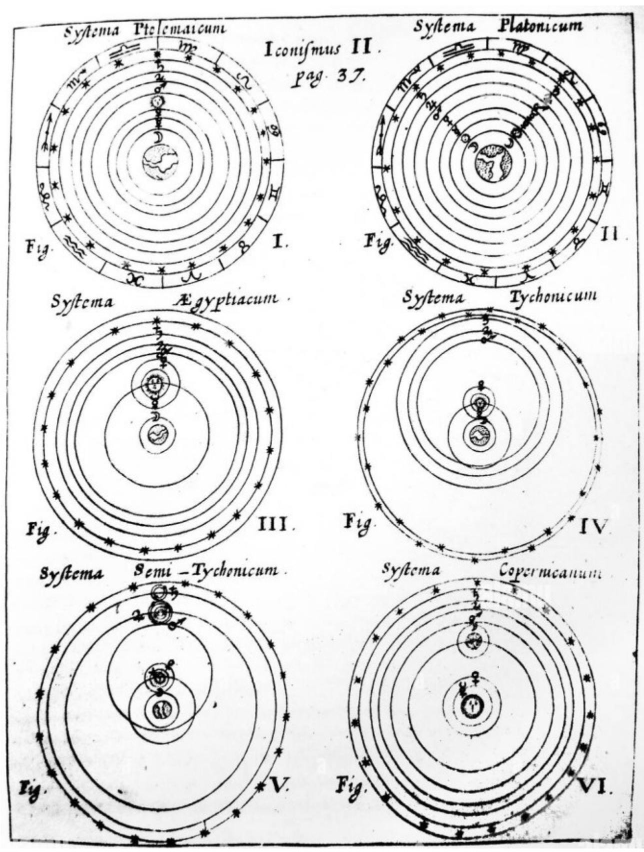
In this image the nucleus sits between the stars γ Ophicuchi (the lower star) and brighter β Ophiuchi (Cebalrai). Below it, the small globular cluster NGC 6426 can be seen. Near the top right of the frame is the open star cluster IC 4665, which is one of the brightest objects not catalogued by either Charles Messier or William Herschel.

Quite by chance the image also contains the 9.5 magnitude red dwarf, Barnard's star (circled in yellow), which holds the distinction of having the largest proper motion of any star at 10.3″/year. In around 10 years' time it will have reached the inner edge of the yellow circle.

The image on page 10 covers 24.2° × 32.3° and was taken at about the same time. It depicts a receding C/2023 A3 (Tsuchinshan-ATLAS) against the backdrop of the stars of the Milky Way. The Scutum Star Cloud occupies the lower left corner of the image. The bright patch to the comet's left is the Wild Duck Cluster, M 11 (see the October 2023 SkyWAAtch, page 20). The image is a stack of 9 two-minute subframes using a Canon 60Da DSLR equipped with a 35-mm f/1.4 lens on a tracking equatorial mount. Individual subframes were aligned on the comet. ■

Proof that the Earth Moves — Larry Faltz

How do we know that the Earth is revolving around the Sun? It's impossible for any of us, except perhaps for Flat Earthers and other idiots, to think that it doesn't. By the third grade, students are well acquainted with the solar system and become firmly committed heliocentrists. The first scientific evidence that the Earth moved was indirect. Galileo observed the phases of Venus in September 1610, although he did not publish his discovery until 1613, in *Letters on Sunspots*.[1] The *Letters* was where he first openly declared his support for Copernicus, inflaming the Jesuits, who had previously been supportive of his discoveries.



From Athanasius Kircher's *Iter Exstaticum* (1671)

Another problem that plagued astronomers was the distance to the stars. The system of nested crystalline spheres of Aristotle and Ptolemy put the stars at a fixed distance. Hipparchus studied the parallax[2] of the Sun and Moon and may have tried to determine the parallax of the planets, but for those measurements his equipment was inadequate. Greek astronomers knew stars were distant. Ptolemy estimated the sphere of the stars to be perhaps 20,000 Earth radii away. That's a distance of only about 80 million miles, less than the distance to the Sun. But to the Greeks it must have seemed vast.

By stellar parallax, astronomers were referring to the small change in a star's celestial coordinates as fixed from Earth (usually determined at the time the star transited the meridian) due to the Earth's location in its orbit. It doesn't necessarily require observing the star's relationship to surrounding, more distant stars, which is how we commonly think of parallax today. That method only arrived in the 1830s.

Detection of stellar parallax would prove that the Earth moved. At the end of the 16th century, Tycho Brahe attempted to measure stellar parallax, but his pre-telescopic equipment, the best of its time, was insufficient to determine if the expected position of a star changed during the course of a year. Tycho concluded that the stars were not so far away and the Earth didn't move. The idea of a vast void between Saturn, then the farthest planet, and the stars was inconceivable to him. The phases of Venus could be explained by Brahe's hybrid solar system, giving the Jesuits, and others, room for continuing to believe in a geocentric, biblically harmonious universe.

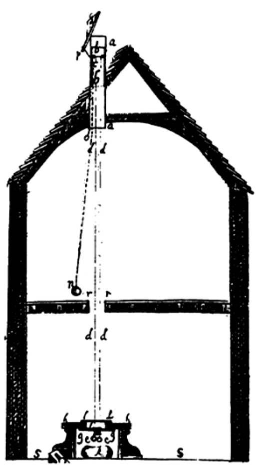
The beginning of science as a collaborative, experimental, mutually stimulating venture might be dated to first meeting of England's Royal Society at Gresham College in 1660. Among the Society's founders were the chemist, physicist and inventor Robert Boyle and mathematician, astronomer, and architect Christoper Wren, who is most remembered for St. Paul's Cathedral in London. In 1663, another polymath, Robert Hooke, was made a fellow and shortly thereafter became the society's Curator of Experiments. Hooke's genius applied itself effectively to many pursuits. He invented the compound microscope, accurately measured the rotations of Mars and Jupiter, built vacuum pumps, and claimed to have discovered the inverse-square law of gravity before Newton, with whom he never got along. He even

[1] His discovery of the satellites of Jupiter was a model for the solar system but *proved* nothing about it.

[2] If you need a refresher on parallax, there are many on the web. See for example https://www.space.com/30417-parallax.html.

made contributions to paleontology and was perhaps the first to propose that the Earth was much older than biblical calculations would suggest. Hooke had a famously acerbic personality. His brilliance was recognized in spite of his personal quirks.

In 1669, Hooke made a zenith telescope, a device that simply pointed straight up. Its advantage lay in the complete absence of refraction by the atmosphere, which would cause even a small deviation from vertical to displace a star's image from its expected position. The thicker the atmosphere (i.e. the lower the observed elevation), the greater the displacement, and the object will appear higher than it actually is. When you are looking straight up, you are looking through the least amount of atmosphere.



Hooke's zenith telescope (from ref. 4)

Hooke built the zenith telescope in his lodgings at Gresham College, drilling through the floors above him so that the 36-foot focal-length instrument could project above the roof. He observed by lying on his back in the basement. A plumb-bob would measure displacement from the zenith. His goal was to see an annual parallax in position of the star Gamma Draconis (Eltanin), which crossed the meridian near the zenith once a day, every day, in London.[3] That would be direct evidence that the Earth was revolving around the Sun and would permit an estimation of the star's distance once the radius of the Earth's orbit could be determined. Gamma Fraconis, at magnitude 2.24, is the brightest star in Draco in spite of being given the label gamma in Bayer's *Uranometria.* Alpha Draconis is magnitude 3.6 Thuban. In Ptolemy's *Almagest*, Thuban, more than 30 degrees from Eltanin, is assigned magnitude of 4 while Eltanin is magnitude 3. Bayer goofed.

