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Reflector

ALCON 2020 HAS BEEN REGRETFULLY CANCELLED DUE TO THE COVID-19 PANDEMIC.

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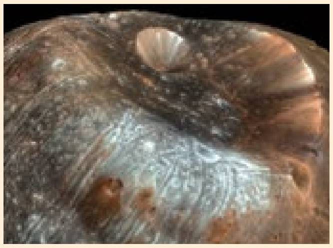

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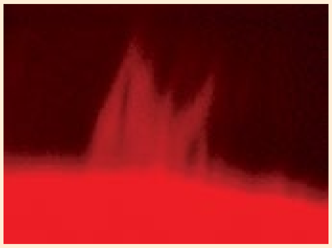

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Cover image: *Steven Bellavia (Amateur Observers' Society of New York) captured this image of the Flaming Star Nebula using a DIY Bellavia Mini 114 mm f/4 Newtonian astrograph with ZWO AZI183MM Pro and ASI183MC Pro CMOS cameras.*

Reflector

The Astronomical League Magazine

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A NON-PROFIT ORGANIZATION
To promote the science of astronomy

- by fostering astronomical education,
- by providing incentives for astronomical observation and research, and
- by assisting communication among amateur astronomical societies.

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Reflector

QUARTERLY PUBLICATION OF THE ASTRONOMICAL LEAGUE

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***REFLECTOR* AND CLUB ROSTER DEADLINES**

March issue	January 1
June issue	April 1
September issue	July 1
December issue	October 1

To the Editor

Planetary nebula observers in the Astronomical League might be interested to know that I have compiled a list of all galactic planetary nebulae. For almost 15 years I have used a comprehensive and inspiring list which was compiled by Kent Wallace and modified by the late Doug Snyder (Planetary Nebulae list Rev 6DS, August 1, 2003) as well as the wonderful book *Planetary Pages* by Kent Wallace. So far I have observed and sketched almost 300 planetary nebulae even though I cannot reach many of the objects in Sagittarius and Scorpius due to my northern latitude (47.5°). However, there are many more objects within reach of my 18-inch Dobsonian.

To identify them, I compiled a list of all known planetary nebulae in SIMBAD (more than 11,000) and manually separated the extragalactic from the galactic ones to come up with a final number of some 2,700 known "true" galactic planetary nebulae. I furthermore included lists of non–planetary nebulae (some objects listed as planetary nebulae in the literature are actually galaxies, reflection nebulae, peculiar stars, and such), possible planetary nebulae, and protoplanetary nebulae, as well as a literature list. I started compiling the list in fall 2017 and had to stop in 2019 for personal reasons. I wanted to include as much information as possible, but I will have to leave that until later. However, the list is usable. For observers that choose observable objects by constellation, as I do, it might be worth noting that the constellations are also given.

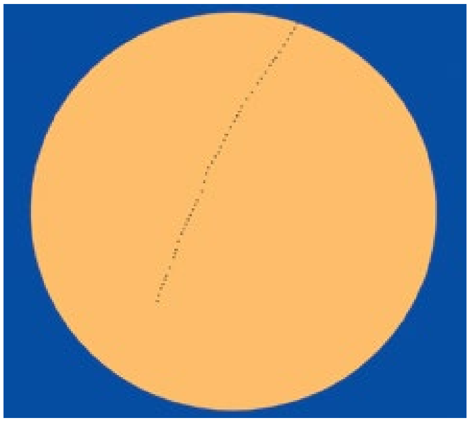
Anybody interested is welcome to download and use the Microsoft Excel file for free. You can find it on my website, *www.astroweis.de.* Simply go to "PN list" and then click "download."

I am aware that the list still contains minor errors and I will try to sort them out as soon as possible, so you may want to check for updates from time to time. I will describe all changes made to the list. In the meantime, I wish you lots of fun observing some of the most wonderful objects in the sky.

Thank you very much, indeed!

—Christian Weis
Tucson Amateur Astronomy Association

I have noted that the images of the November 11, 2019, Mercury transit in the last two issues of the *Reflector* did not have as much of the transit captured as I was able to image from my home in Aiken, South Carolina. I was set up for the entire transit, but due to trees in the east I missed the first 76 minutes. I captured 48 images at approximately 5-minute intervals for the remainder of the transit with my 127 mm f/7 APO Refractor



with a Nikon Z6 mirrorless camera positioned at prime focus. I captured the images by hand, and during the processing I took the individual frames and hand-placed them on the finished image. I have attached an image of me at the telescope during the transit and the final image of the transit on a contact sheet from Photoshop.

—Stephen Miller
Member-at-Large

My club voted to send my following original poem to the *Reflector* for publication:

I slipped the bonds of Earth through prism lenses
and watched Venus alight her night sky.
I have climbed the mountains of the Moon
and slid down its jagged slopes.
Eclipsed the sun through shaded glasses
and watched it darken the day.
I rode upon Mercury as it traversed the sun
and watched as jets left their trails.
I marveled at Saturn's rings and became hooked
as I counted them.
I was amazed by Jupiter (Leader of the Gods)
whose size and gravitational pull is almost

that of a star. Counted most of his moons
and wondered if its hundred years storm
would tear apart Mother Earth.
I looked upon the color of Mars and wondered
if we would ever walk upon his red soil.
I counted all seven sisters of the Pleiades just
to test my eyes.
I watched the Space Shuttle glide across the sky
and Spacelab orbit its Earth.
I sought shelter from a meteor shower
and drank the light of the Milky Way.
I returned to Earth rested on the ground
and foolishly tried to count all the stars
but, of course, could not and fell asleep...

—Joseph F. Moia
Ocala, Florida
Moonstruck Astronomy Club

International Dark-Sky Association

MEXICO'S ENVIRONMENTAL LAW

The United States has no national environmental law that addresses light pollution. IDA has been told that nothing in federal environmental regulations gives an aggrieved party a means to combat light pollution on a local, state, or federal level. The issue of outdoor nighttime lighting is simply not mentioned or addressed in any federal regulation. There are oblique methods of looking at light pollution in federal policy, mainly from the perspective of energy use or possible wildlife harm from improperly situated or colored lighting.

Many local and a few state ordinances address light pollution and light trespass. Usually, the state laws only regulate light controlled by the state itself, such as highway lighting and nighttime lighting associated with state parks and state buildings. While I don't particularly want to see another set of rules and regulations added to the thousands already in place in the federal world, it seems to me that outdoor nighttime lighting needs to be addressed in some fashion, particularly with regard to lighting controlled by the federal government.

In fact, the federal government has let those in southern Arizona know that any state, county, or city ordinance does not apply to lighting associated with federal property. Federal agencies have always expressed a desire to be good neighbors with the community, but, in my experience, that has not applied to any lighting controlled by the federal government. Some of it in southern Arizona is fine, but I can cite several examples of atrocious lighting on federal government properties. We would all be better served if this lighting were made environmentally friendly. The skies would darken a bit, and we taxpayers would ultimately save energy (and money) with the better lighting.

Light pollution is an issue recognized worldwide, and several countries have national laws that regulate outdoor nighttime lighting in some fashion. The latest country to do this is Mexico: last November, the Senate of Mexico unanimously endorsed legislation that classifies light pollution as a form of environmental pollution. This law is the *Decreto por el que se reforman y adicionan diversas disposiciones de la Ley General del Equilibrio Ecológico y la Protección al Ambiente* (Decree for the reform and addition of various provisions of the General Law of Ecological Balance and the Protection of the Environment). It had previously been approved by the Chamber of Deputies (the lower house of the Mexican Congress).

John C. Barentine, PhD, IDA Director of Public Policy, writes in more detail about Mexico's environmental law on the IDA website *(darksky.org/mexico-light-pollution-law).* He notes this is "the first instance of a country explicitly defining light pollution as an environmental pollutant. This law is also unique because it amends previously existing environmental legislation that regulates air, water, and soil quality to also set regulations for light pollution." John's article details information about Fernando Avila Castro, the leader of IDA Mexico and a member of the technical staff of the Institute for Astronomy at the National Autonomous University of Mexico in Ensenada, who leads the team that accomplished this significant lawmaking process.

John's article also provides more details about how this legislation will affect regional and local governments throughout Mexico, as well as public and private property owners. The legislation is intended to not only protect and recover some dark skies but to reduce the expenditure for producing electricity for public lighting. The law may have particularly beneficial effects for astronomical observatories and new tourist developments going forward. A more detailed announcement in Spanish about this law can be found at *comunicacion.senado.gob.mx/index.php/informacion/boletines/46874-avala-senado-reformas-para-regular-contaminacion-luminica.html.*

My hope is that once the turmoil of this election year in the United States passes, IDA and other interested parties can work with Congress and the administration to effect similar changes in U.S. federal environmental law.

—Tim Hunter
Co-founder, IDA

Night Sky Network

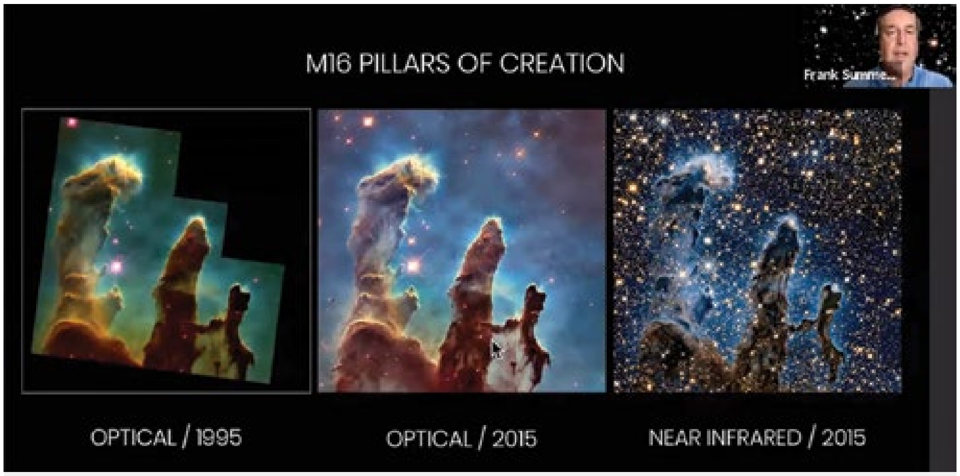
ONLINE RESOURCES FOR VIRTUAL CLUB MEETINGS AND OUTREACH

Most astronomy club events, whether meetings or outreach, happen in person, and the Night Sky Network's toolkits were developed with in-person, physical demos in mind as their primary use. However, the Night Sky Network (NSN) does maintain resources that club members can use both online and offline in their virtual public outreach and club meetings.

One benefit that NSN club members receive is access to monthly webinars with NASA scientists and program specialists. The meeting software also allows members to chat with each other and ask the presenter questions. These talks often focus on a particular NASA mission, such as the Perseverance Rover or Parker Solar Probe, but can also include information about programs broader in scope, such as an overview of NASA citizen science programs, or astronomy visualization software. Some webinars are also livestreamed to YouTube, and all are archived for future reference, but only NSN members can ask questions in the live sessions. Some astronomy clubs have found the series to be a handy addition to their club's activities, making for a convenient substitute in case a speaker was unavailable for their own monthly meeting. You can find an archive of all of our previous webinars at *bit.ly/nsnastrowebinars* and find the schedule of upcoming webinars at *bit.ly/nsnwebinars.*

You will also find collections of items from the NSN outreach toolkits that have proven useful as handouts and online presentations. These resources can be very helpful for indoor outreach events like classroom visits as well as club meetings both in person and online. The NSN's presentations discuss a variety of space science topics such as exoplanets, the Moon landings, stars, black holes, the search for life in the universe, and more. You can find a collection of our most popular presentations in PowerPoint format at *bit.ly/nsnpresentations.*

We even have print-ready handouts: the Night Sky Network includes physical handouts in almost



Dr. Frank Summers reviews a few highlights from 30 years of the Hubble Space Telescope during his webinar for Night Sky Network members on March 24, 2020.

every toolkit, but we make sure that the source PDF files for each handout are available on the Night Sky Network website as well. You can print them out to distribute or just keep them handy as a reference in your computer or tablet. Handouts include Moon maps, the lives of stars, meteor shower observing tips, and observing objects around the Summer Triangle. Download and print them at *bit.ly/nsnhandouts.*

One last note about these handouts and presentations: you are welcome to update them or edit them for your needs. Please do! We encourage anyone to edit, update, and share these resources as they need, but we ask that if you do so, please credit the NASA Night Sky Network and our partner programs and missions, and share them back with us. We love to see how folks use these materials and make them their own. Your feedback helps us design more resources to help clubs stay flexible in their outreach, in an even greater variety of situations – even online.

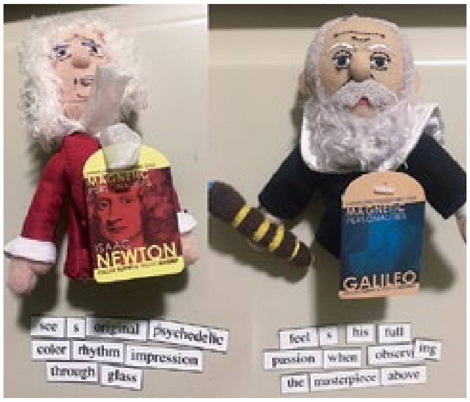
—David Prosper

Full STEAM Ahead

ASTRONOMICAL LEMONADE

With the cancellation of the ALCon 2020 convention, ALCon Jr. will have to make its debut next year (2021), with ALCon held at the same Albuquerque location but in the month of August. Nothing has been formalized as far as changes go, but the desire to maintain this type of schedule and activities including the telescope making workshop will be important. In the next few months, I will set out to confirm the ALCon Jr. 2021 family STEAM conference and will keep everyone posted as to the progress.

Of course, I am putting the finishing touches on the Astronomical League's 2021 calendar, so stay tuned for that as well. Sales of the calendar will benefit ALCon Jr.'s budget, allowing for some potential additions to next year's program. So, until the next *Reflector*, enjoy my "astronomy therapy" recommendations.



When I went to the Very Large Array in Socorro, New Mexico, a few years ago, I brought home plushies of four famous scientists – Galileo and Newton along with Einstein and Tesla. They reside on my file cabinet with accompanying word puzzles where they inspire me at times. I share them here as a reminder why I am an amateur astronomer. At the time of this writing, the nation is practicing social distancing, and we are not able to move about, which has me, a lover of outreach, feeling like a fish out of water.

