SkyWAAtch

The Newsletter of Westchester Amateur Astronomers

January 2022

Partial Lunar Eclipse by John Paladini

A partial phase of the November 19, 2021 lunar eclipse. What's remarkable about this image is that John used a Samsung smart phone and a 200-year old Gregorian telescope with a speculum-metal mirror. As John notes, "I bet nobody has done that for a while!" If ever. See page 20 for more images of the eclipse.

WAA January Meeting

Friday, January 14 at 7:30 pm

On-line via Zoom

Building a Gravitational Wave Telescope out of Stars

Tyler Cohen, BSc
Graduate Research Assistant, New Mexico Tech University

Gravitational waves are ripples in the fabric of spacetime. A consequence of Einstein's theory of general relativity, they were first detected from inspiraling black holes in 2015 by LIGO. Now, another observatory is on the verge of detecting gravitational waves of a different sort. Its detector is the size of the Milky Way galaxy and constructed from some of the most exotic stars in the universe. Tyler will discuss how the North American Nanohertz Observatory for Gravitational Waves uses pulsar timing to search for low-frequency gravitational waves, and the premier radio telescopes that this work has brought him to.

Tyler Cohen is a PhD student at New Mexico Tech and a tour guide at the Very Large Array radio telescope in New Mexico. A Westchester native and former WAA member, he went on to receive his BSc. in physics and astronomy at Stony Brook University. He has since worked at the Gemini Observatory on Mauna Kea, Hawaii and Arecibo Observatory in Puerto Rico.

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

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

Editor: Larry Faltz
Assistant Editor: Scott Levine
Almanac Editor: Bob Kelly
Editor Emeritus: Tom Boustead

WAA February Meeting

Friday, February 11 at 7:30 pm

On-line via Zoom

What's New on the Red Planet?

Br. Robert Novak, PhD
Professor Emeritus, Iona College

Starway to Heaven Star Parties

Ward Pound Ridge Reservation

See page 5 for the 2022 schedule.

New Members

Neereja Sundaresan	Mount Kisco

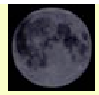
Renewing Members

Andrea Anthony	Yorktown Heights
Robert Brownell	Peekskill
Jake Burk and Monica Carman	Ossining
Jose E. Castillo	Pelham Manor
Daniel Cummings	Croton-On-Hudson
Edgar S Edelmann	Tarrytown
Larry and Elyse Faltz	Larchmont
Sharon and Steve Gould	White Plains
Mark Hefter	Dobbs Ferry
Bob Kelly	Ardsley
William Meurer	Greenwich
Robert Rehrey	Yonkers
Richard Segal	Yorktown Heights
Robert Sour	Bedford
James Steck	Mahopac
Woody Umanoff	Mount Kisco
Cliff Wattley	Danbury

Also In This Issue

ALMANAC For January 2022

Bob Kelly, WAA VP for Field Events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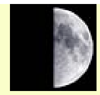
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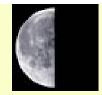
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Celestial Color Matching

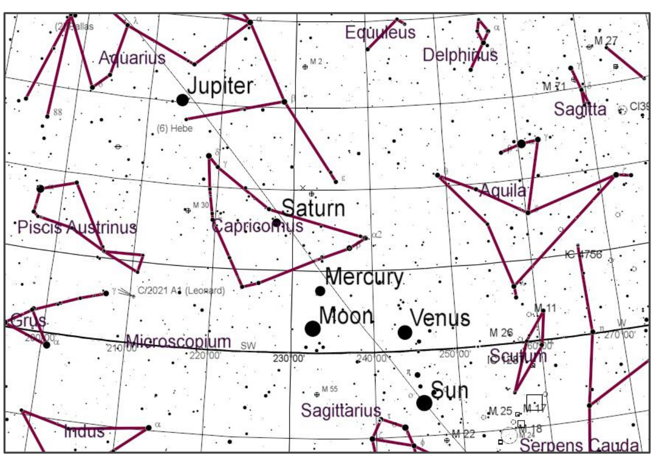
Mars starts the hike up into the morning sky across from Antares during the first week of the month. Maybe you can spot how their colors match. They're only 10 degrees above the horizon when the Sun is only 10 degrees below the horizon, making the red pair a challenging catch before dawn.

Early January Evenings

Find a clear southwestern horizon to start the New Year! It'll be worth it to see four of the five brightest planets. During the first few days of the New Year, magnitude -4.2 **Venus** is already about to set by the time the Sun is 10 degrees below the evening horizon. So, get out there early after Sunset. **Mercury**, at -0.7, is to the upper left, and follows Venus to the ground. **Saturn** is higher, but harder to see at +0.7, and **Jupiter** is well up to the left at a bright -2.1.

Venus will be getting larger and becoming a slim crescent as we move closer together. You might be able to see this in binoculars, and definitely in a telescope. Try for it as soon as you spot Venus in twilight!

Comet Leonard will be off to the left of this scene. Unless it has an unexpected outburst, even binoculars might not show it because it is so far down in the horizon's haze.



Looking to the southwest, 5:15 p.m. January 3, 2022

Solar System Resolutions

Mercury makes a New Year's resolution to reach as high as Saturn in the evening sky, but can't keep it (like so many aspirational goals we humans will be setting). Mercury gets closest to Saturn on the 12th, at 3½ degrees to the lower right. Saturn is so much fainter than Mercury that you may find it easier to use Mercury to find Saturn. Mercury will be in conjunction with the Sun on the 23rd, so look early in the month. Saturn will set only fifteen minutes after the Sun by the 31st. Venus will be long gone, in conjunction with the Sun on the 8th. Only Jupiter will be out there at month's end.

The evening crescent **Moon** points out Saturn on the 4th and is in Jupiter's part of the sky on the 5th.

Give **Neptune** and **Uranus** some attention before they set in the late evening, and after midnight, respectively.

Venus Joins the Morning Shift

Venus soars into the morning sky after passing the Sun on the 9th, presaging a boycott of the evening sky by major planets. It joins Mars in the dawn sky for the last third of January. The Moon will make a nice line-up with Mars to its left and Venus further to the left on the 28th and 29th. Mercury will enter the scene at month's end. It will be well to the lower left, but fainter than Mars. RASC's Observer's Handbook notes Venus gets closer to Earth on the 8th than any other planet for the entire 21st century, 39,760,613 kilometers. Venus won't be back in the evening sky until December.

For Meteors, It's All About the Timing

The **Quadrantid** meteors are famous for their intense, but brief period of maximum meteors. This year, the peak is at 4 p.m. EST, give or take three hours. Does that mean the hours after dusk might be in that peak activity window? Can't hurt to look. Also, the American Meteor Society says the early morning hours of late January have the highest overall rates of meteors, with up to 20 per hour visible before dawn. Another reason to get up early.

Objects are Closer than they Appear

The **Moon** is at perigee in January, closest to Earth this month, on the 1st at a distance of 222,471 miles. It's new 22 hours later, on the 2nd. Earth's perihelion in 2022, when our planet is closest to the Sun for the year, is on the 4th at exactly 1:52 a.m. EST. The Sun will be 91,406,842 miles (17,105,052 km, 0.9833 AU) away.

While being closer to the Sun is not a major factor in the height of the tides, the lunar perigee near the time of new Moon will bring higher than normal tides for several days on and after the 1st. Any coastal flooding from a major storm during that time could be enhanced by these astronomical factors.

Tipsy Moon

The northeastern limb of the Moon will be tipped toward Earth on the night of the 6th-7th, by 9.89 degrees; the maximum amount for 2022. Mare Crisium will be more visible than usual, as will Mare Marginis. A good discussion of libration with illustrations is on the EarthSky website at https://is.gd/28Uq2i. NASA also has a good animation at https://is.gd/0gMrjw.

Winter Star Sights

The **Milky Way** stretches across overhead from Cassiopeia to Canis Major by 9 or 10 p.m., while Orion and his friends and enemies make a wonderful display high in the southern sky.

Who's Up There?

Check http://www.heavens-above.com for updates, but as of now you could see the **International Space Station** before sunrise though the 10th and in the evenings starting on the 15th. **Tinagong**, the space station staffed by China, is smaller but visible in the pre-sunrise skies through the 16th and in the post-sunset skies beginning on the 25th.

Another Movie Telescope

Peter Cook (L) as George Spiggott (the Devil) and Dudley Moore as Stanley Moon, in Stanley Donen's 1967 classic, *Bedazzled*. Stanley is a short-order cook at Wimpy's, hopelessly in love with waitress Eleanor Bron but too inhibited to even speak to her. The Devil appears and grants him seven wishes, all of which fail hilariously. Raquel Welch makes a brief appearance as Lust.

Westchester Amateur Astronomers Club News for 2022

Star Parties: Saturdays. If the Regular star party is held, the make-up will be canceled. We will hold the October 1st date in case we have a run of bad weather or something special happens in the sky.

			Moon			
Date	Type	Sunset	Set	Rise	Illumination	Phase
3/5/2022	Regular	17:50	21:11		11%	Waxing
3/26/2022	Regular	19:13			31%	
4/2/2022	Make-up	19:20	21:07		3%	Waxing
4/23/2022	Regular	19:43		3:21	42%	Waning
4/30/2022	Make-up	19:50			<1%	
5/21/2022	Regular	20:12		1:54	57%	Waning
5/28/2022	Make-up	20:18			2%	
6/25/2022	Regular	20:31		3:28	8%	Waning
7/2/2022	Make-up	20:31	23:14		14%	Waxing
7/23/2022	Regular	20:20		2:01	18%	Waning
7/30/2022	Make-up	20:13	21:42		6%	Waxing
8/20/2022	Regular	19:46		0:37	32%	Waning
8/27/2022	Make-up	19:35	20:09		<1%	Waxing
9/17/2022	Regular	19:00		23:16	49%	Waning
9/24/2022	Make-up	18:48			<1%	
10/1/2022	Regular	18:36	20:15		40%	Waxing
10/22/2022	Regular	18:03			6%	
10/29/2022	Make-up	17:53	21:02		25%	Waxing
11/19/2022	Regular	16:32		2:55	14%	
11/26/2022	Make-up	16:28	18:52		12%	Waxing

Moon phase: Where no phase is given, the Moon won't be in the sky at sunset and won't rise until at least 4 a.m. Dark sky viewing is usually possible 45 minutes to an hour after sunset.

Lectures (all Fridays at 7:30 p.m.). On line until Pace allows us back on campus. Lectures are on the second Friday of each month except September (to avoid the week of Labor Day).

January 14	September 16 (Members' Night)
February 11	October 14
March 11	November 11
April 8	December 9 (Annual Meeting)
May 13	
June 10	

There are no conflicts with Passover, Easter, Good Friday or Rosh Hashanah in 2022 for lectures or star parties.

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WAA Officers for 2022

At the Annual Meeting on December 10th, the following slate of officers was elected by the membership and serve as the Board of Directors:

President	Karen Seiter
Senior Vice President	Jordan Webber
Secretary	Tim Holden
Treasurer	Paul Alimena
VP Membership	Eva Andersen
VP Field Events	Bob Kelly
VP Programs	Pat Mahon
VP Newsletter	Larry Faltz
VP Communications	Frank Jones

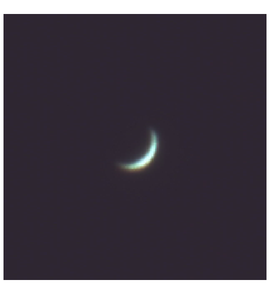
The Nominating and Audit Committees are the standing committees of WAA.

Nominating Committee	Bill Newell
	Charlie Gibson
Audit Committee	Darryl Ciucci
	Joe Geller

In addition to the above individuals, the following members have been appointed the **Advisory Board**. They participate in WAA Board meetings to help guide and implement the club's mission.