Hooke made two pairs of measurements three months apart, finding a 24 arcsecond decrease in declination. Unfortunately, he managed to break the objective, ending the attempt. However, he reported[4]

> Tis manifeft then by the obfervations of *July* the Sixth and Ninth; and that of the One and twentieth of *October*, that there is a fenfible parallax of the Earth's Orb to the fixt Star in the head of Draco, and confequently a confirmation of the *Copernican* System againft the Ptolemaick and *Tichonick*.[5]

Hooke and Wren cooperated on the design of the Monument to the Great London Fire, an obelisk that still stands near London Bridge and the Monument tube stop. It commemorates the gutting in 1666 of the old city within the Roman walls. The conflagration began in a bakery on Pudding Street, close to the site of the monument. It spread east a short distance, stopping just short of the Tower of London, but ravaged the town to the west, jumping the wall at Blackfriars and almost reaching the Strand.

Wren and Hooke's Monument to the Great Fire of London, and a view of its spiral staircase.

The memorial, a 202-foot tower, was completed in 1677. It has a spiral staircase surrounding an open central column that was designed for a zenith telescope as well as for pendulum experiments. There is even a room for a laboratory at the base. Local traffic,

[3] How can it do that? Gamma Draconis is at declination 51° 29'. Kew is at latitude 51° 28'.

[4] Hooke, Robert, *An Attempt to Prove the Motion of the Earth from Observations*, 1674, available on archive.org.

[5] The author apologizes for using the original typeface and spelling (which confounds Microsoft Word's spell checker for sure), but I thought it would much more interesting and fun to do it that way and perhaps allow us to sense the author's voice a bit better. Remember that "esses" are written as "effs" except at the end of words or when capitalized. It's peculiar, but you'll very easily get the hang of it.

even in the horse-drawn transportation era, caused too much vibration for the instrument to be useful. You can climb to the top (admission £6, £4.50 for seniors) and get a nice panoramic view of the City of London.

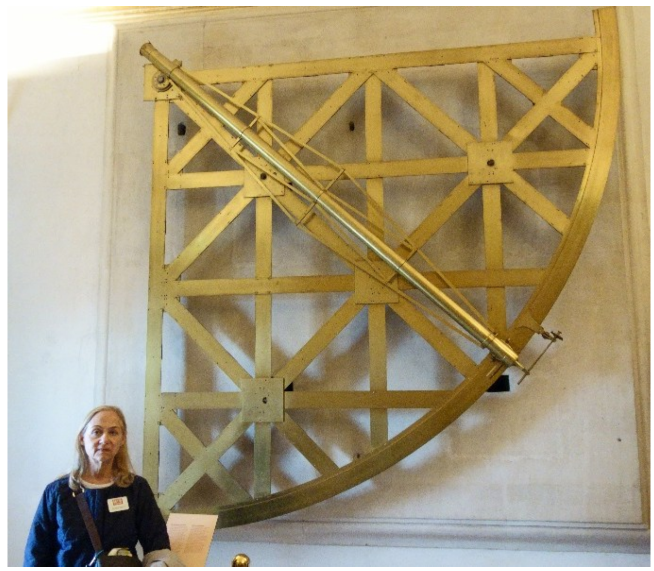
Finding parallax was a major goal of late 17th century astronomers, facilitated by improvements in equipment, including clocks, as well as the sharing of information through letters and publications. The *Philosophical Transactions of the Royal Society* began publication in March 1665, two months after the world's first scientific periodical, the *Journal des sçavans,* made its appearance. It was in the *Journal* that Ole Roemer's determination of the finite speed of light, which he calculated from timing the disappearance and reappearance of Jupiter's satellites, was published in 1676.

The important French astronomer Jean Picard, observing at Tycho Brahe's Uraniborg in 1671 (Brahe had died in 1601 so he wasn't around to host the Frenchman) noticed a 20 arcsecond deviation in the position of Polaris but ascribed it to atmospheric refraction. He published his findings in 1680.

The round brick structure on the lower left is the site of Flamsteed's underground zenith telescope. The cylindrical tube is the remnant of William Herschel's "40-foot" telescope, the largest in the world by far at the beginning of the 19th century. (LF, 2009)

Wren and Hooke also cooperated on the design and construction of the Royal Observatory at Greenwich, which was completed in 1678. A zenith telescope, better known as the "well telescope," was designed by John Flamsteed, the first Astronomer Royal. It was mounted in a deep hole on one side of the observatory and covered by a cupola that could be removed for observation. Apparently, it didn't work well and only two observations were made with it in 1679. In 1955 the objective lens was tested and found to be very poorly figured. It was a single crown glass lens 9.75 inches in diameter with a focal length of 87 feet, giving f/107. The image was "a general blur." It wasn't any fun for Flamsteed to have to observe while lying supine at the bottom of a well, either.

In 1689 Flamsteed installed a more capable device, the mural arc, which allowed him to observe objects along the entire meridian. It replaced several earlier versions of the traditional sextant or octant, one of which had been installed by Hooke.



A mural quadrant (full 90° arc) on display in the Specola in Padua in 2022. This one was made by Jesse Ramsden in London in 1776.

The mural arc, built by Abraham Sharp, was mounted on the west wall of the Quadrant House, now the Royal Observatory Greenwich's Meridian Building and much altered since Flamsteed's time. It consisted of a graduated arc with a small telescope. The observer would measure the zenith distance of a star (or planet or comet) as it crossed the meridian, timing it with an accurate clock. From this information the right ascension and declination could be calculated. Unfortunately, Flamsteed's instrument was taken down after his death in 1719 and must have been broken up, because it disappears from the meticulous records of the Royal Observatory.

In 1697, Flamsteed reported his observations of Polaris made during the previous 9 years. Its declination appeared to vary by 40 arcseconds over the course of a year. He thought this was the result of parallax, but Jean Domenico Cassini of the Paris Observatory and Ole Roemer at Copenhagen Observatory both pointed out that the direction of the deviation, being greater in March and September, was 90° out of phase with what would be expected for true parallax. What Flamsteed had observed was *stellar aberration*, a phenomenon that is independent of distance and depends only on the direction that the Earth moves in its orbit around the Sun. Although his results were initially acclaimed as proof of parallax, Flamsteed had to retract his finding.

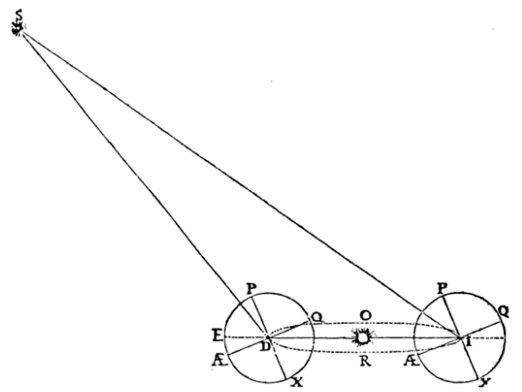


Fig. 1. From Flamsteed's letter to Wallis, reproduced in Wallis's *Opera mathematica*, iii, 706.

Flamsteed's drawing of parallax. Reproduced from Williams, MEW, Flamsteed's Alleged Measurement of Annual Parallax of the Pole Star, *Journal of the History of Astronomy* 10: 102-116 (1979)

It took another quarter of century for stellar aberration to be understood and Earth's motion proven. We owe this result to James Bradley. Bradley was introduced to astronomy by his uncle James Pound. Among several projects, they observed the 1723 transit of Mercury together. Educated at Oxford and like many English astronomers a member of the clergy, he was appointed Savilian Professor of Astronomy at Oxford, a post held earlier by Wren. He was the third Astronomer Royal (1742-1762), succeeding Edmund Halley.

Bradley's report of his findings, a letter to Halley in the *Philosophical Transactions of the Royal Society* in 1729, is online[6] and makes for fascinating reading.

