Published by the Astronomical League
Vol. 73, No. 2 MARCH 2021

Reflector

CELEBRITY VARIABLE STARS

IMAGING TECHNIQUES EXPLAINED

WILLIAMINA FLEMING

SIMPLE CITIZEN SOLAR SCIENCE

Contents

PAGE 10

PAGE 20

PAGE 22

Bernard Miller (East Valley Astronomy Club) took this fantastic image of IC 434 with a PlaneWave 17-inch corrected Dall-Kirkham telescope and a FLI ProLine 16803 CCD camera from Dark Sky New Mexico in Animas.

Reflector

The Astronomical League Magazine

Vol. 73, No. 2 • ISSN: 0034-2963 • MARCH 2021

A FEDERATION OF ASTRONOMICAL SOCIETIES
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.

Astronomical League National Office:
9201 Ward Parkway, Suite 100, Kansas City, MO 64114

Reflector

QUARTERLY PUBLICATION OF THE ASTRONOMICAL LEAGUE

Issued by the Astronomical League in March, June, September, and December, *Reflector* (ISSN: 0034-2963) is sent directly, either by postal mail or via a digital link, to each individual member of its affiliate societies and to members-at-large as a benefit of League membership. Individual copies of *Reflector* are available at the following subscription rates, payable to the League's national office.

PAPER SUBSCRIPTIONS:

USA & possessions: $3.00 each or $10.00 per year (4 issues)
Canada: $5.00 each or $16.00 per year
Mexico: $6.00 each or $22.00 per year
Other countries: $7.00 each or $25.00 per year

DIGITAL SUBSCRIPTIONS:
All countries, possessions, and territories: $10.00 per year

***REFLECTOR* AND CLUB ROSTER DEADLINES**

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

To the Editor

Reading vol. 73, no. 1, of the *Reflector*, I am so satisfied and enthralled reading "My Herschel Objects Project Is Complete." I'm retired now (secondary and higher science education) and still have the need for understanding the developing history as well as cutting-edge astronomy. This is a valuable product by the Astronomical League.

—Lawrence Blanchard
Pontchartrain Astronomical Society

Our senior astronomy club (Moonstruck Astronomy Club, On Top of the World, Ocala, Florida), met for a fantastic viewing session of the Jupiter/Saturn conjunction. The crowd of over 60 seniors gathered to witness the once-in-a-lifetime event. Face masks were worn, social distancing was observed, and members were advised to bring any type of visual aid for personal

viewing. Russell Martin (pictured) was using the same equipment (Spiratone manual tracker and 50 mm guide scope) that he and fellow club member Larry Isenberg used to track and photograph Comet Halley in 1986 while living in Bowling Green, Kentucky. The Moonstruck Astronomy Club was established over two years ago, and we continue to grow in membership through our use of monthly Zoom meetings, observing sessions, field trips, and commitment from our dedicated club officers. In addition, we contribute a monthly article to the *On Top of the World News.*

—Larry Isenberg
Vice President, Moonstruck Astronomy Club

I am writing about the September issue of the *Reflector*. For the last few issues, I have found myself reading the entire contents of your magazine, whereas before I was only reading a few articles here and there. Congratulations to your editor and article writers. One such article that I read with great interest was one by Dr. Dire, "Globular Cluster Meets Gas Giant Planets." I was fascinated to learn about the different types of clusters. There was a lot of valuable information in Dr. Dire's article and I was motivated to do my own research.

All your contributors should be congratulated as they put together a good product. Keep up the good work.

—Rodney R. Nordstrom, Ph.D.

Star Beams

By the time you read this edition of the *Reflector,* hopefully the coronavirus pandemic will have begun receding in a meaningful way, with more people able to get vaccinated. In the meantime, despite the pandemic, a core group of observers are still out observing and earning certificates.

NEW AL IMAGING AWARD

As the Astronomical League moves into its 75th anniversary year celebration this year and we are able to get back under the stars again, I am pleased to announce a new imaging award program for our female League members. This is the Williamina Fleming Imaging Award.

Thanks to the 75th anniversary committee of John Goss, past president; Peggy Walker, STEAM and junior activities coordinator and ALCon Jr. conference chair, who developed the new award program; Maynard Pittendreigh, executive secretary; and Chuck Allen, vice president, for their splendid work with this award and the 75th anniversary celebration of the League. Chuck Allen's article with details for the Fleming Award is elsewhere in this issue. Thanks to Scott Roberts and Explore Scientific for sponsoring the award! Scott has been most generous in supporting the League, including his current sponsorship of the National Young Astronomer Award (NYAA) and the Leslie Peltier Award.

OTHER AWARD COMPETITIONS FOR 2021

If you have not explored the list of Astronomical League award programs lately, please look at the complete list in this issue. There is a wide variety, including youth awards such as the NYAA and the various Horkheimer awards, and adult awards such as the Mabel Sterns Award for a club newsletter editor, the Webmaster Award, or the Sketching Award.

We have a new sponsor for the League's Imaging Awards Program. Explore Scientific has graciously agreed to sponsor this with a major revamp to the program. More details will follow soon.

INCREASED ONLINE PRESENCE

During the past few months, the League has greatly increased its online reach with our joint efforts with Explore Scientific and its online programs. These activities will continue and possibly expand in 2021, and I encourage you to access Facebook to view these special events. Please check the League's Facebook page to see the upcoming schedule. Also, *What's Up With the Astronomical League,* a sporadic publication sent to League members for whom we have an email address on file, is used to communicate upcoming events and share other brief time-sensitive news in between *Reflector* issues.

Our feedback indicates that, in many cases, societies that are conducting online events during this pandemic have greater participation than when they were holding all of their meetings and events in person. Moving forward, hopefully we will all avail ourselves of the opportunity to benefit from online events, when it makes sense, even after the pandemic is a distant memory. From the League side, we are exploring the increased use of online resources, when appropriate, such as a YouTube channel designed to further expand our visibility.

WEBSITE HELP RESPONSE

Thanks to the several people who responded to our call for help with the website. It is so refreshing to see the loyal members who are willing to share their talents with the Astronomical League. We have started the process of integrating these new volunteers into the website staff.

Stay safe!

—Carroll Iorg, President

International Dark-Sky Association

UNDER ONE SKY – 2020 GLOBAL CONFERENCE

2020 was the year of the pandemic. Let us hope 2021 sees the pandemic passing, and we can finally get back together again in person. No matter what, the sky is always there for us. Light pollution, unfortunately, remains ever present. IDA's annual meeting was unique this year and quite wonderful. Because of the pandemic, and because IDA's leadership is always looking for ways to spread our message, the meeting was virtual but with important twists. First, it was free to anyone who wanted to register for it and attend whatever session piqued their interest.