Mike Cefola	Josh Knight Matthew Leone	Sattya Nitta
Darryl Ciucci	Scott Levine (Assistant Editor, SkyWAAtch)	Robert Novak
Dan Cummings	Mike Lomsky (Assistant Treasurer)	David Parmet
Charlie Gibson	Hans Minnich	Olivier Prache
Jeffrey Jacobs	Bill Newell	Deirdre Raver

Members interested in participating in supporting operations as members of the Advisory Board or in helping to respond to inquiries from the public or new members (for outreach or to support new telescope users) should contact outreach@westchesterastronomers.org.



Venus on December 17th by Steve Bellavia

While looking for Comet Leonard just after sunset, Steve couldn't help noticing brilliant Venus 11 degrees above the horizon and shining near its maximum brightness. Although only 13.7% of its surface was sunlit, the 51.5-arcsecond diameter planet blazed at magnitude -4.6. Venus passes inferior conjunction on January 9th and will be Lucifer, the morning star, until the end of October 2022. Steve used a 430-mm f/6 doublet refractor and DSLR. Stack of three images.

Member Profile: Brian Blaufeux

Home town: Larchmont

Family: Wife and 2 teenage children.

How did you get interested in astronomy? I always loved understanding what was in the night sky and appreciated its grandeur. After a vacation in Belize, with many amazing nights of naked eye stargazing, my family decided to get me a telescope for my 50th birthday.

Do you recall the first time you looked through a telescope? What did you see? I'm sure it wasn't the first scope I looked through, but I definitely remember looking through the scope in my high school's newly-created observatory in 1986 and seeing Comet Halley.

What's your favorite object(s) to view? Jupiter and Saturn.

What kind of equipment do you have? Celestron Nexstar 6SE.

What kind of equipment would you like to get that you don't have? I think a dedicated camera for the telescope.

Have you taken any trips or vacations dedicated to astronomy? Tell us about them. Not yet, but I plan to go to Texas for the 2024 total solar eclipse.

Are there areas of current astronomical research that particularly interest you? Determining the content and nature of the early universe.

Do you have any favorite personal astronomical experiences you'd like to relate? Seeing Comet Halley was a real thrill. I also enjoy showing my neighbors the views through my scope.

What do you do in "real life"? I'm an emergency and urgent care physician, and I'm now a full-time medical informatics officer for Northwell Health.

Have you read any books about astronomy that you'd like to recommend? It's not technically astronomy, but I highly recommend *Longitude* by Dava Sobel.

How did you get involved in WAA? I joined after hearing about WAA from Larry Faltz at work.

What WAA activities do you participate in? I attend the monthly Zoom lectures and I've made some visits to the Ward Pound Ridge viewing site.

Besides your interest in astronomy, what other avocations do you have? I enjoy tennis and I keep up with my summer camp alumni association.

Provide any other information you think would be interesting to your fellow club members. I'd like to be able to see more deep sky objects and do some basic astrophotography.

From the backyard. C6, cellphone on a Celestron NEXYZ smartphone adapter.

Now is the Time to Take in the Stars of Orion — Scott Levine

With all the festivities this time of year, candles, turkeys or trees, this is the most festive time in the skies, too. Welcome to Orion season.

Recorded references to the constellation Orion go back close to 40,000 years. We take our view of it from the Greeks and Romans; he's a mighty and aggressive hunter. Other cultures have seen it as a bird, a messenger or any number of other things important to them. He spends his time each night fighting Taurus the bull, while his two dogs, Canis Major and Canis Minor, cheer him on.

The first thing most of us spot is the line of three stars that form his famous belt. With those as our jumping-off point, Orion becomes an amazing constellation to explore.

First, toward the left or above the beltline, let's visit bright orange Betelgeuse, his left shoulder. This is an old and enormous star whose light left for our eyes around 600 years ago.

Draw a line diagonally across and through the belt to icy blue-white Rigel, at his right foot. Rigel is the fifth brightest star we can see in Westchester's nights. That one dot in the black is a system of four stars gravitationally tied to each other.

I love to stop and stare at this pair. Can you notice their colors? They signify that they're different types of stars, but both are among types that will one day die in tremendous explosions called a supernova. It's unlikely, but it may have already happened. With the incredible distances their light must travel, it would take about 600 years for us to learn if Betelgeuse did, around 800 for Rigel.

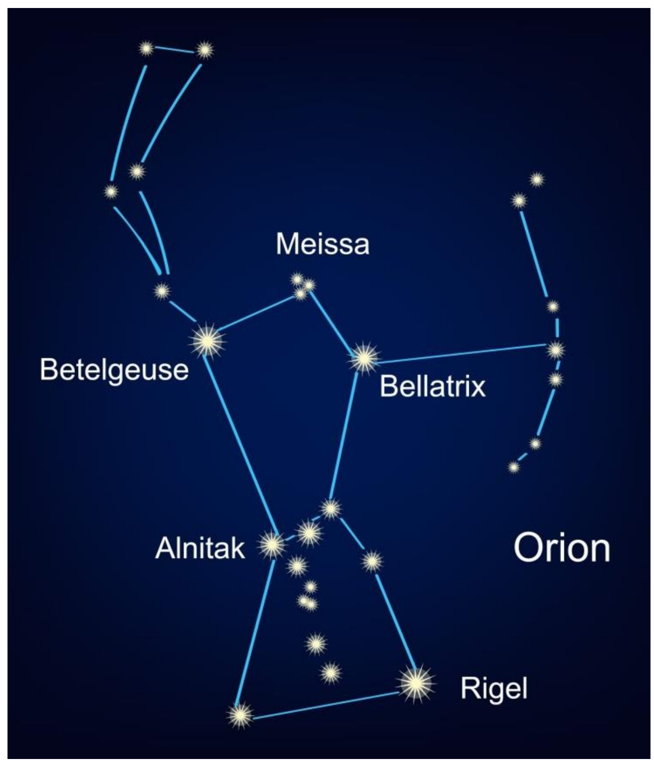
These two stars are incredible, but they have nothing on Alnilam. The belt's middle star is one of the most distant and luminous we can see with the naked eye. Astronomers believe it puts out around 500,000 times more light than our sun. It's truly powerful, and it almost hurts to think what it must be like close up.

I mention these three stars because they are relatively far away as these things go. If we widen our gaze a bit, we can see that Orion is cordoned off from the rest of the sky by a ring of six other very bright stars often called the Winter Hexagon.

The Hexagon's stars all happen to be much closer to us than Orion's more distant stars. The farthest is only a tenth of Betelgeuse's distance to us. This gives us a great chance to see that the sky isn't just a flat sheet but has depth and texture.

Seen this way, Orion's stars aren't just within the Hexagon, but behind it, with its stars drawing our eye deeper and deeper into our galaxy. First, we reach Betelgeuse, then Rigel, and then, much farther beyond, Alnilam. If you can, take some time to soak in this scene, the cold, the smell of food or candles, the depth of the sky, the stars' colors, the entire corner of the sky twinkling like holiday lights on our friends' houses.

These stars will guide us through the nights until they vanish again in the spring. This is a great time to start exploring. Clear skies, everyone!



Scott Levine (astroscott@yahoo.com) is an astronomy writer and speaker from Croton-on-Hudson and Assistant Editor of Sky*WAA*tch.

For more on Orion and the famous Orion nebula that's hanging from his belt, see the February 2016 SkyWAAtch.

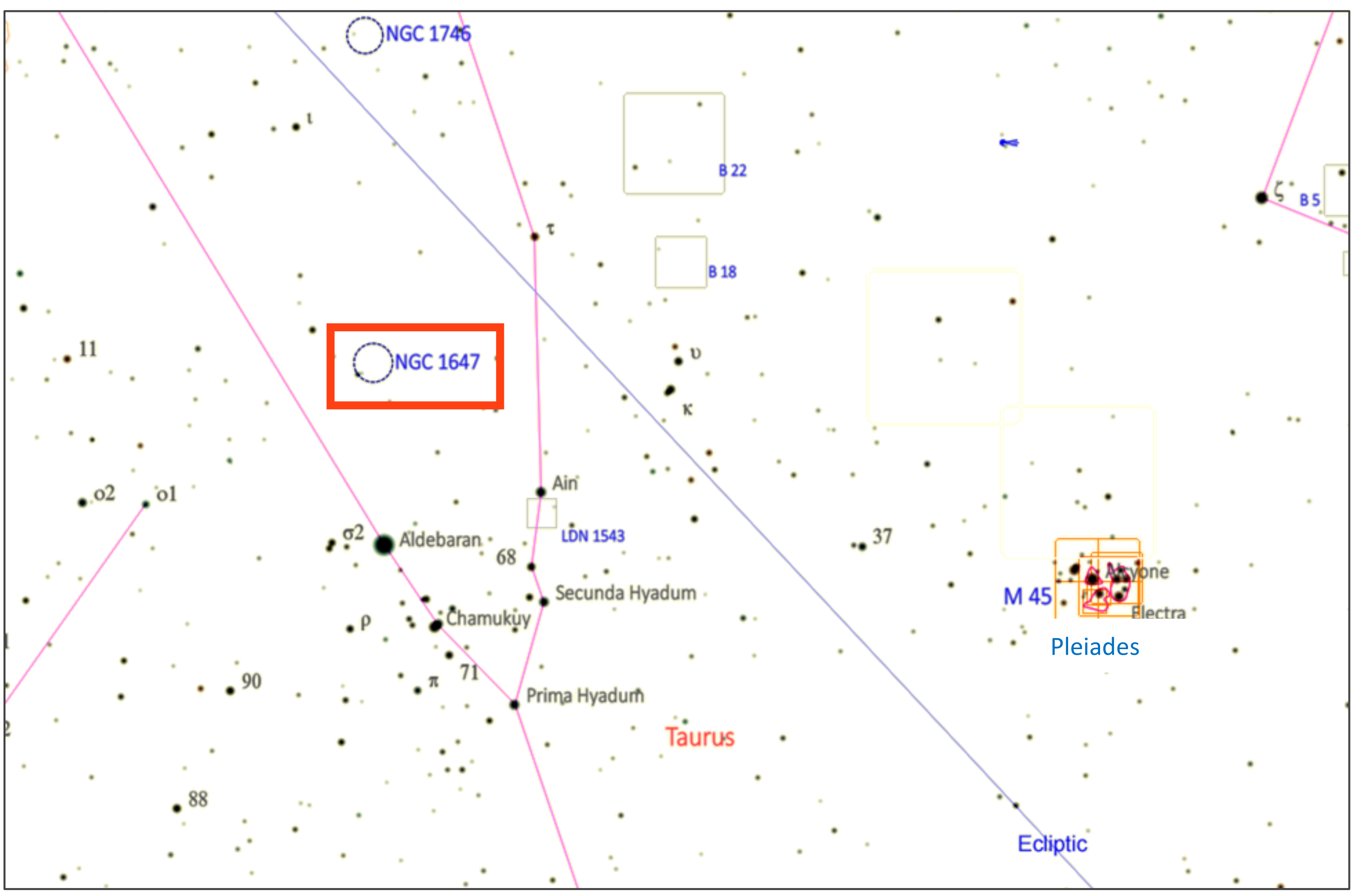
Deep Sky Object of the Month: NGC 1647

NGC 1647	
Constellation	Taurus
Object type	Open Cluster
Right Ascension J2000	04h 45m 54s
Declination J2000	19° 06’ 00”
Magnitude	6.4
Size	45’ x 45’
Distance	1,800 LY
Age	150 million years
Discovery	W. Herschel 1784

Not far from Aldebaran and the Hyades cluster, although 11 times more distant, the large but sparse NGC 1647 is a group of perhaps 200 stars in an area half again as wide as the full Moon. Stephen James O’Meara, in *The Secret Deep*, dubs it the “Pirate Moon Cluster” because of its size and its ghostly appearance at the margin of naked-eye visibility in a dark sky. It is located just south of the “edge” of the Milky Way, making it easier to resolve in a small telescope because there are fewer of our galaxy’s background stars in the field.