Bradley, like Hooke, observed Gamma Draconis. He used a zenith telescope at the home of his friend Samuel Molyneux, an English politician and amateur astronomer, at Kew in southwest London. The telescope, made by clockmaker George Graham,

> to whom Lovers of Aftronomy are alfo not a little indebted for feveral other exact and well-contrived Infruments,

was fixed to the chimney, and it could be moved very slightly with a screw to keep Gamma Draconis in the center, deviation from the vertical measured with a plumb line.

Bradley first observed Gamma Draconis on December 3, 1725. It was in the same position when it crossed the zenith on the 5th, 11th and 12th. He thought

> a farther Repetition of them at this Seafon feemed needlefs.... It was chiefly therefore Curiofity that tempted me

to make another observation on December 17th.

> [I] perceived that it paffed a little more Southerly this Day.

He thought it might be just observational variation, but he looked again on December 30th and saw that

> the Star paffed ftill more Southerly.... This fenfible Alteration the more furprized us, in that it was the contrary way from what it would have been, had it proceeded from an annual *Parallax* of the *Star*.

Had the deviations been due to parallax, the star would have started moving north after the winter solstice.

Bradley checked and rechecked his instrumentation and observing process and concluded that

> there muft be fome regular Caufe that produced

the deviation.

In March 1726 the Star was found to be

> 20" more Southerly than at the Time of the firft Obfervation. It now indeed feemed to have arrived at its utmoft Limit Southward.

The star then moved northward. In June it was as far from the zenith as it was in December. It continued to move northward, as he now expected, and in September it became stationary

[6] https://is.gd/bradleyabb

20" more Northerly than in *June*, and no lefs than 39" more Northerly than it was in *March*.

It then began to move southward, reaching the same position in December 1726 as it had a year earlier.

Bradley was perplexed as to the cause. He first considered the nutation of the Earth, 18.6-year cycles within the 26,000-year precession of the Earth's rotational axis, due to gravitational effects of the Sun and the Moon on the slightly non-spherical Earth, a phenomenon he also discovered. He had observed several other stars with different declinations during the year and noted that they moved in the same direction as Gamma Draconis, but to a lesser degree. Had nutation been the cause, the magnitude of the change would have been the same for all the stars.

Bradley then realized that

the apparent Difference of Declination from the Maxima, was always nearly proportional to the verfed Sine [7] of the Sun's Diftance from the Equinoctial Points. This was an Inducement to think, that the Caufe, whatever it was, had fome Relation to the Sun's Situation with refpect to thofe Points.

Still not sure of the cause, Bradley then had Graham, the fame ingenious Person, make another telescope, this one capable of being skewed about 6¼° from the vertical so he could measure more stars. The instrument was installed at his uncle James Pound's home in Wanstead in northeast London. This telescope was capable of detecting deviations of just ¼ arcsecond.

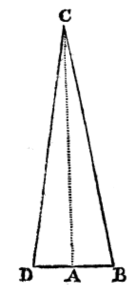
With more observations over the next year he confirmed that the deviations were maximal at the equinoxes, and that

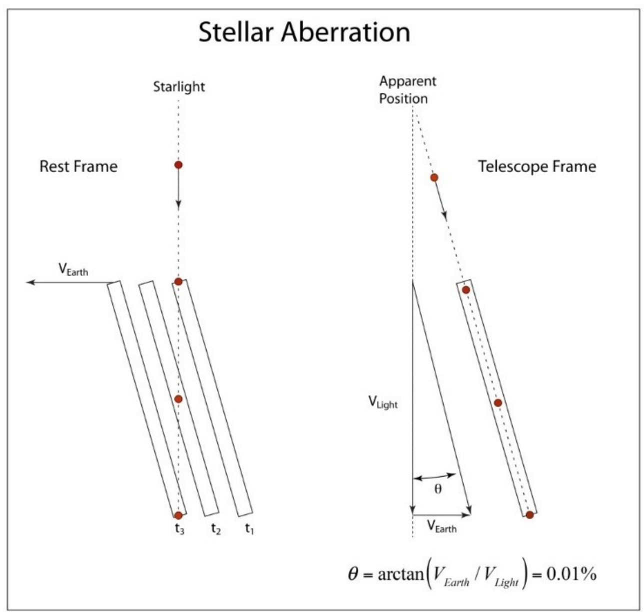
the apparent Motion of every one tended the fame Way.

Pondering the matter further, Bradley finally conjectured,

that all the Phaenomena hitherto mentioned, proceeded from the progreffive Motion of Light and the Earth's annual Motion in its Orbit. For I perceived that, if Light was propagated in Time, [8] the apparent Place of a fixt Object would not be the fame when the Eye is at Reft, as when it is moving in any other Direction, than that of the Line paffing through the Eye and Object; and that, when the Eye is moving in different Directions, the apparent Place of the Object would be different.

To illustrate the concept, Bradley drew this simple diagram. A particle of light[9] is emitted from a distant star at point C and reaches Earth in a straight line at point A. However, the Earth, with an observer on it, is moving perpendicularly from B to A. The observer is looking at the star through a long tube (i.e. a telescope). Now consider what happens when the particle of light enters the tube at a finite velocity. During the time the particle goes through the tube, the tube is moving and the particle won't make it to the bottom of the tube if the tube is positioned vertically. If the tube is long enough, it enters but hits the wall of the tube as the tube moves perpendicular to the light. The tube will need to be at a slight angle in the direction of motion in order to capture the moving particle of light. You can see a 4-second video explanation at https://is.gd/abbvid.





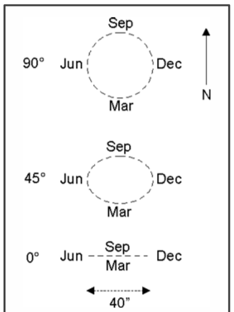
Any easy way to think about stellar aberration is to consider what happens when you take a walk in the rain. When there's no wind, the rain is coming

[7] The archaic function "versed Sine" of an angle is 1-cosine.
[8] In other words, the speed of light is finite, as had been shown by Roemer.

[9] Newton's formulation of light as discrete particles was proposed in *Opticks* (1704) and was commonly accepted until the early 19th century.

straight down. If you want to stay dry, you need an umbrella. If you stand still, holding the umbrella straight above your head will be sufficient. Now start walking. You will find that you have to tilt the umbrella forward slightly. From your perspective, the rain is coming at a slight angle. The faster you walk, the greater the angle. And in whatever direction you walk, you still tilt the umbrella in front of you. Yet from the rain's perspective it's still raining straight down. How is it possible for you to perceive the rain coming at an angle (the angle depending on your velocity and direction) when the rain itself (and any cats and dogs coming down with it) is coming down vertically?

This peculiar conundrum is nothing less than a manifestation of Einstein's Special Theory of Relativity. What is happening is that the star and the observer (or the rain and your umbrella) are in different *inertial reference frames*. Their views of the universe are different, but there is an *equivalence*.



Stellar aberration for stars at different ecliptic elevations

From the point of view of the Earth, the star will be displaced in the direction of the Earth's motion through space. Over the course of a year, during which the Earth moves in an ellipse, a star at the ecliptic pole will also make an ellipse (with the eccentricity of the Earth's orbit) with a semimajor axis of 20.1 arcseconds. Stars away from the ecliptic pole will describe more eccentric ellipses (still with a semimajor axis of 20.1") and a star near the ecliptic itself will describe an ellipse with a semiminor axis of zero, which is simply a line 20.1 arcseconds on either side of the star's position at the equinoxes.

Stellar aberration is caused by the linear velocity of the Earth, while true stellar parallax is due to change in the position of the Earth in its orbit. The angle of aberration, 20.1 arcseconds, is a consequence of the ratio of the speed of light to the Earth's orbital velocity. Bradley realized this and was able to calculate the speed of light because he knew the Earth's velocity. It had been derived by Johannes Kepler in the *Astronomia Nova* in 1609.