Second, it was a true global meeting with speakers from around the world. Moreover, the scheduled times for talks and breakout sessions were purposely scattered around the clock for convenient daytime attendance for some of the sessions no matter where the attendee was located – North America, South America, Central America, Europe, Central Asia, Southeast Asia, Australia, New Zealand, and Pacific Islands. Except for the wonderful keynote address by Annette Lee, all major talks and breakout sessions were from speakers outside the United States. This broadened the scope of the conference and lent an international flavor to an organization that purports to be international but is U.S.-centric because of historical and practical considerations.

To quote from the IDA website, "the organization's annual meeting became a virtual global meeting. Under One Sky showcased the environmental and cultural threat that light pollution poses to people who have been underrepresented in the work to defend the sky."

My focus concerning the night sky and light pollution has always been narrow. I want the sky dark for astronomy and for my enjoyment of it. For many years, I have realized the most passionate advocates of the night sky are not amateur or professional astronomers. They are poets, artists, outdoors persons, ecologists, biologists, wildlife defenders, and dreamers. They see more than just the stars and planets.

Annette Lee, the keynote speaker for the conference, is an astrophysicist, but she is also an artist and director of the Native Skywatchers research and programming initiative, which "seeks to remember and revitalize indigenous star and Earth knowledge." Check out her incredible biography at *annettelee.com/index.php/bio.* Annette is a proud "mixed-race Lakota and her communities are Ojibwe and D/Lakota." A significant portion of her presentation gave an overview of these peoples and their relationship with the sky. After hearing Annette speak and participating in several other sessions as part of the conference, I further realized how light pollution was truly robbing indigenous and other peoples in many parts of the world of their cultural roots, literally blotting out their heritage, and not just making a wonderful hobby or science inconvenient.

The Under One Sky Conference was held November 13–14, 2020. The entire conference was recorded and linked through the IDA website *darksky.org.* You can watch all the presentations at your leisure, just as if you had attended the conference. It is too late to virtually raise your hand to ask a question at the conference, but I am sure the presenters would be receptive to follow-up correspondence from anyone who watched their presentations.

I was going to briefly highlight some of the featured presentations and sessions, but then I thought better of it. No doubt I would overlook something important and do a poor job in the process. The best I can do is inform you about the conference and urge you to view the presentations on the IDA website.

—Tim Hunter
Co-founder, IDA

Night Sky Network

ASTRONOMY OUTREACH DURING A PANDEMIC

What has astronomy outreach looked like in the past twelve months? While 2020 was not a great year for traditional in-person outreach and star parties, it did force many of us to think of new ways to bring the wonders of space to our communities. For many of us, remote software and other online tools helped bridge the gap and kept us in touch with our fellow club and community members. For others, in-person events were held with extra precautions and less foot traffic than usual, and even at the eyepiece new techniques and technologies allowed folks to safely share their views of the skies.

Outreach is at the core of the Night Sky Network program, but as the pandemic emerged in 2020, going out and showing people the stars was a secondary concern to generally figuring out how to be safe and taking care of emergencies. But as the weeks and months marched along, the nature of outreach began to change as we wondered how to do it with new restrictions. After all, what else was there to do?

Conference software like Zoom allowed many clubs to meet again. While the lack of physical connection – and draining nature of screen time – was not a perfect substitute for in-person chats, the online nature of pandemic club meetings bought some unexpected bonuses: long-absent members returned! For some members – due to distance, traffic, or health concerns pre-pandemic – going to regular meetings was not possible. But thanks to the flexibility of virtual meetings, they were able to reconnect. For similar reasons, some

Some behind the scenes shots by Héllen Távora from one of the South Florida Amateur Astronomers Association's online public nights. This evening in particular featured live views of Mars from the Fox Observatory, along with fun presentations about galactic collisions and recent space launch footage.

clubs found that they were able to book many amazing guest speakers that normally would be out of reach.

As folks became familiar with different ways to host online events, some astronomers took to live streaming. Platforms like Facebook Live, YouTube, and Twitch, coupled with studio software like OBS and imaging software like SharpCap, allowed people to share views from their telescopes to audiences both in their community and worldwide. Clubs, planetariums,

Some people did their outreach outdoors, without being immediately present: "Sidewalk Science" offered a chance to dust off some big pieces of colorful chalk and write up fun science facts and observing opportunities on stoops and sidewalks, as seen in this photo by Kirsten Vandstone. Other folks updated existing solar system walks in their local parks and towns, or set up new ones, to give their neighbors a fun outdoor enrichment activity.

observatories, and science centers began trying out new kinds of online outreach, including live 360° planetarium shows, talk shows, panels, news reviews, demos, and expertly edited videos about astronomy, NASA missions, and general science. With practice and experimenting, they shared their experiences and inspired others to contribute or branch out on their own projects.

Not all outreach occurred online in 2020, of course. While most of the major star parties were cancelled this summer, smaller groups still gathered to share views of the skies, especially views of an unexpected visitor: Comet NEOWISE. Amateurs managed distancing requirements, masks, and sanitation to ensure that guests and members stayed safe during these events. Many folks began using adapters to mount phones and tablets to their eyepieces, using these screens to present views of the Moon and planets to visitors at a safe distance from their eyepieces, helping to limit crowding. Some even connected to larger screens or projectors to share their views – an unconventional way to run a star party, but fun and much appreciated by everyone in attendance.

An interesting wrinkle emerged as the pandemic wore on: some clubs found they had boosts in membership and inquiries from the public. While many folks began hobbies like baking bread, gardening, or model-making, some took the stargazing plunge and began observing in earnest. While many businesses suffered, telescope vendors reported a strong increase in sales from newly curious customers, and astronomy clubs also welcomed this new wave of curious newcomers. Maybe you are one of the newest members of the amateur astronomy community – welcome!

At the Night Sky Network, we helped collect and share virtual and physical outreach tips and technologies, and continue to connect clubs with their communities. Webinars on best practices in virtual events were held, and virtual event experts like Dr. Amy Oliver shared their experiences and knowledge from hosting events like the Smithsonian Nationwide Livestream Star Party with members of the NSN community. After these meetings, we distilled these tips into a couple of short guides to help clubs host safe and successful in-person and online events. You can find our virtual event guide at *bit.ly/virtualastro* and our in-person event flyer at *bit.ly/safeoutreachflyer.* We even updated our website's calendar to include a new type of event – virtual events – to allow club members to post online astronomy events for astronomy fans across the country to find, share, and enjoy, regardless of location.

You can find some of these virtual events at *bit.ly/nsnvirtualevents.*

The Library Telescope Program continued, though extra precautions were observed by participants, as seen in this photo from Jerelyn Ramirez of a donation and training session for the Rossville Community Library staff by the Kansas Astronomical Observers.

At the beginning of the pandemic, we sadly thought that we might cancel the NSN's annual outreach award pin program for this year. Thankfully, after all this innovation and hard work by folks across the country, we proudly packed up pins to award dedicated volunteers for their awesome outreach. While we don't know the specifics of what the coming year will bring, we are excited that astronomers have found new and fun ways to continue outreach, connect with their clubs and communities, and continue to share their love of space with everyone – and we'll continue to do our best to help!