Visibility for NGC 1647			
9:00 pm EST	1/1/22	1/15/22	1/31/22
Altitude	64° 59’	67° 53’	64° 04’
Azimuth	148° 03’	180° 14’	216° 12’

NGC 1647 is a good binocular object in a dark sky and should be observed at low power in a telescope because of its size.



Notes from the Junkyard Astronomer

Living with a Speculum Metal Mirror Telescope

John Paladini

On December 25, 2021 NASA launched the infrared-sensitive James Webb Telescope towards the L2 Lagrangian point a million miles from Earth. One of the many interesting things about this instrument is that the 18 gold-coated beryllium hexagonal mirrors that make up the 6.5-meter primary are not glass but metal. In some way we have come full circle from metal mirrors, which have been around for 2000 years, to glass mirrors, which have been around for a few hundred years and back to metal mirrors. The reflecting telescope used a speculum metal mirror from the time of its invention until the glass paraboloid mirror, invented by Leon Foucault, made its appearance in the 1850s.

My Gregorian telescope: 2.75 inch diameter mirror, approximately 10 inch focal length

Of course the Webb's segmented metal mirrors are not quite the same as the old speculum metal mirrors. They are much lighter and stronger but still they are metal. So what does this have to do with my hobby? In 2017 I purchased an antique 2.75 inch speculum-metal mirrored Gregorian telescope and had to learn how to properly care for it.

The Gregorian telescope was first described by mathematician James Gregory in 1663, based on the properties of conics described by René Descartes in 1637. Because the optical surfaces are complicated, one was not made until 1673, when the famous scientist, microscopist and Curator of Experiments at the Royal Society (and enemy of Newton) Robert Hooke built one. His mirrors' figures were inexact, early mirror-making being a very rough craft. Early examples suffered from all three optical faults: spherical aberration, coma and astigmatism. In 1720 John Hadley crafted one that was close to the design's theoretical figures, eliminating at least most of the spherical aberration. Scotsman James Short (1710-1768) perfected the mirrors, making true paraboloids and ellipsoids. His optical shop in London made over 1,000 Gregorian telescopes. These were the most sought-after (and expensive) telescopes on the market in the mid-18th century. Short became fabulously wealthy, but he was also secretive and destroyed all his tools before he died.

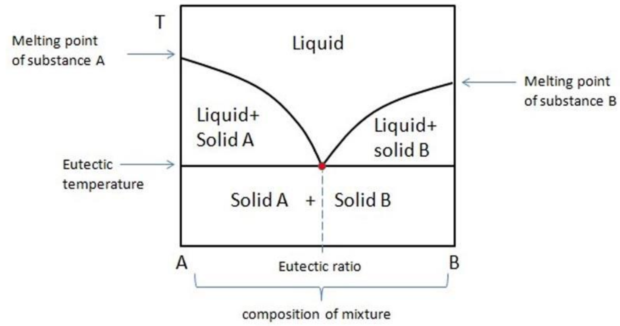
A 4½-inch Gregorian telescope by James Short from 1738 (National Museum of Scotland)

One of the advantages of the Gregorian design is that it produces an upright image without the use of prisms or inverting lenses.

What is speculum metal? It is a mixture of copper and tin in a 2:1 ratio, with other metals in trace amounts, melted together to form a heavy, hard, brittle and, when polished, brightly reflective alloy. It is an example of a bronze alloy. Bronze is a mixture of copper and tin, as opposed to brass, which is a mixture of copper and zinc. Most bronze alloys contain 12-13 percent tin and are durable enough to be used as swords and spear points. Speculum swords and spear points would shatter on first use. Just changing the percentage of one metal, altering the types or amounts trace metals or even varying how the alloy is cooled can totally change its final properties. This is the science, the art and I feel the magic of metallurgy. I view the people who do this work as alchemists. The "perfect" speculum mixture was an achievement of guesswork, trial and error.

On one of my excursions to Stellafane, I had a discussion with telescope maker and antique scope restorer David Grosky about speculum metal. He cleared away some of my misconceptions. First, I thought that speculum mirror production ceased as soon as reflective coating on glass mirrors was invented. That is not true. Speculum mirrors were made commercially until the late 1930s. Later mirrors were used mostly for spectrum gratings. Indeed there are some people still making them today. Second, I assumed that all speculum metal mirrors are doomed to quick tarnishing. That is not so. If well made, a speculum metal mirror can hold on to most of its reflectivity for centuries. I visited the telescope collection in Chicago's Adler Planetarium (see the October 2018 SkyWAAtch) to check and photograph some Gregorians that were made as long ago as the mid 1700s. Some of the mirrors had excellent shines, others not so much. Mostly, it was the larger speculum mirrors that were tarnished. It was probably harder to accurately control the mixture during their preparation. Many were left outdoors for long periods of time.

I also learned a new word: *eutectic*. A eutectic mixture has a melting point lower than each of its components. This is an important property of speculum metal. When they are poured, during a "second melt" the old master mirror-makers would add metals like arsenic that would otherwise vaporize. David stated that it's more correct to think of speculum as a mixture rather than as an alloy. The molecular bonds are very weak and that's why they break very easy.



Phase diagram of a eutectic mixture of A and B

So what does this all have to do with me? It's all about telescope maintenance. This is where speculum metal mirrors are very different from glass mirrors. In a glass mirror, if surface reflectivity is lost you can have the coating stripped and resurfaced. The figure is in the glass not the coating. If a speculum metal surface needs to be cleaned you cannot just rub it clean. Rubbing the surface changes the figure and most likely destroys the parabolic curve. Another issue to keep in mind is temperature. The speculum mirror will shatter if fluid at a very different temperature is applied. While this is true for glass mirrors, speculum metal mirrors are far more sensitive to temperature differential. Also any undue pressure or impact can shatter the mirror.

My telescope was made around 1820 by Robert Brettell Bate (1782-1847). He operated an optical and scientific business in London. In 1804, he took over the business of his uncle and father-in-law (the same person, you figure it out), who had a commission to provide the government with hydrometers. Bate expanded the business to include microscopes and other optical and scientific instruments. He was an optician, and so may have made at least the optical components of the microscopes and telescopes that he sold. In 1833, he served as Master of the Worshipful Company of Spectacle Makers. He was also Optician in Ordinary to King George IV and Queen Victoria (he was an official optician to the Royal Household).

These are rules I learned about speculum metal.

- If there are any rust spots (they look like rashes or measles) all you can do is dab (not rub!) pure white kerosene. Hopefully this will lift the rust but any damage will remain.
- You can use a bulb cleaner to blow off loose particles, just as you should for a glass mirror or lens.

- If you touch polished surface with bare fingers your fingerprint will be permanent within 24 hours. You can wash it off using a mild soap (such as Dawn) plus distilled water, rinse with distilled water and let drip dry. But keep in mind that temperature warning. Wash your hands first. Use nitrile gloves to keep your dirty paws off the mirror!
- I store my scope in airtight box with desiccants and 3M tarnish stripes, which absorb sulfur dioxide and nitric oxide from the air.
- No need to worry about getting fungus or bacterial growth on brass and bronze telescopes. These metals are naturally antiseptic. Within 90 minutes all those critters are dead.

Looking down my scope. The mirror is still highly reflective!

I first determine how humid outside conditions are before using the scope. If the humidity is too high, I opt for glass optics.

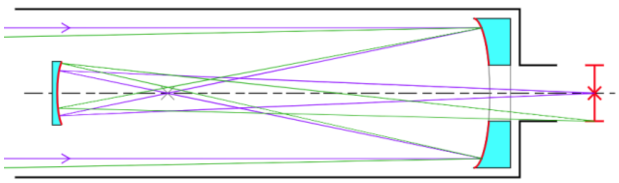
It not impossible to have the surfaced restored or refigured, but it's difficult. You need to place the mirror on a pitch polishing tool that has the proper shape. You then go through the polishing phase and then you have to through the refiguring phase with testing just like final stages of a glass mirror. There are just a few people that can do this. I believe museums and large antique dealers have access to those skilled craftsmen for proper restorations.

In the nearly five years that I have had scope I have not seen any degradation of the mirror surface.

Here are some brief videos that illustrate important aspects of speculum metal mirrors:

- Isaac Newton's original reflecting telescope mirror: https://www.youtube.com/watch?v=4ESW_NTIhBM
- Fragility of a speculum metal mirror: https://www.youtube.com/watch?v=Iyi4QNIimM4
- A Gregorian telescope in the History of Science Museum (Oxford University): https://www.youtube.com/watch?app=desktop&v=vjhZa4GjDas
- Sand-casting a bronze mirror: https://www.youtube.com/watch?v=j15kgNF1qEo
- Figuring a metal mirror: https://www.youtube.com/watch?v=VJqwInBxXko
- Cleaning a speculum mirror: https://www.youtube.com/watch?v=Wp4FHNpOcZY

The Gregorian Telescope



The primary mirror is a concave paraboloid, while the secondary is a concave ellipsoid.

In a Gregorian telescope, the focal point of the primary mirror is in front of the secondary (unlike a Newtonian).

A paraboloid has the formula

$$z = \frac{x^2}{a} + \frac{y^2}{b}$$

If *a*=*b*, it is a circular paraboloid, or a "paraboloid of revolution," a parabola rotated around the *z* axis.

An ellipsoid has the formula

$$\frac{x^2}{a} + \frac{y^2}{b} + \frac{z^2}{c} = 1$$

For the secondary of a Gregorian telescope, *a* and *b* are equal, making the figure a spherical ellipsoid. If all three constants are equal, the figure is a sphere with a radius equal to the constant.

■

Bending Light

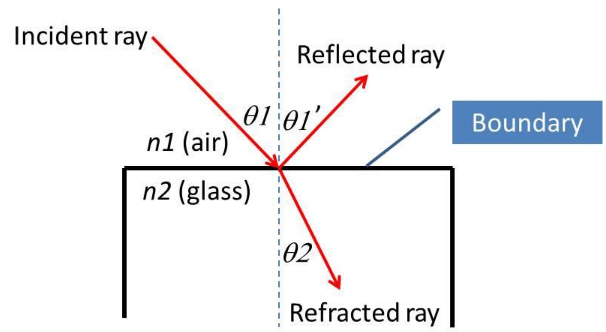
Larry Faltz

Before the telescope, astronomers could only receive beams of light with their eyes, using quadrants, sextants, octants, sighting tubes and astrolabes. Lenses and mirrors bent electromagnetic radiation (EM) in the service of new knowledge. Most astronomy relies on light-bending. Radio telescopes, including microwave detectors like ALMA, also bend and focus EM rays, as do X-ray space telescopes. The most energetic EM energy, gamma rays, can't be bent by our technology (yet) so the Fermi gamma-ray space telescope uses tungsten plates to track the direction of incoming radiation. Neutrino and gravity wave detectors don't detect photons. In the case of gravitational waves, in a real sense it's the detectors themselves that are being bent!

Common experience tells us that light moves in straight lines. Look at a shadow and you get the idea, but the idea that light is a linear "beam" was assumed even in ancient times. Hero of Alexandria, who lived in the first century AD, made this claim in *Catoptrica*,[1] his study of reflections from flat and curved mirrors. But it's not *exactly* true. Only if there's no change in the density or composition of the medium through which the light is traveling, the light path is indeed the shortest distance between two points.

