SkyWAAtch

The Newsletter of Westchester Amateur Astronomers

May 2021

NGC 253, The Silver Coin Galaxy in Sculptor, by Rick Bria

This is the first image made at the Maria Aloysus Hardey Observatory in Greenwich using LRGB filters. The observatory houses a PlaneWave 14” CDK telescope and SBIG STX16803 camera. This unguided image was made from the following subs: L= 90s x 52, R= 90s x 21, G= 90s x 25, B= 90s x 40, darks, flats and bias frames, all processed in PixInsight. Because NGC 253 is fairly low in the sky (declination -25 degrees) there is a good bit of atmospheric extinction. Rick promises to acquire more subs during next year’s imaging season in order to make an already excellent image even more spectacular. NGC 253 is almost as wide as the full Moon, magnitude 8.0, distance 11.4 million light years. It is considered a “starburst” galaxy, with several areas of intense star formation, the result of a collision with a gas-rich dwarf galaxy 200 million years ago.

WAA May Meeting

Friday, May 14 at 7:30 pm

Via Zoom

The Space Race in Review

Andy Poniros

NASA Solar System Ambassador

WAA welcomes engineer, radio host and amateur astronomer Andy Poniros, who has a special interest in the history of the US space program. Andy has interviewed many of the participants in the early Mercury, Gemini and Apollo missions, including several astronauts who set foot on the Moon. Andy will screen excerpts some of these interviews, and discuss current plans for returning to the Moon.

Pre-lecture socializing with fellow WAA members and guests begins at 7:00 pm!

The link is on the opening page of the WAA web site.

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

Also In This Issue

WAA June Meeting

Friday, June 11 at 7:30 pm

Via Zoom

Citizen Science

Rick Bria

Astronomical Society of Greenwich and WAA

Call: 1-877-456-5778 (toll free) for announcements, weather cancellations, or questions. Also, don't forget to visit the WAA web site
http://www.westchesterastronomers.org/

StarWAAy to Heaven

Ward Pound Ridge Reservation, Cross River, NY

May 8 (Rain/cloud date 5/15/2021).

Pandemic restrictions are still in place. Check-in at the entrance to the Meadow Parking Lot will still be required. WAA members can use the park on any clear night for observing or astrophotography with prior notification to the park office.

New Members

Jason Alderman	Pelham
John DeCola	Mt Kisco
Joseph Galarneau	New York
Kerry Kyle	Mohegan Lake
Anthony Mancini	Pleasantville
Geoffrey McFadden	Stamford, CT
Robin Schwartz	Riverdale
Suren Talla	Chappaqua

Renewing Members

Paul Alimena	Rye
Rob & Melissa Baker	West Harrison
Lawrence C Bassett	Thornwood
Jim Cobb	Tarrytown
Everett Dickson	Dobbs Ferry
John & Maryann Fusco	Yonkers
Jimmy Gondek & Jennifer Jukich	Jefferson Valley
Frank Jones	New Rochelle
Gary Miller	Pleasantville
Siva and Ram Narayanan	Scarsdale
Ricciardi Family	Stamford, CT
Neil Roth	Somers
Karen Seiter	Larchmont
Joseph Trerotola	Woodbridge, CT
Ernest Wieting	Cortlandt Manor

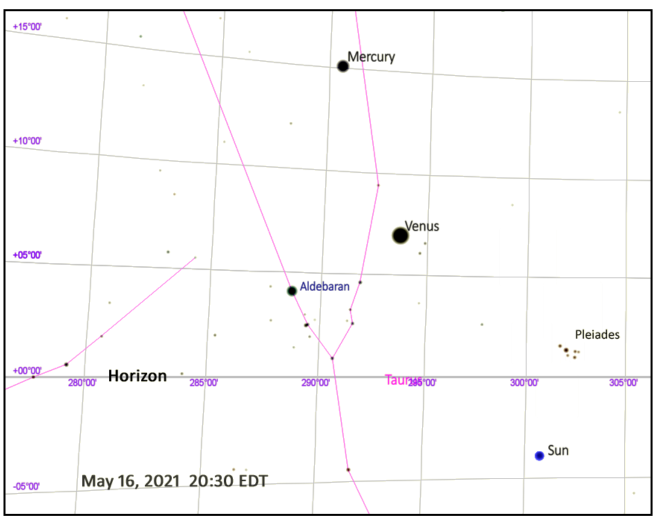
ALMANAC For May 2021

Bob Kelly, WAA VP for Field Events

3Q May 3 | New May 11 | 1Q May 19 | Full May 26

Low Evening Planets

How early in May can you find **Venus** and **Mercury** low in the western-northwestern sky? They climb the steep ecliptic this month. This makes them easier to see than Jupiter and Saturn were when the two gas giants were at a similar elongation from the Sun in the morning sky a few months ago. Back then, the angle of the ecliptic to the horizon was much smaller. It seems rare to have Mercury higher in the sky than Venus. The fleet innermost planet passed Venus on its way out of the solar glare last month. Mercury reaches its apex on the 16th-17th. It'll start May at magnitude -1.1 and lose a whole magnitude of brightness by mid-month. Even though Mercury is getting closer to Earth, its disk is getting thinner and thus less illuminated as it approaches conjunction. This is still Mercury's best show for the northern hemisphere this year.



Venus climbs past Mercury on the 28th. Venus is about as dim at it gets, although still outstanding at magnitude -3.8. Good luck seeing Mercury at +2.2. To compare Mercury's thin crescent with Venus' fully lit disk, even though they are very far apart, is a mind-stretching experience since they will be about the same apparent size in a telescope.

The winter stars pay their respects as they head for the Sun's glare. The **Pleiades** are near Mercury on the 3rd and **Aldebaran** is near Mercury on the 10th. The two-day old Moon lines up to the left of Mercury on the 12th.

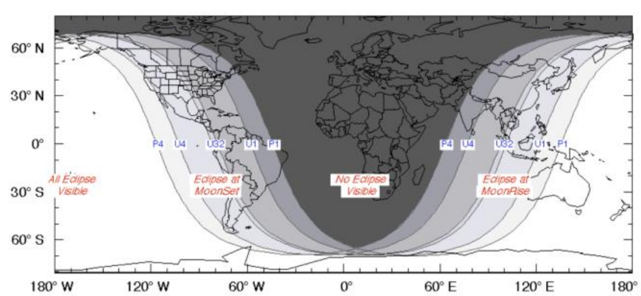
Mars, at magnitude +1.7, slashes across Gemini as it makes an ultimately futile attempt to avoid falling into the solar glare. A crescent **Moon** makes a nice paring on the 15th. Venus won't reach Mars' location in the sky until mid-July.

Low Season (Continued)

It seems like when the Sun is high, everything else is low. **Jupiter** and **Saturn** are low in the southeastern morning sky. Jupiter will be brighter and easier to find, although Saturn will lead the way across the sky, highest at sunrise by the end of the month. Even then, they will only be one-third of the way up from the horizon. That's about as high as they get all year. The Moon makes a pleasing trio with Jupiter and Sat-urn on the 4th.

Throwing Some Shade at a Supermoon

The **Moon** is full on the 26th at 7:15 a.m., just nine and a half hours after it is closest to Earth at 222,117 miles away. Watch out for a large tidal range that week. The Moon has a total eclipse that morning, but not for us. We might see a duskiness on the super-bright lunar disk after 4:47 a.m. The true partial eclipse doesn't start until after the Moon sets below our southwestern horizon at 5:30 a.m.



The May 26th total lunar eclipse will be mostly viewable over the Pacific Ocean (full eclipse in the white area on map)

It's Getting Crowded Up There

The **International Space Station** population count reached 11 occupants in late April. No word on whether a five-on-five basketball game broke out.

May begins with the ISS visible in the pre-sunrise sky. During May, the orbital plane of the ISS will match the Earth's terminator, so the ISS will be in daylight for much, if not all, of its orbit. If the orbit doesn't change much from when these calculations were made by heavens-above.com, the night of May 15/16 will be the night with the most overflights of the ISS for our area, with six. Let's see if anyone can catch them all. The rest of the month, the ISS will be visible from after sunset through the midnight hour.

The Fast and the Few

This month's grains of space rock running into the Earth's atmosphere are the **Eta Aquariids**, wayward particles from **Comet Halley**. This shower is known for its swift meteors with some trails that can persist. The peak is on the morning of the 5th. The Moon will be 38-percent lit in the morning sky. Hope for 10 to 30 meteors an hour; many more if you are in the southern hemisphere.

Occultation

On the evening of May 16th, just after 9:30 p.m., the dark edge of the Moon will cover up +3.6 magnitude Kappa Geminorum on Pollux's right arm (left from Earth's point of view). The star will reappear about 10:38 p.m. on the bright limb of the Moon. This will be harder to see than the disappearance.

Occultation of Kappa Geminorum on May 16

Where'd the Milky Way Go?

The gossamer band of stars wraps itself around our horizon this month. For deep sky folks, this is the month to look out the open top of our galaxy at the other island universes more easily visible than through the stars and dust of our galactic plane. ■

Bob Kelly made this photo of the Moon bisected by an aircraft contrail. It shows that the sunlit part of the Moon subtends less than 180 degrees of the Moon's circumference at this early phase. Canon XS DSLR on tripod, 250-mm zoom lens at f/7.1, for 1 second, at ISO 400. April 13th, 46 hours after new Moon.

Member Profile: Mike Lomsky

Home town: Wilton, CT

Family: Wife, Heather, and Declan 7

How did you get interested in astronomy? Initially, the Space Shuttle program back in the 80s caught my interest. It led to me getting a store scope back then, but not enough help to use it. I lost interest after a few months. Fast-forward to 2008, and the interest in astronomy woke from dormancy and led Heather and me to spend a few hours at night in Bryce Canyon National Park looking at the sky. After we got home, I bought some binos to view planets and such from our apartment. 2 years later we moved to Connecticut and I bought my first real telescope.

Do you recall the first time you looked through a telescope? What did you see? The first target was the Moon that I saw at during the evening at home back in that store-bought telescope. I was very excited until I realized I had no idea how to look at anything else.

What's your favorite object(s) to view? The Orion Nebula and the gas giants are my favorite things to view.

What kind of equipment do you have? Orion XX14g is my telescope for viewing, and sometimes I hook a camera to that to record on my laptop. I have an Explore Scientific AR 152 on a Celestron AV-X mount for traveling, and an Explore Scientific ED 102 for imaging on the same AV-X mount. I just got an autoguider that I am hoping to setup this year.