—David Prosper

Full STEAM Ahead

I WANNA BE AN ASTRO LEAGUE KID

For those of a certain generation, you started to sing the jingle from the Toys R Us commercial from the 1980s in your head when you read my title, right? This particular theme song resonated with me as I assembled monthly presenters for the League's 75th anniversary events, as I talked to people and dug into the archives about the Junior Astronomical Societies that were prominent in the League early on. In fact, in my December 2020 article, I referred to this enlightenment.

As I made calls to gather folks under the anniversary banner, I had the privilege of hearing some great stories from both AL members and members of other organizations, all sharing a common theme – they have loved astronomy since they were children. That's longer than some marriages! Our very own vice president, Chuck Allen, grew up in the AL and is clearly an "Astro League kid!" I heard similar sentiments from Jack Estes. When I contacted him about presenting his Herschel 400 observing program, he shared with me how he and a few boys got together in the 1960s to form a club. After all, we were landing on the Moon, and their parents were not interested in helping. He said that most of his fond memories came out of that experience until the adults showed up and somehow messed it all up. Wayne Wooten shared how he got into astronomy through a youth club, and as a junior society member of the League. Wayne similarly said it lost its fun when the adults showed up! Also, Joe Rao shared how his group of boys wanted to see the Lunar eclipse and knew they needed to get above the clouds. They assembled $60 to pay for the security guard's time for the Empire State Building. Amazingly, the clouds were just a few feet below them, so they saw the whole eclipse with little to no impediment. In fact, this successful sighting wound up in the newspaper.

As I continued to peruse through the junior activities binder archive (courtesy of Chuck Allen), I learned that the whole Junior Astronomical Societies concept came from his own club in Louisville, Kentucky. The files clearly showed this huge youth phenomenon grew significantly in the 1950s and 60s from the genesis of the League in 1939 with Charles Federer Jr. My research yielded 57 club names from 26 states. Where did they all go? They grew up! Many of these clubs still exist, just without "Junior Society" in their names. Was your club a Junior Astronomical Societies member? These clubs demonstrated the youths' intense dedication: they networked with each other, conducted serious observations and meteor counts, were role models and instructors for elementary school students, and put together specific activities to grow their knowledge base. These clubs were so organized and focused that they had their own sessions at the ALCons as presenters, sometimes outnumbering the adults in attendance. They even had their own newsletter to boot!

The Junior Astronomical Societies started a Messier Award, and although students were completing this program, Bob Wright suggested that maybe this Messier Observing Program (now complete with certificate, guide, and pin) should be opened up to adults. You can see it was the younger generation taking hold of this hobby and driving it into the end zone for a huge win for the science. So as we move forward with youth and family activities, it is really not starting something new, but instead going back to being an "Astro League kid."

I hope to see you at the ALCon Jr. convention in August (as of this writing, whether the convention will be held is still up in the air due to circumstances beyond our control). Telescope-making and hands-on activities are still on the schedule. So, in light of the League's 75th anniversary, I toast to another 75 years of youth engagement.

—Peggy Walker

AL STEAM and Jr. Activities Coordinator

Wanderers in the Neighborhood

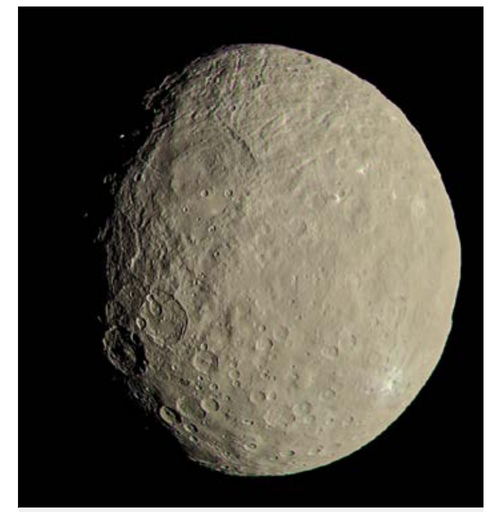
ASTEROID OR COMET?

Our sky is occasionally graced by a bright comet, like recent C/2020 F3 (NEOWISE). Comets have been observed since humans first looked up and saw the stars. These sometimes-brilliant objects with their streaming tails have been objects of wonder and often fear, with the appearance of a comet frequently interpreted as an evil omen, often thought to portend the death of a king. The ancient Chinese recorded these objects as "hairy stars" or "broom stars."

Asteroids (meaning "star-like") were discovered on January 1, 1801, when Italian monk and astronomer Giuseppe Piazzi of the Palermo Astronomical Observatory in Sicily, Italy, found the asteroid 1 Ceres at magnitude +7.9. What made it stand out from the other stars was its daily motion of 350 arcseconds.

The now discredited Titus-Bode law had predicted that there should be another planet in the large gap between Mars and Jupiter. Hungarian astronomer Franz Xaver von Zach headed a group that sent a letter in 1800 to 24 noted astronomers, which he dubbed the "Celestial Police," asking that they work together to locate the missing planet. Piazzi was one of the Celestial Police, but even before he received the letter, he had spotted Ceres.

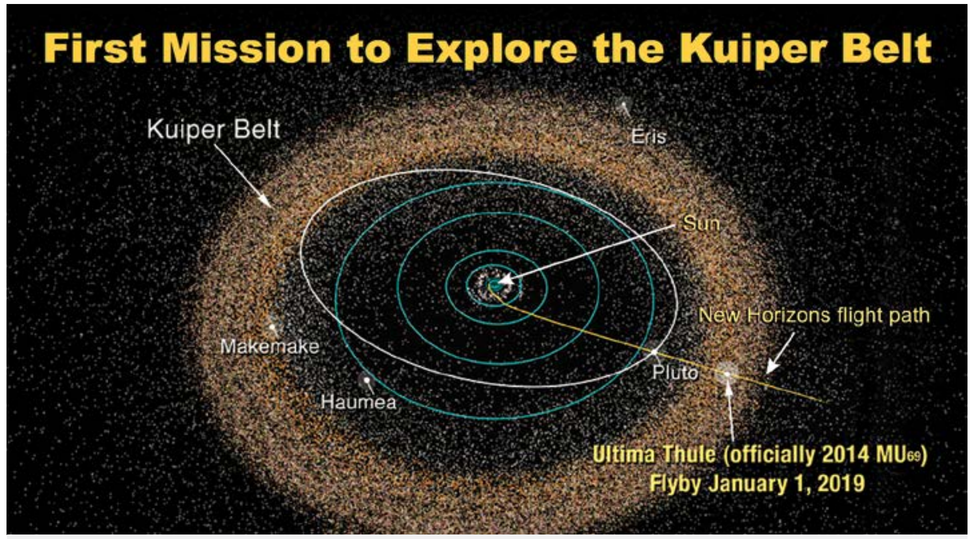
At first, Piazzi thought it might be a comet, even though it did not have a tail. Its slow and uniform motion hinted to Piazzi that this might not be a comet, but a new type of object. After following it for 42 days, he fell ill and could no longer track it. Even though he had reported it as a comet to two fellow astronomers, Ceres became lost. It had moved too close to the Sun to be observed until the end of the year, and then astronomers could not find it because they did not know exactly where to look. German mathematician Johann Gauss heard about the lost object and spent three months devising the least-squares