I have noticed families exercising their dogs as a group, or just walking, conversing, and spending time together. We all got involved in this wonderful hobby for one reason or another and now is a great time to get back to our roots and into our backyards. So, I highly recommend "astronomy therapy." The words of ancient (and not-so-ancient) sages remind us why.

Plato said, ***"Astronomy compels the soul to look upwards and leads us from this world to another."*** Astronomy sparks the imagination and takes us to places unknown.

"It's been said that astronomy is a humbling and, I might add, a character-building experience." – Carl Sagan. Observing will help one take eyes off the self and helps problems fade into their proper place.

"Astronomy's much more fun when you're not an astronomer." – Brian May. It's a great a way to awaken the mind and it fuels the artist.

"My whole entry into astronomy started from a spiritual place." – Carolyn Porco. It soothes the soul and can give one a peaceful journey.

"This sight...is by far the noblest astronomy affords." – Edmond Halley. It sparks discoveries and allows for a "thrill of the hunt" experience.

"He insisted that stars were people so well loved, they were traced in constellations, to live forever." – Jodi Picoult. It reminds us of the rhythm of the ancients and allows for traditional stories and lore.

"The universe is like a safe to which there is a combination, but the combination is locked up in the safe." – Peter de Vries. Science allows one to unlock mysteries and provide answers.

"Astronomy, as nothing else can do, teaches men humility." – Arthur C. Clarke. An observing session helps one get back to the basics and gives us proper perspective.

"Astronomy? Impossible to understand and madness to investigate." – Sophocles. As we all know, astronomy can be quite compelling and remarkably addictive in nature.

"No one regards what is before his feet, we all gaze at the stars." – Quintus Ennius. Stargazing makes one aware of the universal connection and the fellowships without borders.

"When it is darkest, men see the stars." – Ralph Waldo Emerson. Looking up on a regular basis is very grounding and reboots humanity.

"Though my soul may set in darkness, it will rise in perfect light; I have loved the stars too fondly to be fearful of the night." – Sarah Williams. To contemplate the stillness of the cosmos helps us to remain open.

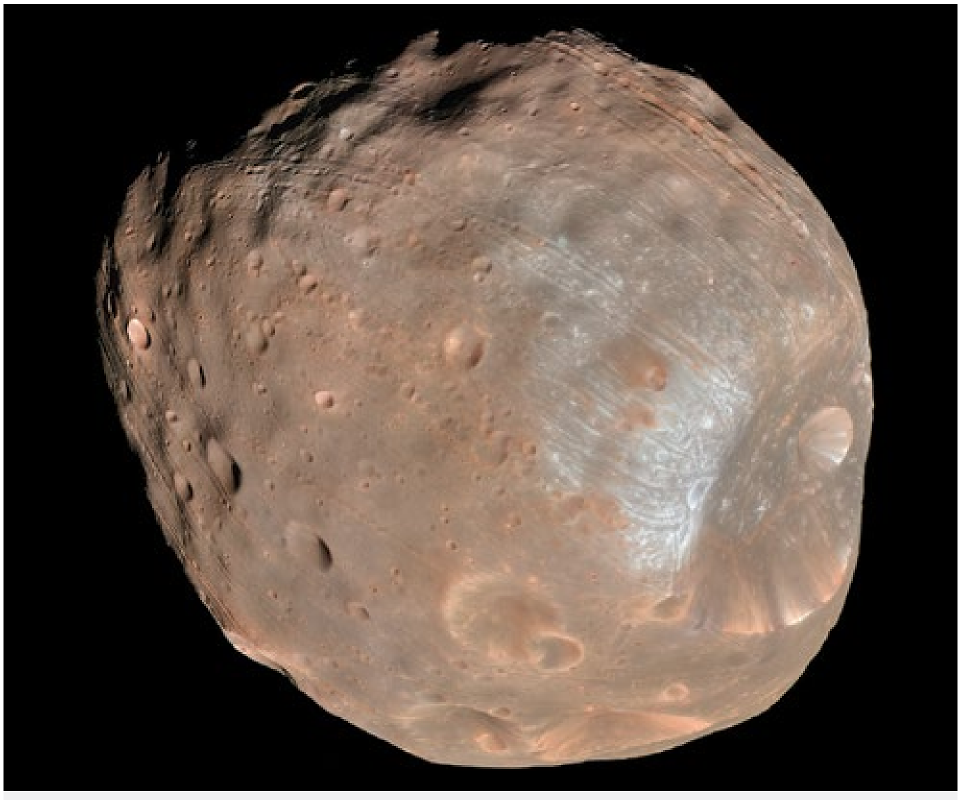
"Mortal as I am, I know that I am born for a day. But when I follow at my pleasure the serried multitude of the stars in their circular course, my feet no longer touch the Earth." – Ptolemy. The stars take us captive and mesmerize us to the point of utter bliss.

S o, as you and your families take advantage of this quiet and mindful time, use this opportunity to bond and connect, and please consider the wonderful options to help with your family therapy. For example, you can 1) conduct the Globe@Night citizen science star counts, 2) order planet coloring books from Amazon, and, for more educational encounters, 3) pursue the AL Observing Programs. **Sky Puppies** is designed for children under 12 years old, while **Beyond Polaris** is meant for those 13 years to adult and parallels with Sky Puppies. The **Constellation Hunter** program is done solely with the naked eye and does not require any equipment, while **Dark Sky Advocate** integrates other sciences and covers light pollution. Older students will enjoy **Astronomy Before the Telescope,** which has students making sextants, sundials, and other astronomical instruments. Of course, intermediate observers who have equipment should consider the **Messier lists** for binoculars and for telescopes.

For more information please go to *astroleague.org/observing.html*, where you can find details, instructions, and log sheets.

No matter which of these programs you choose to do, please enjoy your astronomical lemonade and relish this time before the crazy, stressful, daily routine lands back in your lap.

—Peggy Walker



Phobos, the inner moon of Mars, as imaged by the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter on March 23, 2008. This moon is just fourteen miles in diameter. The color was generated from the blue-green, red, and near-infrared channels on the HiRISE camera. The Viking 1 orbiter was the first spacecraft to get a clear image of this moon. Image credit: NASA/JPL-Caltech/University of Arizona

photojournal.jpl.nasa.gov/catalog/PIA10368

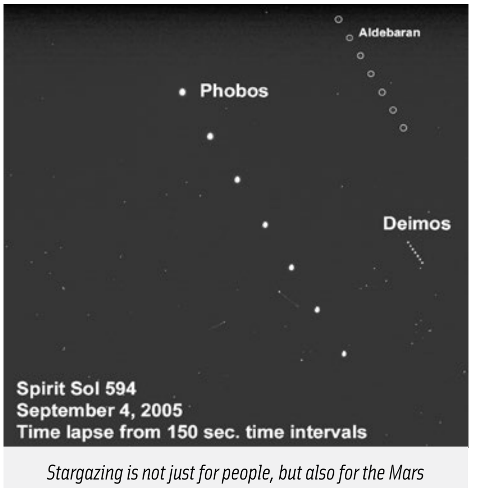
Wanderers in the Neighborhood

PHOBOS AND DEIMOS

"Fear and Dread in Space" may be the title of a future sci-fi horror movie, but it also describes the two moons of Mars, Phobos (fear) and Deimos (dread). They were discovered in August 1877, during a particularly close perihelic opposition when Mars reached a brilliant magnitude –2.86, almost its maximum brightness of –2.94. American astronomer Asaph Hall III was in charge of the 26-inch refractor at the U.S. Naval Observatory. He was observing this close approach when he noticed a "faint star near Mars" on August 11. From its motion, he identified it as a small moon of Mars, which eventually was named Deimos (systematic designation **Mars II**). Another discovery happened six days later, on August 17, when he found the slightly larger Phobos (systematic designation **Mars I**).

These two moons are tiny, with Phobos 14.0 miles in diameter and Deimos only 7.7 miles in diameter. They are not round, but irregular in shape, as would be expected from such small objects whose gravity is not strong enough to pull them into spherical shapes.

The names for these two moons were suggested by Henry Madan, science master at Eton in England. He referred to the Greek epic poem, the *Iliad*, where Ares (the Roman god Mars) calls forth Dread (Deimos) and Fear (Phobos); however, the original spellings were Phobus and Deimus. Curiously, Mars's two moons were anticipated in Jonathan Swift's *Gulliver's Travels,* where the Laputian astronomers reported their discovery of two moons more than a century before Asaph Hall found them. Possibly influencing Swift, Voltaire's short story "Micromégas" (1752) has an extraterrestrial visitor referring to the two moons of Mars.

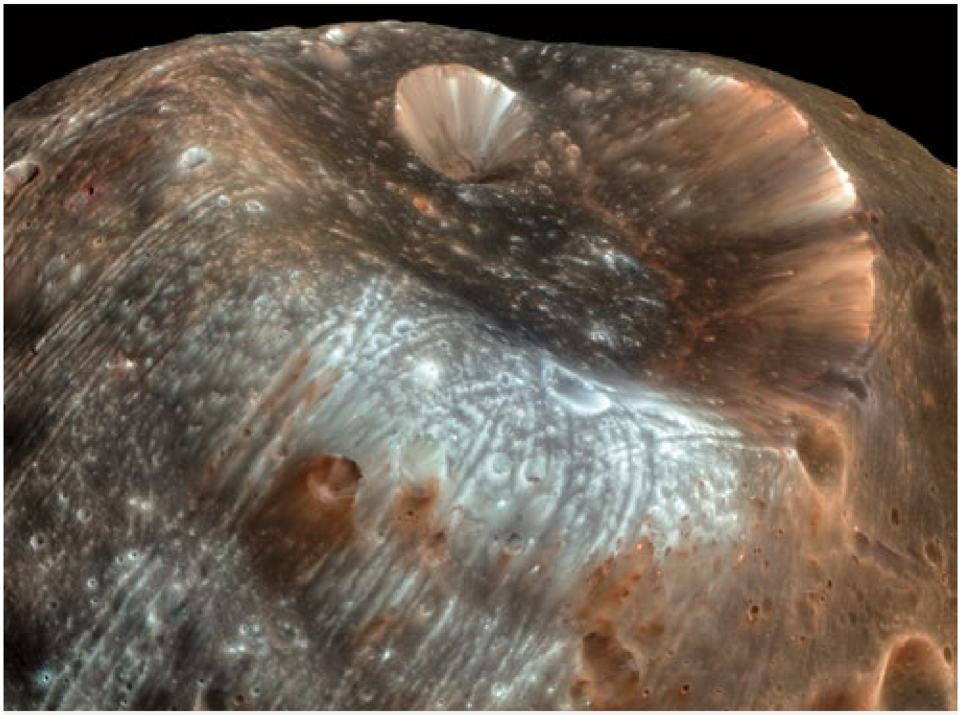


Stargazing is not just for people, but also for the Mars Exploration Rover Spirit perched atop "Husband Hill" in Gusev Crater on September 4, 2005. Taking images every one hundred fifty seconds, the motion of the fast-moving Phobos and the more distant, slower-moving Deimos are clearly visible. Phobos moves with retrograde motion toward the upper left, while Deimos and Aldebaran are moving toward the lower right. Aldebaran's motion is completely due to Mars's rotation, while the motions of Phobos and Deimos are due to Mars's rotation and their orbital motion. Image credit: NASA/JPL/Cornell/Texas A&M

mars.nasa.gov/mer/gallery/press/spirit/20050909a.html

These two small irregular moons are tiny in comparison to our Moon, but are comparable to the small moons of Jupiter and Saturn. The spectra of these moons are similar to C- and D-type minor planets, giving rise to the hypothesis that they are captured minor planets. While Earth recently acquired a temporary mini-moon, orbital mechanics does not provide a way for Mars to capture moons and bring them into circular, equatorial orbits.

The larger moon, Phobos, orbits Mars at a mean distance of 5,827 miles, much closer to the planet than Deimos. Being larger and closer, Phobos spans 12 arcminutes in the sky from the Martian surface. The eclipses it generates are all



A closeup view of Stickney crater, the largest crater on the Martian moon Phobos. Stickney crater has a diameter of 5.6 miles. The white area indicates fresher, newer material. The troughs and crater chains that appear to emanate from Stickney are actually formed from Phobos colliding with material ejected from Mars. The linear features running down the walls of the crater are landslides of material falling into the crater. Image credit: NASA/JPL-Caltech/University of Arizona
photojournal.jpl.nasa.gov/catalog/PIA10368

annular eclipses, since the Sun is 21 arcminutes across at the distance of Mars. Some of these eclipses have been observed by the Mars landers near the equator.

This orbit is only slightly inclined to the Martian equator at 1.093 degrees. It is also almost circular, with an eccentricity of 0.0151 (an eccentricity of zero is a perfect circle). Its low altitude causes it to complete an orbit every 7.66 hours, much faster than Mars's rotational period of 1.025957 Earth days. Here on Earth, we watch many artificial satellites move across the sky from west to east. Similarly, Phobos rises in the west, traverses the sky and sets in the east in just four and a quarter hours. Eleven hours after its first rise, it rises again, to repeat the cycle.

Phobos's low altitude means it is much further away at moonrise than when it is overhead. It is only 8.4 arcminutes across at moonrise. As it moves closer to the observer, it appears larger, reaching 12 arcminutes as it passes overhead. It then shrinks back down to 8.4 arcminutes across as it sets. It also goes through phases like our Moon, but the phase Phobos shows depends on the time of day at the observer's location, and observers at different locations will see different phases. Its low altitude keeps it from being seen from latitudes greater than 70.4 degrees.

While both moons always present the same face to Mars just like our Moon, that tidal locking is slowly lowering Phobos's orbit. Mars's gravity drags on Phobos reducing its orbital speed, bringing it closer in. Eventually, this tidal drag will rip Phobos apart when it gets within the Roche limit. The debris may form a ring around Mars before the pieces end up crashing into the planet. There are crater chains that are more inclined to the equator the older they are, indicating there might have been additional moons of Mars that have already gone through this process.