We've all experienced the change in the angle of light rays when we observe the offset of someone's legs when standing in a swimming pool, or a spoon in a glass of water. This phenomenon is what's at work when we use a lens. The refraction of light by lenses and mirrors was a topic investigated by both Ptolemy and the Arabic scientist Ibn Al-Haytham (Alhazen), but both of them failed to grasp the right formula. In 984, the Persian mathematician Abū Saʿd al-ʿAlāʾ ibn Sahl correctly described the change in the path of light when it crosses the boundary between two different transparent media, for example air and water or air and glass. Thomas Harriot, who some claim had observed the Moon with a telescope before Galileo, also recognized the details and corresponded with Kepler about it although he did not publish his ideas.

Willebrord Snellius was a Dutch mathematician, surveyor and astronomer. In 1621 he independently proposed what is now known as Snell's Law, from the English reduction of "Snellius" to "Snell." Not knowing anything about the nature of light or the composition of transparent materials, or having read ibn Sahl, he nevertheless derived a formula that accurately predicts the change in the path of a light ray when it crosses a boundary.



For a reflecting surface, the angle of incidence equals the angle of reflection, that is θ1=θ1'. But a ray that passes through the interface between transparent media of different compositions is refracted through a different angle, θ2. The formula for this phenomenon, refraction, is

$$\frac{\sin\theta 2}{\sin\theta 1} = \frac{n_1}{n_2}$$

where n is a dimensionless value called the "refractive index." When a light ray crosses the boundary orthogonally, that is directly face-on, θ1 is zero, sin θ1 is also zero and so there is no refraction regardless of the difference in refractive index. The light ray goes straight through [with some reflected directly back, sin(180°) also being zero.] At all other angles, the ray will deviate according to the formula.

Refractive Indices of Various Materials	
Vacuum	1
Air (0° C, 10^5 pascals [1 bar])	1.000293
Pure water, 20° C	1.333
Olive Oil	1.47
BAK-4 glass	1.57
Flint glass	1.69
Diamond	2.42

[1] "Catoptric" in English means "pertaining to a mirror or reflector." It is derived from καθρέφτης , the Greek word for "mirror." It also the root of "catadiptric," meaning involving both the reflection and the refraction of light, for example Schmidt-Cassegrain telescope, which has both a lens-like component (the corrector plate) and a mirror.

The path of the refracted light ray is not the shortest distance between two points on either side of the interface. So how does the light "choose" which path to take? The answer is that the path is the one that takes is the least time between the two points. This is Fermat's Principle, articulated by the French mathematician (and bane of a dozen generations of mathematicians with his "last theorem") Pierre de Fermat in 1662. Fermat was able to derive this principle without knowing anything more about light, or materials, than Snellius.

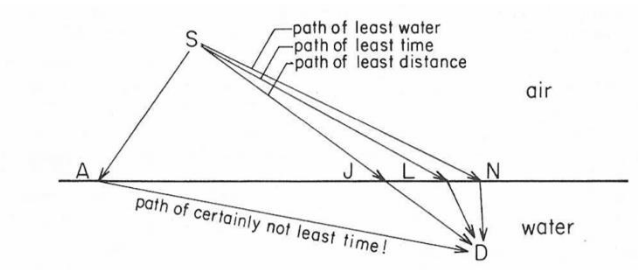


Fig. 30 from Feynman's *QED*, showing the possible paths of a light beam emitted from a source S and detected by a detector D. The actual path that we detect is S-L-D.

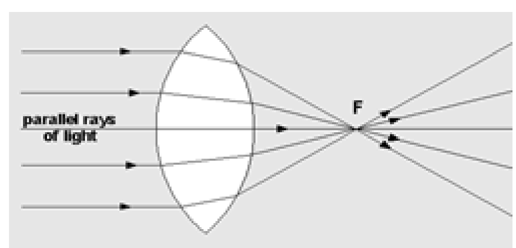
The speed of light was thought to be infinite until Ole Rømer, timing the eclipses of Jupiter's moon Io, proposed in 1677 that it was finite albeit amazingly fast. His value, 220,000 km/s, was slow by 26% but it was still a remarkable result given the equipment of the day and the difficulty of the observations. He reported the finding in a letter to Christiaan Huygens and the following year composed a manuscript with more observations, although he never published it. The finding nevertheless circulated widely. Initially disbelieved by Rømer's boss at the Paris Observatory, Giovanni Domenico Cassini, it rapidly gained adherents, including Newton, and by the first quarter of the 18th century the finite velocity of light was a central pillar of physics. [2]

We now know that the refractive index is a direct measure of the velocity of light in a material, so we can rewrite Snell's formula as

$$\frac{\sin\theta 2}{\sin\theta 1} = \frac{v_2}{v_1} = \frac{n_1}{n_2}$$

As an example, if you shine a laser at a flat glass block at 45 degrees (θ1) and observe that the beam in the glass block (θ2) is at 30 degrees, you can calculate that the speed of light in the glass is 212,000 km/s and the index of refraction of the glass is 1.41. Fermat's Principle can be derived whether we take light to have the properties of a wave or a particle. As quantum mechanics tells us, light is both. In *QED: The Strange Theory of Light and Matter*, Richard Feynman provides a clever quantum interpretation: light always appears to take the least time to go from A to B (S to D in the diagram) but it actually takes every path between A and B. It's the nature of quantum interference that all the other paths cancel out. That's true for both reflection and refraction. Feynman's explanation is surprisingly straightforward, and I refer you to this highly readable account, which was based on four lectures that he gave to a general audience at UCLA in 1983.

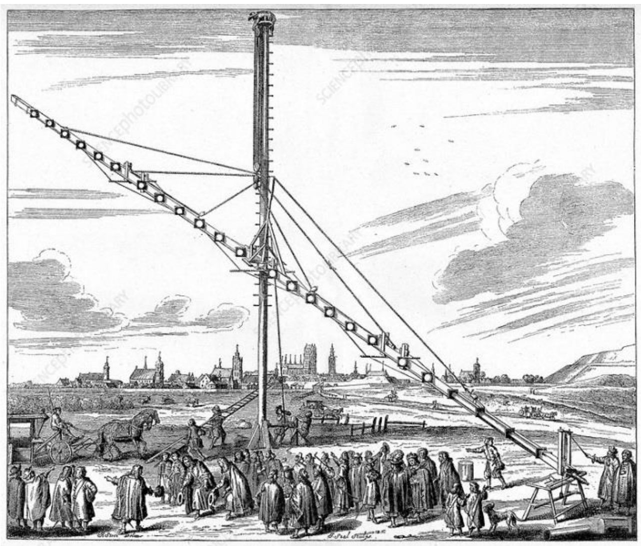
When we apply Snell's Law to lenses, we measure the angles θ1 and θ2 at each point on the curved surface. Each light ray strikes the front surface of the lens at an angle θ relative to the tangent of the surface's curve at that point. It then changes its path according to Snell's law, traverses the lens by Fermat's Principle, and emerges on the other side of the lens, again changing its path per Snell's law, tangent to the surface. If we wanted to focus parallel light rays onto a point, which is what the objective of a telescope does, we can use a convex lens. If the curve is figured properly, the rays will come together at the focal point.



In many media, the velocity of the light is dependent to a small degree on the wavelength. This variance is the major source of chromatic aberration in lenses. It is less of a factor when the lens curvatures are relatively mild (that is, θ1 is small and so very small changes occur in the light ray's direction). A mild curvature means a long focal length. This is one reason why early single-lens telescopes had extremely long focal lengths. One of Galileo's telescopes had a focal length of 1330 mm and aperture of 26 mm, giving f/51.2. Johannes Hevelius built a telescope 150 feet in

[2] The velocity of light is dependent on the medium but maximum in a vacuum, 299,792,458 meters per second.

length. It purportedly had an 8-inch objective, giving f/150, but I seriously doubt a lens that large could be figured properly in the 1670s. If it was a 4-inch glass, the focal ratio would be f/300!



Hevelius' 150-foot telescope. You think your mount is unsteady?

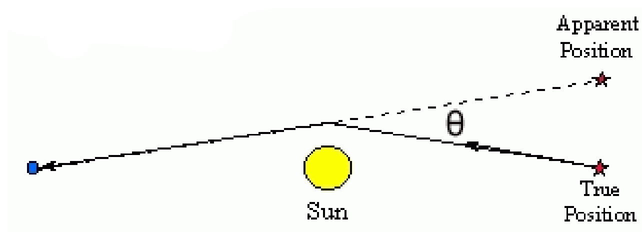
Newton showed that a single lens could never eliminate chromatic aberration. The crown-flint achromatic doublet was invented by optician Chester Moore Hall in 1736. It was perfected and patented by John Dollond in 1758. It helped substantially but not completely. Commercially made 2-element refractors, large or small, were often f/15 or even slower so that color fringing on bright objects would be acceptable. Modern advances in lens-making, glass formulations and multiple lens configurations meant that suppressing chromatic aberration no longer required long focal lengths. The famous (and expensive) Takahashi FSQ-106 is a 4-element f/5 instrument. A number of WAA imagers are using the diminutive William Optics Redcat 51 f/4.9 that also uses four lens elements of exotic glasses. Both of these are Petzval designs (see sidebar on page 19). Borg makes a 55-mm f/3.64 6-element imaging refractor.

Newton's *Opticks* was published in 1704. It details his experiments with prisms and lenses. Newton believed that light consisted of particles, and the particles of the different colors had different masses. Having already figured out gravity (in the 1687 *Principia*), he considered whether light rays would be subject to gravitational forces. At the end of the *Opticks*, Newton made a list of 31 "queries," topics of unresolved scientific interest. Here's the first query:

Query 1. Do not Bodies act upon Light at a distance, and by their action bend its Rays; and is not this action (cæteris paribus) strongest at the least distance?

(*cæteris paribus* = "other things being equal").

Newton's reasoning was straightforward. The gravitational force on any mass that is substantially smaller than the attracting body is independent of the object's mass.[3] The Earth accelerates all masses at 32 feet per second per second at its surface, so why not light? We can't see the effect locally, even if it exists, because the light is travelling so fast, but Newton predicted that a light beam passing a much more massive body, like the Sun, would be deflected. Once past the gravitational mass, it would resume a straight course. We would perceive that the light ray was coming from a slightly different direction.



Newton was right, for the wrong reasons. The brilliant but unsung genius John Michell foresaw the existence of black holes. He considered that the gravitational force of a sufficiently massive body would slow the speed of light, eventually making it zero, making the star invisible. Although very close to the truth, this isn't quite the right explanation (as we shall shortly explain). Michell's fascination with gravity led him to invent the torsion balance that Henry Cavendish used to measure the gravitational constant (see "Weighing the Earth" in the December 2018 SkyWAAtch). Cavendish himself proposed a formula for the deflection of light around a gravitational object based on Newton's arguments, coming up with a deflection $\theta = 2GM/rc^2$, where G is Newton's gravitation-

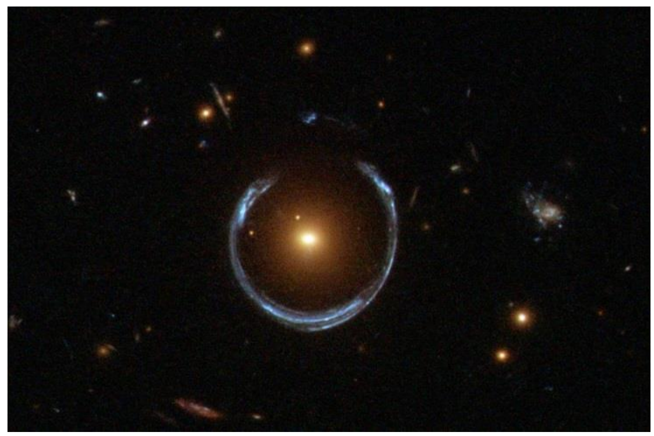
[3] The gravitational force on a mass is $F = G\frac{m_1 m_2}{r^2}$ where m_1 is the mass of the lighter body and m_2 is the mass of heavier body. But the lighter body feels a force $F = m_1 a$. Setting these forces to be equal, the m_1's cancel and so $a = G\frac{m_2}{r^2}$. The acceleration of m_2 due to m_1 is negligible. That's why absent any other forces like air resistance, two bodies of different m_1 masses fall at the same rate. Need proof? https://is.gd/feqsma.

al constant, *M* the mass, *r* the distance of the beam to the object and *c* the speed of light. In 1804, Johann Georg von Soldner calculated a deviation of 0.84 arcseconds for a star positioned just at the Sun's limb. Observing the phenomenon was considered impossible.