What kind of equipment would you like to get that you don't have? I would love a personal observatory, which would require some open land. My home is not a good place, having too many trees. I'd love to build the observatory myself.

Have you taken any trips or vacations dedicated to astronomy? About 5 years ago, we took Declan to Acadia National Park in Maine for hiking by day, and for me, viewing on Cadillac Mountain at night. I highly recommend it to anyone. Heather had no problem watching the baby while I was outside.

Are there areas of current astronomical research that particularly interest you? I am most interested in the space launch hardware systems from all the public and private space agencies. Better, cheaper launch hardware will lead to better telescopes in the future. At the moment, I am just a huge fan of the many big new rockets.

Do you have any favorite personal astronomical experiences you'd like to relate? One night, while viewing on the top of Cadillac Mountain, I was able to get a large crowd around me. I just kept calling people over to view whatever I was looking at in the summer sky. Folks were from all over the country and really appreciative and friendly. I was even asked if I was a Ranger, and I replied, "I'm just a nerd who loves sharing my hobby with folks." It was a great evening.

What do you do (or did you do, if retired) in "real life"? I am a database developer with an electrical engineering degree.

Have you read any books about astronomy that you'd like to recommend? Sky and Telescope's *Pocket Sky Atlas* was a great starter book for me. Just looking at the maps taught me a lot about what's up there.

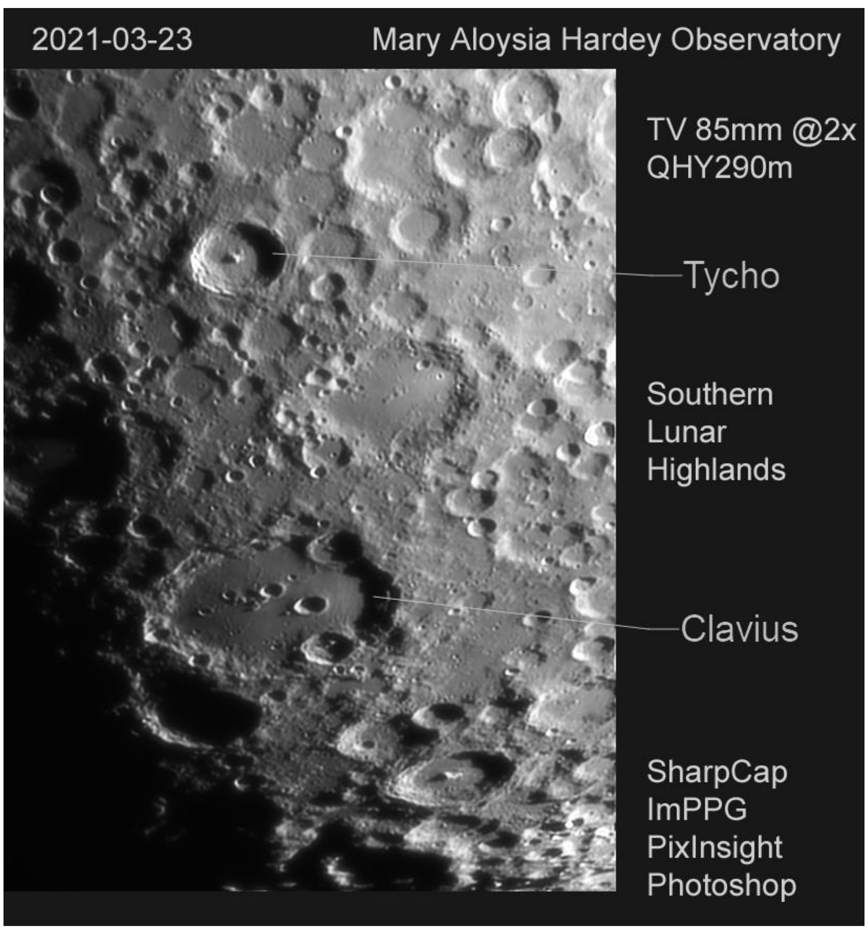
How did you get involved in WAA? I found this club via an astronomy message board which is no longer there.

What WAA activities do you participate in? I love doing the outreach events and star parties. For me, it's the most fun to be involved in events where I can talk about this great hobby of ours.

If you have or have had a position in WAA, what is it, what are/were your responsibilities and what do you want the club to accomplish? I have helped out a little bit with the website a bit in a past. I'm also a member of the Advisory Board.

Besides your interest in astronomy, what other avocations do you have? I love making things with my son and hiking with my family and our friends. In the last year I made a wooden dice tower, a trail through our woods, a new large astronomy/emergency battery, and several model rockets. I just love making things. I also wrote a new program for astronomy to tell me what is available to see at what time and location without having to manually program a website tool.

Tycho and Clavius — Rick Bria



Both Tycho and Clavius are impact craters located in the Southern Lunar Highlands. Impact craters dominate this region and smooth areas are almost nonexistent.

Tycho is almost 5,000 meters deep and 85 kilometers wide. It is about half the size of Connecticut. It is thought to have formed 100 million years ago from an asteroid impact. Like many craters, Tycho has an obvious central peak, thought to be formed by *rock rebound* following the violent impact that formed the crater.

Tycho has a spectacular system of rays. These form when pulverized lunar material is ejected during asteroid impact. Rays are most visible near the full Moon.

South of Tycho is the much larger impact crater **Clavius**, over three kilometers deep and 230 kilometers in diameter. Clavius formed almost four billion years ago. Many younger crater impacts have damaged its walls and floor. Considering its age, Clavius is amazingly well preserved.

If I had a time machine, there would be many events I would wish to see. Among them would be witnessing the formation of Tycho or Clavius.

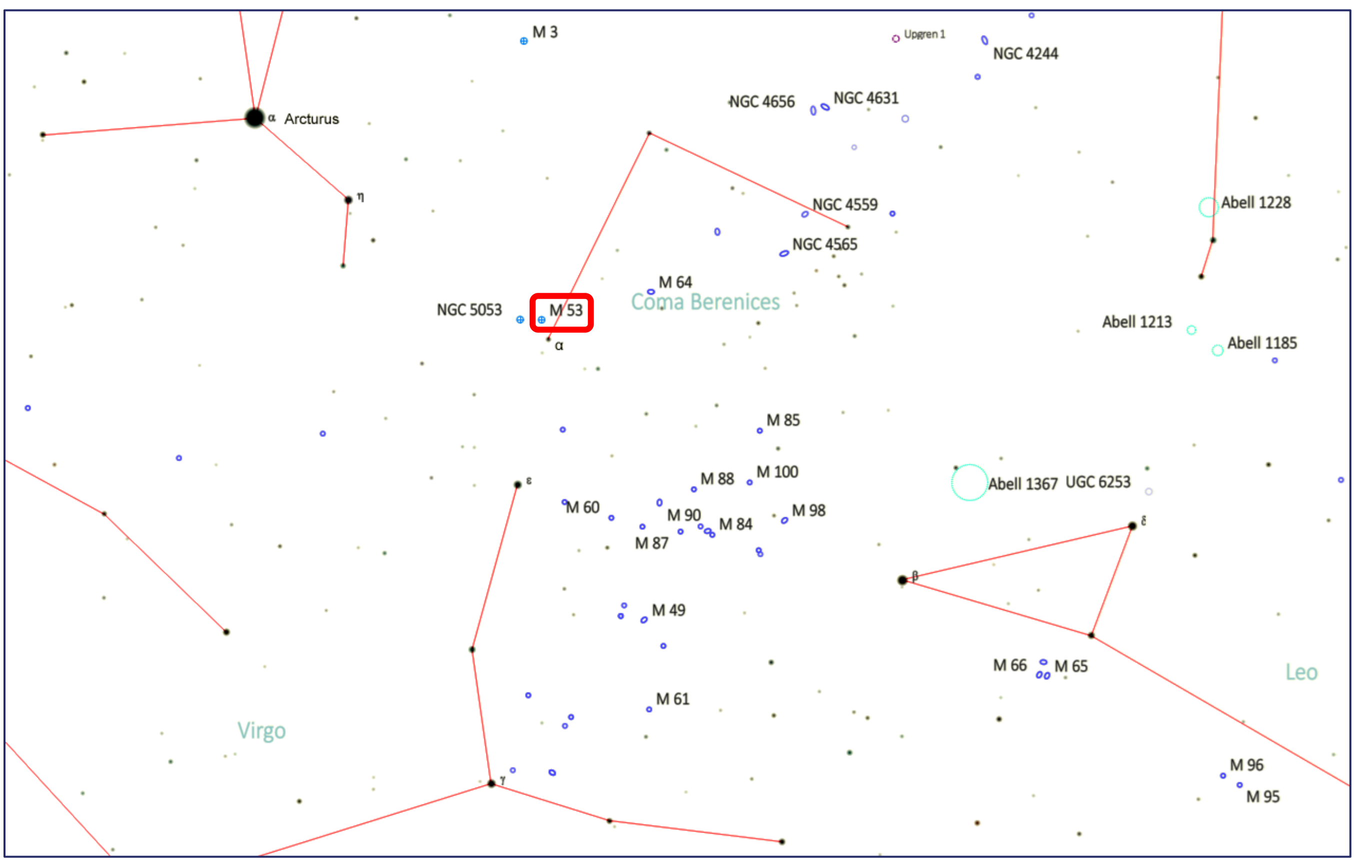
Deep Sky Object of the Month: Messier 53

Messier 53	
Constellation	Coma Berenices
Object type	Globular cluster
Right Ascension J2000	13h 12m 54.0s
Declination J2000	+18d 10m 00s
Magnitude	7.7
Size	14.4’ (diameter)
Distance	58,000 LY
NGC designation	NGC 5024

May is a good time to look for the galaxies in the Virgo and Coma Berenices clusters; the brightest ones are between mag 8.5 and 8.8. With a small telescope you might miss them, but you should be able to see the more condensed globular cluster M53. It’s just one degree away from the brightest, but not very bright, star in Coma Berenices, Diadem (magnitude 4.3). A brighter–and–closer globular M3, magnitude 5.3, is 12 degrees north of M53. It forms a nice triangle with Arcturus, to the east. If you have enough aperture, look for 9.8-magnitude NGC 5053, another globular, just one degree west of M53.

Visibility for Messier 53			
10:00 pm EDT	5/1/21	5/15/21	5/31/21
Altitude	60° 11’	65° 47’	65° 53’
Azimuth	134° 33’	160° 59’	198° 09’

M53 is of course a Milky Way object, but it’s one of the most distant globulars we can see.