The first asteroid to be discovered was 1 Ceres, which is now categorized as a dwarf planet. Most asteroids are irregularly shaped, but a dwarf planet has enough mass for its gravity to pull itself into a sphere. This color image is a combination of red, green, and blue filters on NASA's Dawn spacecraft's framing camera, and closely approximates what the human eye would see. This image was taken during the first science orbit in 2015. While Ceres appears rocky, there is brine under the surface that occasionally bubbles up to the surface. This image was produced by the German Aerospace Center in Berlin, Germany. Image credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

method of orbit determination. He used it to calculate an ephemeris for Ceres. On December 31, 1801, Ceres was recovered within half a degree of where Gauss had predicted it.

Over the next six years, three more asteroids were discovered: 2 Pallas, 3 Juno, and 4 Vesta.



The Kuiper Belt is much larger than the main asteroid belt (represented by the white spots inside the orbit of Jupiter). Its members are also icy and not rocky, so if they get near the Sun, they release dust and gas to become comets. This belt extends outward from Neptune. Pluto and Arrokoth (2014 MU69 or, informally, Ultima Thule) are in the Kuiper Belt, but it extends far beyond both. Image credit: NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute

Thirty-eight years passed before another asteroid was discovered. Then improved telescopes allowed many more to be found in rapid succession. Photographic and electronic imaging have allowed over a million asteroids to be discovered.

Piazza's initial uncertainty about the nature of Ceres nature was well-founded. Asteroids appear as starlike objects even in large telescopes. Comets far from the Sun also appear starlike. Astronomers could not find a good model for the composition of comet nuclei until American astronomer Fred Whipple developed the "dirty snowball" model in 1950. In this model, comets are composed mainly of ices with dust particles mixed in. Gas and dust are released when a comet enters the warm inner Solar System and the ice sublimates (changes directly from solid to gas), releasing the dust to form a tail. Far from the Sun, the ice remains frozen, so there is no gas or dust to form a tail or coma and a comet appears starlike.

One difference between comets and asteroids is their orbits. Most asteroids are located near the plane of the Solar System in roughly circular orbits that lie between the orbits of Mars and Jupiter, in what is called the main asteroid belt. Comets have a larger variety of orbital sizes, shapes, and inclinations. They can be in the ecliptic plane or come at us from almost any direction. Their orbits divide comets into two groups, long-period and short-period.

Long-period comets have orbital periods of two hundred years or more (sometimes much more). These comets have very eccentric (long and narrow) orbits that can stretch from near the Sun to far beyond Pluto. The outer boundary of the Solar System is the Oort Cloud, a hollow sphere of comet nuclei that extends between very roughly two hundred billion miles (2,000 astronomical units or AU) out to the edge of the Sun's gravity well (around two light-years). This is a region that is cold enough for ices to accumulate, intermingled with dust. Occasionally, the gravitational field of a passing star or the galactic bulge will start one of these nuclei falling toward the Sun. This results in a long-period comet that may not return to the inner Solar System for a hundred thousand years. While it has never been directly imaged, the Oort Cloud's existence is deduced by the seemingly random directions from which these comets approach (rather than being confined to the ecliptic plane).

The only Kuiper Belt object besides Pluto that we have seen close-up is the contact binary 2014 MU69 (officially named Arrokoth). This image from NASA's New Horizons spacecraft was taken on January 1, 2019, with the Long Range Reconnaissance Imager (LORRI). It approximates the color of the object as it would be seen by the human eye. New Horizons does not currently have a new target, but if one is discovered, we may get another image from the Kuiper Belt. Image credit: NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute/Roman Tkachenko

Short-period comets come from the Kuiper Belt, a disk of mostly icy bodies extending from just beyond the orbit of Neptune out to about 1.8 billion miles (20 AU) from the Sun. Once these icy bodies depart the Kuiper Belt, they fall toward the inner Solar System where they develop tails. Their orbits will bring them back in less than two hundred years. Their orbits are still eccentric, just not as squashed as those of long-period comets. The Kuiper Belt's flat shape, rather than spherical like that of the Oort Cloud, is suggested by the fact that the orbits of short-period comets tend to lie closer to the ecliptic plane than those of long-period comets.

Another difference between asteroids and comets is their composition. Asteroids are mainly rocky, with dust, pebbles, and boulders on their surface. Some smaller asteroids are nothing but "rubble piles," composed of those pebbles and boulders loosely held together by their own gravity. The largest asteroid in the main belt, Ceres, is 584 miles across, while the largest trans-Neptunian asteroid, 136199 Eris, is 1,445 miles across. Both objects are large enough to have sufficient gravity to have achieved a roughly spherical shape and are classified as dwarf planets.

Comets are mainly icy bodies with dust and pebbles embedded in the ice. Comets are tiny compared to many asteroids; the largest comet is only 60 miles across, and they average around 16 miles across. The inner core of some comets is a rocky body that will remain after the ice and dust have escaped, becoming an extinct comet that looks much like an asteroid. Other comets disintegrate into thousands of tiny pieces and disappear when they come near the Sun.

Although asteroids and comets appear to be distinct bodies, they are really rather similar. Ceres has a rocky surface, but its crust is almost 30 percent ice. It emits water vapor at levels much lower than comets but it is the largest of the active asteroids. Active asteroids appear to be asteroids, but on occasion they are surrounded by a hazy cloud, similar to a comet's coma. A notable example is 3200 Phaethon, the parent body of the Geminid meteor shower.

Asteroid 7968 Elst–Pizarro was discovered in 1979, but it was not until August 7, 1996, that Eric Elst and Guido Pizarro discovered it had a tail. It was then reclassified as comet 133P/Elst–Pizarro. Other asteroids have since been found to intermittently have tails and comas. These were originally called main-belt comets. They exist in colder areas of the Solar System, from the outer edges of the main asteroid belt to beyond the orbit of Jupiter. Some of these objects are icy like comets, but others are rocky.

Active asteroid 133P/Elst–Pizarro has a tail for only two to five months at a time when it is nearest the Sun, much like any other comet, but it is still 246 million miles from the Sun. It is probably icy, but the gas and dust may come from an area about 2,000 feet across, probably an impact crater that exposed fresh icy material from under the surface.

Originally designated a comet, P/2010 A2 (LINEAR) was discovered in January 2010. Initially thought to be emitting gas and dust, it was later determined that the dust cloud resulted from two asteroids colliding. The debris cloud initially appeared cometary. Other "comets" have also appeared after asteroid collisions.