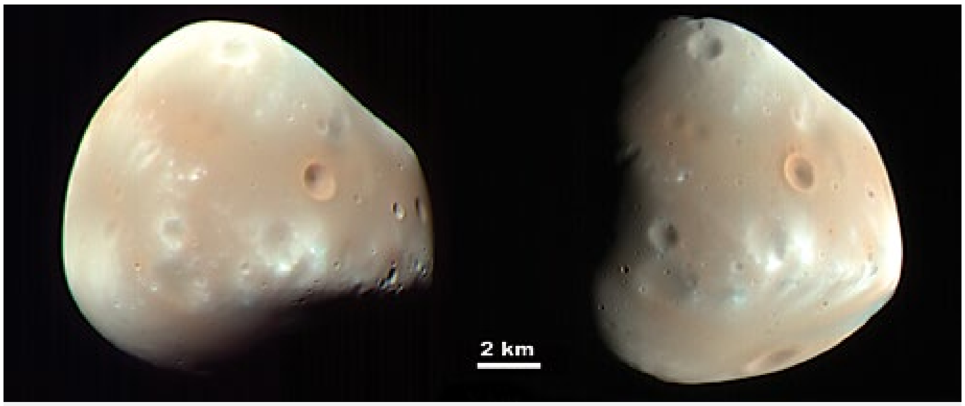
Deimos is three times further away from Mars than Phobos. Deimos's orbit takes 30.312 hours to complete, longer than Mars takes to rotate. This allows Deimos to rise in the east and set in the west like our Moon. The distance variation as it traverses the sky is much less than Phobos, so it does not change size greatly from moonrise to overhead. With its orbital period just six hours longer than Mars's rotational period, Deimos moves much more slowly across the sky than the stars do, allowing it to be visible for 2.7 days as it travels from east to west.

Deimos's smaller size and greater mean distance of 14,580 miles provides only a 2.5 arcminute disk in Mars's sky. Its eclipses are more like transits, since its angular diameter is only 2.5 times that of Venus as seen from the Earth. Mars landers have imaged these transits as well. Its higher altitude allows it to be seen up to latitude 82.7 degrees. Deimos's higher orbit allows Mars's gravity to slowly accelerate Deimos into an even higher orbit.

The surfaces of the two moons are heavily cratered. Deimos is substantially smoother as the regolith (sand and rock fragments) has partially filled in some of the craters. Only two of Deimos's features have names: craters Swift and Voltaire named for the two authors mentioned above. Phobos, on the other hand, has many named features. All of Phobos's names are either from astronomers who studied Phobos or were people and places from Jonathan Swift's *Gulliver's Travels*.

The largest crater on Phobos is named Stickney after Chloe Angeline Stickney Hall, wife of Phobos's discoverer, Asaph Hall. It was discovered in images from Mariner 9, the first spacecraft to orbit the planet. Stickney is 5.6 miles in diameter. Many of the grooves on Phobos were the result of boulders ejected from Mars rolling around on the surface of the moon.

The Japan Aerospace Exploration Agency



The surface of Deimos is much smoother than Phobos thanks to a blanket of regolith – powdered rock, sand, and dust particles composed of heterogenous material. These two images were taken by the HiRISE camera on NASA's Mars Reconnaissance Orbiter. They are of the same area, but were taken 5 hours and 35 minutes apart, allowing the Sun to be in the upper left in the left image and to the right in the right (later) image. Reddish areas have been exposed to the space environment longer than the bluer areas where there have been meteorite impacts or movement of the regolith. Image credit: NASA/JPL-Caltech/University of Arizona hirise.lpl.arizona.edu/deimos.php

The Indian Space Research Organization's Mars Orbiter Mission entered Martian orbit on September 24, 2014. After checkout, its Mars Color Camera began imaging the planet. One image taken toward the limb of the planet captured the larger moon Phobos silhouetted against the Martian surface. The thin atmosphere of Mars is the semitransparent layer just above the Martian limb. Image credit: Indian Space Research Organization

www.isro.gov.in/pslv-c25-mars-orbiter-mission/pictures-mars-colour-camera-mcc-onboard-india%E2%80%99s-mars-orbiter

(JAXA) has received approval to launch the Mars Moons Exploration (MMX) probe to visit Phobos, analyze the surface, and take samples of the moon to be returned to Earth. The launch is scheduled for 2024, with an arrival at Mars the next year. If everything goes as planned, we will have samples of Phobos to analyze in 2029.

—Berton Stevens

Deep-Sky Objects

NGC 6603

By the end of astronomical twilight during summer months, the constellation Sagittarius is rising above the southern horizon as viewed in the contiguous 48 states. Sagittarius hosts the center of the Milky Way Galaxy, so the constellation is exceedingly rife with galactic and globular star clusters, bright and dark nebulae, and uncountable colorful stars. From cities and bright suburbs, all that might be recognizable in the constellation are the eight stars that make up the famous Teapot asterism. But from dark regions without light pollution, the bright swath of the Milky Way, with the dark dust lane that parts the plane of the galaxy in two, blazes across the Archer and practically drowns out the Teapot.

The famous French astronomer Charles Messier discovered myriad nebulae and star clusters in Sagittarius, which he published in his famous catalog. As a comet hunter, Messier cataloged these objects so he wouldn't confuse them with comets that he might find. He ultimately discovered 13 comets.

On the night of June 20–21, 1764, Messier came across two star clusters in Sagittarius at declination –19°. He ultimately catalogued these objects as M23 and M25. In sweeping back and forth between these clusters, Messier observed a large region of nebulosity halfway between them. Although not a galaxy, nebula, or star cluster, Messier entered this patch of the Milky Way into his catalog as his 24th entry. He wrote this about his discovery of M24:

> *In the same night, June 20 to 21, 1764, I have discovered on the same parallel as the star clusters I have just been talking about and near the extremity of the bow of Sagittarius, in the Milky Way, a considerable nebulosity, of about one degree and a half extension: in that nebulosity there are several stars of different magnitudes; the light which is between these stars is divided in several parts.*

Today we know M24 as the Small Sagittarius Star Cloud. This cloud lies above the Teapot on the northern boundary of the constellation and should not be confused with the larger and brighter Large Sagittarius Star Cloud centered above the Teapot's spout.

Nestled within the Small Sagittarius Star Cloud is a small cluster of stars six arcminutes in diameter known as NGC 6603. This cluster contains the highest concentration of stars in M24. The cluster's magnitude is 11.1, fainter than any object in Messier's catalog. This might be why Messier did not find NGC 6603.

NGC 6603 is located three degrees west and 40 arcminutes north of M25. If M24 is divided into two lobes, with the north lobe the brighter, NGC 6603 lies on the southwest edge of the brighter lobe. NGC 6603 can be seen in a 4-inch telescope, but an 8-inch or larger telescope is required to resolve it into scores of stars and see the hues of red, yellow, and blue.

NGC 6603 has multiple linear and arcing chains of 11th and 12th magnitude stars. Just north of the cluster is a beautiful chain of four alternating red and blue stars between magnitude 10 and 11 with brighter colorful stars scattered throughout that region.

The accompanying image of NGC 6603 was taken with a 10-inch f/6.9 Newtonian with a SBIG ST-2000XCM CCD camera. The exposure was 30 minutes. In the image north is up and east to the left. The bright red star on the south side of the cluster is cataloged as SAO 161294 and is magnitude 7.4. The bright yellow star on the lower left of the image is magnitude 7.7 whereas the brightest blue star near the top of the image, one-third of the way from left to right, shines at magnitude 9. The faintest stars in the image are dimmer than magnitude 18.

NGC 6603 was discovered by John Herschel on July 15, 1830. The cluster is estimated to be from 10,000 to 12,000 light-years away. The cluster is often mistaken for M24, but Messier made it clear in his notes that M24 was the larger star cloud. →

NGC 6603 and M24 are part of the Norma Arm of the Milky Way, an interior spiral arm to the Sagittarius-Carina Arm lying 5000 to 7000 light-years away. The dark nebulae around M24 are located in the Sagittarius-Carina Arm, which also contains the Lagoon, Trifid, and Omega Nebulae.

During warm, clear, late summer nights when panning the Milky Way for those myriad Messier objects, take some time in M24 to spy the superb star cluster NGC 6603.

—Dr. James R. Dire
Kauai Educational Association for Science and Astronomy

How to Submit Articles & Photos to the *Reflector*

This is *your* magazine, and we welcome your submissions of articles and photos. The "From Around the League" section is the perfect place to let the rest of the League know what your club is up to. "Gallery" is the place to publish your best astrophotos where the whole league membership will see them. Have you made a presentation to your club about some astronomical topic? Why not expand it into an article for the magazine?

Articles may be submitted as Microsoft Word or just about any kind of text document attached to an email, or even as the body text of an email. Send them to editor Kris larsen at ***larsen@ccsu.edu.*** Kris and assistant editor Kevin Jones read all submissions and may provide editorial help. Of course your submission must be relevant and scientifically accurate, and we will reject items that are not. Short items of interest may be published as letters to the editor. If your submission includes photos,it is best to compress article and photo(s) in a .zip archive for emailing. If the total size of the package exceeds 10 MB it's advisable to break it up into multiple emails. See deadlines on Page 4.

Photos should be at least 300 pixels per inch of width in print.

← **725 PIXELS** →

This means that a photo which will print one column wide should be *at least* 725 pixels wide; two-column width would be 1500 pixels, and a full page upwards of 2200 pixels wide. Photos must be either your own, specifically permissioned under a written license, or in the public domain, and must be credited. Parental permission is required if minors appear in a photo. If you have any question about photo submissions to the magazine, contact our designer, Michael Patterson, at ***michael.patterson@stellafane.org.***

Gallery section and potential cover photos should be submitted to photo editor Dan Crowson at ***photoeditor@astroleague.org.***

Advertising in the *Reflector*

This magazine is a great place to promote your astronomy-related business, product, or event. The audience could not be more targeted, and our rates are far lower than the national astronomy magazines, both absolutely and in terms of cost per thousand readers—even before the generous discount for Astronomical League members.

For a rate card and other information, contact ad representative Carla Johns at ***advertising@astroleague.org.*** Ads must meet the resolution standards for photos detailed just to the left.

From Around The League

2020 STELLAFANE CONVENTION AND NERAL MEETING CANCELLED

As we were about to go to press in early May, Springfield Telescope Makers president Jeff Lowe announced that due to the C-19 pandemic the annual Stellafane Convention will not be held this year. The NERAL business meeting, traditionally held during the convention, is also cancelled.

Attendees at the first Stellafane Convention

The first Stellafane Convention was held in July 1926 and was attended by 29 people. It has been held every year since, except during and just after the Second World War. Around a thousand amateurs generally attend.

The next Stellafane Convention is planned for August 5–8, 2021. For more information, visit *stellafane.org/convention*.

SPYGLASSES FOR PUERTO RICAN CHILDREN

Members of the Escambia Amateur Astronomy Association based in Pensacola, Florida, aided in constructing 100 spyglasses for the children of Puerto Rico. In the wake of a series of natural disasters, many children on the island not only remain out of school but are still living in shelters. The project was spearheaded by Wayne Wooten and Merry Edenton-Wooten, who designed the inexpensive STEM Spyglass that can be built for about $20 out of surplus parts with little machining. Distribution throughout earthquake-damaged Ponce was done in coordination with Astronomers Without Borders and Ciencia PR, a U.S.-based nonprofit organization that advocates for science in Puerto Rico. Observing guides were provided in Spanish and English. For more information on the design of the spyglasses, see *www.facebook.com/media/set/?set=oa.10156000093404302.*

YOUR ASTRONOMICAL LEAGUE IS GIVING AWAY UP TO ELEVEN LIBRARY TELESCOPES!

Through the vision of the Horkheimer Charitable Fund, the Astronomical League is again offering a free Library Telescope to a lucky Astronomical League club in each of the ten AL regions and to a Member-at-Large.

This wonderful program consists of an Orion 4.5-inch StarBlast Dobsonian or a Zhumell Z114 (or equivalent) and a Celestron 8–24 mm zoom eyepiece (or equivalent), and a name plate commemorating the late Jack Horkheimer. The value of this opportunity is approximately $300; the potential of the program is enormous.

Submit your completed entry form electronically so that the Astronomical League national office receives it by July 14, 2020. If mailed, the entry must be postmarked no later than July 10, 2020. The winning entry for each region will be selected July 18, the date when ALCon 2020 was scheduled. Full details of this wonderful program can be found at *astroleague.org/content/library-telescope-program.*

The Library Telescope Program is a great club project, one that brings members together while benefiting their community. Indeed, it is the perfect outreach program!

MILLSTREAM ASTRONOMY CLUB AWARDS ANOTHER LIBRARY TELESCOPE

2019 saw the presentation of a second library lending telescope in Findlay, Ohio. Pictured at left presenting the scope is J.T. Senghas, the vice president of the Millstream Astronomy Club and AL Great Lakes Region member. At right is Jeff Winkle, the director of the Findlay Hancock County Public Library. This scope was won by the Millstream Astronomy Club of Findlay in 2018 and prepared by club president Steve Rice. It was one of ten scopes donated that year by the Horkheimer Charitable Fund and distributed by the Astronomical League. It is now loaned to library patrons on a weekly basis.

In 2017, a similar presentation was made of the first library telescope prepared and supported by the Millstream Astronomy Club. This one had been purchased in May 2017 by the volunteer organization Friends of the Library. This decision, spearheaded by J.T.'s wife, Audrey Senghas, was inspired by the Horkheimer Charitable Fund donations of these Orion StarBlast reflectors.

STIMULATING INTEREST IN ASTRONOMY THROUGH A TOOTSIE ROLL TELESCOPE

Neil (left) and Jai Shet with their homemade scopes

We have long been fascinated with astronomy and enjoy photographing the night sky. To further our passion for astronomy, we decided to build our own telescopes. We volunteer at schools during astronomy outreach events to share our knowledge of astrophotography and telescope making. Our hope is that it will inspire other kids to build their own telescopes and take an interest in the night sky.

We decided to make a refractor because it was easier to construct than a reflector. Being homeschooled high school students, we found all the materials right at home. We used a Tootsie Roll canister for the main tube. How we acquired the canister is an interesting story. We had traded it for tickets at a prize redemption booth at an arcade. We could have exchanged 200 tickets for either a hundred Tootsie Roll candies or for one large Tootsie Roll canister coin bank. Being kids, we assumed the canister would have one giant

Tootsie Roll candy in it and thought that was a better deal. To our disappointment, we found the canister had only twenty bite-sized Tootsie Rolls inside, and we felt cheated. Nevertheless, we decided to use it as a coin bank. A year later, in 2018, as we started building the refractor, we realized the Tootsie Roll canister was the perfect tube for the telescope. It was better suited for actively gathering light instead of passively collecting coins and dust.