Art and Astronomy
A Porcelain Inkstand with Celestial and Terrestrial Globes

This spectacular soft-paste porcelain inkstand caught my eye on my first visit to the Wallace Collection in London two decades ago, and I've gone back to look at it on several subsequent trips. It was designed by Jean-Claude Chambellan Duplessis and made at the Sèvres works in France in 1759. Most likely it was made for King Louis XV (the "Après moi, le déluge" guy) as a gift for his daughter Marie-Adélaïde. It carries on the tradition of pairing celestial and terrestrial globes, a practice apparently begun by early 17th century globe-makers in Holland like Blaeu and Hondius. The tray is about 16 inches across; the globes are about three inches in diameter.

The globes were lined with gold-plated silver, serving in one as an inkwell and in the other as a container for sand or powdered metal for drying the wet ink. The celestial globe on the left has star-shaped perforations in the correct positions of the brightest stars, and the gold would have brilliantly reflected candlelight in a darkened room. The terrestrial globe has inscriptions showing the longitude and latitude of major cities.

The crown held a bell. Princesses do not take their letters to the mailbox—that's a servant's job. The writing instruments would have rested on the platter. The cherubs (there's also one behind the crown) were painted by Charles-Nicolas Dodin, after figures by the well-known French rococo artist François Boucher, who was "first painter" to the King. The figure on the cartouche in front is that of the King himself. The constellation figures on the celestial globe seem to me to be closer to those on Pierre-Charles Le Monnier's maps of the celestial hemispheres, published in 1743, than to John Flamsteed's *Atlas Coelestis*, from 1729, which was the most widely circulated celestial atlas of the day. Le Monnier was another favorite of Louis XV and I suspect this was a factor in the choice. "It's good to be the king!"

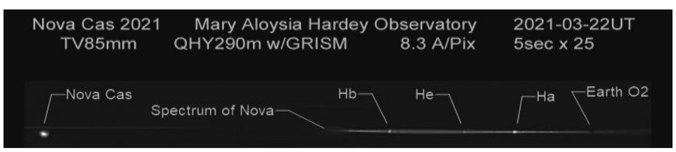
LF

Nova Cassiopeia 2021 Rick Bria

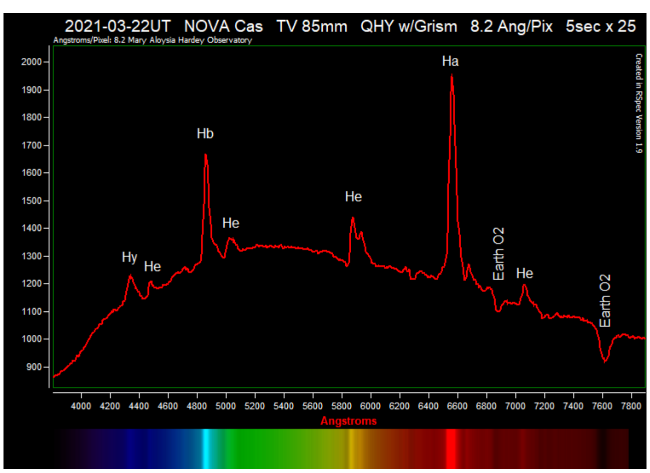
On March 18, 2021, a Japanese amateur astronomer discovered a bright nova. Previously, Nova Cas 2021 was a faint star that could only be recorded in large telescopes. What happened to make it brighten so dramatically?

Nova Cas 2021 (officially designated V1405 Cas) is a classical nova, which can occur when a white dwarf orbits close to much larger star. The white dwarf star pulls material onto its surface from the nearby giant star. This extra material is heated by compression and ignites in a violent thermonuclear explosion on the surface. This is different than a Type Ia supernova, in which the whole star explodes due to unopposed gravity after accreting mass from a companion.

On March 22, I recorded the spectrum of the nova using a GRISM and our 85-mm refractor telescope at the Mary Aloysia Hardey Observatory. A GRISM is a combination of a prism and optical grating. Together, they spread the light from the object into a spectrum. With spectroscopy, we can then identify elements produced by the nova.



I labeled the location of hydrogen and helium emissions in the spectrum image above. They are the bright knots in the otherwise thin spectrum line. Their location and appearance in the spectrum reveals the elements that are present. I have also graphed the spectrum in software (RSpec) to better display hydrogen and helium emission features.



Photometry is the measure of brightness over time. Graphing the brightness of a nova this way will produce a particular shape and show what type of star exploded.

The image of Nova Cas 2021 was taken with our CDK14 telescope and STX camera. When compared to nearby stars of known brightness, Nova Cas 2021 was at magnitude 7 on March 22. Over the next few weeks Nova Cas 2021 will fade dramatically as amateurs and professionals take measurements at a frantic rate. As of April 25, 5,147 photometric measurements from 152 observers have been submitted to the American Association of Variable Star Observers. There are two types of classical novas: fast novas decrease their brightness by two magnitudes over less than 25 days, while slow novas take more than 80 days. Nova Cas appears to be a slow nova.

Nova Cas 2021 is almost 6,000 light years away, so this explosion happened almost 6,000 years ago but we are just seeing it now. Most of what we know about stars comes from spectroscopy and photometry. How amazing that we can learn about stars by carefully examining the light that reaches Earth from mind-boggling distances.

[To see the nova's up-to-date light curve, go to https://www.aavso.org/, scroll down to "Resources/Pick a Star," enter "Nova Cas 2021" into the box and click "Plot a Curve." – Ed.]

Rick first published this report in the April newsletter of WAA's "sister" club, the Astronomical Society of Greenwich.

How Do We Know What the Sun is Made Of? Larry Faltz

When your cat is curled up at the window on a sunny day, the photons in which she is luxuriating were created 100,000 years ago in the center of our star. They bounce around inside the Sun for that long until they emerge at a substantially longer wavelength (and lower energy) than at their birth. Most of the energy is transferred to kinetic energy of the Sun's mass, which counterbalances its gravitational contraction.

The total power output of the Sun is 3.85×10^{26} watts. We're far enough away that the solar energy density at the Earth's surface is 1,379 Watts/square meter, a nice heat lamp for kitty. Unfortunately, it's not a nice heat lamp for the whole Earth, since not enough of the energy is being reflected and re-radiated back into space nowadays to prevent an inexorable rise in the Earth's surface temperature. Climate change is a political mess with an uncertain scientific solution (see, for example, "Geoengineering: Good for the Earth? Bad for Astronomy?" SkyWAAtch, January 2019). But solar physics is pretty well understood. Like everything else, it once wasn't.

Kitty obviously understands that the Sun produces heat, but that wasn't totally obvious to the earliest philosophers, even though we presume they were smarter than cats. Pythagoras was reputed to believe that there was a "Central Fire" that we weren't able to see from Earth because of the intervening *antichthon* ("counter-Earth"), and the Sun merely reflected the Central Fire's rays. This concept was elaborated by his disciples Parmenides and Philolaus. Philolaus believed that there was also a fire at the periphery of the cosmic sphere and that the Sun was a glass-like body that transmitted the light and heat of this fire to the Earth. Parmenides' contemporary Anaxagoras differed, describing the Sun as a "fiery mass of molten metal larger than the Peloponnese" (the Greek peninsula), ignited by rapid rotation. By the time of Socrates' pupil Plato, the concept of the Central Fire seems to have been dispensed with. In the *Timaeus*, Plato writes "God lighted a fire, which we now call the Sun, in the second from the Earth of these orbits, that it might give light to the whole of heaven." So, even though it was not the center of the universe, it provided the light. Exactly what burned in the fire was not made clear, and usually the question was ignored. It was just…fire.

Aristotle seems to mostly avoid the question, although in the *Metaphysics*, he discusses the causes of things, and says

> But evidently there is a first principle, and the causes of things are neither an infinite series nor infinitely various in kind. For neither can one thing proceed from another, as from matter, ad infinitum (e.g. flesh from earth, earth from air, air from fire, and so on without stopping), nor can the sources of movement form an endless series (man for instance being acted on by air, air by the sun, the sun by Strife, and so on without limit).

The concept of Strife and Love as universal causes dates back to the pre-Socratic philosopher Empedocles, who also originated the idea of the four elements, but it's not very illuminating in this context. In *On the Heavens*, Aristotle suggests that the Sun is hot because of its motion, but he doesn't delve into this in any detail.

The size and distance of the Sun was a subject of much interest to later Greek astronomers. In addition to his Sun-centered model of the cosmos, Aristarchus was the first to attempt to measure the distance between the Earth and the Sun, extrapolating from the angle between the Sun and the Moon when the Moon is at first or last quarter. He estimated the angle to be 87 degrees, and came up with a solar distance of 18-20 times farther than the Moon. Assuming their perceived sizes are proportional to their distances, he arrived at a similar value for the ratio of their diameters. Both results are wild underestimations.[1] The magnitude of the astronomical unit, the distance between the Sun and the Earth, that Aristarchus derived was less than 2% of its actual value. A similar although somewhat less egregious error was made by Eratosthenes when he calculated the ratio of the diameters of the Sun and the Earth. His value was 27 times, but the actual figure is 109.

Other ancient astronomers used parallax measurements and came up with a range of results, also mostly too low. Hipparchus and Ptolemy obtained results between two and five percent of the actual value, while Archimedes and Posidonius were in the

[1] The actual angle is 89° 50′. The Sun is 400 times farther away than the Moon, and its diameter is 249 times that of the Moon.

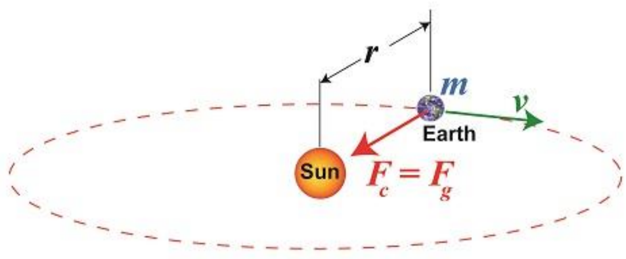
42% range. It wasn't until astronomy became a technological science (*i.e.* after the invention of the telescope) that measurements congealed around the truth. Lalande's calculation, based on data from the 1761 and 1769 Transits of Venus, was just 2.3% over the correct value, quite an achievement given the difficulty of timing the Sun-Venus contacts due to the "black drop" effect. A century later Simon Newcomb measured the AU to within 0.06% of its current value.