It fell to Albert Einstein to work out how light would be subject to gravitation. As he began to develop general relativity, he realized that the curvature of space surrounding massive objects would alter the path of a light ray. The light would follow the geodesics in spacetime because of Fermat's Principle. His original calculation in 1911 gave the same result as Soldner's. But then, by considering the equivalence of gravity and acceleration, Einstein realized that the relativistic effect of gravitation on spacetime led to "time dilation." Clocks simply tick slower in a strong gravitational field. So not only did the light deviate and take a longer path because the geodesics are curved, while doing so the local clock is slowed down, and so more time passes. Special relativity tells us that as far as the light beam was concerned it was still moving at *c*, but from our perspective it appeared as if it was moving a tiny bit slower. Einstein came up with the correct formula, $\theta=4GM/rc^2$. His final answer was 1.75 arcseconds. Eddington's famous eclipse measurements in 1919 proved that Einstein was right and that made him the most famous scientist of all time. Eddington's result was 1.74 arcseconds. A known relativity enthusiast, Eddington was accused by some doubters of fiddling with the data to have it come out so close to the predicted value. A 1979 reanalysis of the eclipse plates from Brazil, which were not used in the original analysis because they were out of focus, showed the deviation on those images to be 1.55±0.32 arcseconds, encompassing the 1.75 theoretical and measured results with ease. General relativity has been confirmed repeatedly since then.

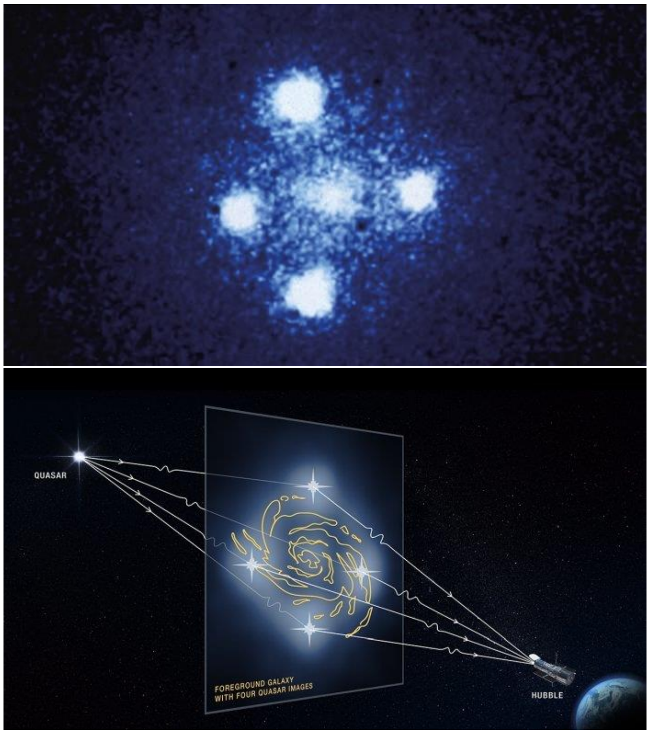
Massive gravitational objects are thus lenses, and that property can be exploited by astronomers. Using them as such was first suggested by Eddington and Einstein. Einstein even imagined "microlensing," where a foreground star is precisely aligned with a more distant star, causing an increase in brightness but not resolving the distant object. The foreground mass focuses more than one light ray on the observer, boosting the brightness. He was doubtful that the effect would be observed.

In 1937, Fritz Zwicky suggested that galaxies and galaxy clusters would be more effective lenses than stars since they have much greater mass and their spatial extent would mean we are more likely to find them in front of other bright objects. In 1979, the quasar QSO 0957+561 A/B in Ursa Major was found to be a single active galactic nucleus lensed into a pair by a foreground galaxy (see the May 2020 SkyWAAtch, page 20, for an image and an in-depth discussion of this object). The quasar's spectrum showed that it was over 8 billion light years distant, with a red shift of 1.41. Hubble subsequently imaged the lensing galaxy. Since that time, gravitational lensing has become an important astronomical tool and lensed objects are found all over the sky.

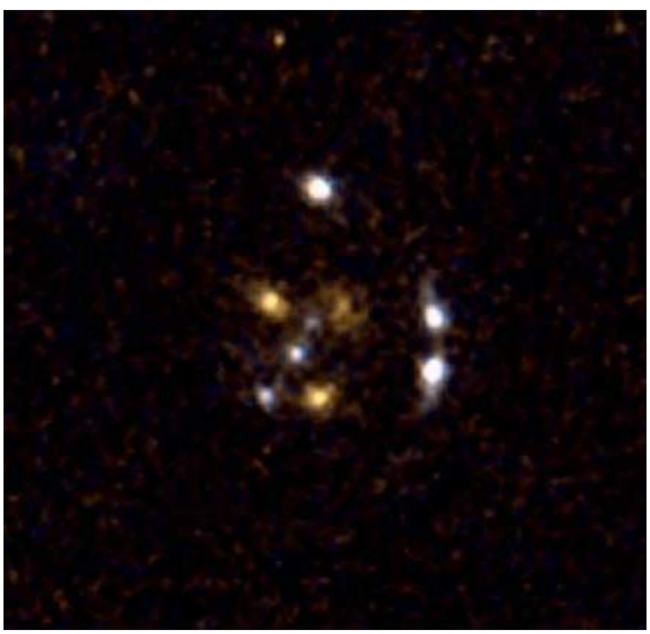


The Cosmic Horseshoe, LRG 3-747, a young blue galaxy morphed into a horseshoe by a closer elliptical galaxy. HST image. This object was imaged in May 2021 by amateur astronomer Jerry Macon from Taos, NM. He needed over 30 hours of exposure with a 14" PlaneWave. See https://www.astrobin.com/enokjo/B/.

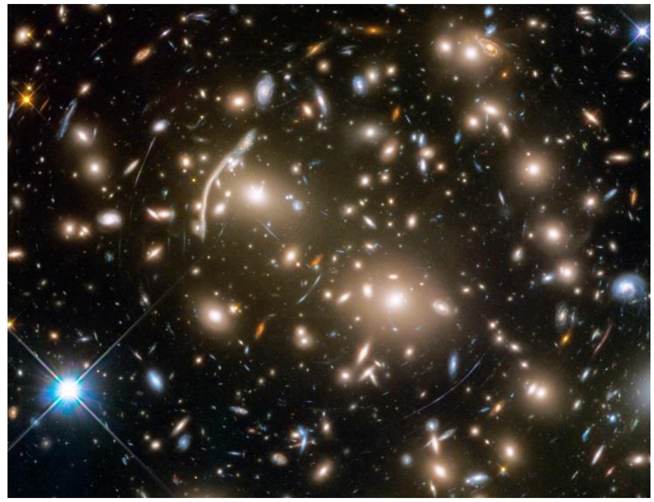
The Twin Quasar is an example of *strong gravitational lensing*, which occurs when an object is almost exactly in the line of sight of a dense gravitational field. The lensed object can be plausibly reconstructed as if it was directly observed. The Hubble Space Telescope, with is superior resolution, has imaged many of these objects: "Einstein Crosses" with multiple quasar images, "Einstein Rings" where a galaxy is spread around the foreground mass, and distant early-universe galaxies situated behind galaxy clusters, the background galaxies deformed into arcs and rings. Background objects can be magnified and brightened as much as 20-30 times. Advanced spectroscopic technology can be used to measure the distant galaxy's red shift, and determine star-forming rates and other cosmological dynamics. In addition, the amount of lensing is a probe of the mass of the foreground object. Much of the evidence for the presence and distribution of dark matter in clusters comes from these studies.



Q2237+030 (8 billion LY) lensed by foreground galaxy ZW 2237+030 (400 million LY, “Huchra’s Lens”). The diagram shows how the quasar is lensed by the foreground galaxy. (STSI)



CLASS B1359+154, a galaxy 11 billion light years distant (white objects) split into six images by a cluster of three closer galaxies (reddish objects, 7 billion light years). Hubble Space Telescope.



Abell 370 (HST)

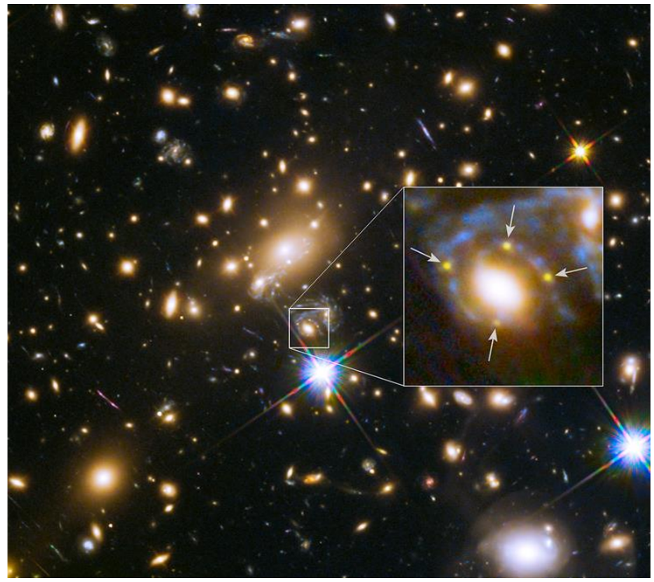
Galaxy cluster Abell 370 lies 500 million light years from Earth. Its 100 or so galaxies lie in front of a number of more distant galaxies, which are seen as radially aligned arcs. One large spiral has been distorted into a prominent arc, nicknamed “The Dragon.” The galaxy is least distorted at the Dragon’s head, but the entire arc is a collage of gravitationally distorted images of that single galaxy, some 5 billion light years distant.

Detail of The Dragon. The entire structure derives from multiple images of the same galaxy. The spiral nature of that galaxy is more evident on the left, but it’s all one background galaxy, stretched and brightened by the foreground cluster.

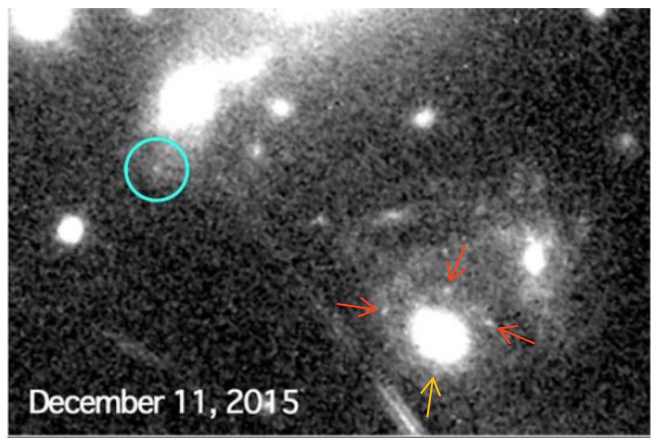
Strong lensing can be used to measure the Hubble constant, H_0, the rate of the expansion of the universe. Quasar radiation output varies as matter falls in bits and pieces into the black hole at the quasar’s nucleus. When there are multiple lensed images of a quasar, as in Q2237+030, the lensed images won’t all vary in sync because the path length of each image is slightly different. The timing differences can be used to calculate the expansion rate. This was a goal of the "H0 Lenses in COSMOGRAIL's Wellspring" collaboration, better known as HOLICOW. Making observations of gravitationally lensed quasars with some of the world's largest ground telescopes and the Hubble Space Telescope, the collaboration came up with a value for H_0 of 71.9±2.7 km/s/Mpc. This is consistent with the "late universe" measurements using Cepheids and supernova observations, but it's in conflict (astronomers like to use the more peaceful word "tension") with lower results (around 67) from "early universe" measurements that use cosmic microwave background data. It's hard to think of an object 9 billion light years away in a 13.8 billion year-old universe as being "late." But if you use red shift as the measuring stick for "early" and "late", a galaxy 9 billion light years away is at a red shift of about 1.5, but the "early" cosmic microwave background radiation, 13.8 billion light years away, has a red shift of 1096. The rapid expansion rate of the nascent universe is what makes even the oldest galaxies (z=11) "late."