With larger telescopes now observing asteroids, more asteroids are being found than ever before. Each new discovery brings up the question of whether it is a comet or an asteroid. Only careful observations will tell.

—Berton Stevens

Deep-Sky Objects

REFLECTING ON THE HUNTER

The constellation Orion is undoubtedly the most recognizable constellation in the winter skies. During spring, the Hunter is still high above the western horizon as twilight fades to darkness, allowing ample time to explore this exciting constellation.

Orion is best known for its vast network of nebulae. A majority of the constellation is embedded in nebulae as captured in ultrawide-field long exposures with digital cameras. When we look towards the constellation Orion, we are looking along the plane of the Milky Way galaxy through the spiral arm that hosts our Solar System. This arm contains an abundance of gas and dust, accounting for the nebulae in and around the constellation.

Most famous among these nebulae are the Great Orion Nebula (M42 and 43), the Running Man Nebula (NGC 1973, 1975, and 1977), the Horsehead Nebula (IC 434), and the Flame Nebula (NGC 2024). Lesser known, as indicated by the fact it carries no common name, is a bright reflection nebula known as M78.

M78 is one of the brightest reflection nebulae is the sky, if not the brightest. It is easily found by starting at the star Alnitak (the leftmost and brightest star in Orion's Belt) and stopping one-quarter of the way to Betelgeuse. Then make a 90-degree turn to the left and pan another 40 arcminutes to arrive at M78. The nebula shines at magnitude 8.3 and is 8.0 by 6.0 arcminutes in size, easily visible in a 50 mm finderscope under transparent skies away from city lights.

M78 was first recorded by Pierre Méchain in the year 1780. He described it as a pair of stars surrounded by nebulosity. Charles Messier saw it later in 1780 and described it as a cluster with much nebulosity. The nebula became the 78th entry in Messier's famous catalog.

M78 is located 1,600 light-years away, slightly more distant than M42 and twice as far away as both the Horsehead and Flame Nebulae. M78 is located on the celestial equator.

The two stars Méchain alluded to are HD 38563 and HD 290862, both around tenth magnitude. HD 290862 is a double star with components of magnitude 10.81 and 11.50 separated by 2.1 arcseconds. The pair are foreground objects to M78, lying a mere 42 light-years away. HD 38563 is also a double star with components of magnitude 10.42 and 11.50, also separated by 2.1 arcseconds. Both have stellar classification B. They are hot, young stars embedded in the nebula, and their light contributes significantly to the reflection nebula's luminosity. The brighter component is an erupting variable star. On a night of good seeing, both sets of double stars can be split. In each pair, the components are practically along an east-west line.

Like many of the nebulae in Orion, M78 is a stellar nursery. The nebula contains around 45 known T Tauri stars – bright F and G stars that are nearing the final stages of formation. The nebula contains a small cluster of 192 stars and 17 Herbig-Haro objects, which are bright jets of matter streaming from newly born stars.

The accompanying image of M78 was taken using a 10-inch f/6.9 Newtonian with an SBIG ST-2000XCM CCD camera. The exposure was 280 minutes. North is up and east to the left. The brightest star in the image, near the right edge, is HD 290863, magnitude 10.01. The bright red star on the lower left has no HD or SAO catalog number but is magnitude 10.93. The faintest stars in the image are magnitude 20.

My image is centered on the brightest region of M78, also known as NGC 2068. The bright star near the top center of this region is the aforementioned foreground star HD 290862. Below it and slightly to the right is HD 38563.

A prominent dark lane arcs around the north and west side of M78, shielding from our sight brighter regions which may lie beyond. The tiny bright patch just southwest of the main nebula is known as NGC 2064. The larger, more diffuse bright region to the northwest is NGC 2067. While M78 can be seen in a 4-inch telescope, and seen quite well in an 8-inch telescope, telescopes 16–20 inches or larger in aperture should reveal nice detail throughout the entire M78 complex.

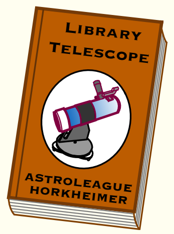
Regardless of telescope size, any stop to view the myriad nebulae in Orion should include Messier's 78th catalog entry!

—Dr . James Dire

From Around The League

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. The Library Telescope consists of an Orion 4.5-inch StarBlast Dobsonian or a Zhumell Z114 (or equivalent), 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.



We prefer that you submit your completed entry form electronically so that the Astronomical League national office receives it by the deadline of **Friday, July 16, 2021.** Please email it to *HorkheimerLiTel@astroleague.org*. If mailed, the entry must be postmarked no later than July 16, 2021. The winning entry for each region will be selected August 5, the date when ALCon 2021 is currently scheduled. Full details of this program can be found at *astroleague.org/content/library-telescope-program*.

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

ANNOUNCING THE WILLIAMINA FLEMING IMAGING AWARD

Pending formal approval by council in August, the League executive committee has created a new League national award to be offered in 2021. The purpose of this award is to encourage women in their pursuit of astronomical imaging.

The award will be given annually and is created to complement the League's 75th anniversary recognition of key women in League history. The award honors the work of Scottish astronomer Williamina Paton Stevens Fleming who worked at Harvard College Observatory. During her career, she helped develop a common designation system for stars and cataloged thousands of stars and other astronomical phenomena. She is best known for discovering the Horsehead Nebula in 1888.

Eligibility: The award is open to female League members who are 19 years of age or older. Images submitted by professional astrophotographers or using professional observatory facilities will not be accepted. "Professional astrophotographers" means persons whose astronomical imaging produces income exceeding $2,500 during the 12 months preceding the submission deadline. Award rules and entry forms will be posted on the League website in due course, but you may request them now by emailing the League vice president, Chuck Allen, at *vicepresident@astroleague.org*.

Submissions are made by emailing the entry form and up to three JPEG attachments (not exceeding a total of 25 megabytes) to *flemingaward@astroleague.org*. The submission deadline is May 31, 2021. All submissions must consist of images taken and processed solely by the individual.

The award consists of a single category of astronomical imaging, which may include atmospheric phenomena, deep-sky imaging, Solar System imaging, or wide-field imaging. First-, second-, and third-place plaques will be presented at ALCon each year or mailed to recipients not in attendance. Cash and/or non-cash prizes will be awarded as sponsorship of the award allows. First-place winners will not be eligible to compete for the Fleming Award in the following two award cycles.

LAST CALL FOR AWARD SUBMISSIONS

The deadline for submissions or nominations for the National Young Astronomer Award, the Horkheimer Youth Awards (Service, Imaging, and Journalism), the Webmaster Award, the Mabel Sterns Award (newsletter), and the Astronomics Sketching Award is **March 31, 2021.** Details of these awards are summarized in the December issue of the *Reflector* and applications are found on the League Awards webpage. Information is also available by contacting the League vice president, Chuck Allen, at *vicepresident@astroleague.org*. Due to ongoing website construction, the 2020 application/nomination forms may be used for the 2021 awards.