Referring to his diagram, Bradley wrote,

> From what hath been premifed, it will appear that the greateft Alteration of the apparent Declination of Gamma Draconis, on account of the fucceffive Propagation of Light, would be to the Diameter of the little Circle which a Star...would feem to defcribe about the Pole of the Ecliptick, as 39" to 40",4. The half of this is the Angle ACB (as reprefented in the *Fig.*) This therefore being 20",2, AC will be to AB, that is, the Velocity of Light to the Velocity of the Eye (which in the Caf□may be fuppofed the fame as the Velocity of the Earth's annual Motion in its Orbit) as 10210 to One, from whence it would follow, that Light moves, or is propagated as far as from the Sun to the Earth in 8' 12".

After examining the displacements of another dozen or so stars, and taking into account the precession of the equinoxes, Bayer recalculates the average maximum displacement and finds it to be 40½" and corrects the Sun-Earth light travel time to 8' 13". The modern value for the light travel time from Sun to Earth is 8' 20". Bradley was only off by 1.4%, a vast improvement from Roemer's value, which was 24.4% below the modern value. Bradley reports that

> I find the fame Velocity of Light from my Obfervations of fmall Stars of the fifth or fixth, as from thofe of the fecund and third Magnitude, which in Probability are placed at very different distances from us.

Bradley presents a table for Gamma Draconis showing the actual observations and the predictions from his model:

1727.	D.	The Difference of Declination by Obfervation. "	The Difference of Declination by the Hypothefis. "	1728.	D.	The Difference of Declination by Obfervation. "	The Difference of Declination by the Hypothefis. "
October 20th --		4½	4½	*March* -	24	37	38
November -	17	11½	12	*April* - -	6	36	36½
December -	6	17½	18½	*May* - -	6	28½	29½
- - -	28	25	26	*June* - -	5	18½	20
1728				- - -	15	17½	17
January -	24	34	34	*July* - -	3	11½	11½
February -	10	38	37	*Auguft* -	2	4	4
March - -	7	39	39	*September* -	6	0	0

He shows a similar table for Eta Ura Majoris (Alkaid, the tip of the handle of the Big Dipper). He notes that the maximum error is less than 2 arcseconds for all his observations,

> Except in one, which is mark'd as doubtful on Account of the Undulation of the Air, &c. And this does not differ 3" from the Hypothefis.

With this level of accuracy, Bradley points out that actual stellar parallax, a function of the star's distance, has to be less than 1 arcsecond; had it been that much, he would have detected it.

> It seems very probable that the Parallax of [Gamma Draconis] is not fo great as one fingle Second; and that consequently that it is above 400000 times farther from us than the Sun.

Gamma Draconis is 154.3 light years from us, and so 9,758,100 times further than the Sun-Earth distance. Its actual parallax is 0.02114 arcseconds.

Even in 1729 there must have been a few geocentrists left in the astronomy world, and those who still believed the speed of light was infinite. Bradley concludes his paper with an appeal to reason, directed to Halley:

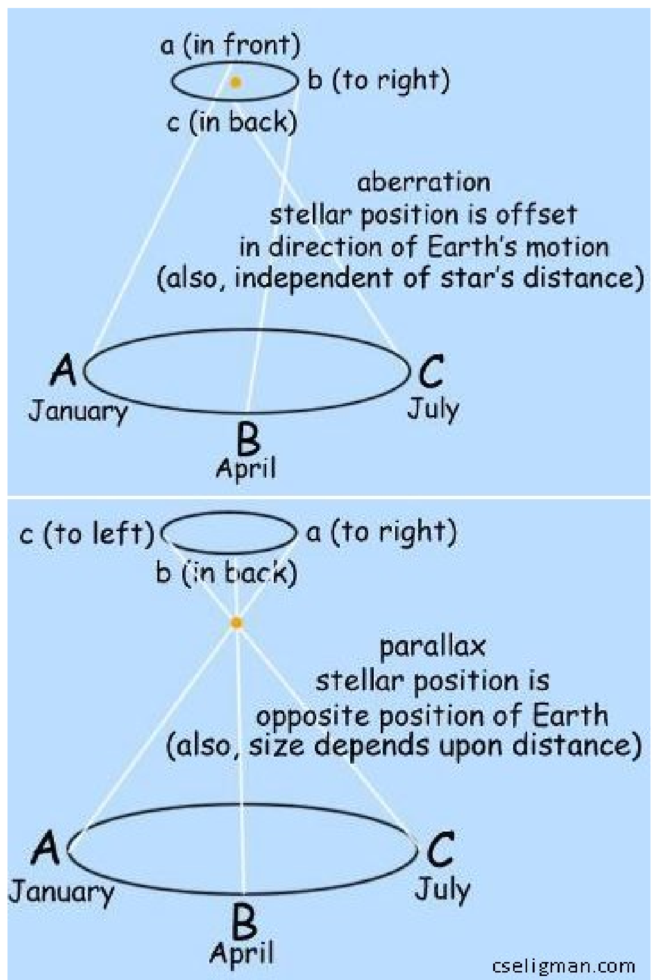
> There appearing therefore after all, no fenfible Parallax in the fixed Stars, the *Anti-Copernicans* have ftill room on that Account, to object againft the Motion of the Earth; and they may have (if they pleafe) a much greater Objection againft the Hypothefis, by which I have endeavoured to folve the fore-mentioned Phænomena; by denying the progreffive Motion of Light, as well as that of Earth.
>
> But as I do not apprehend, that either of thefe Poftulates will be denied me by the Generality of the Aftronomers and Philofophers of the prefent Age; fo I shall not doubt of obtaining their Affent to the Confequences which I have deduced from them; if they are fuch as have the Approbation of fo great a Judge of them as yourfelf. I am,
>
> Sir, Your moft Obedient
>
> Humble Servant
>
> J. BRADLEY

Eppure si muove! Galileo is avenged. Science works.

An exact calculation of stellar aberration should take relativistic effects into account (the velocity of the Earth is 0.01*c*) but the correction is extremely small. On the other hand, an astronomer on an exoplanet that is whipping around its host star at some appreciable fraction of light speed might need the full relativistic equation if he wanted to be precise.

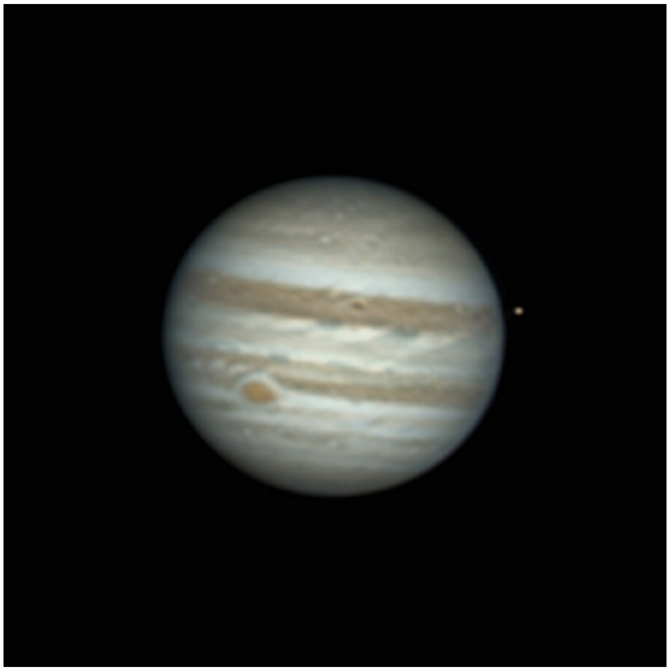
Actual stellar parallax and distances waited for further advances in telescope technology. Excellent lenses, precise mounts and accurate clocks allowed Thomas Henderson in Cape Town to measure the parallax of the nearest bright star, Alpha Centauri, in 1835, but he didn't publish his results until 1839. Using the Great Refractor at Dorpat, Friedrich Georg Wilhelm von Struve, in 1838, measured the parallax of Vega in 1837, obtaining 0.125 arcseconds. Friedrich Bessel at Königsberg measured the parallax of 61 Cygni, the star with the highest proper motion, as 0.314 arcseconds. In the face of Bessel's data Struve rashly revised his estimate upwards. Astronomy history tends to award provenance to Bessel, but Struve's first determination was correct.