In 1964 Norwegian astrophysicist Sjur Refsdal predicted that H_0 could be measured by finding a gravitationally lensed supernova. Obviously the relatively infrequent occurrence of supernovas made this a speculative endeavor. On the other hand, supernovas were more common in the very early universe. Sure enough, in 2014 a gravitationally lensed supernova was found by HST. It was naturally dubbed Supernova Refsdal. Its discoverers predicted that other lensed light paths would eventually reach us, revealing new images of the supernova, and that's exactly what happened. To date, three lensed supernovas have been detected. The supernovas will fade, as all supernovas do, but for a while, meaning time intervals up to decades, new images may appear elsewhere in the galaxy cluster as the light from more extremely displaced paths reach Earth. One is predicted to show up in 2037!

While strong gravitational lensing depends on a fortuitous alignment of foreground and bright background objects, all the photons passing through foreground matter are perturbed by intervening matter (baryonic or dark). Slight distortions in the shape of background galaxies, particularly elliptical galaxies, can be studied statistically to plot out the shape of the foreground gravitational potential. This is the process known as *weak gravitational lensing*.

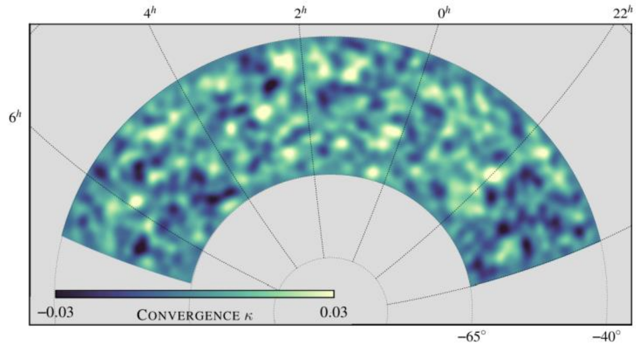


Supernova Refsdal. Galaxy MACS J1149.6+2223 is 5 billion light years distant. The lensed galaxy behind it contains a supernova at a distance of 9.3 billion light years. HST image 2014.



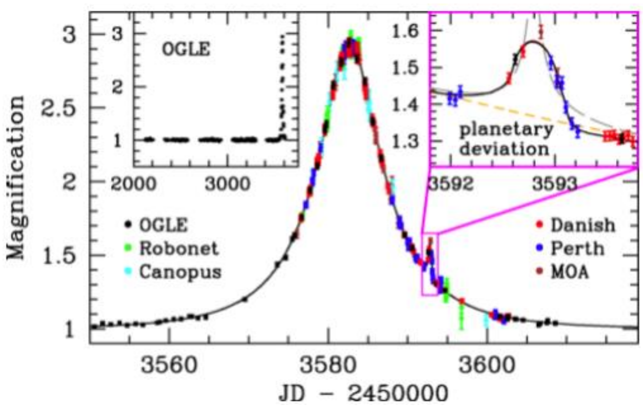
HST image of SN Refsdal showing a new image of the supernova (blue circle) displaced from the discovery images (arrows). One of the original images was starting to fade (orange arrow).

Statistical analysis of the shapes of distant elliptical galaxies, of which there are millions, can reveal the distribution of dark matter everywhere in the sky, since in every direction light from distant galaxies is being subtly deflected by the intervening dark matter structures, a phenomenon known as "cosmic shear." Weak lensing is a powerful probe of the large-scale structure of the universe. Even cosmic microwave background photons are subtly displaced by gravitationally warped space as they travel from the "surface of last scattering" and the intervening matter can be statistically evaluated and mapped. See a blinking gif that shows the subtle gravitational distortion of the CMB at https://is.gd/cmblens.



A map of the gravitational lensing potential in the southern sky using data from the South Pole Telescope and the Planck satellite. This is not temperature data, but the distribution of gravitational fields from all the matter (baryonic and dark) that create them. Omori, et. al, *Astrophysical Journal*, 849:124, 2017

Unlike strong and weak lensing, *gravitational micro-lensing* events are transient, generally with time frames of hours to days. A discrete object is not visualized by the lens. When one star passes in front of another, the background star's light is significantly amplified. If a planet is orbiting the foreground star and passes in front of the background star before or after the stellar occultation, it also acts as a gravitational lens and a secondary brightness peak can be recorded, revealing the presence of an exoplanet. There are several surveys looking for these events. Microlensing is well suited to find low-mass planets, including Earth-like planets.



OGLE-2005-BLG-390, a 5.5 Earth-mass exoplanet, discovered in 2006 (Beaulieu, J-P, et. al, *Nature* 439:437-440, 2006)

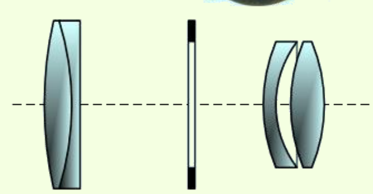
One of the main confounders in microlensing is to distinguish lensing events from other transient changes in a star's brightness. About 2% of stars in a typical field are naturally variable. In addition, the fortuitous alignment of foreground and background stars is a rare event to begin with. It's estimated that about one in 400,000 stars is undergoing a lensing event at any given time.

The next generation of large telescopes, particularly the Vera Rubin Telescope in Chile, will find many more examples of lensing of all types, contributing to progress in exoplanet research, galactic organization and evolution, cosmology, dark matter, dark energy and even tests of general relativity and its potential theoretical competitors. ■

What is a Petzval lens?

In 1840, just a year after Louis Daguerre and William Henry Fox Talbot's breakthroughs in recording images on light-sensitive emulsions, mathematics professor Joseph Petzval in Vienna invented a 180-mm focal length f/3.6 lens. It was much faster than Daguerre's and Fox Talbot's lenses. Exposure times could be reduced by a factor of more than 20. It was the first lens whose figure was based on optical calculations rather than trial and error. The calculations required the combined efforts of nine members of the Austrian artillery corps (since targeting artillery shells used similar computations).

The Petzval design has two groups of two lenses each, separated by a field stop. While highly color-corrected, the design suffers from coma at the edges, which can be corrected by a field flattener.



The original Petzval lens was made by Voigtländer, a hallowed name in lens and camera manufacture. Among many innovations, Voigtländer made the first 35-mm zoom lens. The firm operated from 1797 to 1971. A Japanese company now makes lenses under the Voigtländer brand name.

Images by Members

November 19, 2021 Lunar Eclipse

A peculiar "total" eclipse that wasn't total: 99.1% of the Moon was in the umbra of the Earth's shadow. This was the longest partial eclipse in 580 years. The Moon was at apogee, so moving slower in the umbra. Maximum eclipse was at 4:02 a.m. EST.

←
John Paladini's image at maximum eclipse through a Jaegers 80-mm f/5 refractor and ASI533 camera. Tracking. Stack of 100 frames. John had a good view from his driveway in Mahopac.

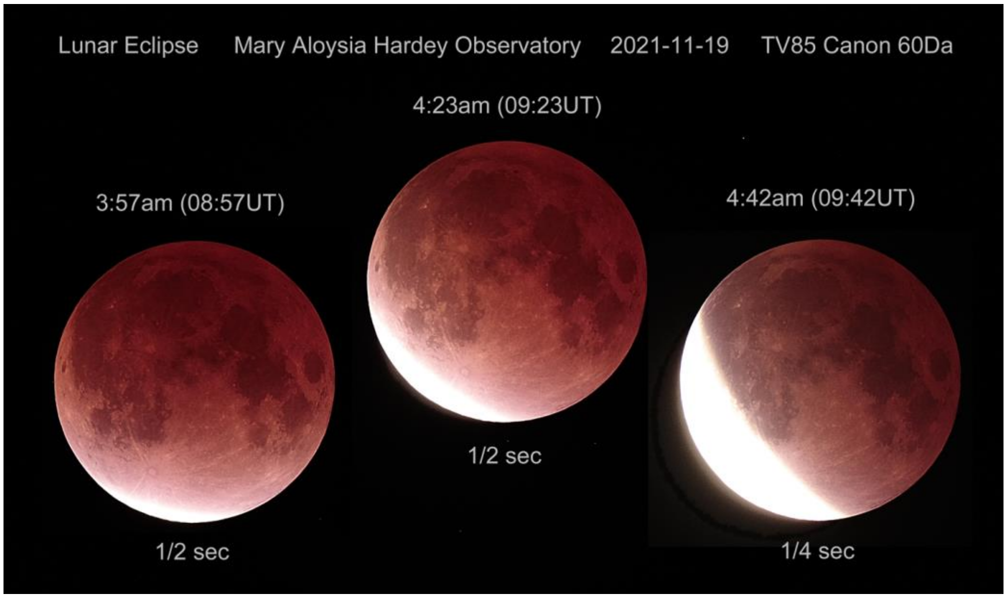
→
Larry and Elyse Faltz and **Charlie Gibson** observed at the Crossways ballfield on Old Mamaroneck Road in Scarsdale. Larry's image was made at maximum eclipse through a Stellarvue 80-mm f/6 refractor, Canon T3i DSLR. Single exposure, ISO 200, 0.4 sec.

←

Here's **Chris Plourde's** image, also at maximum eclipse, with a Nikon Coolpix P900 camera mounted on a tripod. Chris set up in the parking lot of his apartment house in New Rochelle.

→

Alex Mold made this image seven minutes after maximum eclipse with a 5-inch Maksutov and cell phone camera.



← **Rick Bria** gave us an annotated trio of images made in Greenwich, CT, showing the progress of the eclipse from just before maximum to 40 minutes later.

A lunar eclipse is actually very difficult to photograph if your goal is to reproduce exactly what you saw with your own eyes. The quality, color and intensity of the illumination all vary across the Moon's face and they change as the eclipse progresses. Local lighting and atmospheric condition also impact the view. Our eyes vary. And even if they didn't, camera sensors don't have the same response characteristics or spectral sensitivity as the human eye, even with software manipulation in the camera or during processing (and most of us fiddle with the controls as we try to reproduce our mutable recollection of the scene). The first three images were taken within one minute of each other, and the fourth just seven minutes later, and yet they are different. None of them reproduce what the imager actually saw, but they should still be considered faithful recordings of the event. Depending on the exposure parameters, the bright penumbral zone changes its dimensions. You can see how much larger it appears in Chris's and Alex's exposures, in exchange for greater visibility of the fully eclipsed area.

In an effort to objectify observations of lunar eclipses, the French astronomer André-Louis Danjon (1890-1967) proposed a scale for evaluating the visual appearance and brightness of the Moon during total lunar eclipses. The Danjon scale goes from "L" (for luminosity) zero for the darkest eclipses to 4 for the brightest. The eclipse should be rated at "maximum" but even then the Moon is almost never centered in the umbra, meaning the illumination will vary across its face. And it's hard to apply it when the Moon is not fully eclipsed.