The Tootsie Roll telescope was such a success that it inspired us to build a reflector telescope, which was more challenging. It was not surprising that we once again found all the materials at home. This time we used a salt container for the telescope as the concave mirror from a makeup kit we had at home fit perfectly inside. It took a lot of planning to make the reflector, including drawing elaborate diagrams, constructing the support for the secondary mirror, and accurately aligning the different elements of the telescope. We even constructed a steady mount for the telescope. Our two telescopes together made a sweet and salty duo.

In addition to building telescopes, we also have a passion for photographing the night sky. We use our camera and lenses, along with a tracking mount, to capture stunning photographs of deep-space objects. We have photographed the Moon, nebulae, star clusters, meteors, and the

Milky Way. To photograph these objects, we have traveled to dark-sky places in Texas, New Mexico, Utah, and California, to name a few.

Our experiences have motivated us to inspire others to make their own telescopes. We volunteer at various schools to share our passion for astronomy in outreach events called Astronomy on Wheels (AOW) organized by the Fort Bend Astronomy Club in the Houston area. Since building

Photo by Jai and Neil Shet

our telescopes, we have presented at many schools, including elementary and middle schools. We have shared our astrophotography pictures in presentations and inspired kids of all ages, as well as adults, to make their own telescopes using materials they can find at home. We have also developed a telescope-building kit to help kids gain hands-on experience in building a telescope.

We hope to continue spreading the awareness of astronomy among school-age kids and their parents. It also motivates us to continue exploring the wonders of astronomy through our telescopes and cameras. We have enjoyed sharing our experiences and skills with others, and nothing is more satisfying than seeing the reaction of a little kid after looking through a homemade telescope. This is our small step to furthering the field of astronomy.

Jai Shet and Neil Shet
Fort Bend Astronomy Club

2020 Officer Candidate Bios

CARROLL IORG
2020 Candidate for Astronomical League President

I am a candidate for president of the Astronomical League.

I am thankful for the excellent service from John Goss, Bill Bogardus, and Ron Kramer, our past three presidents. My goal is to build on the solid foundation these three provided. I have served as vice president of the Astronomical League since November 2018, after the untimely death of Bill Bogardus.

Within the past year, our webmaster, Vern Raben, retired, and we now have a new webmaster, John Martin, firmly in place. We are also lucky to have in place our new *Reflector* editor, Kristine Larsen. So with all the changes that have occurred, we are very close to being back to normal operations. Thanks to all for your patience during these transitions.

During my first tenure as League president (2010–14), we made communication, both in person and electronically, a priority, striving to make contact with our members across the country. I would like to extend this initiative, particularly by scheduling electronic town halls and possibly establishing a YouTube channel. I am a longtime member and former president of the Astronomical Society of Kansas City.

I believe it is essential that we boldly pursue additional grant and sponsorship opportunities. These opportunities will allow us to provide new programs and services to our membership.

The League has made positive strides with international astronomy groups. Besides adding astronomy societies as international members, I hope to pursue the ideas of co-hosting international ALCon conferences, possibly with the Royal Astronomical Society of Canada.

I would appreciate your support of my candidacy for president.

DR. JAMES DIRE
2020 Candidate for Astronomical League President

After starting a paper route at age 12, one of my first purchases was a 60 mm refractor, which gave me good views of lunar craters and let me follow the moons of Jupiter and see Saturn's rings. I was hooked.

I attended the University of Missouri in Kansas City and joined the Astronomical Society of Kansas City, eventually serving as their president my last year in college (1981–82). I can honestly say I learned more practical astronomy as a member of this amateur club than in any of my undergraduate classes!

After leaving Kansas City, I continued to observe with local astronomy clubs: the Central Florida Astronomical Society, the Baltimore Astronomical Society, the Astronomical Society of New Haven, the Thames Amateur Astronomical Society, Cleveland County (North Carolina) Astronomical Society, the Las Vegas Astronomical Society, the Peoria Astronomical Society, and the Kauai Educational Association for Science and Astronomy.

While president of the ASKC, I initiated the Powell Observatory project, which houses a 30-inch (0.75 m) Newtonian. Also, I constructed and served as the initial director of the Coast Guard Academy Astronomical Observatory in Stonington, Connecticut, which houses a 20-inch (0.51 m) Ritchey-Chrétien Cassegrain telescope.

I earned an MS in physics from the University of Central Florida and an MA and PhD from The Johns Hopkins University, both in planetary science. For many years early in my career, I was a professor of physics and astronomy. Currently, I am the chancellor of Methodist College in Peoria, Illinois.

I have authored the Deep-Sky column in the *Reflector* magazine since 2010 and regularly contribute articles published in *Astronomy Technology Today.*

CHARLES E. "CHUCK" ALLEN III
2020 Candidate for Astronomical League Vice President

Chuck Allen is currently secretary of the Astronomical League and is a past League president (1998–2002) and vice president (1994–98). He is also a past Great Lakes chair (1991–98) and currently serves as regional Treasurer. Chuck founded the League's 28-year-old National Young Astronomer Award in 1991, chairing the program for seven years. He received the G. R. Wright Award for service in 1998, holds the League's Master Outreach Award with over 900 hours logged, and is a League Master Observer, earning his Master–Silver certificate in 2019. His imaging won top awards at ALCon, Apollo Rendezvous, and NIAG competitions in the 1990s.

Chuck is past president of the Louisville Astronomical Society (1991–94) and current program director for the Evansville Astronomical Society. In 1992, he co-founded Stars-at-the-Beach at Patoka Lake, Indiana, an event drawing hundreds of visitors for 29 summers. He also served as lead judge in Earth and space science for the Intel International Science and Engineering Fair (1995–2001) and as a director of the Louisville Regional Science Fair.

Chuck graduated from Duke University in 1970, served as a U.S. Air Force officer (1970–74), and graduated from the University of Kentucky College of Law in 1977. He was a partner in Kentucky's largest law firm for 27 years.

An amateur astronomer since age 7, Chuck began giving public programs at age 12. In 1965, he attended his first ALCon in Milwaukee, received the League's Advanced Junior Certificate, and became president of the Louisville Junior Astronomical Society.

IN MEMORY OF ALAN RIFKIN 1950–2019
NERAL Chair • Inventor • Astronomer
Stellafaner • One-of-a-Kind Human Being
"May the winds always favor your tail."

Double Star Observing: Expand Your Toolbox

What makes double star observing rewarding? Is it the ability to use almost any kind of telescope, or even binoculars? The flexibility to observe on moonlit, partly cloudy, or otherwise crummy nights from light-polluted locales? Is it the often-spectacular contrast in color, magnitude, or separation? Success in splitting a close pair or in seeing a far-dimmer companion? The thrill of estimating a position angle that agrees reasonably well with its published value? Realizing that double star observing has developed your skill set? If you answered "All of the above, Jon!" give yourself a blue-and-gold double star! Double star observing is forgiving, flexible, occasionally frustrating, and frequently even fulfilling and fun.

The Astronomical League's Double Star Program, which invites League members to locate and observe 100 of the finest double and multiple star systems, made me think differently about *all* my observing. It effectively expanded my "toolbox." Now, when I observe an elongated galaxy, I want to record the direction of the elongation: is it north-south? Northwest-southeast? Now, when I want to identify which galaxy in a close pair is which, I want to know and report that one is "5–10 arcminutes west" of the other. It was an "aha!" moment to realize that, especially for writing complete astronomical descriptions, *directions matter.*

Unlike some AL Observing Programs, this intermediate-level exercise demands that we understand directions, and specifically, how to mark the *cardinal points* (north, south, east, and west) on a simple sketch of the stars. Too often, even experienced observers are confused about which direction is which in the eyepiece. However, finding west is easy. Turn off any tracking, center a star, and watch it drift out of view. The drift direction is always west. Equipment will dictate the direction of north. For a Newtonian reflector, north is 90 degrees *counterclockwise* from west. For a Schmidt-Cassegrain or a refractor—either one equipped with the typical star diagonal—north is 90 degrees *clockwise* from west.

A challenge of the AL program is the requirement of a sketch that (1) clearly shows which star of a pair is the brighter, or "primary," star; (2) accurately marks at least two cardinal points, for example, west and north; and (3) demonstrates reasonably good agreement (that is, within 10–20 degrees) with the published position angle (PA). I recently revised the League's observing log sheet and intentionally omitted any marking for cardinal points. Sketch what you see, note the drift direction to mark west and north, then compare your estimated PA with the published value.

So how do we estimate the position angle? On your sketch of the star pair, with the primary star at center, imagine a solid line from the primary star to north. Imagine a dotted line connecting the stars. Now trace an arc from the solid line to the dotted line *from north to east.* What is the angle? When the dimmer (secondary) star is due east of the primary star, the PA is 90 degrees; when the dimmer star is due south of the primary star, the PA is 180 degrees, and so on. Other angles can be estimated. When the stars have equal magnitudes, compare both possibilities, and report the angle that has a lower value. When the stars are well separated, the PA is more easily judged; estimating PA for a close pair can be challenging.

A thorough descriptions should include, in addition to the usual suspects (equipment, magnification, location, date, time, seeing, and transparency), any colors seen, the relative difference in magnitudes, how well separated the stars are, and whether the separation and your estimate of the position angle agree reasonably well with the published values. The AL's observing list includes this information. In *Double Stars for Small Telescopes,* Sissy Haas uses simple sketches to illustrate differences in separation such as "figure 8," "kissing," up to "super wide."

Although color should help us identify large temperature differences, many uncontrolled variables could impact color perception, including the equipment used, weather conditions, whether the stars are near the horizon or the zenith, and who is observing.

As a program coordinator with access to "big data," I performed a quick, non-scientific survey in which I compiled color results from ten different observers of the eleven well-separated (10–35 arcseconds) "showcase" pairs shown in the accompanying table. The targets, which included Albireo, Polaris, and Iota Cancri, are some of the best double stars in our night sky. The results surprised me because I expected more variation in color perception. In row C, I indicated a consensus of this group of anonymous AL members, or what you might expect to see. The minor differences among observers are (at least from this scientist's vantage) "within experimental error." Row 10 shows colors from the Haas reference.

I hope this article whets your appetite to observe double stars and submit your observations for a pin and a certificate. Or perhaps to record, for the first time, double star observations of astral treasures you've long appreciated. But what I really hope is that your observation of double stars, and your now-heightened attention to directions and position angles, will expand your "toolbox" and change the way you think about *all* your observing. ✷

—Jon Schuchardt
Double Star Observing Program Coordinator

REPORTED COLORS OF DOUBLE STAR PAIRS

	ψ1 Psc	λ Ari	γ And	α UMi	η Per	Σ 331	19 Lyn	ι Cnc	β Cyg	δ Crv	8 Lac
1	BL-WH/BL-WH	YEL-GRN/IVORY	OR-RED/BL	YEL-WH/BL	RED-OR/BL	BL-WH/WH	WH/GRN-WH	GOLD/BL	GOLD/BL	BL-WH/BL-WH	BL-WH/WH
2	WH/WH	FAINT YEL/WH	LT. OR/BL	WH/WH	WH-OR/BL	WH/WH	WH/WH	YEL/LAVENDER	LT. OR/LT. BL	WH/GREY	WH/WH
3	BL/GOLD	WH/WH	YEL-GOLD/BL	YEL/WH	GOLD/BL	WH/WH	WH/BL-WH	YEL-OR/BL	GOLD/BL	YEL-WH/WH	WH/WH
4	WH/WH	WH/RED	YEL-OR/BL-WH	BL-WH/WH	OR/WH	WH/BL	WH/WH	YEL/BL	OR/BL	BL-WH/RED	PALE YEL/BL
5	WH/WH	YEL/BL	NOT REPORTED	WH/BL	YEL/BL	YEL/BL	BL-WH/BL-WH	NOT REPORTED	YEL/BL	WH/WH	WH/WH
6	WH/WH	YEL/WH	OR/WH	WH/BL	OR/WH	YEL/BL-WH	BL/YEL	YEL/BL	OR/BL	WH/YEL-OR	YEL-WH/YEL-WH
7	WH/WH	YEL/WH	YEL-WH/BL	WH/WH	WH/BL	WH/WH	WH/WH	YEL/BL	YEL/BL	WH/WH	WH/WH
8	WH/WH	BL/WH	YEL-OR/BL	WH/WH	OR/WH	YEL-WH/WH	WH/WH	YEL/BL	OR/BL-GRN	WH/WH	WH/WH
9	AQ/AQ	WH-GOLD/PALE GRN	GOLD-YEL/BL	WH/BL	GOLD/BL	WH/BL-WH	BL-WH/BL-WH	GOLD/BL	GOLD/BL	WH/PALE BL	AQ/AQ
10	YEL/YEL	WH/SILVER	OR/DEEP BL	AMBER/GREY	APRICOT/COBALT BL	YEL-WH/BL-GRN	WH/WH	YEL/ROYAL BL	OR/ROYAL BL	YEL/GREY	WH/WH
C	**WH/WH**	**YEL/WH**	**YEL-OR/BL**	**WH/BL**	**OR/BL**	**WH/BL-WH**	**WH/WH**	**YEL/BL**	**OR/BL**	**WH/WH**	**WH/WH**

Format is A/B where A = reported color of primary star and B = reported color of secondary star. WH = white; BL = blue; YEL = yellow; AQ = aqua; GRN = green; OR = orange. Rows 1–9 contain reports from different AL observers; row 10 contains observations from S. Haas, Double Stars for Small Telescopes *(2006). Row C shows group "consensus" results.*

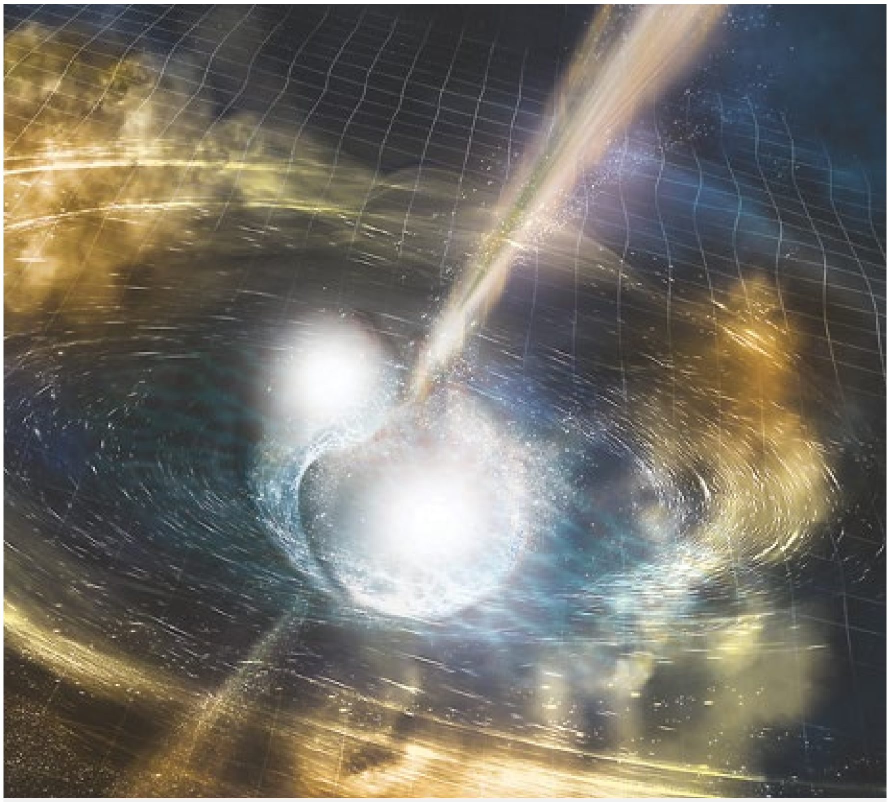
The Elements of Surprise

THE NEUTRON STAR MERGER OF GW 170817

By Dave Tosteson

The most anticipated eclipse of all time was eclipsed by an event that shook the world. That surprise was studied by more astronomers than any in history, vindicated Einstein, explained a long-standing puzzle in theoretical physics, and revealed the origin of most elements on the periodic table. But it was kept secret for months. Those of us basking in the dark were kept in the dark. Our chance to see something that had never been seen before was gone, never offered, and no one knows how long it will take to get another.