LAST CALL FOR OFFICER NOMINATIONS

Two League national offices are up for election this year. These offices include the 2-year term of secretary (2021–2023) and the 3-year term of treasurer (2021–2024). The duties of these offices are summarized in the December issue of the *Reflector*. If you are interested in running or in nominating someone else, please submit a headshot photo and a background statement/bio not to exceed 250 words, both for publication in the *Reflector*, to the nomination committee chair, Chuck Allen, at *vicepresident@astroleague.org*. In order to be included on the ballots, nominations must be received by **March 31, 2021.**

UPDATING THE MID-EAST REGION OF THE ASTRONOMICAL LEAGUE (MERAL) WEBSITE

Many AL Regions and clubs are using the pandemic as an opportunity to revise their web pages. These pages are important for keeping members informed and allowing potential members to connect with your region or club.

For those of us who do not know HTML programming, several template-based website builders can now be used to construct a website. Although one must be familiar with typical computer programs, no programming is needed to create a professional-looking website. Options include Squarespace, WordPress, GoDaddy, Wix, and several others. I recently created a website for the Mid-East Region of the Astronomical League (MERAL).

In this case, Wix was used to create the *meralastronomy.org* website. Wix offers many images and video backgrounds at no additional cost. A website can be created for no cost, although the no-cost option leaves a lot to be desired. The no-cost option uses a Wix-assigned domain name that is clumsy at best, there are Wix advertisements on every page of the website, and storage and bandwidth are limited.

For approximately $20 per month, a domain name of your choice can be selected and all Wix advertisements are removed from your website. Bandwidth is unlimited and 10 gigabytes of storage is provided.

Wix allows a preview of how your website will look on a desktop computer and a mobile device. At least half of all web traffic is now estimated to be from mobile devices. If we want to reach young people – and we do – the way to do it is through their mobile devices. We need to generate interest in astronomy among young people to keep amateur astronomy growing.

If any regions or local clubs would like assistance creating a website using Wix, I will be happy to provide some virtual classes to aid your website-building efforts. Please note that I have no financial interest in Wix; I selected the Wix platform because I learned of it in a night school class on building a website without HTML. I can be contacted at *observing@ccas.us*.

—Don Knabb

Chester County (Pennsylvania) Astronomical Society; MERAL chair

FREE AAVSO WEBINARS

Have you considered completing the AL's Binocular Variable Star or Variable Star Observing Programs? Perhaps you weren't sure what variable stars were all about, or how valuable observations by amateur astronomers are to the professional community. The American Association of Variable Star Observers (AAVSO) is offering two free online series in 2021 that could be just what you need to get you started on these AL programs (or variable star observing in general). The first is a webinar series celebrating variable star science results and introducing projects of interest, and the second is "How-to Hours," introductions to specific practical aspects of variable star astronomy to aspiring observers. To register, visit *aavso.org/2021-webinars*.

RICHARD BELL WINS GLRAL WEBMASTER AWARD

Richard Bell, president of the Kalamazoo Astronomical Society (KAS), is the recipient of the Great Lakes Region's Webmaster Award for 2020. Richard has served as webmaster of the KAS website for 23 years, taking it through seven redesigns, and has edited the KAS's online newsletter, *Prime Focus,* for 19 years, producing 225 issues.

Both the KAS website and *Prime Focus* create a visually stunning and colorful online presence for the KAS. Both online publications are extraordinarily easy to navigate, are kept meticulously current, feature a wide range of menu selections, and boast one of the largest galleries the award committee has seen on any club website nationwide.

Richard is the longest serving president in KAS history, has been involved in substantial fundraising for the club over the years, hosts online viewing sessions featuring a remote telescope in Arizona, and conducts a five-part "Introduction to Amateur Astronomy" lecture series.

The GLRAL recommends you visit the Kalamazoo Astronomical Society webpage at *kasonline.org* to see the extraordinary work that a dedicated webmaster like Richard Bell can do.

—Terry Mann

JOHN EDWARD VENTRE WINS HANS BALDAUF AWARD

John Edward Ventre has been awarded the Great Lakes Region's Hans Baldauf Award for 2020. The award is the highest honor given by the GLRAL and recognizes contributions to astronomy and to astronomy education and public outreach.

A retired engineer, John has been a dedicated public educator and a lifelong patron of the Cincinnati Observatory Center, the University of Cincinnati, and the Cincinnati Astronomical Society.

John spearheaded the effort to save the famous Cincinnati Observatory from destruction, housing a telescope that was once the world's second largest. His efforts led to designating the observatory as a National Historic Landmark and leasing the observatory to a newly formed Cincinnati Observatory Center. He served as the center's first executive director, also serving on its executive and education committees and as secretary. He has contributed a virtual lifetime of volunteer work to the observatory, donating more than 20 hours a week for 20 years to the observatory. He has conducted two to four observatory tours a month, led historical tours of the observatory on Sundays, and given countless talks to scout troops, senior groups, historical societies, the University of Cincinnati, Mt. St. Joseph University, Xavier University, the Cincinnati park system, the Cincinnati Nature Center, STEM programs, and iSpace.

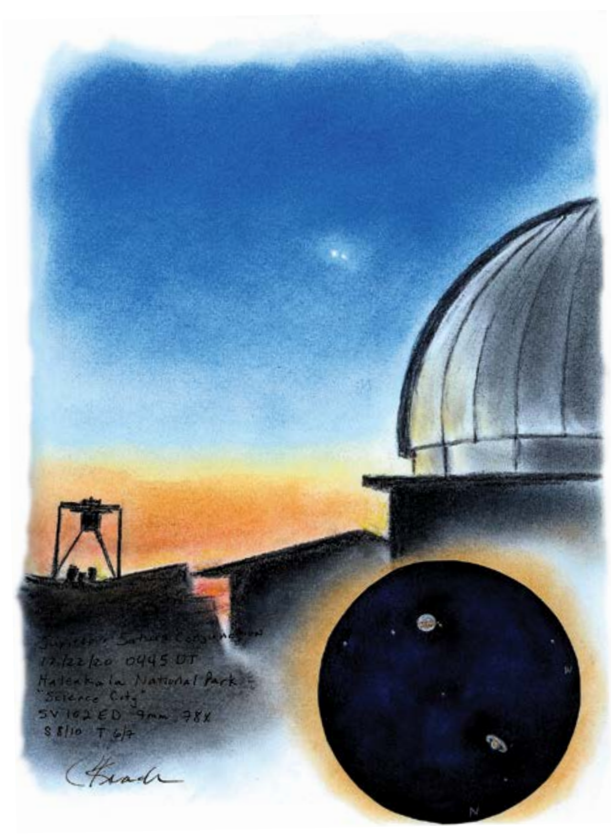
John has a special passion for the Moon and meteorites and is recognized as an authority on astronomical history and antique telescopes. A contributing sponsor of the Antique Telescope Society, John famously used his knowledge of antique telescopes and his contacts with historians to track down a lens that was stolen from the observatory in 1981 and later donated to a college in Tennessee, even identifying the thief.