Knowing the Sun's distance allows us to determine its mass. Isaac Newton provided the mathematical tools, and the calculations are simple.[2]

The gravitational force F_G between two masses is given by Newton's famous equation,

$$F_G = G\frac{mM}{r^2}$$

where *m* and *M* are the masses of the two objects, *r* the distance between their centers, and *G* is Newton's gravitational constant, 6.6743 × 10^{-11} cubic meters per kilogram per second per second.[3] Let's take *M* to be the Sun and *m* to be the Earth.



The Earth is in a stable orbit around the Sun, and the centripetal force on the Earth must equal the gravitational force exerted on it by the Sun (the very definition of a stable orbit). The centripetal force F_c is also given by Newton in the *Principia* as

$$F_C = \frac{mv^2}{r}$$

where *m* is again the Earth's mass, *v* its orbital velocity and *r* is again the distance between the Earth and its center of rotation, which we can take to be center of the Sun. Note that the vector of the Earth's *velocity* is tangent to its orbit, while the vector of the centripetal force is at a right angle to the orbit, that is, directed at the Sun. Since the forces must be equal ($F_G = F_C$),

$$G\frac{mM}{r^2} = \frac{mv^2}{r}$$

Rearranging the terms to solve for *M*, you will notice that the mass of the Earth cancels. You don't need to know the mass of the orbiting body, just its distance and velocity!

$$M = \frac{v^2 r}{G}$$

We know *G*, and *r* is simply the astronomical unit (149,597,870 km, converted to meters and rounding to get 1.496 × 10^{11}), so how do we find *v*? It's easy. The essentially circular orbit of the Earth (eccentricity 0.01667 in 2021) has a length of 2π*r* and it takes 365.25 days to go around in one year, or 31,557,600 seconds (3.16 × 10^7). Since velocity is simply distance over time, the velocity of the Earth is (2 × 3.14159 × 1.496 × 10^{11})/(3.16×10^7), or 2.978 × 10^4 m/s. So we can now solve for M:

$$M = \frac{(2.978 \times 10^4)^2 \times (1.496 \times 10^{11})}{6.67 \times 10^{-11}}$$
$$= 1.98 \times 10^{30} \text{ kilograms}$$

Knowing the Sun's mass allows us to speculate on how long it might burn if chemical energy was responsible for its heat generation. This calculation, made by Julius von Mayer in 1848, was 5,000 years. But it was known by then that the Earth was many millions of years old, and combustion would have resulted in perceptible shrinkage of the Sun, which of course had not been detected in spite of two millennia of observation.

Experiments by Foucault and Fizeau in 1844, performed by exposing the newly invented Daguerreotype plates to various light sources, showed that the Sun was 146 times brighter than "incandescent lime," better known as "calcium light." They also showed it was at least four times brighter than the brightest electric arc they could create. In 1878, Langley showed that the Sun was 5,300 times brighter than the blinding light of molten steel in a Bessemer converter. It did not appear that any process that could be recreated on Earth was responsible for the energy of the Sun.

[2] The reader is encouraged not to be afraid of the algebra. "The universe … is written in mathematical language." Galileo, *The Assayer* (1623)

[3] $m^3\ kg^{-1}\ sec^{-2}$. We only know G to four decimal places, the most imprecise of the major physical constants. See "Weighing the Earth" in the December 2018 SkyWAAtch.

Alternative non-chemical theories were advanced. There were two that competed for attention in the mid-to-late 19th century: the in-fall of meteorites and gravitational contraction.

Sir William Thompson, Lord Kelvin, (1824-1907), the most important British physicist of the 19th century, addressed the problem in 1862 in an article entitled "On the Age of the Sun's Heat" in *Macmillan's Magazine*, a literary journal that carried both fiction and non-fiction articles. He wrote

> How much the sun is actually cooled from year to year, if at all, we have no means of ascertaining, or scarcely even of estimating in the roughest manner. In the first place we do not know that he is losing heat at all. For it is quite certain that some heat is generated in his atmosphere by the influx of meteoric matter; and it is possible that the amount of heat so generated from year to year is sufficient to compensate the loss by radiation. It is, however, also possible that the sun is now an incandescent liquid mass, radiating away heat, either primitively created in his substance, or, what seems far more probable, generated by the falling in of meteors in past times, with no sensible compensation by a continuance of meteoric action.[4]

The meteoric theory is based on the idea that the mechanical energy of meteor and comet impacts would be converted to heat and then radiated as the energy we perceive as the Sun's light and heat. Although he assumed that many meteors impacted the Sun during its formation, Kelvin was skeptical that there were enough meteors and comets at later times to replenish ongoing heat loss. He invoked LeVerrier's calculations of the anomalous orbit of Mercury and noted the paucity of observations of small bodies near the Sun. These bodies were looked for during the search for the planet Vulcan. This quest reached its peak at the total solar eclipse of 1878 (see "The Brief Life of the Planet Vulcan" in the December 2019 SkyWAAtch), after which it was generally accepted that there was little if any matter, planetary or otherwise, inside Mercury's orbit. But in the 19th century it was impossible to conceive of a form of matter other than what was found on Earth, and Kelvin wrote "We also have excellent reason for believing that the Sun's substance is very much like the Earth's." He references studies of spectroscopy, which by the time of this article (1862) had found sodium, iron, manganese and several other metals in the solar atmosphere.

If there was no input of new energy, Kelvin estimated, using arguments from thermodynamics, that the Sun's specific heat[5] might be in the range of 10-10,000 times that of water, in which case the temperature would sink 100° Celsius over a period between 700 and 700,000 years, enough to have radically changed conditions on Earth that should be detectable, historically or geologically. But even considering the latter figure, Kelvin says "What then are we to think of such geologic estimates as 300,000,000 years for the 'denudation of the Weald?'"

Charles Darwin's *The Origin of Species* was published in 1859 and was instantly influential. It contains only one calculation, his estimation of "the denudation of the Weald." The Weald is a valley formed by the erosion of between the North and South Downs, chalk ridges south of London in Surrey and Kent. His calculation is exact: 306,662,400 years.

Kelvin believed that the Sun was hotter in the past and is inexorably cooling. Rejecting Darwin's Weald calculation, he concludes

> It seems, therefore, on the whole most probable that the Sun has not illuminated the Earth for 100,000,000 years, and almost certain that he has not done so for 500,000,000 years. As for the future, we may say, with equal certainty, that inhabitants of the earth can not continue to enjoy the light and heat essential to their life for many million years longer unless sources now unknown to us are prepared in the great storehouse of creation.

In 1853, Hermann von Helmholtz proposed that gravitational contraction powered the Sun.[6] This was extended later by Simon Newcomb and then in the early 1890s by Kelvin. The generalized phenomenon is now known as the Kelvin-Helmholtz contraction: as a body cools, it contracts. This is a process currently happening with Jupiter, which is apparently shrinking at a rate of one to two centimeters per year. Using

4 https://is.gd/KelvSun

5 Specific heat is the ratio of the quantity of heat required to raise the temperature of a body one degree centigrade to that required to raise the temperature of an equal mass of water one degree.

6 This is an implication of the "nebular hypothesis" of the formation of the solar system, which Immanuel Kant proposed in 1775, amplified by Laplace in 1796.

estimates of the physics of this phenomenon and calculating backwards, Kelvin continued to reject an age for the Sun (and thus the Earth) that was consistent with Darwin's calculation. He also calculated that the Sun would cool below temperatures that would support life in the not-too-distant future, something on the order of 10 million years.

The oldest astronomy book I own is Charles Augustus Young's *The Sun*, the revised edition printed in 1896. A faded signature on the flyleaf of my copy, a gift from a close friend, shows it was once owned by another physician, one John C. Clark, MD of Port Franks, Ontario. I suspect he was also an amateur astronomer, observing with a small refractor in the first decades of the 20th century. I am sure that Dr. Clark would be as astonished by the progress in astronomy since his day as he would with the progress in medicine. C.A. Young was the foremost solar astronomer in the United States at the time. He taught at Case Western, Dartmouth and Princeton. The book is a scholarly examination of everything known about the Sun as of the end of the 19th century.

Near the end of the book, Young finally addresses the question of the Sun's substance.

> What, then, maintains the fire?... Many theories have been proposed, two of which now chiefly occupy the field. One of them finds the chief source of the solar heat in the impact of meteoric matter, the other in the slow contraction of the Sun. As to the first, it is quite certain that a part of the solar heat is produced in that way; but the question is whether the supply of meteoric matter is sufficient to account for any great proportion of the whole. As to the second, one the other hand, there is no question as to the adequacy of the hypothesis to account for the whole supply of solar heat; but there is as yet no direct evidence that the sun is really shrinking.

After describing the strengths and weaknesses of the two competing mechanisms, both of which augur a short lifespan for the Sun, Young notes

> Neither is it wholly safe to assume that there may not be ways, of which we yet have no conception, by which the energy apparently lost in space may be returned, at least in part, and so the evil day of the sun's extinction may be long postponed.

Young reports a theory proposed in 1882 by the eminent German-British engineer and inventor Sir C.W. Siemens, brother of the founder of the Siemens conglomerate. The theory was based on the dissociation, compression and re-association of various compounds in the solar atmosphere. However, Young shows that this theory, "while there is nothing *absurd* about it," isn't tenable.[7]

These were not the only speculations in 1896.

> While we have mentioned only three theories of the solar heat, the reader will understand that a multitude have been proposed and rejected, some as absurd and others as inadequate. To the former class belong the speculations of those who liken the sun to the armature of a dynamo or the whirling plate of an "influence machine," forgetting that in both these cases the energy radiated as light and heat must be derived ultimately from the Sun's energy of rotation; and a simple calculation shows that this energy of rotation is not sufficient to maintain the radiation for even one hundred and fifty years.
>
> Those theories, on the other hand, that seek to account for the solar heat as the simple cooling of an incandescent body, like a red-hot ball of metal, or by the "combustion" of solar material, in the chemical sense of the word, or by the simple condensation of vapors into clouds and the liberation of the so-called latent heat of vaporization—these all, like the meteorite theory, are utterly inadequate.

In his "retiring lecture" as President of the Royal Astronomical Society of Canada on January 15, 1916,[8] J.S. Plaskett notes the importance of the spectroheliooscope, which Hale George Ellery Hale invented while an undergraduate at MIT around 1890. Plaskett reviews some of the new data on the Sun's surface provided by this device, emphasizing newly discovered magnetic phenomena, details of the solar atmosphere and the existence and evolution of prominences. He notes the favored gravitational contraction theory, concluding "The contraction theory seems the only one in sight for accounting for the maintenance of the solar radiation." Solar astronomers continued to assume that the elemental composition and even the geophysical structure of the Sun was not all that much different from Earth, missing hints from the prominent hydrogen absorption lines in the solar spectrum and the magnetic oddities revealed by the

[7] Emphasis his.