The *Great American Eclipse* of August 21, 2017, had been predicted for a long time. Solar eclipses occur in a seemingly random but very foreseeable way, and none had crossed the entire continental United States in nearly a century. There had not even been a touch of totality for the previous thirty-eight years in the lower forty-eight. In 1979, I was attending the University of Minnesota but was not yet interested in astronomy. Friends asked me if I wanted to travel to Winnipeg to see totality, but I turned them down. Who would travel so far just to see a little more darkness? After all, Minneapolis was going to be *almost* as exciting, right? Big mistake. Nature would get its revenge by enticing me to travel all around the world in later years to chase these shadows and the incomparable experience of witnessing the Sun's photosphere fully blocked by the Moon. All previous total eclipses I had viewed were marked by the uncertainty of clouds, with half requiring last-minute changes in location to see them. Little could anyone imagine that something was occurring just as millions were gathering for totality that would overshadow its darkness. But that event remained a secret, not announced to the public at the time, so the opportunity for amateurs to observe this unprecedented event did not occur.



Artist's illustration of two merging neutron stars. The rippling space-time grid represents gravitational waves that travel out from the collision, while the narrow beams show the bursts of gamma rays that are shot out just seconds after the gravitational waves. Swirling clouds of material ejected from the merging stars are also depicted. The clouds glow with visible and other wavelengths of light. Credit NSF/LIGO/Sonoma State University/A. Simonnet

In 1915, Albert Einstein published his *general theory of relativity* and the worlds of physics and astronomy were set on their heads. This was a revolutionary shift in thinking comparable to the discoveries of Copernicus and Galileo. Its 1919 confirmation during a total solar eclipse, where the exact deflection of starlight by the Sun's gravity was explained, is a poignant link to what occurred a century later. Among the many predictions of relativity is the production of gravitational waves in specific patterns as massive bodies orbit each other. The denser they are, the stronger the energy held within the waves, and the densest things we know are black holes and neutron stars. When two orbit one another the energy lost in wave production causes the orbits to inspiral toward the barycenter of the system. The inevitable outcome is contact and merging of the two bodies. Theory predicts a specific pattern for this cosmic dance, and scientists wanted to build instruments sensitive enough to detect gravitational waves.

The LIGO Laboratory operates two detector sites, one near Hanford in eastern Washington, and another near Livingston, Louisiana. This photo shows the Livingston detector site. Credit: Caltech/MIT/LIGO Lab

In 1962, two Russian physicists outlined the concept of using laser interferometry to detect gravity waves. The idea is that the alternating compression and expansion of space-time caused by the waves could be measured, and the pattern of their strength and timing would reveal details about their source. The source's masses could be inferred, giving information about whether it was two neutron stars, two black holes, or one of each, since there is a bimodal mass distribution between the two types of bodies. The distance from Earth could also be obtained, independent of the visible light redshift usually used. Kip Thorne of Caltech is one of the scientists who worked for decades on getting this instrument built, and he was awarded a Nobel Prize in 2017 for his contribution to this project.

The *Laser Interferometer Gravitational-Wave Observatory,* or LIGO, does not look like a traditional telescope. It has mirrors, but they are not pointed at the sky. Shaped like an L with a building at its vertex, two 2.5-mile-long perpendicular pipes carry lasers that bounce back and forth between the mirrors. The precision necessary to detect the tiny effect of gravitational waves produced up to hundreds of millions or even billions of light-years away is almost beyond comprehension. The interferometer needs to detect distance changes much smaller than the diameter of proton: about one billionth the width of an atom. LIGO started observing in 2002, but nothing was detected and its operators realized they needed to upgrade the sensitivity of the instrument to capture these tiny fluctuations. In 2013 it was shut down, and in 2016 it reopened with ten times its previous precision. Almost as soon as it started looking it found two black holes orbiting and merging about a billion light-years away. Its new sensitivity was predicted to see more powerful black hole events to five billion light-years out. Merging neutron stars, which are much less massive, were thought detectable within a smaller range, out to a few hundred million light-years.

Since black holes contain no matter such as protons and neutrons, no electromagnetic radiation was expected when they merged. The only energy radiated for us to find was in gravitational waves. Neutron stars are different. These strange cosmic beasts hover on the brink of collapsing into themselves and are held up only by the quantum dynamical force called the Pauli exclusion principle. The neutron star stellar remnants (between the mass of our Sun that form white dwarves and the larger ones that make black holes) are generated when fusion ceases in these stars' cores. The majority of electrons and protons within the star combine to produce neutrons. The remaining electrons and protons near the surface, coupled with stellar rotation rates up to hundreds of times per second, produce intense magnetic fields and the collimated jets we see as pulsars. Binary neutron stars are of great interest not only for their gravity waves, but for their role in creating elements heavier than iron. An added bonus for amateurs is that their merging events, called kilonovae, can be visible in large reflectors.

The excitement for the total eclipse of August 21, 2017, was ramping up. I was asked a full forty-two months before the event if I would speak at the Astronomical League convention in Casper, Wyoming. That annual summer conference coinciding with the historic eclipse had been in planning for over five years. The usual attendance of two to three hundred people had swollen to a thousand. “Mr. Eclipse,” Fred Espenak of NASA, possibly the world's expert on these events, was scheduled to speak and hold workshops for the lucky attendees. As the days approached to where more accurate forecasts could be made, the weather looked to be clear for eclipse day. That was something I had never experienced, and my wife Monica and I were anticipating an eclipse without clouds. As chance had it, Jim Fox was attending ALCon and, unbeknownst to him, was receiving the AL's highest lifetime achievement award. He was AL president in the 1990s, and had started the group that would become the Minnesota Astronomical Society back in the 1970s. When I got into astronomy in a serious way in the mid 1980s, my first telescope was a 10-inch Dobsonian made by Jim.

The eclipse that was seen by millions of people across the country, and gave the ALCon attendees a perfect, cloudless view for just under two and half minutes, was not the most significant event in astronomy that week. Something that figuratively and literally shook the professional community had occurred four days before the syzygy that wowed us all. In the early Cretaceous Period around one hundred forty million years ago, when leafy trees and grasses were just emerging and the remote ancestors of current mammals were competing with (and mostly hiding from) the dinosaurs, two neutron stars were about to merge in a disturbed elliptical galaxy in the constellation of Hydra. Large galaxies interact in various ways, but if a medium-sized neighbor comes close but does not make a direct hit, gravitational resonances can occur which produce *shells* in the outer sections of the primary galaxy. The best example is NGC 474 in Pisces, where Hubble images show numerous shells, along with rings and streams of stars expelled by the presumed interaction with the smaller galaxy NGC 470 to its west.

On March 26, 1789, the most prolific discoverer of astronomical objects in history, William Herschel, sighted what we now call NGC 4993. This 13.3-magnitude galaxy is located 2.3 degrees west of Gamma Hydrae. It is a shell galaxy with an irregular core that resembles Perseus A and contained a pair of dying stellar embers that had likely been dancing toward each other for over a billion years. These stars' treks had taken them to the deadly years at the end of their lives. The wounded were about to be reborn in a conflagration of heavy elements that would enrich not only the space around them but, by their timing, creatures in a faraway time and place who were prepared to receive their gift of information.

At 12:41:04 UTC on 8-17-17 the first signal of this event was received at the Louisiana LIGO station, followed 3 milliseconds later by its partner in Washington State. The sine wave pattern of its detection lasted for 100 seconds, increasing in frequency and amplitude as the two neutron stars circled each other faster and faster, ending in a climax of energy as they merged. Reverberating gravity would affect the large-scale structure of this galaxy to tens of thousands of light-years, and all subatomic space for hundreds of millions.

Within a short time after the gravity-wave detection of this event, word went out to a number of observatories. From a history of premature announcements (dating back to 1958!), and the desire to be absolutely certain about such a momentous discovery, all involved parties agreed not to go public with their findings. They had to get it right the first time. Using data from Fermi, Integral, and the two LIGO observatories, along with the non-detection from the Italian gravity-wave instrument VIRGO (it was in its blind spot), researchers localized the event. The initial search area was large: about 28 square degrees, or 150 times the area of the full Moon. The race to identify the host galaxy was won by the team at Las Campanas Observatory in Chile, using the Swope 1-meter reflector.

Hubble Space Telescope images of the kilonova's visible light flare. The insets show the decline in brightness over 6 days in August 2017. Credit: NASA and ESA; N. Tanvir (U. Leicester), A. Levan (U. Warwick), and A. Fruchter and O. Fox (STScI)

They first saw visible light at 10 hours and 52 minutes after LIGO, and the IAU designated this source as AT 2017gfo. It took that long for the evolving ejecta to produce visible light. Because of the immense heat, it was about one magnitude brighter in the infrared, and peaked in the visible about three days after the event at magnitude 18.8, within visual range of 25-inch amateur reflectors. By five days after the LIGO trigger it had faded to magnitude 20 in the visual.

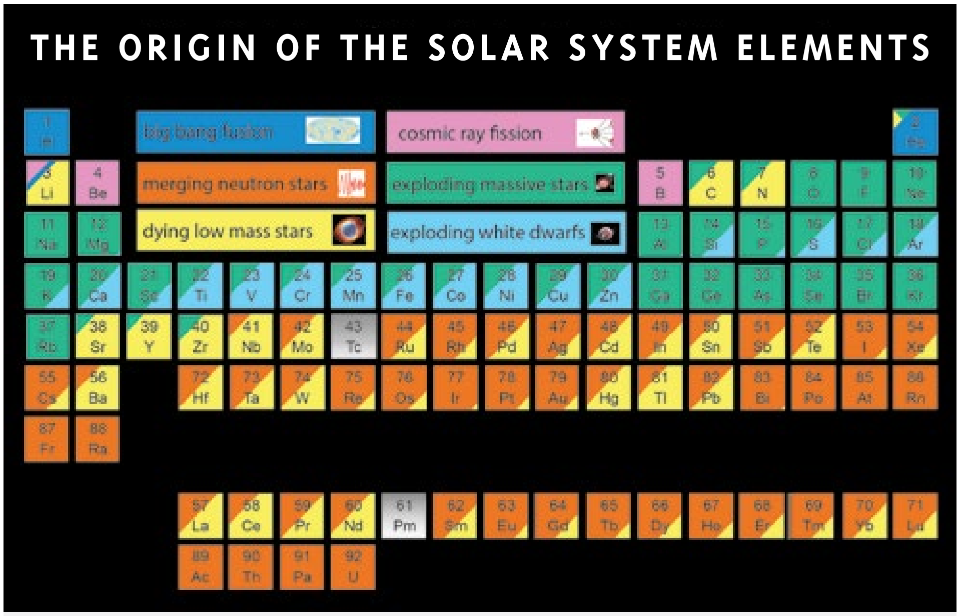
The timing of the different signals received indicates the sequence of production of the various types of messages. Gravitational and electromagnetic waves all travel at the speed of light. That speed can vary in different media through which the waves pass, and information about those media can be gleaned by studying arrival times. But the times of reception mostly indicated when they were produced within the evolving event. The gamma-ray burst came 1.74 seconds after the LIGO detection, and visible and infrared light took about half a day to be seen. Chandra found X-rays nine days later, followed by radio waves in the VLA sixteen days after LIGO.

This *kilonova* evolved as it cooled and expanded, changing from blue to red. Initially, its spectrum was featureless, but after a few days it showed expansion at about ten percent the speed of light. Brian Metzger of Columbia University coined the term kilonova in 2010 to predict the visual properties of the rapidly evolving remnant and ejecta of a binary neutron star merger. These intermediate brightness explosions are a thousand times brighter than novae, but only one to ten percent as bright as supernovae. His interpretation of the GW 170817 data offered that, in the first 1.5 seconds after the merger, rapid rotation allowed a hypermassive *magnetar* to form, whose energy affected and accounted for some of the findings in the earliest stage of that event. Through mass loss, rotational braking, and further production of gravitational waves, this highly magnetized, rapidly spinning neutron star quickly collapsed into a black hole, the final resting place of the original neutron star pair. Over the next few months this highly anticipated event would become the most studied object in the history of astronomy, as fully one third of the world's astronomers became involved. Over three thousand would analyze its historic information, and one paper counted among its 109 pages only five of actual data. The rest were the names and institutions of those involved. So much for "et al." Everyone wanted in on this.