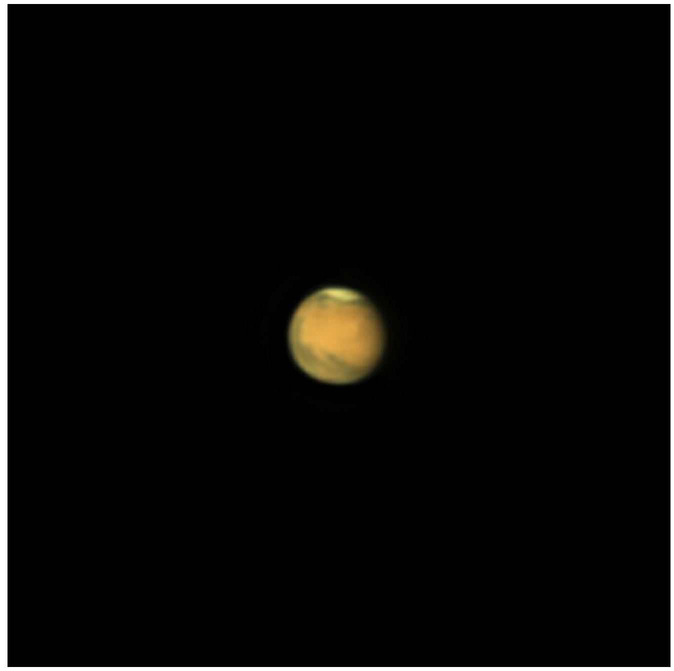
By 1910, the parallax (and thus the distances) of only 108 stars were known. The Hipparchos satellite measured parallax for 120,000 stars (1993), and the most recent data (DR3, 2022) from Gaia provides parallax and proper motion data for 1.3 billion stars. ■



Images by Members

Jupiter and Mars

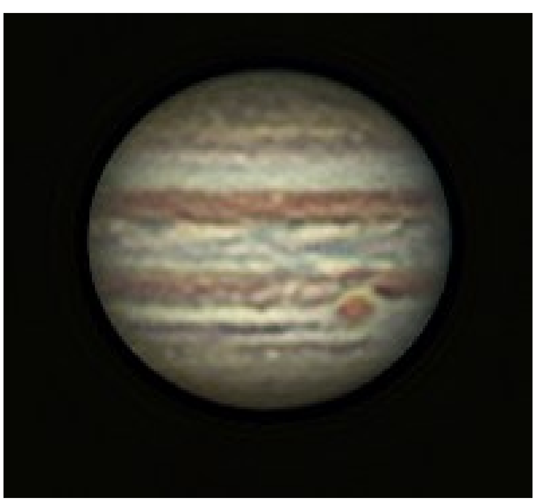




Steve Bellavia wrote from his new home in Smithfield, Virginia to tell us that on December 23rd "they predicted good seeing until midnight so I went out and captured Jupiter and Mars at around 11:30 p.m." He reported that the conditions were "mostly clear and somewhat dry, temperature -2° C, no wind. Transparency: 6/10, Seeing: 3/5." He used the Explore Scientific 152mm Maksutov-Cassegrain that he got at NEAF last year. It has a 2400mm focal length (see below). The camera was a ZWO ASI 183MM Pro on a Sky-Watcher EQ6R Pro mount,

For Jupiter he took the best 25% of 8925 frames from a 3-minute SERS video, at 50 fps, 20 millisecond exposures, gain 200. Jupiter was 67° above the horizon, shining at magnitude -2.8. For Mars, the best 25% of 11902 frames from a 3-minute SERS video, at 66 fps, 15 millisecond exposures, gain 200. Mars was 51° above the horizon at magnitude -1.0. The two images are at the same scale. Jupiter's diameter was 47.6 arcseconds, while Mars diameter was 13.7 arcseconds.

Jupiter's moon Io is just off the eastern limb of the planet.

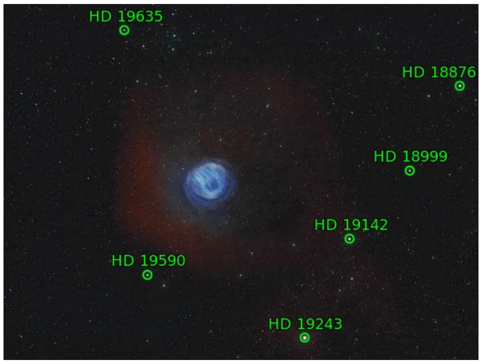


Rick Bria sent in this December 3rd image, made just before Jupiter's opposition on December 7th. He used a Televue TV101is, 2X Barlow and Skyris camera. The image is a stack of the best 1500 frames selected from four different videos containing 2500 frames each. Processing was done in AutoStakkaert!4, AstroSurface3, WinJUPOS, Pixinsight, and Photoshop.

Rick made a video showing Jupiter's rotation and the movement of its closest satellite Io over a 15-minute period. You can download it at https://is.gd/briajupvideo. There are three loops within the 6-second video.

The Bear Claw by Steve Bellavia

SH2-200 (Sharpless 2-200), also called HDW 2 (Hartl-Dengl-Weinberger 2) and the Bear Claw Nebula, is a large but very faint planetary nebula in Cassiopeia. This nebula was first discovered by the astronomer Stewart Sharpless in 1959. He included it in his second catalogue of HII regions under as Sh2-200. It was included in a list of possible planetary nebulae by astronomers Herbert Hartl, Johann Dengel and Ronald Weinberger, published in German in 1983 (https://articles.adsabs.harvard.edu/pdf/1983MitAG..60..325H) and later described more fully in Hartl, H, Weinberger, R, Planetary nebulae of low surface brightness, *Astronomy and Astrophysics*, Suppl. 69:519-525 (1987) https://articles.adsabs.harvard.edu/pdf/1987A%26AS...69..519H.



The field of view, per astronometry.net, is 83.2x55.5 arcminutes. Steve's technical information is at https://www.astrobin.com/ddf87x/.

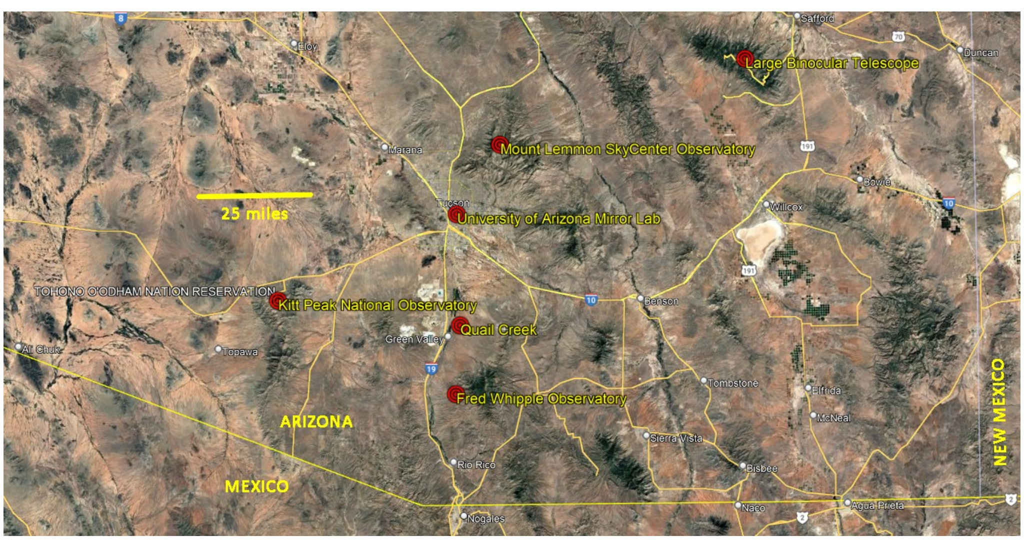
In case you want to find this nebula yourself but don't have the Sharpless catalogue in your software, here's the solved image from astronometry.net labeling the surrounding stars with their HD (Henry Draper) designations.