[8] https://is.gd/Plaskett1916. Plaskett refers to Young's book in several places in his talk. Young describes the spectrohelioscope but only shows pictures of prominences. The more revealing work with the instrument came after 1896.

spectrohelioscope, behavior so unlike anything known in terrestrial magnetism.

With the discovery of radioactivity in 1896, a new mechanism was suggested. In 1905, Ernest Rutherford proposed dating rocks using radioactivity, leading to the idea that radioactivity could be a source of heat in the Earth's interior. Perhaps the Sun was similarly powered. This would occur by the emission of alpha and beta particles and gamma rays from the decay of unstable isotopes, and not fusion or fission, neither of which were known to exist, or even conceived of, at that time. It was not a subject for any quantitative analysis, however. All Plaskett could say about it in 1916 was "We have no evidence as to the existence of radium in the Sun, but it or some of its radio-active relations may be there to assist in giving long life to the Sun and to the planets which draw their sustenance from the Sun."

By 1919, progress in science, particularly in physics and nuclear chemistry, made the available theories of stellar energy formation thoroughly untenable. The eminent Princeton astronomer Henry Norris Russell, he of the seminally important Hertzsprung-Russell diagram, wrote

> It must therefore be assumed that there exists within the stars some unknown store of energy of enormous magnitude, which is made available to supply the heat lost by radiation.[9]

Although he understood the relationship between heat and gravitation, he was unable to propose an actual mechanism for ongoing energy generation.

> This hypothesis suggests for the internal constitution of a giant star: (1) a nucleus, for which the temperature is above the critical limit where the liberation of energy by the "unknown process" becomes sensible and within which practically all the energy required to maintain the surface radiation is liberated, and (2) an outer shell of lower temperature, in which very little heat is produced, but which is in a state of radiative equilibrium and conditions the rate at which the internal energy can reach the surface and escape into space. The problem of determining the law of distribution of density or temperature within such a body, tho *(sic)* perhaps difficult, is doubtless capable of solution by known methods.

In 1920, Arthur Eddington proposed that atomic transformations could power stars. He didn't call it fusion, and he didn't have a mechanism, but he too was informed by recent progress in atomic science. Newly published measurements of the mass of helium and hydrogen had revealed an unexpected mass difference, and as an enthusiastic follower of Einstein, he understood the meaning of $E=mc^2$. When you read the following excerpt, recall that the neutron had not yet been discovered, having to wait until 1932 for Chadwick to find it.

> Aston has further shown conclusively that the mass of the helium atom is less than the sum of the masses of the four hydrogen atoms which enter in to it; and in this, at any rate, the chemists agree with him. There is a lost mass in the synthesis amounting to about 1 part in 120, the atomic weight of hydrogen being 1.008 and that of helium just 4…. Now mass cannot be annihilated, and the deficit can only represent the mass of the electrical energy set free in the transmutation. We can there-fore at once calculate the quantity of energy liberated when helium is made out of hydrogen. If five percent of a star's mass consists initially of hydrogen atoms which are gradually being combined to form more complex elements, the total heat liberated will more than suffice for our demands, and we need look no further for the source of a star's energy.[10]

In 1925, Cecelia Payne Gaposchkin (then still Cecelia Payne, her marriage to Russian astrophysicist Serge Gaposchkin coming in 1934) became the first woman to receive a doctoral degree at Harvard. Born in England, she was encouraged to pursue a career in music by none other than Gustav Holst, the composer of *The Planets*. In 1919, while studying at Cambridge, she heard a lecture by Eddington about his expedition to measure the deflection of starlight by the Sun, confirming Einstein's General Theory of Relativity. She decided to pursue a career in astronomy. Eddington recommended her to Harlow Shapley, the director of the Harvard College Observatory, and she came to the United States to study in a fellowship program created by Shapley for women astronomers. Her PhD thesis[11] was entitled "Stellar Atmospheres; A Contribution to the Observational Study of High Temperature in the Reversing Layers of Stars."

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[9] On The Sources Of Stellar Energy, *Publications of the Astronomical Society of the Pacific*, Vol. 31, No. 182, p.205, at https://is.gd/Russ1919

[10] The Internal Constitution of Stars, *Nature* 106:14-20, Sept. 2, 1920. https://is.gd/EddStars1920

[11] The full dissertation is in the NASA/ADS repository; use this link: https://is.gd/PG1925

Payne's work was directed at stars in general. She used data from the famous Draper plates of stellar spectra that had been analyzed and classified by the women "computers" of the Harvard Observatory. She made a meticulous analysis of the dynamics of outer stellar layers, based on theoretical work by the Indian physicist Meghnad Sala, She correlated the spectral lines with stellar temperatures and showed that the lines reflected the state of ionization of the elements, and not merely their abundances. She found that hydrogen was a million times more abundant than on Earth, and found an enormous excess of helium as well.

Payne is rightly credited with discovering that stars are made almost totally of hydrogen and helium, but that wasn't the focus of in dissertation and she even questioned the veracity of her own findings. In this she was influenced by Henry Norris Russell. Although his 1919 paper, quoted earlier, suggested that he had creative insights into the problem of stellar composition, he was still an advocate of the traditional theory, backed by Eddington, that the Earth and stars, the Sun included, had similar elemental compositions. Russell was sent a draft of Payne's thesis and responded to her in a letter of January 14, 1925, a copy of which is in his papers at Princeton. He was impressed, but nevertheless admonished her that "it is clearly impossible that hydrogen should be a million times more abundant than the metals [elements heavier than helium]." The oracle had spoken, and Payne was not in a position to challenge. So, near the end of Chapter XIII, "The Relative Abundance of the Elements," Payne's thesis reads

> The enormous abundance derived for these elements [hydrogen and helium] in the stellar atmosphere *are almost certainly not real*.[12] Probably the result may be considered, for hydrogen, as another aspect of its abnormal behavior, already alluded to;[13] and helium, which has some features of astrophysical behavior in common with hydrogen, possibly deviates for similar reasons. The lines of both atoms appear to be far more persistent, at high and low temperatures, than those of any other element…. The uniformity of composition of stellar atmospheres appears to be an established fact. The quantitative composition of the atmosphere of a star is derived, in the present chapter, from estimates of the "marginal appearance" of certain spectral lines, and the inferred composition displays a striking parallel with the composition of the Earth.

She concludes the chapter, however, by stating

> The observations on abundance refer merely to the stellar atmosphere, and it is not possible to arrive in this way at conclusions as to internal composition. But marked differences of internal composition from star to star might be expected to affect the atmospheres to a notable extent, and it is therefore somewhat unlikely that such differences do occur.

In other words, the top of a star isn't going to be different from the inside, and if she's really right, Norris and Eddington must be wrong. One wonders if, when Payne was caving to Henry Norris Russell and composing the disclaimer in her thesis, she thought something along the lines of Galileo's *"Eppur si muove."* For the rest of her life, according to her daughter, she "lamented her decision" not to challenge Russell. At the absolute bottom of the astronomy hierarchy as a female PhD candidate she had no choice, but soon the reality of her finding and the priority of her discovery were acknowledged.

The thesis was described later by Otto Struve, director of the Yerkes Observatory, as "the most brilliant PhD thesis ever written in astronomy." By 1929, Russell himself found evidence to support the enormous abundance of hydrogen throughout a star, and the matter was put to rest in 1932 by Bengt Strömgren, a Danish astronomer who had studied theoretical physics in Copenhagen with Niels Bohr.

Having a lot of hydrogen, as flammable as it is (as the *Hindenburg* would shortly find out), isn't sufficient to create the enormous power output of the Sun. Russell was correct that an "unknown process" was needed, and Eddington was correct that it involved the conversion of hydrogen to helium, with the resulting mass difference transmuted to energy. How could Eddington's scheme actually work?

While Cecelia Payne was writing and defending her thesis, in Europe the study of the atom was yielding insights that would provide an explanation for the Sun's power. The truth came from the new field of quantum mechanics, and we'll discuss that next month. ■

[12] Emphasis mine.

[13] Here, she refers to an earlier part of the thesis, which references papers by Russell and Donald Menzel, who had been, like Shapley, Russell's graduate student.

More Moonlight — Robin Stuart

In my article last month in SkyWAAtch, I examined how the brightness of moonlight changes with the lunar phase and how its intensity varies across the lunar surface. This article deals with how the brightness of the full Moon changes from one lunar month or *lunation* to the next.

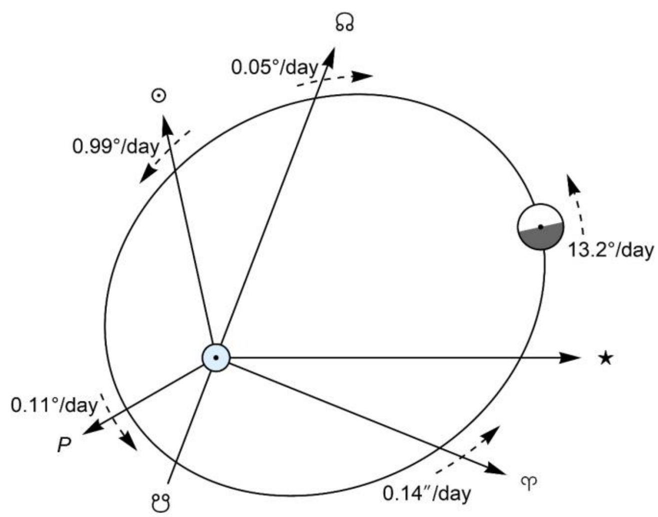
The intensity of sunlight falling on the Moon's surface is inversely proportional the square of the distance from Sun to Moon. The reflected light that then reaches the Earth is in turn inversely proportional to the square of the distance from Moon to Earth. At perigee the Moon is around 12% closer to the Earth than it is at apogee. By comparison the Earth is only 3% closer to the Sun at perihelion than it is at aphelion. These differences translate into 25% and 7% variations respectively in the intensity of moonlight reaching the Earth with the Moon-Earth distance obviously being the dominant factor.

In popular lore, a full Moon occurring near perigee has come to be known as a *supermoon*. The term has a dubious pedigree, however, having been first coined by an astrologer in 1979. No universally agreed upon definition exists as to just how close the full Moon must be to qualify as "super". Most sources put the limit at somewhere around 360,000 km, which is the value that will be adopted here.