Dr. Eliot Quataert of UC Berkeley has lectured on the processes and findings surrounding GW 170817, and I was fortunate to hear him speak at the University of Minnesota in October 2019. He gave their annual Karlis Kaufmanis lecture, named after a beloved professor from the 1960s and 70s from whom I took my undergraduate astronomy class. I was in Riga, Latvia, in the summer of 2019 and went to their university's astronomy dept, where Dr. Kaufmanis earned his degree. I wanted to see if anyone remembered or knew him, but no one was there! The whole department was on holiday from the end of July until September. Dr. Quataert revealed that a few percent of the mass of the original neutron star pair was converted into elements heavier than iron. But, even though this represents a relatively small fraction of their mass, Adrian Cho calculated in an October 2019 *Science* paper that over half the elements heavier than iron are produced in neutron star mergers. This occurs through the *r-process,* or rapid capture of neutrons by growing nuclei within the ejecta, an idea first proposed in 1957 by physicists Hans Suess and Harold Urey. In this context "rapid" connotes a speed not allowing beta decay of the nucleus before another neutron arrives.

For decades researchers have wondered about and debated the origin of the heavier elements in the periodic table. Those up to iron can be made in medium to large stars, and some heavier elements are known to be produced during supernova explosions. But scientists were not certain if all elements over the atomic number of 26 could be made in that manner and wanted hard data on what happened when neutron stars merged. The 2017 GW event appears to have made one hundred Earth masses of just gold and platinum alone. The uranium that helps power convection in the Earth's mantle, a key process aiding our biosphere in being conducive to the life that now flourishes within it, was likely made in a neutron star merger that seeded our region of the Milky Way long before the Solar System formed. There was theoretical speculation about where such exotic events may have occurred. The ultrafaint dwarf Reticulum II, discovered in 2015 by the Dark Energy Survey, is the only galaxy in its class to show enriched levels of certain heavy elements. From the three peaks of elements predicted and found within this galaxy, researchers concluded they originated in a neutron star merger maybe a billion years after the Big Bang. Using what is known as "galactic archaeology," these two events, GW 170817 and finding r-process enrichment in Reticulum II, have greatly advanced understanding of heavy element formation. One estimate for Earth is that it took about ten supernovae and neutron star mergers to account for the amounts and ratios of elements we measure within it.

Gamma-ray bursts (GRBs) come in two durations: long and short. Supernovae appear to explain the longer ones that last up to several hours. Short bursts, from ten milliseconds to two seconds, were long thought to occur from neutron star mergers, but no data had confirmed the hypothesis until GW 170817. A 2012 paper by Tsang in *Physical Review Letters* proposed that a resonance between the core and crust in the last few seconds before the merger shattered the crust and produced the gamma rays. One concern for researchers was that a 2013 paper noted that none of the short GRBs in the first eight and a half years of the *Swift* satellite's data were nearer than a redshift of 0.12, about 1.5 billion light-years away. Studying a neutron star merger across the electromagnetic spectrum at such great distances is difficult. Thus was the fortune and beauty of the 2017 event. At the relative proximity of 140 million light-years (z = 0.01), all the great telescopes such as Hubble, Chandra, and the VLA could get accurate data. Amateurs would have had a short window, just a few days, to try to see it in visual wavelengths with large instruments if it had been made public.



Graphic by Jennifer Johnson of the Sloan Digital Sky Survey. Credit ESA/NASA/AAS-Nova

In the third observing run of the GW observatories, just a few weeks after its latest upgrade in sensitivity where events were now expected weekly, a second neutron star–neutron star merger candidate was found on April 25, 2019. But this one was three to four times farther than GW 170817, at about 500 million light-years, meaning it was about two magnitudes fainter. At a peak magnitude of perhaps 21, this is beyond the visual limit of my 32-inch reflector. Amateurs are hoping to get a fresh chance at another kilonova close enough to observe visually, now that data are released immediately through the Gamma-ray Coordinates Network (GCN: *gcn.gsfc.nasa.gov*) and the LIGO alert system (*gracedb.ligo.org/latest*).

For an observer sitting equidistant from the equator and the north pole, the host galaxy of GW 170817, NGC 4993, emerges from the morning twilight in late November, but its declination makes it a difficult target at only ten degrees above the horizon. At month's end in colder December it doubles its height at 6 a.m., about the latest time it is visible before daylight intervenes. On the morning of December 22, 2019, only seven hours after solstice, I spotted this now-historic galaxy with my 15-inch reflector using a 9 mm eyepiece. Near the waning crescent Moon to the east with brilliant Earthshine, the slightly hazy sky barely revealed this low-hung fruit of the sky as it danced between trees on my southern horizon. Though its kilonova was long gone, it was still a thrill to visit this Outer Bank with my own eyes, the Kitty Hawk of neutron star mergers.

GALLERY

MEMBER ASTROPHOTOGRAPHS

ABOVE: Dan Crowson (Astronomical Society of Eastern Missouri) captured this image of M105 from Dark Sky New Mexico using an Astro-Tech AT12RCT with a SBIG STF-8300M.

BELOW: Jeff Lepp (Fort Bend Astronomy Club) captured this image of M51 using a Takahashi FSQ-106EDX IV with a ZWO ASI294MC Pro camera.

ABOVE: Jeffrey O. Johnson (Astronomical Society of Las Cruces) took this image of the Cocoon Nebula from his backyard in Las Cruces, New Mexico, with a Takahashi FS-60C refractor with a QSI 690wsg CCD camera.

BELOW: Don Taylor (Houston Astronomical Society) captured this deep image of central Orion over two years using a Takahashi FSQ-106 and a SBIG STI-1100M camera.

Finishing Unfinished Business

AFTER MORE THAN 90 YEARS, STELLAFANE FINALLY HAS ITS HALE SPECTROHELIOSCOPE

Michael Patterson, Matt Considine, and Dave Groski contributed to this article

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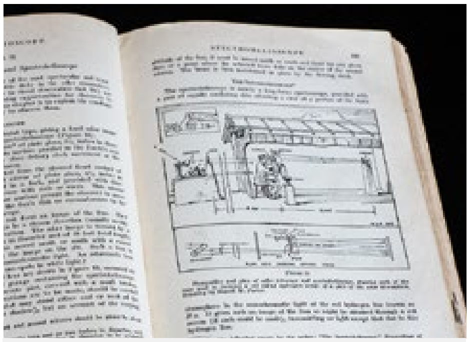
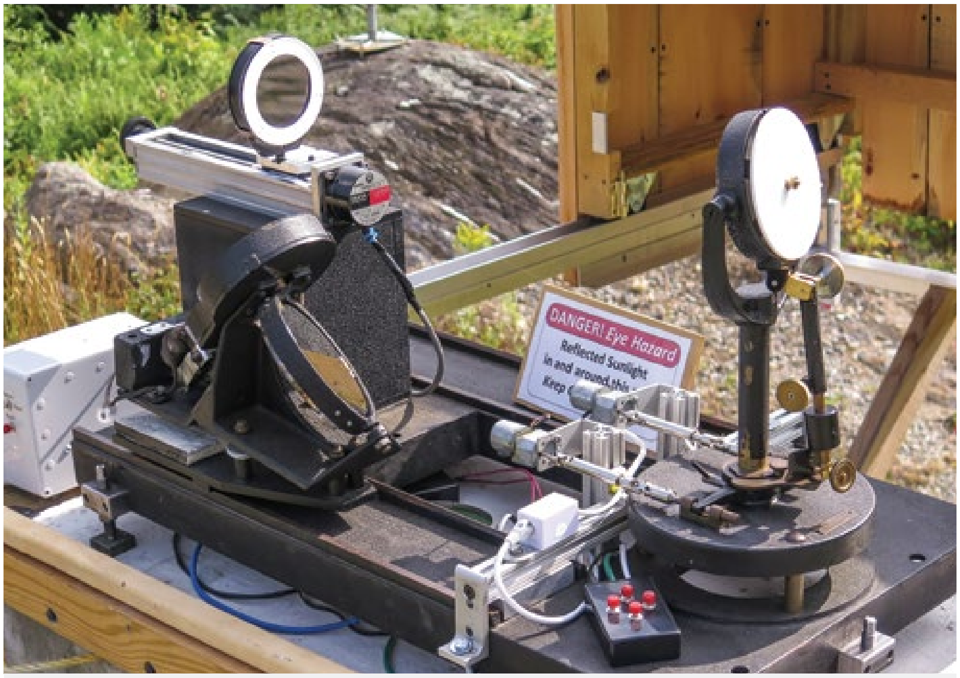


Russell W. Porter's sketch of the Hale Spectrohelioscope, as published in early editions of the first volume of Albert Ingalls' "Amateur Telescope Making."

It was a sweltering 95-degree July day in Philadelphia in 2006. After finally finding parking spaces blocks away, Matt Considine and Dave Groski made their way to the University of Pennsylvania physics building, and then to the roof, where the object of their quest dwelt forlornly in a little observatory with a roll-off roof. But the roof wouldn't roll off – the motor was broken. It must have been 125 degrees inside. The only light came from a tiny bulb in the back. Matt and Dave dripped sweat as they worked to unbolt the heavy parts of an old instrument in the hot, cramped darkness. It took a couple of hours of withering labor, punctuated by Dave's sprint to stuff more quarters into the parking meters, to get all the parts of the thing loose. There was no working elevator to the roof or the top floor, so they had carry the parts down from the roof to the top floor, where they could stack them on a little metal cart, and then inch the cart, with two or three hundred pounds of cast iron parts precariously stacked on it, down another flight of stairs to get to the elevator and finally to ground level. Dave stood on the sidewalk outside the building with the cart, sweat-drenched, bedraggled, and a little worried some cop would find him questionable, and waited while Matt ran to get his car. Matt drove up and double-parked, and they threw the parts of the spectrohelioscope into his hatchback.

So began the fulfillment of a plan that had its inception at Stellafane in the late 1920s, had been stymied by unfortunate circumstances in the 1930s, and had lain dormant for many decades until Matt, Dave, and other Springfield Telescope Makers revived it, almost a century later. Matt, who lived at the time north of Philadelphia, and Dave, who lives in Delaware, had met after Matt had posted to an ATM listserv looking for leads on blueprints for George Ellery Hale's invention. Dave responded, and the two struck up an email conversation about the unique instrument. They had each long been fascinated by Hale's elegant solution to the problem of producing an image of the Sun in a very narrow wavelength band, like the hydrogen-alpha or the calcium-K lines, well before narrowband interference filters had been developed. Even today the spectrohelioscope remains unique in that it can vary the wavelength it works with, from one end of the visual spectrum to the other. They'd read about it in Hale's article in early editions of Albert Ingalls' first "Amateur Telescope Making" volume, published by *Scientific American*.

The Simoni Observatory houses the spectrohelioscope at Stellafane. The roll-off "doghouse" in the foreground shelters the coelostat and objective singlet on their concrete pier. Light enters the building through the small tube protruding from the wall; the scanning prisms, slits, diffraction grating, and collimating and focusing mirrors are mounted inside on two concrete piers anchored in the bedrock below. The entire observatory is powered by batteries charged by the small solar panel in the background. Photo by Michael Patterson.



The coelostat assembly, and objective lens (top left) mounted on its new focusing slide. New electronically controlled actuators have been added to focus the lens and move the steering flat that directs sunlight through the objective. This would originally have been done with long metal rods reaching the operator's position. The objective is a singlet because only a very narrow wavelength band is observed; because of its long focal length, it must move through several inches to focus at different wavelengths. It is stopped down because it was found to have a turned edge. Photo by Sal LaRiccia.

Russell W. Porter, founder of the Springfield Telescope Makers, had contributed drawings for that article. Dave, who had previously built several solar instruments, had contemplated building a spectroheliоscope from scratch.

The 1931 Mt. Wilson Observatory Annual Report listed 23 locations worldwide that were building or buying spectrohelioscopes. The Report noted the addition of one at "the private observatory of G. W. Cook, Wynnewood, Montgomery County, [Pennsylvania]." Gustavus Wayne Cook was an avid amateur astronomer wealthy enough to have built his own observatory and furnished it with telescopes ranging up to a 28.5-inch Fecker reflector.

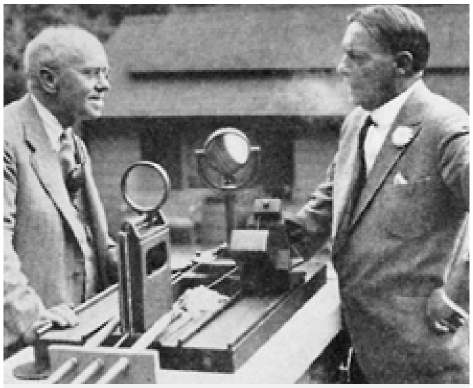
Very proud of the work that his spectrohelioscope produced, Cook hosted a visit by Porter to Philadelphia, a trip memorialized in an August 1932 *Scientific American* article entitled "One Very Happy Man." In the Stellafane clubhouse is an inscribed photograph taken next to the Cook spectrohelioscope, a memento of the relationship between Cook, Porter, and the Springfield Telescope Makers.

When Cook died, he left his instruments to the University of Pennsylvania, which merged them with its observatory to form the Flower and Cook Observatory. Apparently seeing little use, the instrument seems to have been lent to the U.S. Navy at one time for research purposes, as well as to La Salle University, where it was used as a spectroscope. When it came back to Penn, it was installed at the top of the physics building and also configured as a spectroscope. That twist of fate – that it was not returned to the Flower and Cook Observatory – seems to be why the instrument survived that observatory's demise in 2007.

Matt Considine has a strong interest in astronomical – and Stellafane – history, and had been trying to track down a surviving spectrohelioscope, or at least blueprints, for some time. He had contacted most of the institutions listed in the 1931 report with little luck: the instruments were long gone and nobody had blueprints. The only surviving instruments seemed to be at Penn and at Wellesley College. He made contact with staff at Penn, and traveled with Dave to Philadelphia to see the instrument. Both were thoroughly familiar with the principles behind it and could see that it was mostly intact. Only the rotating prism armature, one slit, a support structure for the singlet, and some control rods were missing. Eventually Penn decided to "de-accession" the instrument, into a dumpster if necessary. They called Matt and told him that if he wanted it, to come and get it. Matt called Dave, and off they went to Philly to rescue it.