L	Eclipse	Description
0	Very dark eclipse	Moon almost invisible, especially at mid-totality.
1	Dark Eclipse, gray or brownish in coloration.	Details distinguishable only with difficulty.
2	Deep red or rust-colored eclipse.	Very dark central shadow, while outer edge of umbra is relatively bright.
3	Brick-red eclipse	Umbral shadow usually has a bright or yellow rim.
4	Very bright copper-red or orange eclipse.	Umbral shadow has a bluish, very bright rim.

Eclipse guru Fred Espinak encourages making and even submitting readings.[4] Your editor thinks the subjectivity is too great to make readings reliable, so the Danjon scale is just an adjective to describe the scene, rather than a scientific measurement.

Maybe we should say that although everyone is *looking* at the same lunar eclipse, they are not *seeing* the same eclipse, and unless you are the rare individual with an eidetic memory, the eclipse you saw is not the one you remember. [Literary recommendation from the Editor: The great Argentinian writer Jorge Luis Borges' short story "Funes the Memorious," in the collection *Labyrinths*. Someone scanned it and put it on line at https://marom.net.technion.ac.il/files/2016/07/Funes-the-Memorious.pdf] ■

[4] https://eclipse.gsfc.nasa.gov/OH/Danjon.html

Steve Bellavia's November Comets

57P/du Toit–Neujmin–Delporte

November 19

This comet, really a fragment of a comet, had a major outburst on October 17, brightening from mag 17 to mag 12.

Imaged at Custer Institute in Southold, NY with Steve's home-made 114-mm f/4 Newtonian astrograph and ASI533MC camera.

67P/Churyumov-Gerasimenko

November 3

This comet was the target of the Rosetta mission. It was about magnitude 10.5 in early November.

Imaged with Canon f/2.8 200-mm L II USM, stopped down to f/3.8 and ASI294MM camera. Mattituck, NY.

C/2021 A1 (Leonard)

November 13

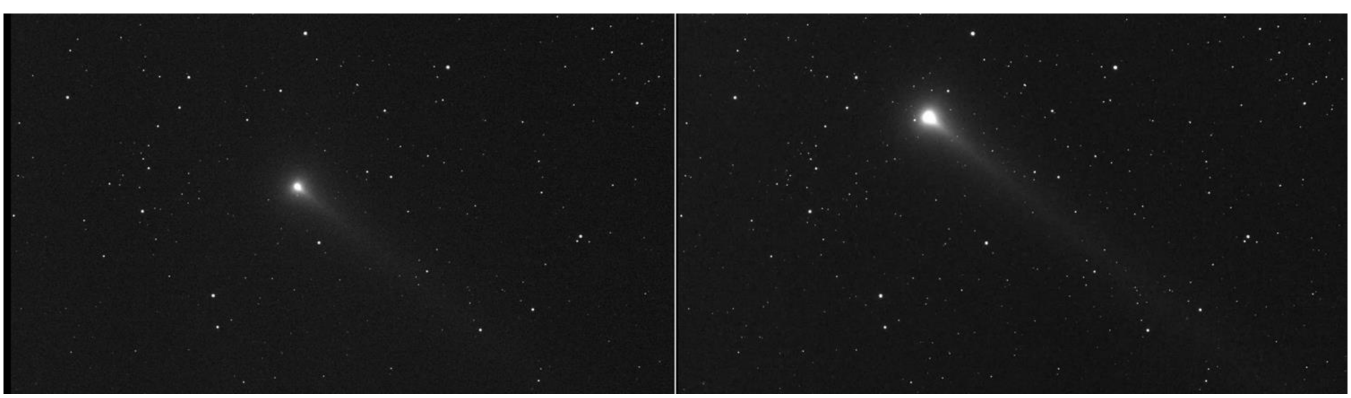
This comet was discovered at Mt. Lemmon Observatory near Tucson, AZ, in January 2021. It was magnitude 9.5 when Steve imaged it with a TS-Optics Photoline 72-mm FPL-53/Lanthanum Doublet refractor with TSO-Flat72 (f/6, 432-mm FL) and an ASI533MC camera cooled to -5C. Mattituck, NY.

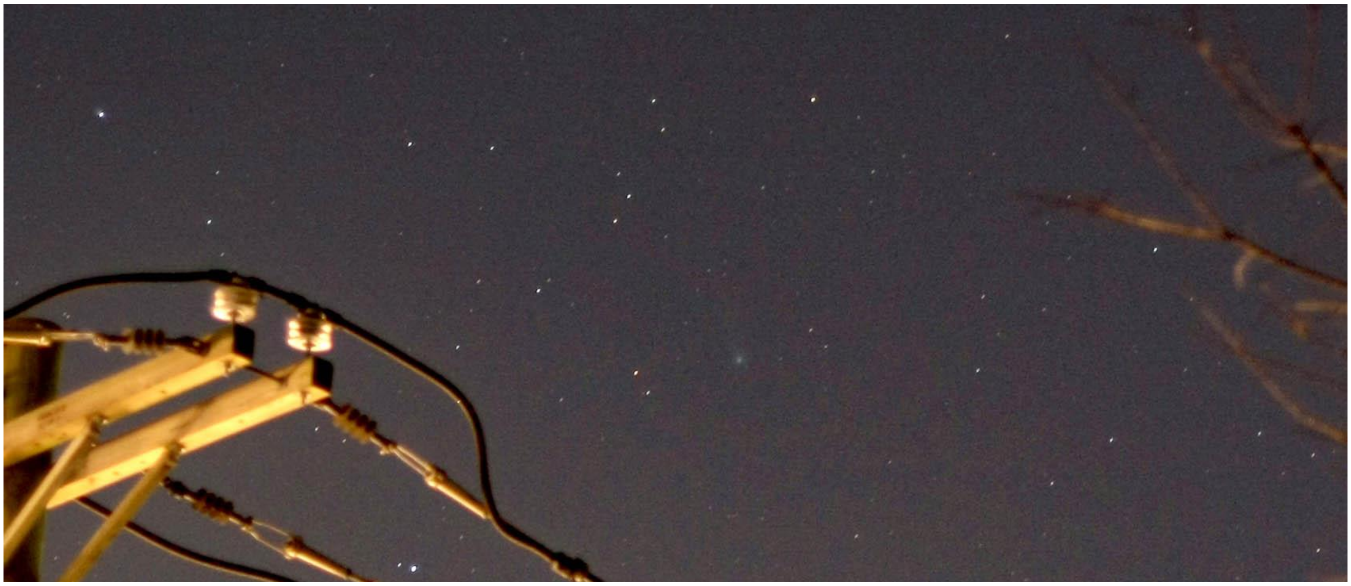
Comet C/2021 A1 Leonard in December

Steve Bellavia writes:

"I woke up at 2:15 a.m. on December 7. There are too many trees to the east at my home, so I headed to Custer Institute (in Southold, LI). I set up at the southeast corner of the sheds in an attempt to block the strong, cold northwest wind. It was almost completely overcast. So I waited. Around 5:00 a.m. a small hole in the clouds developed around the comet. It lasted 45 minutes, but that was all I needed to capture Comet C/2021 A1 Leonard and its very long tail." Technical information at https://www.astrobin.com/zdd12w/G/.

Steve mixed in an image of the background stars on taken on a clearer night to improve the contrast and resolution of the comet. He also made a time-lapse movie of the comet's movement over 50 minutes. https://is.gd/bell2021CA2. Here are the first and last frames of the movie to show the comet's distinct movement among the stars.





On December 9 the comet was at about 6th magnitude based on observations reported to aerith.net, although it had been predicted to be at magnitude 4.4. It was only 17 degrees altitude at 5:00 a.m. (14 degrees lower than when Steve Bellavia imaged it two days earlier at the same time of night) and therefore further dulled because of the substantial airmass. At around 5 a.m. **Bob Kelly** made a wide-angle image with a Canon DSLR, 50 mm lens, ISO 400, 6 second exposure. He cropped and enlarged it to reveal the fuzzy blob of Leonard's coma in the middle of the frame. Neither Bob in Ardsley nor Larry Faltz in Larchmont could find it in binoculars, Westchester's light pollution adding to the difficulty of finding a 6th magnitude object.

Steve Bellavia was able to image the comet in the evening sky at 5:47 p.m. on December 19th. He used a 72-mm refractor and Canon EOS SL3, making a single 0.5-second image. It was barely visible in binoculars.

Planetary Nebula Jones 1 in Pegasus by Gary Miller

A very faint planetary nebula in Pegasus. Catalogued as PK104-29.1. RA: 23h 35m 53.5s Dec: +30° 28' 01. Magnitude 15, Size: 5.5 arcseconds (3.5 LY in diameter), Distance: 2300 LY.

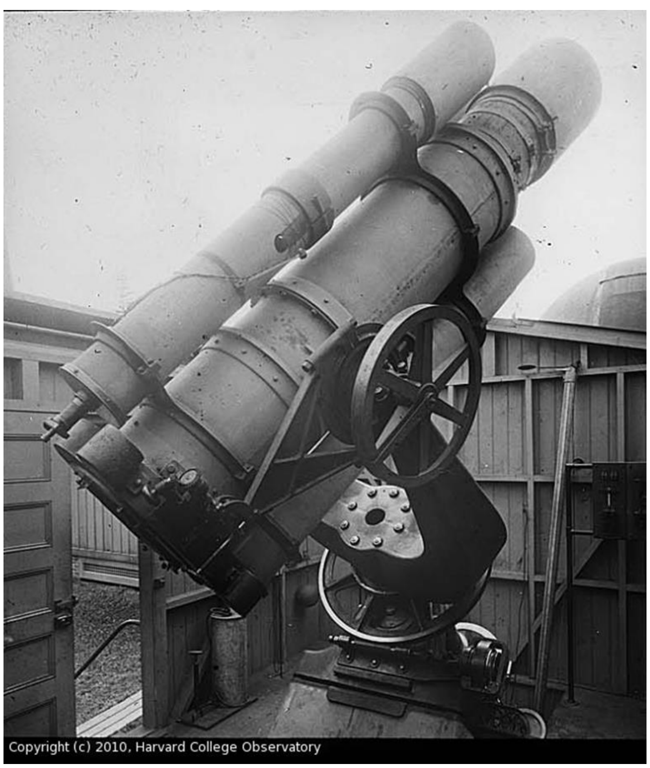
As we wrote in an article accompanying Gary Miller's image of the planetary nebula Jones-Emberson 1 (a different object than Jones 1) in the October 2020 SkyWAAtch, page 23, Rebecca Jones was a young Harvard astronomer whose career shifted to the new field of digital computers in the 1940s. She discovered two faint planetary nebulas that bear her name. Jones-Emberson 1, a co-discovery with Richard Emberson, was reported in the *Harvard College Observatory Bulletin* in 1939. The second object, simply known as Jones 1, was apparently was discovered without the help of a colleague, but there is no publication by Jones that reports its existence, as I noted at the conclusion of the article. I also couldn't find any literature references in any of the astrophotography web sites that show and describe the object. Yet all descriptions on the web credit Jones with the discovery. How did that happen? More research on the NASA ADS site, using a somewhat broader range of search terms, tracked it down.

In May 1948 the *Astrophysical Journal*, vol. 109, p. 537-538, carried a brief report by F.D. Miller of the University of Michigan Observatory and E. van Dien of the Bosscha-Sterrenwacht, Lembang, Java, entitled "A Large New Planetary Nebula." The authors examined plates made by the Jewett Schmidt telescope of the Harvard College Observatory. The object was seen on two plates of 30-minute exposure on blue-sensitive Kodak 103a-O emulsion (see the September 2021 SkyWAAtch, p. 11, for spectral curves of the Kodak astronomical films). The authors also note that the object could be made out on a "190-minute exposure taken in 1941 with the 16-inch Metcalf doublet. It had been noted and marked on this plate at some time in the past, but its character was not recognized or verified." Who did the marking? That person was the real discoverer.