As it approaches full, the Moon draws nearer to the antisolar point[1]. Its angular distance from that point is the phase angle, α, which is close to 0° at full, 90° at the quarters and 180° at new. As discussed last month, for phase angles less than about 10° the Moon's brightness experiences a rapid uptick in an effect known as the *opposition surge*. If it approaches the antisolar point closer than about 1.5° it enters eclipse and is once again diminished. As the Moon's orbit is inclined at 5.15° to the plane of the ecliptic, this is the maximum angular distance that the full Moon can be from the antisolar point. Precise photometric measurements made by the USGS Robotic Lunar Observatory (ROLO) indicate that between a phase angle, α = 5.15° and 1.5° the Moon's brightness increases by 25%, comparable to the effect from variations in the Moon-Earth distance. The brightest full Moons due to the latter effect will occur when the Moon is near perigee. The brightest full Moon arising from opposition surge, however, will occur when it is near the plane of the ecliptic or equivalently near its ascending or descending node.

The Moon-Earth distance and opposition surge effects work in concert and make the variation in the brightness of the full Moon from one lunation to the next quite complicated. To disentangle this, it is helpful to have an understanding of how the Moon's orbit evolves over time.

The Orbit of the Moon



The diagram above shows a stylized view of the Moon's orbit around the Earth which, in deference to Carl Sagan, is represented by a pale blue dot. The viewpoint is high above the north pole of the orbital plane. The orbital eccentricity, e = 0.0549, has been exaggerated by a factor of 10 for clarity. As noted earlier, the orbit is inclined at an angle i = 5.15° with respect to the plane of the ecliptic, which it crosses along the *line of nodes*. This is the line that joins the ascending node, ☊, and descending node, ☋. In the diagram the Moon is represented by the half-illuminated disk to the right. It is approaching the ascending node and is therefore located on the southern side of the plane of the ecliptic. From the Earth it would appear as a waning crescent. Under the perturbing influences of the Sun and planets, the Moon's orbit changes noticeably over relatively short times

[1] The point in the sky diametrically opposite to the position of the Sun.

scales. The diagram shows a number of key directional reference markers used to describe the orbit's properties.

The arrow labelled ★ represents an arbitrary direction fixed in space relative to the distant stars. Starting from a point aligned with a star, the Moon takes around 27.3 days to complete one orbit and realign with that star. This defines the *sidereal* month. The arrow labelled ⊙ shows the direction of the Sun, which from a geocentric viewpoint migrates eastward at just under 1° per day relative to the distant stars. As the ⊙ reference marker is a moving target, the time between successive passages by the Moon is longer than sidereal month by about 2.2 days. This defines the *synodic* month where the term "synod" refers to a meeting, in this case of the Sun and the Moon. It is the interval between successive new Moons. Again from a geocentric standpoint, since the Sun completes one revolution in a (sidereal) year, there is exactly one less synodic month in that period than there are sidereal months.

Other labelled arrows in the diagram show reference directions that define alternative kinds of lunar months. Since these directions change at varying rates, their associated months all have different lengths. *P* is the direction of the Moon's perigee which defines the *anomalistic month*. As the direction of *P* advances so too does the orbital ellipse as a whole. The direction of the First Point of Aries or vernal equinox (the crossing point of the ecliptic and the celestial equator) is indicated by the symbol, ♈. It migrates slowly eastward due the precession of the Earth's axis about the pole of the ecliptic with a period of around 26,000 years and defines the *tropical month*. Because the direction of the First Point of Aries changes only slowly, the length of the tropical month is just 7 seconds longer than a sidereal month. The time interval between successive passages through the ascending node, ☊, defines the *draconic month*. When the Moon is near a node it is close to the ecliptic. The potential exists for the Sun, Earth and Moon to line up in space and eclipses may occur. A mythical dragon, from which the draconic month takes its name, is said to lurk at the nodes and consume the Sun or Moon when that happens. As indicated the nodes move in a retrograde direction and consequently the draconic month is shorter than a sidereal month.

The various lunar months are summarized in the table below. The numbers in the "Length" column are simply related to those in the "Reference Period" column. Starting from a given reference direction the time, *T*, needed for the Moon to complete one lap and return to that direction is

$$\frac{1}{T} = \frac{1}{T_1} \mp \frac{1}{T_2} \text{ or } T = \frac{T_1 T_2}{T_2 \mp T_1}$$

where T_1 is the Moon's sidereal period and T_2 is the reference period. The + sign is used only for the draconic month due to the retrograde motion of the nodes, other the minus is what is needed.

Month	Length (days)	Reference	Reference Period
Sidereal	27.321662	★	27.321662 days
Synodic	29.530589	⊙	365.256363 days = 1 sidereal year
Anomalistic	27.554550	*P*	3232.6054 days ≈ 8.85 years
Draconic	27.212221	☊	6793.4765 days ≈ 18.60 years
Tropical	27.321582	♈	25,772 years

The same formula can be used to determine the frequency with which other pairs of reference directions coincide. Using the ⊙ reference period for T_1 and ☊ reference period for T_2 (with the '+' sign) in the equation given above shows that the time between successive passages of the Sun through the ascending node is 346.6 days. As noted earlier, at such times the dragon may open its terrible maw and, to the delight of astronomers, cause an eclipse to happen. This phenomenon happens at either ascending or descending nodes and the interval between successive passages is 346.6/2 = 173.3 days. The 35 day period centered around these times is called the *eclipse season* and within it either two or three eclipses must occur. The 346.6 day period is called the *eclipse year*.

Given the passage of enough time any configuration of the Sun, Moon, ascending node and perigee will eventually recur and so will the sequence of eclipses that it spawns. The perigee is relevant here because it governs the Earth-Moon distance and hence the type of solar eclipse, total or annular, that will occur. By coincidence, in 233 synodic months there are 241.999 draconic months and 238.992 anomalistic months. The characteristics of the sequence of eclipses seen from Earth repeats in just over 18 years. This is the *saros* cycle. If you missed the total solar eclipse of August 21, 2017, it's playing again in Japan on September 2, 2035! As the periods involved in the saros are not exact integer multiples of one another, over time the properties of the eclipses within a cycle will slowly change.

For a supermoon to occur, the Moon must be near perigee and hence the Sun must lie close to the direction of apogee. Using the ⊙ reference period for T_1 and P reference period for T_2 shows that this occurs every 412 days and might by analogy be called the *supermoon season*.

The Brightness of the Full Moon

The bar graph below plots the brightness of every full Moon in the decade 2021 to 2030. The bars represent the brightness compared to a benchmark dimmest possible full Moon. The benchmark was computed by setting the Moon-Earth and Sun-Moon distances to their apogee and aphelion values. The phase angle was set to $\alpha = 5.15°$ which is the maximum possible for a full Moon. The horizontal axis displays the percentage by which a given full Moon is brighter than the benchmark. The brightest full Moons can be up 74% brighter than the dimmest.

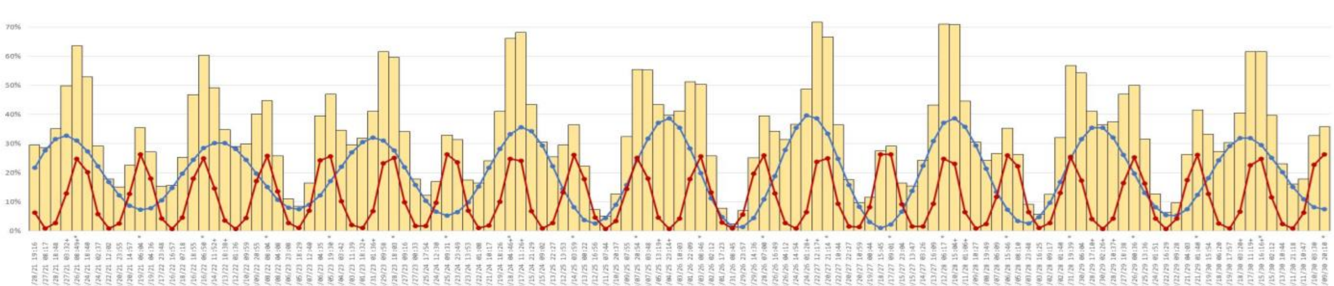
The horizontal axis gives the date and Universal Time (UT) of full Moon. The dates followed by a **+** are supermoons. A ***** indicates that there is a lunar eclipse. [Enlarge the page to see the markers more clearly.] In that case, the Moon's brightness was calculated immediately prior to first contact and immediately after last contact. The reported date and time is the brighter of the two. The contact time was computed using the mean equatorial radii of the Earth, Moon and Sun without further adjustment and may differ by a couple of minutes from the contact times of the penumbral phase listed by other sources.

The red line plots the component of the total brightness coming from the opposition surge. This is a function of the phase angle, α, at full Moon. Its contribution is greatest for small α which happens when the Moon is near the nodes. Consequently it exhibits a period of 173.3 days or half an eclipse year.

The blue line plots the component of the total brightness coming the combined effects of Moon-Earth and Sun-Moon distance. The dominant variation is attributable to the Moon-Earth distance at full Moon and is greatest when the Moon is near perigee. As noted earlier this is associated with a 412 day period. As can be seen in the plot the amplitude of oscillations of the blue curve is modulated by variations in the Sun-Moon distance. The amplitude is greatest when the Moon's perigee and Earth's perihelion lie close to the same direction as will be the case in 2027. From the table it can be seen that these circumstances recur every 8.85 years.

Operating together and going in and out of phase, these cycles produce a complex pattern in the brightness of the full Moon from one lunation to the next. The brightest full Moon for 2021 is both a supermoon *and* an eclipse. On May 26, the Moon will be at its brightest just prior to first contact, visible from Westchester County but strongly diminished by atmospheric extinction before the Moon sets while still in the penumbral phase. The dimmest full Moon of the decade will occur on May 31, 2026 and be close to the minimum possible.