–2–

Soon after moving from Vermont to California in 1929 to work with Hale on the 200-inch telescope, Russell W. Porter began a set of illustrations for use in Hale's four-part article "The Spectrohelioscope and Its Work" in *The Astrophysical Journal*. This article followed a 1926 article describing Hale's first spectrohelioscope, and it showcased Porter's visualization skill, including an early example of the "cutaway" drawings for which he would become known on the Palomar project. To further his broader goal of having the sun under constant visual observation to watch for solar flares, Hale wanted his spectrohelioscopes to be "of a cost sufficiently low to render them widely available." Mount Wilson offered blueprints, and Howell & Sherburne, a Pasadena instrument shop, fabricated parts. Gustavus Cook purchased his instrument from Howell & Sherburne.



Russell Porter (left) and Gustavus W. Cook discussing Cook's spectrohelioscope. Photo by James Stokely.

Russell Porter was clearly enamored of the potential of the spectrohelioscope, and wrote to the Springfield Telescope Makers:

> *"Quite a little of my time is taken up with Dr. Hale's spectrohelioscope, which as most of you know, is only a contrivance to watch the changing spots and prominences on the sun. And while it is a remarkable little instrument, all the awe and mystery it had for me is gone now that I have become familiar with it. We shall surely have one in Springfield where you can see those enormous plumes around the spots changing their shapes from hour to hour. We can use either form, vertical with the windmill tower at Stellafane or down on the ground horizontally."*
>
> (*Springfield Reporter*, February 28, 1929, p. 5)

The club became engaged, and acquired blueprints and started fabricating components in 1930. Porter provided the all-important diffraction grating, and the club began thinking about the selection of a site and construction of an observatory. They hoped to have the instrument operational in time for the August 31, 1932, eclipse, the path of which would pass through New England.

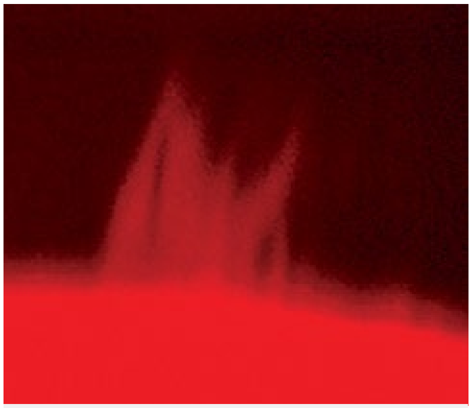
Parts fabrication seems to have lagged, however, and Henry Prescott, an amateur astronomer in Wells River, Vermont, borrowed the unused grating to complete his own version of the Hale spectrohelioscope. While photographs of it exist, the instrument itself is long gone; a house fire in the mid-1930s destroyed it, including the Springfield Telescope Makers' grating.

Even with the grating gone, meeting minutes suggest that club members sporadically worked on parts for a spectrohelioscope through most of the 1930s, and one prosperous member offered to pay for another grating if the club finished the instrument. Somehow, though, it never came to fruition, and when World War II arrived, the STM spectrohelioscope project was apparently abandoned. Despite Albert Ingalls' articles in *Scientific American*, few other amateurs had taken up the challenge. Prescott appears to have been the only successful one.

-3-

Well aware of the intentions of Porter and the early Springfield Telescope Makers, and mindful of the unique nature and provenance of this particular example, Matt Considine offered the Cook/Penn instrument to the club on the condition that it be put back into its intended use.

The Springfield Telescope Makers' consensus was that building a solar observatory



The Sun has given us little to photograph, but here's a tiny prominence from 2019 (color added). Photo by Jim Daley.

would not only finish business that had lain dormant since the 1930s, but that it would also complement the other telescopes on the site and provide an additional attraction at the annual Stellafane convention. So in 2010 the club voted to accept the donation and build the observatory, in an area to the northwest of the Stellafane clubhouse.

Dave began working to restore the existing parts of the spectrohelioscope. The goal was to restore the instrument to working order while retaining as much of its original character as possible. It was clear from the start that some components had to be replaced, starting with the grating. Ruled at 600 lines per millimeter on a speculum metal substrate, its quality was poor by comparison to what is now available. The fact that it had suffered significant water damage in its years under a roll-off roof did not work in its favor either By summer of 2012, Dave and Matt had taken everything apart, determined the function of each part, cleaned and refinished everything, and reassembled the instrument. Dave had fabricated a replacement for the rotating prism assembly, by far the most difficult mechanical part to remake.

Ken Slater was also finalizing the observatory's design. In order to keep the interior relatively cool in summer heat, he planned a simple structure with outward-facing infrared reflective film lining the inner panel of hollow walls, which would vent into a fan-cooled attic space (see diagram on page 26). The exhaust fan, LED lighting, and operation of the spectrohelioscope itself would be powered with direct current from a solar panel and a bank of storage batteries. Ken would eventually build a "steampunk"-style electrical control panel utilizing a scary-looking knife switch from the Stellafane clubhouse's original electrical system.

Construction began in earnest in 2014, largely thanks to the efforts of one man, David Prowten, who nearly single-handedly laid out the polar alignment axis of the building and custom-designed and built footing forms that followed the contours of the rocky outcrops on the site, in a manner evocative of Porter's design style. Members gathered to mix and pour, bucket by bucket, the tons of concrete that went into the footings and the piers to support the instrument. Prowten framed up the building, with much of the lumber harvested and rough-sawn on the Stellafane site using the club's small sawmill.

Members nailed up board-and-batten siding, and under Ray Moritz's guidance, metal roofing segments were customized and crimped together. Interior beadboard paneling and trim were installed. John Martin sawed, planed, and milled hardwood shiplap flooring for the observatory, and he and others nailed it in place. Ray made a very apt wooden sunburst for the building's south gable.

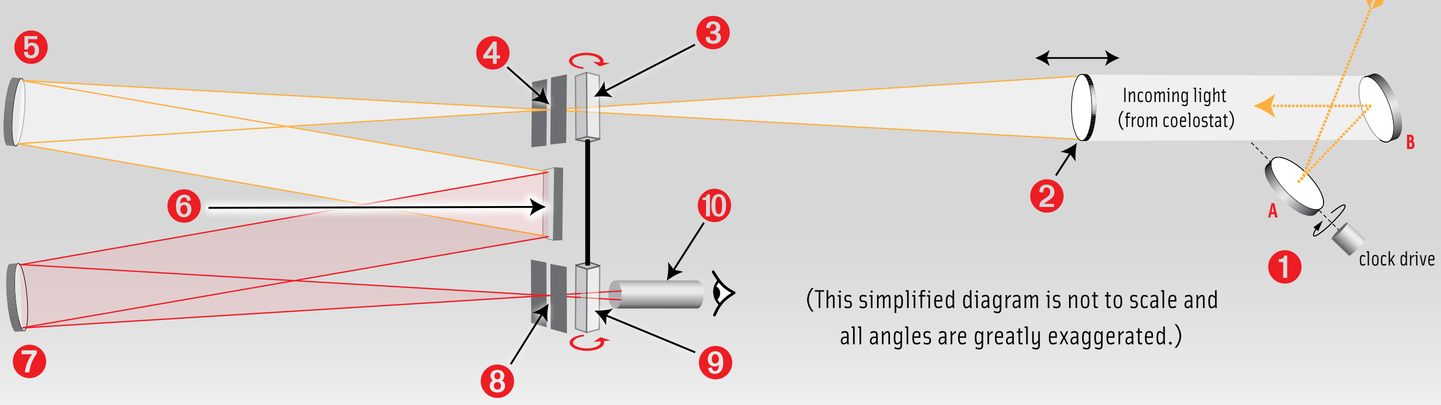
By the 2016 Stellafane Convention, with the building partially completed, Dave, Matt,

Summer 2014: it all starts with poured concrete piers. Plywood forms were shaped to fit the contours of the bedrock. Members mixed the concrete with the mixer in the foreground. Photo by Michael Patterson.

Dave Prowten in 2016 with temporary support for the coelostat, before its concrete pier was poured. New controls for the coelostat and primary had not yet been added. Photo by Sal LaRiccia.

Dave Groski and Matt Considine aligning the polar axis of the clock-driven coelostat mirror in 2016. This mirror reflects the Sun to the steering mirror, which directs the beam into the observatory. Photo by Michael Patterson.

HOW THE HALE SPECTROHELIOSCOPE WORKS



1 COELOSTAT consists of two flat mirrors arranged to direct the Sun's light in a fixed direction. The first **(A)** is mounted equatorially, and driven by a clock drive to follow the Sun's path. The second **(B)** is alt-az mounted and adjusted to reflect the beam from the first mirror to the objective lens.

2 Long-focus **SINGLET OBJECTIVE** forms a 2-inch image of the Sun's disk on the entry slit. The lens moves longitudinally through a range of about 7 inches to bring light of the desired wavelength to a focus at the slit.

3 ROTATING SQUARE PRISM (Anderson prism) scans image of Sun across entry slit.

4 ENTRY SLIT admits only a very narrow strip of the Sun's image.

5 Concave **COLLIMATING MIRROR** brings the expanding beam of light from the objective lens into a collimated beam.

6 The angle of the **DIFFRACTION GRATING** is adjusted to reflect the desired wavelength back to the focusing mirror.

7 Concave **FOCUSING MIRROR** re-forms the image at the second slit.

8 OUTPUT SLIT admits light only from a very small angle of the grating's reflection, so only a narrow wavelength band gets hrough.

9 Second **ROTATING PRISM**, mounted on the same shaft as the first, reconstructs the image scan to form a 2-dimensional image of a portion of the Sun's disk.

10 EYEPIECE allows observer to examine the image.

Bert Willard, and Jim Daley had the instrument temporarily set up to figure out alignment procedures and work out bugs. There was a "first light" of sorts, but the instrument did not create good solar images until the fall of that year.

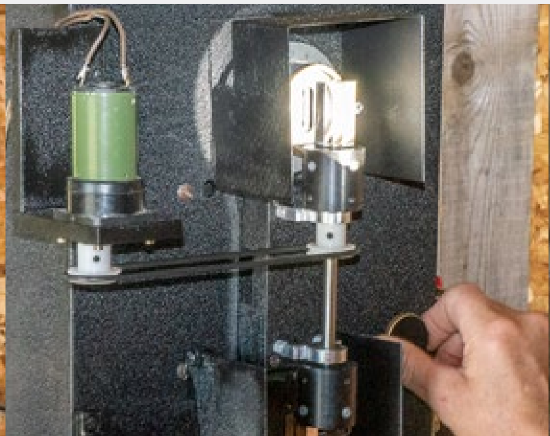
Over the next few years, Jim, Dave, Matt, and Bert solved many problems through trial and error. For instance, mysterious moving dark lines appeared in the image, which Matt eventually traced to the motor that drives the rotating Anderson prisms. Mounted on the main assembly that supports the slits, grating, and associated parts, it introduced vibration that caused the problem. Moving it to a separate support structure cured it.

Another persistent problem was poor tracking by the coelostat drive, with its original 1920s-vintage synchronous motor. Eventually Matt, who had found entries in the U. Penn observing logs that referred to poor tracking, realized that the problem was inherent in the mechanism; he counted the teeth of all the gears and discovered that one pinion had 18 teeth but should have had 16 – apparently an error in the original fabrication of the drive.

Jim Daley may have made more improvements than anyone else, far too many to recount here. In general, he carefully and patiently repaired old parts, created new ones, and developed procedures that tease better performance from this elderly instrument than it has ever before been able to achieve. For example, he fabri-

A laser aided in alignment of the mirrors. With 5 reflections in the system, alignment is a painstaking process. This must have been a much more difficult task before lasers! Photo by Michael Patterson.

A solar image focused on the input slit. Note the rotating prism in front of the slit, which scans the image across the slit. A second prism on the same shaft (out of frame) reconstructs the image after the exit slit. Photo by Michael Patterson.



JJim Daley, Matt Considine, Dave Groski, and Dave Prowten (left to right) celebrate first light in the unfinished observatory at the 2016 Stellafane Convention. Photo by Michael Patterson.

cated a new higher-magnification eyepiece, built a camera adapter, and devised a way to make photographs using a single scan (a single quarter-rotation of the prisms). He also carefully worked out fine alignment issues and fashioned parts to facilitate proper positioning of the coelostat mirrors as the Sun's elevation changes seasonally.

Dave located two good flats made from low-expansion glass to replace the original tracking and steering flats, one of which was a badly pitted stainless steel mirror. He also acquired two modern 1200 lines per millimeter gratings, blazed for H-alpha and calcium-K, and replaced the missing slit with one from a discarded PerkinElmer spectrometer. Matt refigured the two very-long-focus 4-inch collimating mirrors. This was not easy because their 13-foot focal lengths must match very closely. The objective singlet, having been found to have a slight turned edge, was stopped down (with the refurbished optics and modern grating, the image is still very bright).

Jim Daley in the now-completed Simoni Observatory, 2018. Photo by Sal LaRiccia.

Originally, the operator would have moved the steering mirror and changed the focus position of the objective singlet with the aid of long rods extending from the observer's position to the coelostat pier. As these rods were missing, Dave and Ken modernized those functions with pushbutton-actuated electronically controlled motor drives that make it easy to control the instrument.

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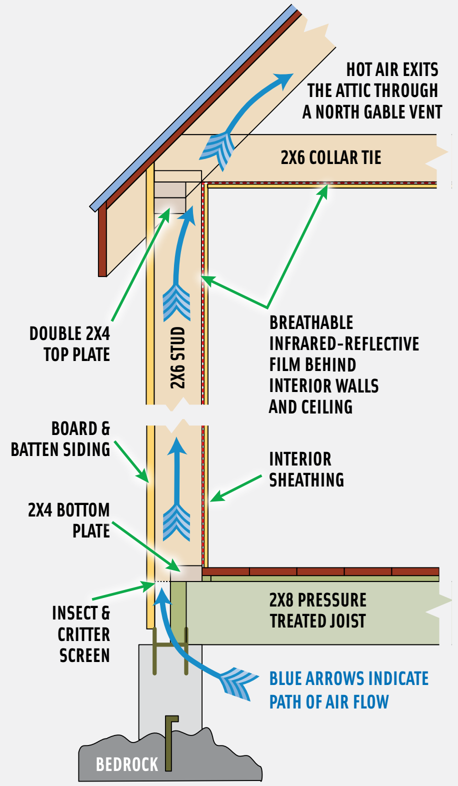
The construction of the observatory was largely funded with a generous donation from the family of Andrew E. Simoni, whose faithful attendance at the Stellafane Convention spanned his long life; he may well have been the only person who, at conventions separated by many decades, was in turn both the youngest conventioneer and the oldest. The formal dedication of the Andrew E. Simoni observatory was held at the 2018 Stellafane Convention.