The name Bear Claw Nebula has an uncertain origin. We could not find a definitive reference for the name. NGC 2537, a galaxy in Lynx, has been given this name (or "Bear Paw") as well. Perhaps the name was used because the striations in the central zone look like a bear's claw marks. There is a lovely Kiowa legend about the Pleiades that attributes the striations on the sides of Devil's Tower in Wyoming to bears that were chasing seven maidens, who were placed there by the Great Spirit for their safety. The bears gouged the steep walls of the mesa as they tried to reach the maidens.

Messier 33 by Arthur Miller

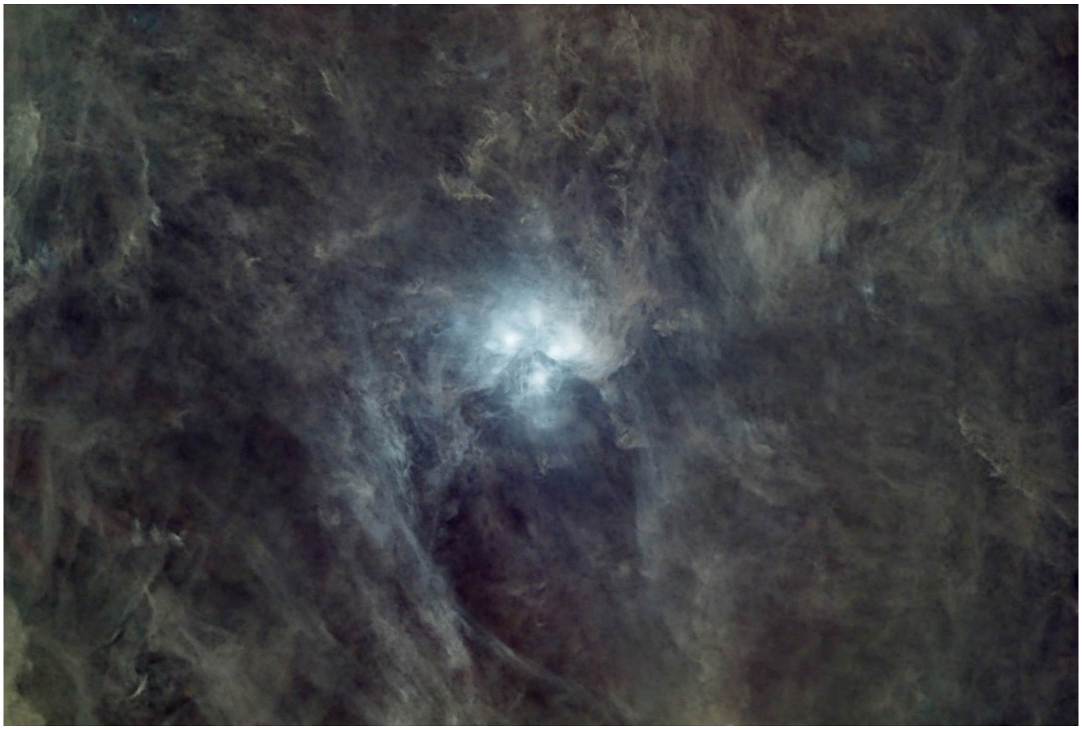
Messier 33 has been a popular object for WAA imagers. It's the third-largest member of the Local Group of galaxies, after the Milky Way and Andromeda.

Arthur spends the winter in Quail Creek, Arizona, a community south of Tucson. The development has a lightning ordinance to keep the night sky as dark as feasible. Arthur has transitioned from an 11-inch Celestron SCT to a Sky-Watcher Esprit 120 mm f/7 triplet ED refractor, on an AstroPhysics mount, to which he's added a 5-slot filter wheel. For this image he used a QHY 268c CMOS color camera and just a UV/IR cut filter. He stacked 12 subs of 300 seconds each. The image was processed with Photoshop and Affinity Photo 2.



Here's a Google Earth image of the Tucson area showing the location of Quail Creek and the important astronomical facilities in the region.

The Environs of the Pleiades by Robin Stuart



The Pleiades, Messier 45 or the Seven Sisters, are undergoing a chance encounter with an interstellar dust cloud. As they pass through at a relative velocity of 18 km/s the stars illuminate the surrounding dust and create delicate blue-white reflection nebulas as shown in images of the cluster, for example my image in the December 2022 SkyWAAtch, page 21.

The greater extent and structure of the surrounding dust cloud can be seen in the top image, from which the stars have been removed. The pair of images each span 10.3° x 6.9° and are a stack of 58 3 minute subframes giving a total exposure of 2 hours 54 minutes. They were taken on October 28, 2024 at my observatory in Eustis, Maine, using a ZWO ASI2600MC camera attached to an f/2 Rokinon 135-mm telephoto lens. The images were processed in PixInsight and the StarNet2 plugin was used to separate the stars and nebulosity, which were then processed separately.

— Robin Stuart

The Elephant Trunk Nebula by Tony Bonaviso

IC 1396 is a large (more than 2 degrees across) emission nebula located 2,400 light years from the solar system. It contains IC 1396A, the actual Elephant's Trunk, the dark lane with sharp borders seen in the 4 o-clock position on Tony's image (triangulate blue markers). The field is 4.17° x 3°. Straight up is 40° west of north and the orientation is correct. The bright star at the top of the nebula is the famous Mu Cephei, better known as Herchel's Garnet Star. The nebula is powered by HD 206267 (triangulate the red markers), a magnitude 5.74 triple system of three class O stars, a member of the open cluster Trumpler 37 (Tr 37) at the core of the nebula.

Tony made the image at Ward Pound Ridge Reservation with a William Optics RedCat 51-mm f/4.9 refractor, Optolong L-eXtreme filter, and ZWO ASI294MC Pro-cooled camera. He captured 60 180-second subs using N.I.N.A., then stacked and processed them in PixInsight v1.9.2, Lockhart Photoshop 2019, and GradientXtractor.

The Elephant Trunk and its surrounding nebula has become popular in the "imaging era," the period since the late 1990s of ever more affordable CCD and CMOS cameras, digital mounts, guiding and powerful software. Stephen James O'Meara's *Deep Sky Companions: Hidden Treasures*, published in 2007, is one of his excellent observing guides but it is not a handbook for imagers. O'Meara seems far more interested in Tr 37 although he does call the cluster "and its associated nebulosity IC 1396" Cassiopeia's "largest and brightest deep sky wonder, although it is also one of its least admired." Although he mentions the dark lanes in the nebula, he doesn't use the epithet "Elephant's Trunk" in his 4½ page essay on the object, entitled "The Misty Clover Cluster, Trumpler 37." Nowadays the entire nebula (which resembles a four leaf clover) is the "Elephant's Trunk" even though the actual trunk is just one of many molecular clouds within IC 1398, and no one seems too interested in Tr 37.

Moon-Venus Conjunction by Larry Faltz

A relatively close conjunction of our two brightest nighttime bodies occurred on January 3rd. This image was made at home in Larchmont at 6:05 p.m. when the two orbs were just 3° 15’ apart (center to center), the closest approach. A very thin upper cloud layer haze was present. It cleared later but by then the pair was too low for me to get a good view. I used a tripod-mounted Canon 600D (T3i) with a Canon EF 75-300 zoom at 160 mm (giving an effective focal length of 257.6 mm because the APC sensor gives a 1.61 magnification factor with this lens). The image is a single, full frame (originally 5,184x3456 pixels) at ISO 800, 1/100 sec at f/5.