John served the League as GLRAL representative for eight years and has coauthored six books and publications on astronomy education. He is a fellow of the Royal Astronomical Society (U.K.) and also served as vice president, secretary, and trustee of the Cincinnati Astronomical Society, which named him an honorary life member in 2015.

The mayor of Cincinnati, Mark Mallory, proclaimed December 1, 2009, as "John Ventre Day" to celebrate the massive contributions that John has made to public education in the Cincinnati community. The GLRAL is honored to recognize the incredible achievements of this selfless public educator.

—Terry Mann

THE "GREAT CONJUNCTION" OF 2020



With all the challenges of 2020 it's nice to add a special event to memory. I spent a socially distanced masked evening with a few friends and my daughter at the Haleakala Amateur Observers site at 10,000' elevation for the Saturn-Jupiter conjunction. The weather cooperated with some upper atmospheric disturbance, but otherwise very good conditions. The sunset made for a lovely backdrop to the telescopes at the site. The cloud decks of Jupiter were visible but without clear distinction. Saturn looked like a tiny toy in the eyepiece. The open telescope on the left is the 1-meter Faulkes Telescope North. The lower inset sketch is the eyepiece view but at a little later time as the sky darkened further.

Inset sketch from SV102ED, 78x magnification.

White paper, Conté cayons, charcoal

—Cindy L. Krach

Astronomical League Sketching Observing Coordinator

Haleakala Amateur Astronomers Maui, Hawaii

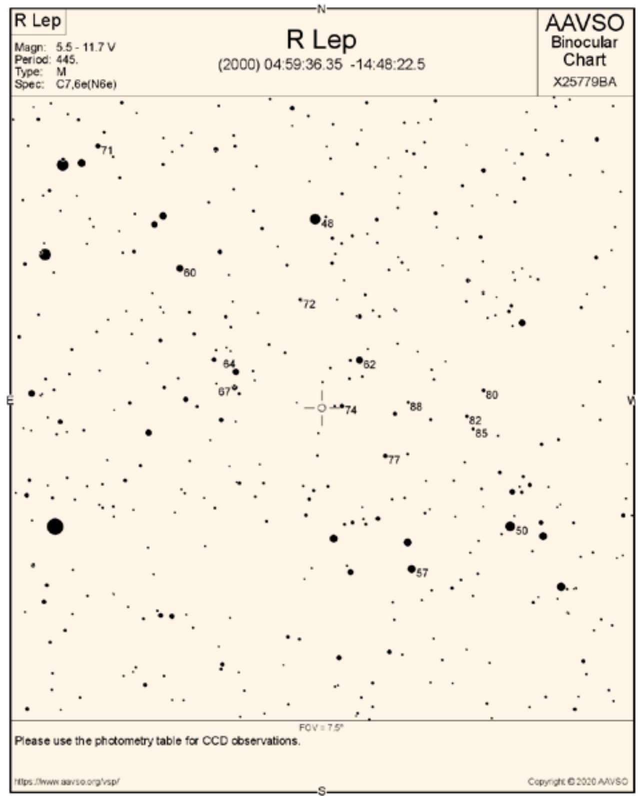
12 CELEBRITY VARIABLE STARS

By David Dickinson

Thinking there's nothing new in deep-sky astronomy? Variable star observing is a great way to catch changes in the heavens, sometimes from one night to the next. Observing variable stars is real science that you can do tonight. The American Association of Variable Star Observers (AAVSO) has been archiving such measurements from dedicated volunteers since 1911. Here are some of our evening favorites for northern hemisphere observers, month by month:

JANUARY — R LEPORIS (HIND'S CRIMSON STAR)

Around the time of every Winter Star Party, my wife always asks me to show viewers the "red star" near Orion, R Leporis, also known as Hind's Crimson Star, in the constellation Lepus, the Hare. A massive star actually 1,300 light-years distant, R Lep varies once every 427 days from magnitude 6 – in range of binoculars – to a faint magnitude 11. R Lep always pops out in the field as a blood-red dot, one of the reddest stars in the sky. R Lep is what's known as a carbon star, an ancient sun exhausting its nuclear fuel and accumulating carbon soot in its outer shell, giving it a reddish hue. Form a right triangle with Rigel in the knee of Orion and look three degrees west of Mu Leporis to find Hind's Crimson Star.



FEBRUARY — BETELGEUSE

In late 2019, I received a startling message across social media: the bright star Betelgeuse in the shoulder of Orion, the Hunter, was starting to dim. Alpha Orionis was actually a bit fainter than Rigel, the Beta star for the constellation. Betelgeuse typically varies from magnitude 0 to magnitude 1.3, though the 2019/2020 dip took the orange-tinged star down to magnitude 1.6, the faintest for the star on record. Located about 720 light-years distant, Betelgeuse is on the short list for nearby stars that could one day go supernova. Though close galactically speaking, a future Betelgeuse turned supernova is far enough out of the 50 light-year "kill zone" that it won't present a hazard to the Earth. Instead, it will simply put on a good show, easily visible in the daytime and providing an unprecedented opportunity for astronomers to study a supernova up close.

MARCH — U GEMINORUM

Located about five degrees southeast of the bright star Pollux, U Geminorum is one of a rare class of stars known as cataclysmic variables. Located 305 light-years distant, U Gem spends most of its time at a faint, barely detectable magnitude 15. Every 62 to 150 days, however, U Gem can vault up to a respectable eighth magnitude, in range of binoculars.

U Gem consists of a red dwarf star orbiting a white dwarf once every 4 hours and 11 minutes. An accretion disk is building around the dense white dwarf as it strips the red dwarf of material, causing it to frequently erupt in a violent flash. U Gem is the archetype of a whole class of variable stars known as dwarf novae.

APRIL — R LEONIS

Another red giant variable star rides high on April evenings. The field for R Leonis is an easy find, located about five degrees due west of the brilliant star Alpha Leonis (Regulus). Located 330 light-years away, R Leo can vary seven magnitudes or over 600 times in brightness over a span of 310 days, from a faint magnitude 11.3 to naked-eye visibility at magnitude 4.4. R Leonis is a great northern hemisphere example of a Mira-type variable star, the archetype for which is the star Mira (Omicron Ceti) in the constellation of Cetus, the Whale.

Mira-type variables are massive red giants at the end of their lives, pulsing and throwing off their outer shells. A similar fate awaits our Sun in around five billion years, briefly swelling into a red giant for a hundred million or more years, sloughing off its outer layers and creating a planetary nebula, leaving behind the cinder of a dense white dwarf.