KEEPING OUR COOL IN THE HOT SUMMER SUN

The Simoni Observatory is obviously used in bright sunlight, and it's desirable to keep the doors closed to provide a dark observing environment. There is no AC power in the building; all the electronics and motors are powered with low-voltage DC from storage batteries charged by a small solar panel – so air conditioning is out of the question. Ken Slater's design for the building incorporates passive cooling by means of hollow stud walls that let hot air flow up into the attic space, where it exits the building through a vent. On very hot days, a ventilation fan can be used to augment the convection. Infrared-reflective film is used behind the interior wall and ceiling sheathing to keep heat out. The building stays comfortable on hot summer days.

(adapted from drawing by Ken Slater)

For many Springfield Telescope Makers, it feels immensely satisfying to have finished something that Russell W. Porter and the original members planned, but due to circumstances beyond their control were unable to bring to completion. The solar detail visible through this old instrument is remarkably close to what is seen in the best current solar telescopes, albeit with a much narrower field of view. Small adjustments in the observed wavelength can bring out visual details of solar material moving toward or away from the observer and thus shifted in frequency, something no other instrument can do. It's a little frustrating that the Sun has been so quiescent lately, but the Springfield Telescope Makers look forward to years of observations and photography using the spectroheliosope, and we will continue to tweak it to achieve its very best performance. ✷

For more about Stellafane, the Simoni Observatory, and the Stellafane Convention, visit stellafane.org.

Then STM president Dave Tabor speaks at the dedication ceremony for the Simoni Observatory at the 2018 Stellafane convention. Photo by Sal LaRiccia.

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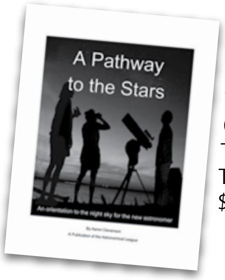

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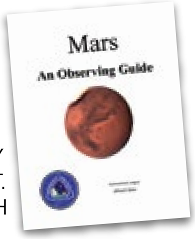

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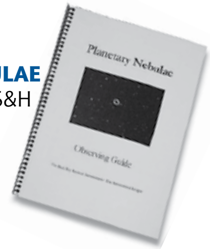

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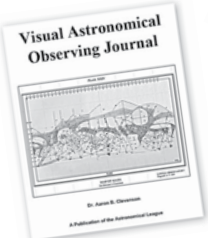

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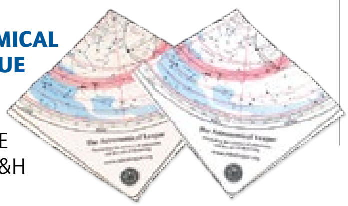

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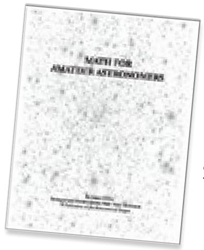

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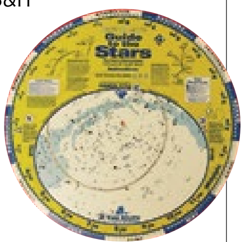

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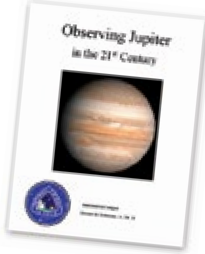

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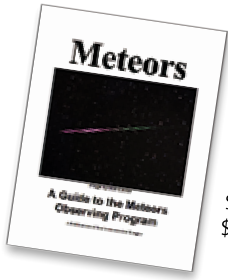

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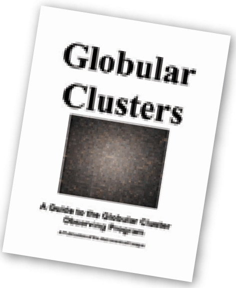

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Observing Awards

Active Galactic Nuclei Observing Program

No. 19-V, **Charles E. Allen III,** Evansville Astronomical Society; No. 20-I, **John Sikora,** Member-at-Large

Arp Peculiar Galaxies Northern Observing Program

No. 96-V, **Charles E. Allen III,** Evansville Astronomical Society; No. 97-V, **Lisa Judd,** Denver Astronomical Society

Asterism Observing Program

No. 56, **William Clark,** Tucson Amateur Astronomy Association; No. 57, **Rakhal Kincaid,** Haleakala Amateur Astronomers

Asteroid Observing Program

No. 57, **Tom Richter,** Regular, Austin Astronomical Society; No. 65, **David Whalen,** Gold, Atlanta Astronomy Club

Beyond Polaris Observing Program

No. 36, **Fred Schumacher,** Member-at-Large; No. 37, **Bernard Venasse,** Member-at-Large

Binocular Double Star Observing Program

No. 154, **Brian McGuinness,** Northern Colorado Astronomical Society

Binocular Messier Observing Program

No. 1184, **Brian McGuinness,** Northern Colorado Astronomical Society; No. 1185, **Bruno Pancorbo,** Member-at-Large; No. 1186, **Stanley Davis,** Astronomy Club of Tulsa; No. 1187, **Ken Hugill,** Minnesota Astronomical Society; No. 1188, **Sam Finn,** Central Pennsylvania Observers

Binocular Variable Star Observing Program

No. 39, **Aaron Clevenson,** North Houston Astronomy Club; No. 40, **Dennis Means,** Tucson Amateur Astronomy Association; No. 41, **Brook Belay,** Atlanta Astronomy Club; No. 42, **Kevin Carr,** Minnesota Astronomical Society

Bright Nebula Observing Program

No. 14, **Roy Troxel,** Advanced, Member-at-Large; No. 15, **Rodney Rynearson,** Advanced, St. Louis Astronomical Society; No. 16, **Paul Harrington,** Advanced, Member-at-Large

Carbon Star Observing Program

No. 106, **Ron Hospelhorn,** Albuquerque Astronomical Society; No. 107, **Val D. Ricks,** Houston Astronomical Society; No. 108, **Paul Olson,** Member-at-Large

Citizen Science Observing Program

No. 1, **Michael Hotka,** Observational Gold Class 2, NEO, Longmont Astronomical Society; No. 1, **Douglas Slauson,** Observational Gold Class 1, Variable Stars, Cedar Amateur Astronomers; No. 1, **Brad Young,** Observational Gold Class 15, TruSat, EOS, Astronomy Club of Tulsa; No. 1, **Russell F. Pinizzutto,** Active Bronze, SuperWASP Variable Stars, Southern Maine Astronomers; No. 1, **Russell F. Pinizzutto,** Active Bronze, Radio Meteor Zoo, Southern Maine Astronomers; No. 1, **Russell F. Pinizzutto,** Active Bronze, Backyard Worlds Planet 9, Southern Maine Astronomers; No. 1, **Joshua Novak,** Active Bronze, Radio Meteor Zoo, Member-at-Large; No. 1, **Steve Boerner,** Active Silver, Radio Meteor Zoo, Member-at-Large; No. 1, **Al Lamperti,** Active Gold Class 3, Star Notes, Delaware Valley Amateur Astronomers

Comet Observing Program

No. 111, **Mark Folkerts,** Silver, Everett Astronomical Society

Constellation Hunter Northern Skies Observing Program

No. 240, **William Clarke,** Tucson Amateur Astronomers; No. 241, **Kiefer Lacaruso,** Harford County Astronomical Society; No. 242, **David Downs,** Albuquerque Astronomical Society

Deep Sky Binocular Observing Program

No. 412, **James Pryal,** Seattle Astronomical Society; No. 413, **Jeffrey S. Moorhouse,** La Crosse Area Astronomical Society; No. 414, **Al Hamrick,** Raleigh Astronomy Club; No. 415, **Jeff Willson,** Rose City Astronomers

Double Star Observing Program

No. 643, **Michael Nameika,** Colorado Springs Astronomical Society; No. 644, **Andrew Jaffe,** New Hampshire Astronomical Society; No. 645, **M. Eric Olmstead,** St. George Astronomy Group; No. 646, **Brad Payne,** Northern Virginia Astronomy Club; No. 647, **István Mátis,** Member-at-Large; No. 648, **Debra Wagner,** Member-at-Large

Flat Galaxy Observing Program

No. 38-H, **Keith Kleinstick,** Member-at-Large

Globular Cluster Observing Program

No. 340-V, **Mitch Luman,** Evansville Astronomical Society; No. 341-V, **Mark Folkerts,** Everett Astronomical Society; No. 342-V, **Bruce Scodova,** Richland Astronomical Society

Herschel II Observing Program

No. 108, **Jim Chenard,** Manual, Member-at-Large; No. 109, **Charles E. Allen III,** Manual, Evansville Astronomical Society; No. 110, **William Kocken,** Device-Aided, Minnesota Astronomical Society.

Herschel Hustle

No. 1, **Jim Ketchum,** Astronomical Society of Kansas; No. 2, **Bruce Scodova,** Richland Astronomical Society; No. 3, **Kim Balliet,** Richland Astronomical Society

Herschel Society

No. 11, **Jim Chenard,** Silver, Member-at-Large

Hydrogen Alpha Solar Observing Program

No. 47, **Jim Kaminski,** Member-at-Large

Local Galaxy Group and Galactic Neighborhood Observing Program

No. 44-DA, **Mark Simonson,** Everett Astronomical Society; No. 45-M, **Jim Chenard,** Member-at-Large

Lunar I Observing Program

No. 1090-B, **Stijn Brand,** New Hampshire Astronomical Society; No. 1091, **Michael Keefe,** Raleigh Astronomical Society; No. 1092, **Istvan Matis,** Member-at-Large; No. 1093, **Richard Wheeler,** Northeast Florida Astronomical Society; No. 1094, **David Beggs,** Albuquerque Astronomical Society; No. 1095, **John Zimitsch,** Minnesota Astronomical Society; No. 1096, **Albert Smith,** Member-at-Large

Lunar II Observing Program

No. 103, **Neil Perlin,** Member-at-Large; No. 104, **Wayne Frey,** Imperial Polk Astronomical Society

Messier Observing Program

No. 2827, **James Zappa,** Honorary, Member-at-Large; No. 2828, **Ed Foley,** Regular, Tucson Amateur Astronomy Association; No. 2829, **Daniel Beggs,** Honorary, Albuquerque Astronomical Society; No. 2830, **Bruno Pancorbo,** Honorary, Member-at-Large

Meteor Observing Program

No. 183, **Mark Colwell,** 18 hours, Member-at-Large; No. 189, **David Whalen,** 30 hours, Atlanta Astronomy Club; No. 190, **Fred Schumacher,** 18 hours, Member-at-Large

Multiple Star Observing Program

No. 2, **Brad Young,** Astronomy Club of Tulsa; No. 3, **Aaron Clevenson,** North Houston Astronomy Club; No. 4, **Charles E. Allen III,** Evansville Astronomical Society; No. 5, **David Douglass,** East Valley Astronomy Club

Outreach Observing Program

No. 691-M, **Sharon Flemings,** Ancient City Astronomy Club; No. 765-M, **Dan A. Chrisman Jr.,** Roanoke Valley Astronomical Society; No. 836-M, **Raymond L. Bradley,** Roanoke Valley Astronomical Society; No. 921-S, **Sean Neckel,** Flint River Astronomy Club; No. 1109-S, **Eric J. Hoin,** Central Florida Astronomical Society; No. 1109-M, **Eric J. Hoin,** Central Florida Astronomical Society; No. 1131-M, **Sam Pitts,** Temecula Valley Astronomers; No. 1189-O, **Ernest F. Jacobs,** Buffalo Astronomical Society; No. 1189-S, **Ernest F. Jacobs,** Buffalo Astronomical Society; No. 1190-O, **Mason Erikson,** Flint River Astronomy Club; No. 1191-O, **David Wickholm,** San Antonio Astronomical Association; No. 1192-O, **Terry Conner,** Astronomical Society of Kansas City; No. 1193-O, **Jamie Canfield,** Austin Astronomical Society; No. 1194-O, **Richard Hendricks,** Austin Astronomical Society; No. 1195-O, **Thomas Richter,** Austin Astronomical Society; No. 1196-O, **Bill Honea,** Flint River Astronomy Club; No. 1197-O, **George Ruff,** Flint River Astronomy Club; No. 1198-O, **Frances Camera Kaplan,** Brevard Astronomical Society

Planetary Nebula Observing Program

No. 80, **Cliff Mygatt,** Advanced Manual, Olympic Astronomical Society; No. 81, **Ken Boquist,** Popular Astronomy Club; No. 82, **Benjamin Jones,** Advanced, Albuquerque Astronomical Society; No. 83, **Jim Chenard,** Advanced, Member-at-Large

Sketching Observing Program

No. 40, **Brian Chopp,** Neville Public Museum Astronomical Society

Solar System Observing Program

No. 153-B, **John Strebeck,** St. Louis Astronomical Society; No. 154, **Aaron Roman,** Kalamazoo Astronomical Society; No. 155, **Terry Trees,** Amateur Astronomers Association of Pittsburgh

Stellar Evolution Observing Program

No. 76, **Mark Bailey,** Member-at-Large

Two in the View Observing Program

No. 36, **Charles E. Allen III,** Evansville Astronomical Society; No. 37, **Maynard Pittendreigh,** Brevard Astronomical Society

Universe Sampler Observing Program

No. 142, **Jeffrey Moorhouse,** Telescope, LaCrosse Area Astronomical Society; No. 143, **Paul Harrington,** Telescope, Member-at-Large; No. 144, **Daniel Beggs,** Telescope, Albuquerque Astronomical Society; No. 145, **Mark Colwell,** Naked-Eye, Member-at-Large

Variable Star Observing Program

No. 36, **Richard W. Roberts,** Back Bay Amateur Astronomers; No. 37, **Dennis Means,** Tucson Amateur Astronomy Association; No. 38, **István Mátis,** Member-at-Large

Master Observer Progression

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Scott Cadwallader, Baton Rouge Astronomical Society; **Brian Chopp,** Neville Public Museum Astronomical Society

MASTER OBSERVER AWARD

No. 237, **Brad Payne,** Northern Virginia Astronomy Club

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