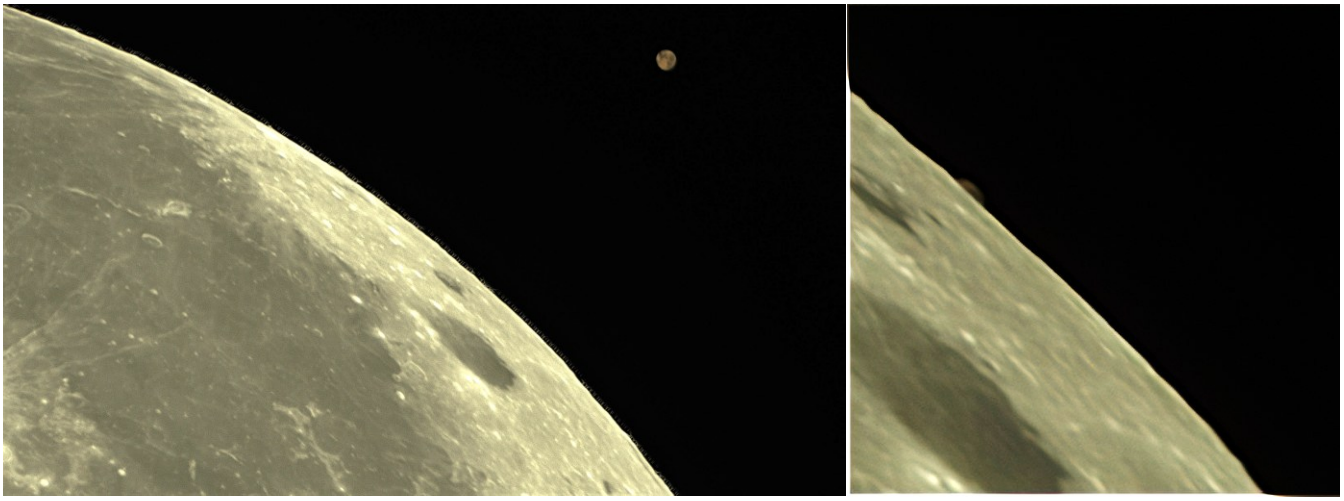
Venus will be a fine object in February, at magnitude -4.6 all month. As it heads for inferior conjunction (between the Sun and Earth) on March 23, it will get larger and develop more of a crescent as shown but its brightness will not diminish. Here is a table to help you plan your observing sessions.

Date	Sunset EST	Nautical Twilight ends	Illumination	Diameter	Altitude at end of Nautical Twilight
Feb 1	5:12 p.m.	6:13 p.m.	37.3%	32.6”	30° 33’
Feb 8	5:21 p.m.	6 21 p.m.	32.1%	36.1”	29° 31’
Feb 15	5:29 p.m.	6:29 p.m.	26.4%	40.1”	27° 06’
Feb 22	5:37 p.m.	6:37 p.m.	20.2%	44.8”	23° 27’
Mar1	5:44 p.m.	6:44 p.m.	13.7%	49.9”	18° 14’

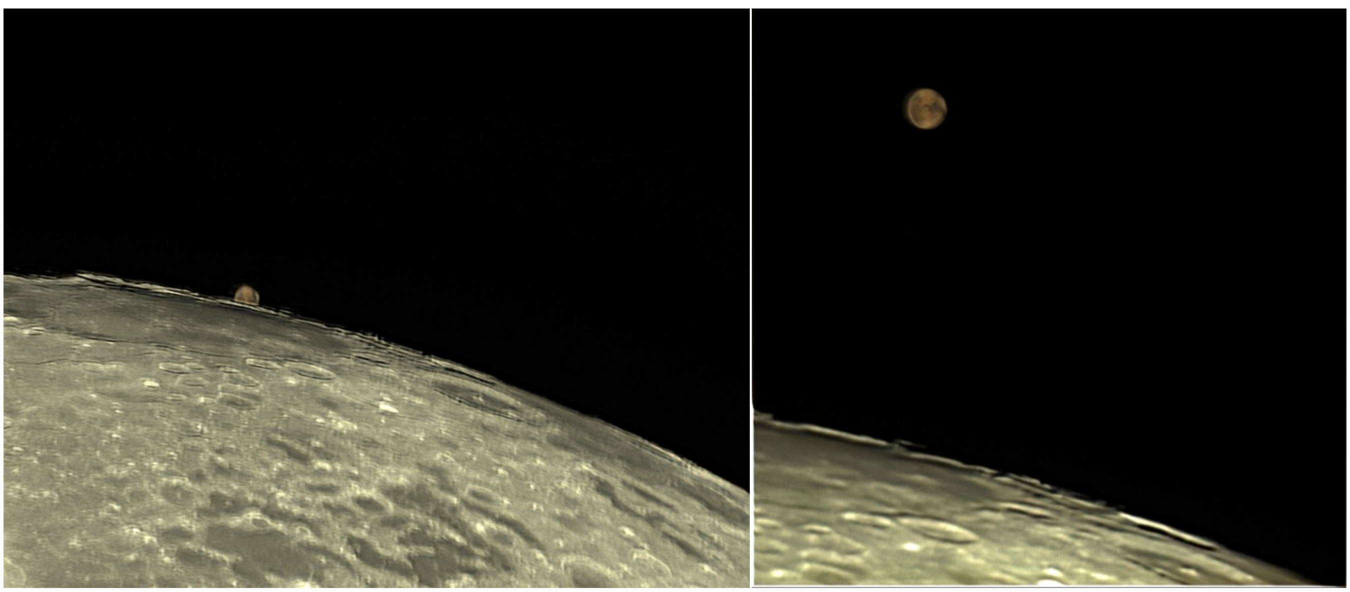
As it gets lower in the sky, atmospheric refraction will add (unwanted) color even with the best optics. Some observers like atmospheric dispersion correctors, which use two thin prisms to reverse the refraction. If the planet is extremely bright, a neutral density or variable polarizer could also help.

More Mars-Moon Occultation Images

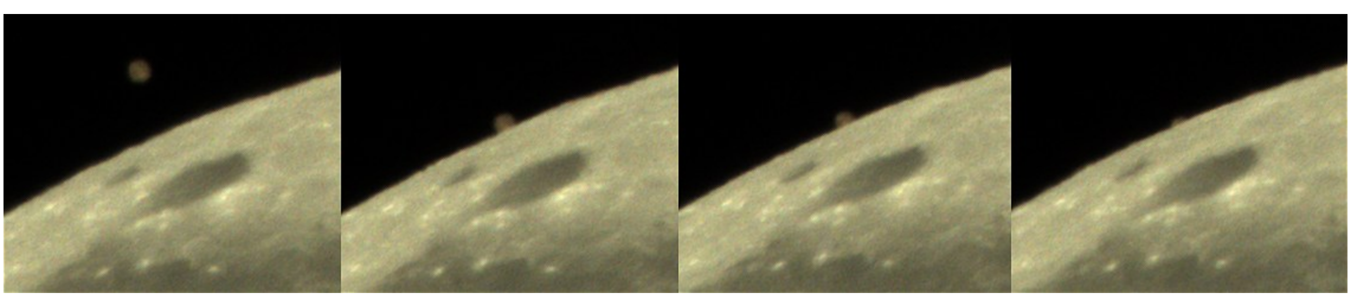
Ingress (John Paladini)



Egress (John Paladini)



Ingress sequence (Larry Faltz)



Research Highlight of the Month

Vasilyet, V, et. al., Sun-like stars produce superflares roughly once per century,
***Science* 386:1301-1305 (Dec. 13, 2024)**

Solar eruptive events (SEEs) are electromagnetic flares, often (but not always) associated with coronal mass ejections (CMEs). Over a period of tens of seconds to minutes, electromagnetic energy carried in the solar magnetic fields is emitted and some of it generates accelerated particles, heated plasma, and ejected solar material. When short-wavelength energy reaches Earth, it can influence the ionosphere, causing radio blackouts. High-energy particles cause radiation hazards to satellites and aircraft and create cosmogenic isotopes that are recorded in tree rings and ice cores. Of the thousands of flares observed over the past 200 years, only a dozen or so are estimated to have exceeded a bolometric (all-wavelength) energy of 10^{32} ergs, the strongest being the Carrington event of September 1, 1859, which is estimated to have been 5±1 x 10^{32} ergs. Can the Sun emit superflares, which have even greater energies (and greater disruptive power)? The data from examination of cosmogenic isotopes suggest that at least five, and possibly eight, superflares have occurred in the past 10,000 years, suggesting a rate of about one per thousand years (1 x 10^{-3} per year). Before the invention of electrical devices, these superflares would have gone unnoticed in terms of their practical effects, but nowadays they would be extremely disruptive. Superflares would create truly spectacular auroras.