Calculations of the positions of the Sun and Moon were carried out using the freely available Python software package, Skyfield https://is.gd/skyfld. The Moon's brightness was computed using the ROLO Irradiance Model https://is.gd/mooncal ignoring the effect of lunar librations and variations in the Sun's selenographic latitude. ■



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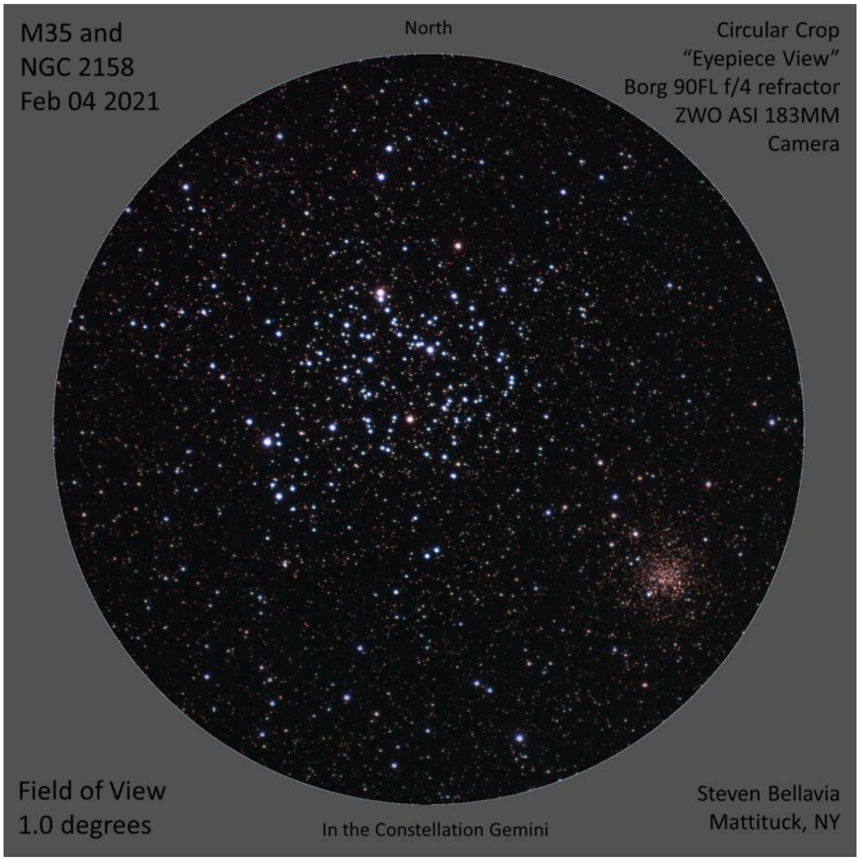
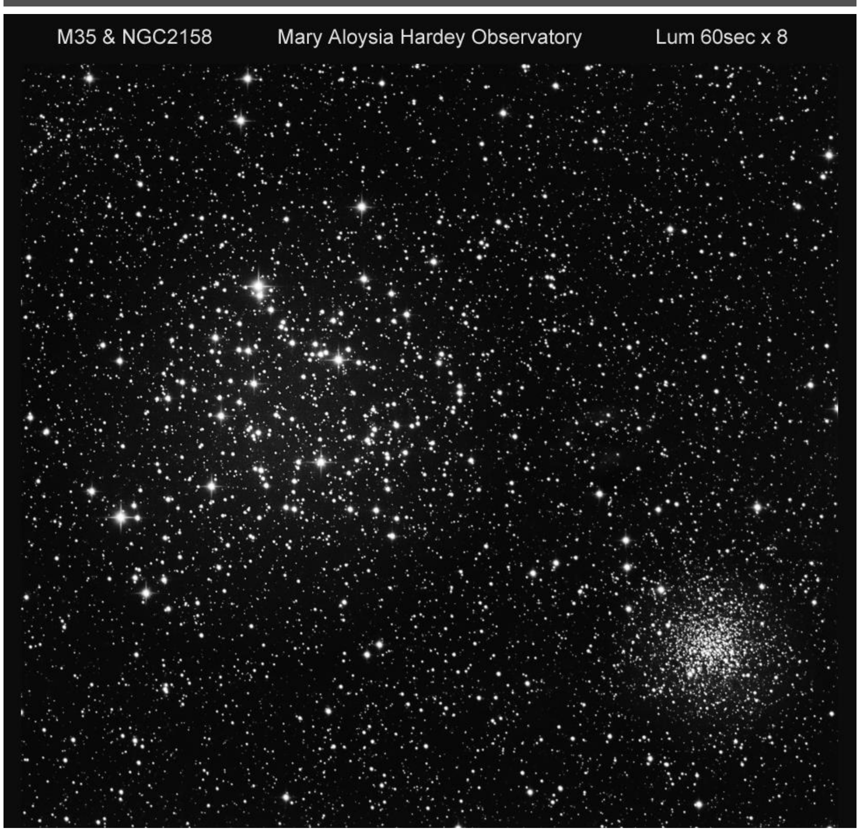




Two Views of Messier 35

Top: **Steve Bellavia**
Bottom: **Rick Bria**

The bright open cluster Messier 35 (NGC 2168) in Gemini is just above the tip of Orion's club. It's almost the diameter of the full Moon. At magnitude 5.1 it's a fine binocular object and a telescopic favorite if you are observing in the late winter or early spring. It is about 3,800 light years away from us. It is accompanied by another open cluster, NGC 2158, just half a degree to its southwest. NGC 2158 is more condensed and looks almost like a globular cluster, which it was originally thought to be, but it's not. It's 11,000 light years distant, magnitude 8.6. It's ten times older than M35.

Steve's color version with a 90-mm refractor shows to two clusters as they would be seen in an eyepiece with a one degree field, but of course unless your telescope was 24 inches or larger you wouldn't detect the reddish hue of the older, more distant cluster. The hot blue and white stars that formed when NGC 2158 condensed two billion years ago are gone, leaving their cooler, redder siblings.

Steve imaged with a 90-mm (3.5-inch) refractor and a monochrome camera with color filters; Rick's image was made with a 14-inch PlaneWave CDK telescope and a monochrome camera without filters.

The Belt and Sword of Orion In Color by Steve Bellavia

See next page for information about this image

We published Steve's monochrome image of this large field in the February 2021 SkyWAAtch. When I saw this version, with added subs from a color camera, I imagined how black-and-white Dorothy must have felt when she opened the door and saw technicolor Oz.

Orion sits in Barnard's Loop, a vast region of hydrogen ionized by ultraviolet radiation from the constellation's many hot young stars. The main arc of the Loop is over 10 degrees across, just outside of the generous field of this image, but there is a lot of nebulosity throughout the area. E.E. Barnard photographed this nebula in 1894 at Lick Observatory. In his report "The Great Photographic Nebula of Orion, Encircling the Belt and Theta Nebula," subtitled "Experiments With a Very Small Lens in Photographing Very Large Nebulae, etc." (*Popular Astronomy*, Vol. 2, pp. 151-154) he notes that he used a lens that "belongs to a cheap (oil) projecting lantern and is 1½ in in diameter and 3½ inches focus (from the rear lens). It gives a field of about 30°, only one-half of which, however, is at all flat—but on this portion the stars are fairly good…. The ratio of aperture to the focal length is 1:2.3." After describing his images of the Wild Duck Cluster, "the great mass of nebulosity near Alpha Cygni" [undoubtedly the North American Nebula], the Pleiades and NGC 1497 [a lenticular galaxy in Taurus], Barnard describes his two hour exposure centered on Orion. "To my surprise these pictures showed an enormous curved nebulosity encircling the belt and the great nebula [M42], and covering a large portion of the body of the giant. A description of this nebula would not only be complicated but it would fail, also, to give any impression of its form and magnitude." For the paper, Barnard made a drawing of the nebula rather than printing a photograph, but the on-line copy of the report (https://is.gd/Barn94) doesn't reproduce the image well enough to see it. Although the nebula is now named for him, in his report Barnard acknowledges that William H. Pickering had imaged the nebulosity from "Wilson's Peak" (during the brief existence of a Harvard observatory on the site of the future Mt. Wilson Observatory) and reported it in the *Sidereal Messenger* in 1890 (vol. 9, p. 2). Pickering used "a Voightländer portrait lens of 2.6 inches aperture and 8.6 inches equivalent focus, with an exposure of three hours." In his report (https://is.gd/Pick1890) Pickering refers to the object as "a large spiral nebula," which it's not.

To capture the huge field without having to make a mosaic, Steve used a Canon EF 100-mm f/2 lens stopped down to f/3.7, cognizant of the fact that most lenses are not sharpest at their full aperture. You can see the step-down ring on the front of the lens. Most lens-camera adaptors keep the internal diaphragm wide open, so you have to stop it down in this manner (in addition to mounting the filters).

Cameras:
- ZWO ASI 183MM (Dec 14)
  - Astronomik 6nm H-alpha filter
- ZWO ASI 183MC (Mar 02)
  - IDAS UIBAR-III filter
- Both cooled to -15C

Integration:
- Dec-14-2020: 51 x 3 minutes
- Mar-02-2021: 105 x 1 minute

Mount: Sky-Watcher EQ6-R Pro

Guidescopes
- Dec 14: ZWO 30mm, f/4 mini-guidescope
- Mar 02: Modified SvBony SV165 mini

Guide Camera: ZWO ASI 224MC

Location: Mattituck, NY

Temperature: Dec 14, -2C, Mar 02, -3C

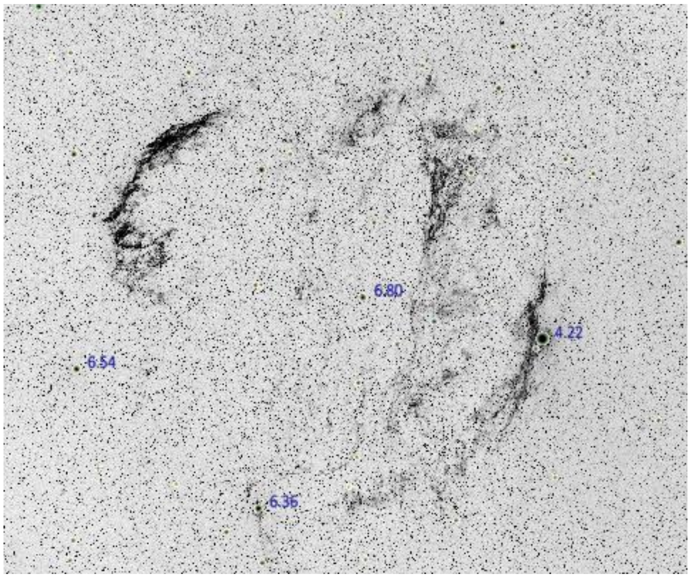
Seeing-& Transparency:
- Dec 14: 2/5 & 9/10
- Mar 02: 2/5 & 7/10

Steve Bellavia's lens/guider scope combination. This is the SvBony guidescope. It has been modified with an internal 2X Barlow to give f/8, which Steve finds gives better tracking. The Canon's lens hood has been removed to show the step-down rings that slow the lens from f/2.0 to f/3.7, and allow the filters to be mounted. The ring is a stock ZWO item with a dovetail shoe added.