This article's entry on the NASA ADS site reveals that the following year, an "errata" was published in the *ApJ* (vol. 110, p. 104). A click brought up this reference. It reads:

> The following paragraph should be added to the note by Miller and van Dien, "A Large New Planetary Nebula" (*ApJ*, vol. 109, 537, 1949): "We are indebted to Dr. Minkowski for informing us that he learned of this object by letter from the Harvard College Observatory in 1941, that it was found on the Metcalf plate by Miss Rebecca Jones, and that no description of it has been published. The data presented above may therefore be of some interest."

Rudolph Minkowski was the nephew of Hermann Minkowski, who was Einstein's teacher. He proposed the concept of spacetime that Einstein developed into special relativity. Rudolph was one of the most prominent astronomers of the mid-20th century, working frequently with Walter Baade at Mt. Wilson and Palomar Observatories. He made significant contributions to a wide range of astronomical problems.



16-inch Metcalf doublet

The Jewett Schmidt and Metcalf telescopes were located at the Oak Ridge Observatory in Massachusetts, the site of the still-extant but mothballed (and guano-covered) 61-inch Wyeth reflector that we wrote about in the January 2021 SkyWAAtch article "On the Fate of Telescopes." The Metcalf began life on the Harvard campus in 1909 but was moved to Oak Ridge when it was established in 1932 and was in use until 1992. Harlow Shapley used this telescope as part of his survey that identified over half a million galaxies.

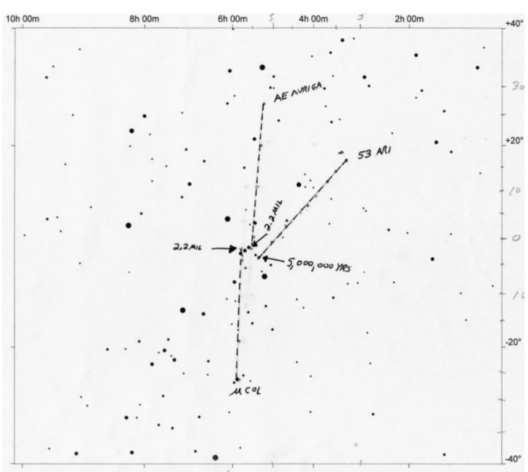
Entering "Jones 1" (or "Jones-Emberson 1" for that matter) in the search engines at the CDS portal (http://cds.u-strasbg.fr/) does not return any objects, although "PN Jn 1" will bring up the information for Jones 1, as will "PN JnEr 1" for Jones-Emberson 1. The databases need formal catalog entries to search. The Strasbourg-ESO catalog, from 1993, contains 1143 objects. The Perek-Kohoutek (PK) catalog, 2000 edition, lists 1,510 objects. You can download it from *Astronomy* magazine, at https://is.gd/PKCat. The two catalogs are similar but use a slightly different naming convention. Both catalogs identify objects by their galactic coordinates, but the Strasbourg-ESO catalog uses the prefix "PN" rather than "PK," adds a "G" in front of the numerals and uses a single decimal place in each coordinate. For example, in the Perek-Kohoutek catalog PK 119+06 1, the planetary nebula closest to 0 degrees right ascension, is listed as PN G119.4+06.5 in the Strasbourg-ESO catalog. The single digit at the end of the PK entry is used in case there is more than one object in the same square degree of space. The default is 1, and the maximum is 13. Planetaries are particularly numerous in the direction of the galactic center (Sagittarius).

The central star of Jones 1 is a hot blue B star that is on its way to being a white dwarf, but isn't there yet. This detail of Gary's image shows it's really blue!

Gary made the image in November 2021 at Ward Pound Ridge Reservation over two nights, with a 127-mm refractor and ASI2600MCPro camera. ■

The Flaming Star Nebula, IC 405 by Steve Bellavia

The 6th magnitude hot, variable O star AE Aurigae, the brightest star in Steve's image, lights up the Flaming Star Nebula in Auriga, but it was not formed within the cloud of hydrogen gas. From its proper motion and approximate age, the star was born somewhere around the belt of Orion and is now 35 degrees distant from it, moving through space at 109 km/sec. It's an example of a "runaway star," a star that was ejected from an open cluster or binary system due to the machinations of gravity or a blow from a nearby supernova. Knowledge of proper motion coupled with spectral analysis to determine age, allows a reconstruction of the younger Milky Way galaxy. The stars AE Aurigae, 53 Arietis and Mu Columbae all likely were ejected from the same region within Barnard's Loop, heading in different directions. Evidence from the Hipparchos satellite showed that a single event, previously hypothesized, could not account for the motions and ages of these stars.



IC 405 is both a reflection and emission nebula. The area of gas closes to the star reflects some of the star's blue light, while the rest of the gas fluoresces in the red wavelength of hydrogen. In about 20,000 years, AE Aurigae will have finished its traverse of the gas, and the Flaming Star nebula will have burned out.

Image technical details at https://www.astrobin.com/ama9zt/F/.

Map from http://www.poyntsource.com/Richard/runaway_stars.htm.

Research Highlight of the Month

Lam, KWF, et. al. (79 authors), GJ 367b: A dense, ultrashort-period sub-Earth planet transiting a nearby red dwarf star, *Science* 374: 1271-1275, December 3, 2021

Abstract:

Ultrashort-period (USP) exoplanets have orbital periods shorter than 1 day. Precise masses and radii of USP exoplanets could provide constraints on their unknown formation and evolution processes. We report the detection and characterization of the USP planet GJ 367b using high-precision photometry and radial velocity observations. GJ 367b orbits a bright (V-band magnitude of 10.2), nearby, and red (M-type) dwarf star every 7.7 hours. GJ 367b has a radius of 0.718 ± 0.054 Earth-radii and a mass of 0.546 ± 0.078 Earth-masses, making it a sub-Earth planet. The corresponding bulk density is 8.106 ± 2.165 grams per cubic centimeter—close to that of iron. An interior structure model predicts that the planet has an iron core radius fraction of 86 ± 5%, similar to that of Mercury's interior.

Using data from The Transiting Exoplanet Survey Satellite (TESS) and ground-based observations with the High Accuracy Radial Velocity Planet Searcher (HARPS) spectrograph on the 3.6-meter telescope at the La Silla Observatory in Chile, an international team found a small exoplanet orbiting a red dwarf small star located close (9.4 parsecs, 30.6 light years) to our solar system. The amount of data crunching was prodigious. First the team had to be sure that their signal was really that of an exoplanet and not a nearby binary star that was within TESS's visual field (the Gaia Data Release 2 catalog lists 25 sources within 30 arcseconds of the star GJ 367). Various scenarios had to be modeled and calculated for all of the different parameters that were being considered. A neural-network/machine learning process was used to test the composition models.

Because of the planet's proximity to its host star, and even though that star is a relatively cool red dwarf with a surface temperature of 3522 K, the planet is so close that the temperature on the day-side surface of the planet is 1745 K, high enough to have evaporated any atmosphere. Any silicates or metallic iron on the surface will also begin to melt. The composition of the planet is mostly an iron core. It is possible that it started out as a larger body whose surface has been progressively vaporized by its proximity to its star, where it is receiving 576 times the irradiation that Earth receives from our Sun. The planet resembles Mercury in many respects, although it is much closer to its host star and has a much hotter surface.

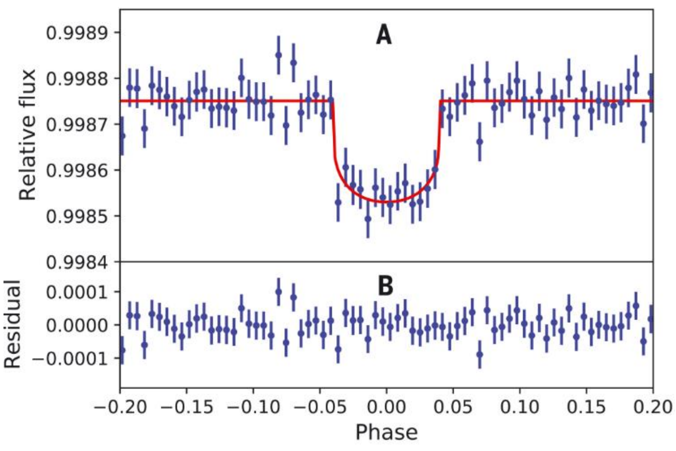


Fig. 1A &B from Lam, et. al. showing the light curve from TESS with the best-fitting transit model. Error bars are 1-sigma. B shows the residua: note the very small values.

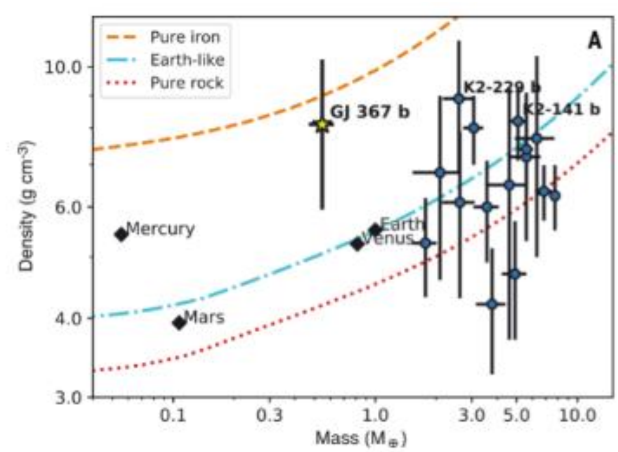


Fig 3A from the paper showing the mass-density diagram for various exoplanets as well as the solar system's four rocky planets.

Member & Club Equipment for Sale

Item	Description	Asking price	Name/Email
Stellarvue 90-mm triplet refractor	90 mm f/7 triplet refractor, aluminum tube, 2½-inch Stellarvue focuser, clam shell mounting ring with standard Vixen dovetail, soft case. Excellent condition.	$400	Thomas Boustead bousteadtom@gmail.com
Meade 390 refractor	90-mm f/11 doublet refractor in very good condition with several eyepieces, Barlow, aluminum tripod, accessory tray, straight-through finder. The alt-az mount head is very solid. An image of the mount head is here. Proprietary Meade interface between tube rings and mount (two thumb screws). Slow-motions with flexible stalks. A few minor blemishes on the tube. A great lunar/planetary scope.	$100	WAA ads@westchesterastronomers.org
Celestron 114-mm Newtonian OTA	A Celestron “Cometron” 114-mm f/3.9 reflector optical tube, excellent condition. Great “sweeper.” Includes an Orion Sirius 25-mm 52° Plossl giving 2.92° field of view, exit pupil 6.4 mm at magnification 17.8x. Standard dovetail. Red-dot finder. Celestron lists this scope on a flimsy photo tripod with 2 mediocre Kellner eyepieces for $198. Donated to WAA.	$65	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 $80.	$50	Larry Faltz lfaltzmd@gmail.com
75-mm Tube Rings	Pair of 75-mm inside diameter rings with 3-point nylon centering screws. Can accommodate tubes between 40 and 75 mm. You supply the dovetail bar. Great for finder, guide scope, small camera lens. Like new condition. Photo https://is.gd/75mmrings.	$25	Larry Faltz lfaltzmd@gmail.com
Celestron X-Cel 5-mm eyepiece	60-degree field, 6 elements, fully coated. Retractable rubber eye guard. Excellent condition, unmarked. Lists at $99.95. Donated to WAA.	$40	WAA ads@westchesterastronomers.org
Laser Collimator	Orion LaserMate Deluxe II Telescope Laser Collimator (for Newtonian reflectors). Donated to WAA. It works. Uses CR2032 battery. Manual and instruction video on line on Orion’s web site.	$35	WAA ads@westchesterastronomers.org

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 members.

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