Another way of gauging the frequency of superflares is to examine Sun-like stars. One earlier study showed that superflares with energies of 10^{34} ergs occur at about the same rate as those recorded in the cosmogenic isotope data, but other studies showed a lower rate, about $3x10^{-4}$ per year. This difference was probably due to the criteria for selection of stars in each study, which included color/surface temperature and rotation rates. Detection of rotation rates is difficult and the rotation rates of most stars similar to the Sun would have been unknown, resulting in these stars being excluded from the studies and introducing possible bias.

To get a better sample of Sun-like stars, the group used data from the Kepler telescope and Gaia data release 3. They included stars with unknown rotation rates. They selected stars with effective temperatures between 5000 K and 6500 K (the Sun is 5772 K) and an absolute G-band magnitude of 4 to 6 (the Sun is 4.68). They excluded binary stars and stars rotating less than 20 days per revolution (the Sun rotates once every 25 days at its equator) because these stars are probably younger than the Sun and would be expected to have more flares. They developed an automated flare-detection algorithm as well as analyzing images to rule out various confounding events (cosmic ray strikes, background star flares, transient solar system objects in the field, etc.)

They analyzed 56,450 stars over a 4-year period (220,000 star-years, 18 times longer than the cosmogenic isotope record for the Sun). They detected 2,889 flares on 2,527 stars, with energies of 10^{32} to 10^{36} ergs.

The authors write "the cumulative distribution of stellar superflares indicates that Sun-like stars… generate superflares with energies greater than10^{34} ergs with a frequency of (8.63±0.20) x 10^{-3} per year," or almost once per century. The rate in stars with known rotation periods (30% of the sample) was not different than for stars with unknown rotation periods.

There is an indirect connection between flares and the intensity of energetic particle release, which is why the $7x10^{32}$ erg flare of October 28, 2003, more intense than the Carrington Event, was not extremely destructive to terrestrial power grids, although 12 transformers in South Africa were destroyed and Sweden was dark for an hour. However, if these data are correct, the frequency of superflares in our Sun may be greater than previously predicted. ConEd & FEMA, take note.

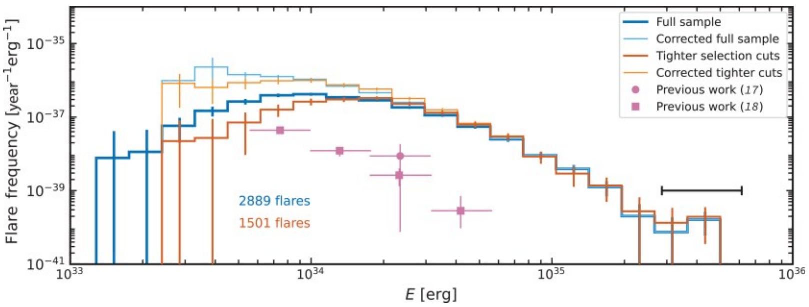


Fig. 3 from the paper. Frequency-energy distribution of stellar flares.

Member & Club Equipment for Sale

Item	Description	Asking Price	Name/Email
6-inch f/8 reflector optical tube	Orion 6-inch f/8 reflector in very good condition. 2-inch focuser. Has Telrad finder base; you'd need to buy a Telrad. You would also have to supply tube rings or figure out how to make it into a Dobsonian. Mirror has center dot for collimation. Image of scope is here.	$25	David Parmet davidparmet@icloud.com
Skywatcher 120-mm f/5 refractor	This 600-mm focal length doublet achromat comes on a Sky-Watcher AZ-GTI mount. 2-inch diagonal, red dot finder. Eyepieces not included. The AZ-GTI mount is operated via wi-fi connection to a phone or tablet [it works well; your Editor has one]. You need to download the free SynScan app. A new AZ-GTI mount alone is $400. A great beginner scope	$550	Anthony Maida lvam1521@yahoo.com
Explore Scientific 10-inch f/5 Hybrid Truss Tube Dobsonian.	25-mm and 10-mm eyepiece s, red dot finder, collimation rod, two 2.5 lb. counterweights for using heavier 2-inch eyepieces. Just a few months old. Excellent condition, optically and cosmetically. Have the original box and packaging. Image at https://is.gd/XPwDUh. Local pickup; asking price reduced.	$500	Manish Jadhav manish.jadhav@gmail.com
iOptron IEQ45Pro equatorial mount head	Traditional German equatorial mount. Includes Go2Nova 8407 hand control (358K objects), counterweight, QHY PoleMaster for easy polar alignment, but no tripod. Payload 45 lbs (without counterweight). Mount weighs 25 lbs. This model is also discontinued by iOptron. The current very similar mount (GEM45) lists for $2,598 (plus $269 for the PoleMaster). A 1.75" iOptron "Lite-Roc" steel tripod costs $350; piers and other tripods are available. Specs for the IEQ45 are still on iOptron's web site. Donated to WAA.	$400	WAA ads@westchesterastronomers.org
ADM R100 Tube Rings	Pair of 100 mm adjustable rings with large Delrin-tipped thumb screws. Fits tubes 70-90 mm. You supply the dovetail bar. Like new condition, no scratches. See them on the ADS site at https://tinyurl.com/ADM-R100. List $89.	$50	Larry Faltz lfaltzmd@gmail.com
iOptron CEM25P equatorial go-to mount	A complete IOptron "center-balanced" equatorial mount. Includes Go2Nova 8408 hand control with >50,000 objects, 4.7 kg counterweight, heavy-duty tripod, QHY PoleMaster for easy polar alignment (laptop required). Low periodic error. Payload 27 lbs (without counterweight). The mount weighs 10.4 lbs. Excellent condition. Although this model is discontinued by iOptron, the current very similar mount lists for about $2,097. Details of the CEM25P and an image are still available on iOptron's web site. Donated to WAA.	$350	WAA ads@westchesterastronomers.org
1.25" Filters	Thousand Oaks LP-3 Oxygen III (2 available)	$50	Eugene Lewis genelew1@gmail.com
	Astronomic UHC (2 available)	$75	
	High Point Neutral Density (2 available)	$10	

Want to list something for sale in the next issue of the WAA newsletter? Send the description and asking price to ads@westchesterastronomers.org. Member submissions only. Please offer only serious and useful astronomy equipment. WAA reserves the right not to list items we think are not of value to our members. All receipts for items owned by WAA goes to support club activities.

Buying or selling items is at your own risk. WAA is not responsible for the satisfaction of the buyer or seller. Commercial listings are not accepted. Items must be the property of the member or WAA. WAA takes no responsibility for the condition or value of the item, or for the accuracy of any description. We expect but cannot guarantee that descriptions are accurate. Items are subject to prior sale. WAA is not a party to any sale unless the equipment belongs to WAA (and will be so identified). ***Prices are negotiable*** unless otherwise stated. Sales of WAA equipment are final. *Caveat emptor!*

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