NGC 6992, the Eastern Veil, by Bill Caspe

The whole Veil Nebula in Cygnus is almost three degrees in diameter. A complex structure, its two main components are the Eastern Veil, NGC 6992 (with NGC 6995 as part of it) and the Western Veil, NGC 6960. It is the remnant of a supernova explosion some 15,000 years ago, at a distance of about 2,500 light-years. Visual observations are sensitive to light pollution. Larger telescopes (11 inches and above) at Ward Pound Ridge can show it, while under dark skies smaller telescopes and even binoculars can resolve it quite nicely. It helps to use aggressive contrast-enhancing filters such as an Orion Ultrablock.

The view of the Eastern Veil, above, is oriented with north to the right. NGC 6995 is the clump of gas on the left side of the arc, projecting downward. The image above is about 1.2 degrees in diagonal extent.



Here is a Sloane Digital Sky Survey image of the entire Veil with north up. The magnitudes of the four brightest stars in the area are noted. The field is about 3¾ degrees wide. The 4.22 magnitude star in the middle of the Western Veil is 52 Cygni, a giant star that is either burning hydrogen in a shell around an inert helium core, or already starting to fuse helium. It's much closer than the nebula, at 291 light-years.

Bill used an AstroPhysics 130 GTX refractor with Hα and OIII filters. The camera is an FLI Microline with a KAI-16070 16-megapixel full-frame sensor. Forty-three 600-second OIII exposures and 41 600-second Hα exposures were processed in Pixinsight.

Sh2-188

Gary Miller

Sh2-188 is also catalogued as PK 128-4.1 and Semeis 22. It's the remnant of a planetary nebula that has more interaction with the interstellar medium on one side than the other, accounting for its asymmetry.

Messier 94

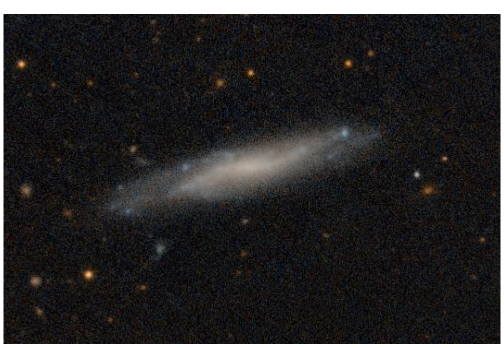
Steve Bellavia

Steve's image shows both the bright inner ring surrounding this barred spiral galaxy, and the faint outer ring. The outer ring may have formed by gravitational disruption of one or more companion galaxies. M94 is unusual in that it apparently has very little dark matter within it, based on rotation curves.

Messier 51 by Olivier Prache

Olivier's image shows the advantage of large aperture, fine optics, a sensitive camera and time, in this case 11 total hours of exposure. Hyperion 12.5-inch CDK, MicroLine KAF-16803 camera, from Pleasantville, NY.

In the lower right corner of the image, Olivier has captured spiral galaxy IC 4263. This 15th magnitude object has an apparent size of 1.5 x 0.4 arcminutes. It was discovered in 1899 at Lick Observatory with the 36-inch Crossley reflector. Distance 125 million light-years, much farther away than M51 (31 million).



IC 4263. PanSTARRS DR1 image

The Crossley reflector, which is still *in situ* at Lick, was originally constructed in England in 1879 by amateur astronomer Andrew Ainslie Common, who had it in his backyard observatory in Ealing, then a suburb west of London. He donated it to Lick, where it saw first light in 1895. It was the largest reflector in the United States until the 60-inch was installed at Mt. Wilson in 1908. It was used for astrophotography and had a distinguished research history. Perhaps its most famous discovery was Mayall's Object, later catalogued as Arp 148, a pair of interacting galaxies. It was found on March 13, 1940 by Nicholas Mayall. The telescope was taken out of service in 2010.

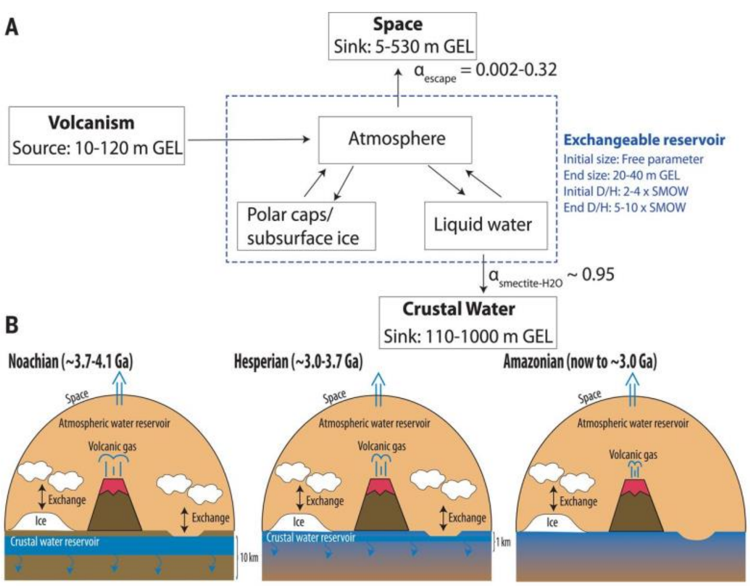
Research Highlight of the Month

Scheller, EL, Ehlmann, BL, Hu, R, Adams, DJ, Yung, YL, Long-term drying of Mars by sequestration of ocean-scale volumes of water in the crust, *Science* 2021; 372:56-62 (April 2, 2021)

Most planetary scientists agree that early in its existence Mars had a fairly substantial surface ocean, with a volume perhaps half that of the current Atlantic Ocean. Lacking a magnetic field, Mars' surface was bombarded by the solar wind. The atmosphere thinned and water molecules were dissociated. Hydrogen escapes a bit faster than deuterium and is preferentially lost to space. The thin atmosphere of Mars (6 millibar at the surface) now contains, on average, 0.03% water vapor, enough for just 1-2 km^3 of ice (Earth's atmosphere holds about 12,900 km^3, a small part of Earth's total water volume of 1,386,000,000 km^3). Evidence for the larger water content on early Mars comes primarily from the D/H ratio in Martian meteorites as compared to current values from the MAVEN satellite orbiting Mars and the Curiosity rover. Earth water currently has 1 deuterium for every 6420 hydrogen atoms; the current ratio in the atmosphere of Mars is about 5-10 times that, whereas the D/H ratio in early meteorites is 2-4 times. Water on Mars today is either in the polar caps, in subsurface ice, or locked up in hydrated minerals.

However, the current flux of hydrogen loss, estimated to be 10^{26}-10^{27} H atoms s^{-1} cannot fully explain all the water loss from the earlier epochs on Mars, nor can the observed D/H ratio. A group from Caltech and the Jet Propulsion Laboratory developed a sophisticated model that incorporated all of the possible mechanisms of water loss, including crustal hydration, volcanic degassing and atmospheric escape, and extrapolated backwards to the earliest Martian oceans. Crustal hydration is the process in which water molecules are strongly bound to inorganic molecules in minerals on or near the surface, integrated into their crystalline structures.

On Earth, plate tectonics pulls hydrated minerals into the mantle via subduction, where heat liberates the water molecules and they will be injected back into the atmosphere through volcanic action. Mars' lack of plate tectonics means that once locked up into minerals, the water remains sequestered. This process, if vigorous enough in the early epochs of Mars, could account for the drying of the planet even more than atmospheric loss.



Schematic illustration of water sink and source fluxes in the simulations. (**A**) Box model representation with ranges of integrated water sinks, sources, reservoir sizes, and fractionation factors adopted in the simulations. (**B**) Schematic representation of assumptions for the Noachian, Hesperian, and Amazonian periods. (Fig 1 from Schller *et. al.)*

The simulations show that irreversible crustal hydration could account for between 30 and 99% of the water loss. The range is wide because the exact history of atmospheric water loss isn't known. It could vary due to a wide variety of factors, so the simulations play out in various ways to account for the possible variances.

The authors state "We conclude that the increasing aridity of Mars over its history was caused by the sink of chemical weathering of the crust, which was recorded in the widespread Noachian hydrated minerals on the planet's surface....The ancient age of most hydrated minerals indicates that [tectonic] recycling did not persist on Mars."

So the water may be there, and might be a source for human habitation, but it won't be easy to get out. It's true you can't get blood from a stone, but water is almost as hard.

Member & Club Equipment for Sale

Item	Description	Asking price	Name/Email
Explore Scientific 127-mm refractor NEW LISTING	Air-spaced ED APO f/7.5 triplet OTA with tube rings, 2” diagonal, Orion focus extender. Like new condition; rarely used. See https://is.gd/es127gb for more information.	$1000	Greg Borrelly gregborrelly@gmail.com
Orion Alt-Az mount	Orion alt-azimuth mount on 4 foot adjustable aluminum tripod. Slow motions on both axes. Accessory tray. Suitable for a small refractor or spotting scope.	**FREE**	Robin Stuart robinstuart@earthlink.net
Ritchey-Chrétien 6 inch astrograph	Astro-Tech f/9 imaging instrument. Barely used with original shipping box. These scopes list at $399. See https://is.gd/RCf9scope.	$200	John Paladini jpaladin01@verizon.net
Denkmeier 60-mm spectrum 60 upgrade (OTA) for PST	Unscrew the 40-mm PST tube and screw in the upgrade, and now your PST is a 60-mm solar scope. It does work with newer PST's. Original price $599	$240	John Paladini jpaladin01@verizon.net
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. 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
Losmandy G11G mount	Pristine condition observatory-quality yet portable German equatorial mount. 2018 model. 60 lb. weight capacity. Heavy-duty tripod. Includes brand-new Gemini II go-to system new in box (never mounted). See http://losmandy.com/g-11.html.	$2500	Dante Torrese torresedds@optonline.net
Explore Scientific 40 mm eyepiece	68° field of view. Argon-purged, waterproof, 2" eyepiece. New in original packaging, only used once. Lists for $389.	$340	Greg Borrelly gregborrelly@gmail.com
Atco 60-mm f/15.1 refractor	A classic Japanese refractor from the early 1970s. Obtained from the original owner about five years ago. It had been used only a few times, then stored for 40+ years. Current owner used it maybe seven times. Very good condition. Comes with three eyepieces and a 1.25" eyepiece adaptor star diagonal. Straight-through finder. Equatorial mount with slow-motion adjustment knobs (screws). Wooden tripod, metal tube. Everything is original.	$150	Robert Lewis lewis@bway.net

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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