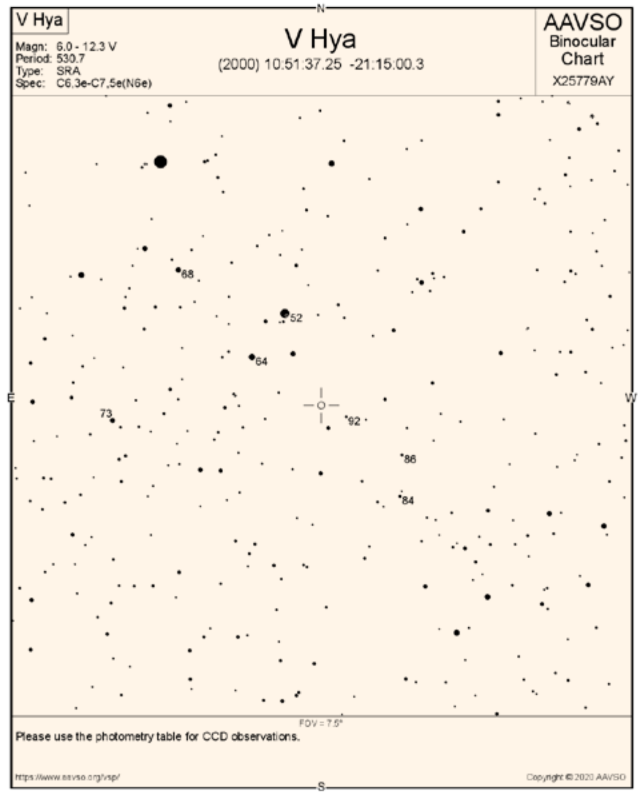
MAY — V HYDRAE

May skies host one of my favorite star party "secret weapons." Set off in the meandering constellation of Hydra, the Sea Serpent, V Hydrae is a deep cherry-red carbon star that can easily compete with R Leporis for the title of the sky's reddest star. Located roughly five degrees due south of the third-magnitude star Nu Hydrae, V Hya varies from magnitude 6.5 to 12 once every 531 days and sits about 1,500 light-years distant. Once every 8.5 years or so, V Hydrae puts on an especially fine show, spiking in the ultraviolet as an unseen companion in an eccentric orbit dips through the primary star's outer atmosphere. Conversely, the star experiences a deep minimum about once every 17 years, probably caused by a disk of accreting material surrounding the star.

JUNE — Y CANUM VENATICORUM (LA SUPERBA)

In 1867, astronomer and Jesuit priest Father Angelo Secchi was sweeping a region of the sky in the constellation of Canes Venatici, the Hunting Dogs, with the Vatican Observatory's 16-inch Merz refractor when he came upon a surprise: a ruddy-hued star, which he named La Superba, or "the Splendid One." Another fine example of a carbon star, Y Canum Venaticorum or Y CVn is located about a third of the way between the star Chara (Beta CVn, one of the "dogs") and the famous pair Mizar and Alcor in the handle of the Big Dipper.

Located 750 light-years distant, Y CVn



varies from magnitude 5.0 to 6.4 and peaks roughly every 158 days.

JULY — U SCORPII

Summer nights are shorter up north, but seeing the span of our home galaxy, the Milky Way, makes up for it. One region to keep an eye on is just a degree north of the fine double star Nu Scorpii in the head of the Scorpion. U Scorpii is a member of a rare class of stars known as recurrent novae, only ten of which are known. These stars may spend decades out of range of even large backyard telescopes, only to suddenly burst into brilliance. In the case of U Sco, observer Barbara Harris raised the alarm that the star was once again in outburst on the morning of January 28, 2010. U Sco eventually topped magnitude 7.5 until once again fading into obscurity. U Sco also erupted in 1999, 1987, and 1979. A close companion is likely dumping material onto a dense white dwarf, which occasionally builds up, compresses, and erupts. You can see the rough once a decade pattern in U Sco, so we could well be due for another eruption in coming years.

AUGUST — R AQUILAE

Looking northward across the span of the constellation of Aquila, the Eagle, brings us to another fine variable star for summer nights. R Aquilae is another example of a Mira-type variable. Located about five degrees due south of the double star Zeta Aquilae in one wingtip of the Eagle, R Aquilae is about 1,400 light-years distant. R Aql varies from magnitude 5 to 12 once every 270 days. Curiously, the pulsation of this star has been speeding up slightly over the past century, decreasing from a period of 320 days to the present span. As is the case with many variable stars, there may be longer oscillations juxtaposed over shorter periods.

SEPTEMBER — DELTA CEPHEI

One of the most crucial variable stars in astrophysics rides high in the sky on September evenings for northern hemisphere observers. Located in the constellation of Cepheus, the King, Delta Cephei has allowed observers to measure the scale of the cosmos.

Delta Cephei lends its moniker to the class of stars known as Cepheid variables. Its variability was first noted by astronomer John Goodricke in 1784. Henrietta Swan Leavitt identified Cepheids in the Magellanic Clouds in 1908, allowing astronomers to gauge their distance from the Earth. Cepheids exhibit a unique trait known as a period-luminosity relationship, meaning their period is correlated with their brightness – find a Cepheid in a distant cluster or galaxy, and you can gauge its distance. Delta Cephei itself is about 865 light-years distant.

Delta Cephei varies from magnitude 3.5 to 4.4 once every 5.4 days. Good nearby comparison stars include magnitude 3.6 Zeta Cephei and magnitude 4.2 Epsilon Cephei.

OCTOBER — WZ SAGITTAE

Lost among the more glamorous constellations of the Summer Triangle formed by the stars Vega, Altair, and Deneb, the tiny constellation of Sagitta, the Arrow, punches above its weight in terms of interesting variable stars. WG Sagittae is another fine example of a cataclysmic dwarf nova star. Located 147 light-years distant at three degrees southeast of the star Gamma Sagittae, WZ Sge can vary from magnitude 7 to 16, nearly a 10,000-fold change in brightness. The last outburst for WZ Sge was in 2001, and twentieth-century outbursts occurred in 1913, 1946, and 1978, for a very rough period of 30 years. The 1913 event was an especially fine one, topping magnitude 7. WZ Sge is what's known as an SU Ursae Majoris–type cataclysmic variable, characterized by normal weekly outbursts punctuated by super-outbursts. Like a fine novelist, WZ Sge seems to only be interested in producing super-outbursts in activity once every few decades or so.

NOVEMBER — EPSILON AURIGAE

Long before the mystery of Tabby's Star (KIC 8462852) was evoking thoughts of alien mega-structures and Dyson spheres in the press, there was the strange case of Epsilon Aurigae in the constellation Auriga, the Charioteer. Located about 2,000 light-years distant, this placid third-magnitude star pulls a vanishing act, fading below naked-eye visibility once every 27 years, and staying there for 640 to 730 days, about two years. Clearly, something obstructs our view of this star, but what is it? Today, a good working model for the Epsilon Aurigae system includes a small companion star enveloped in a torus of gas and dust that blocks our view once every 27 years. You can see Epsilon Aurigae with the unaided eye (when it's not dim) equidistant from the "Kids" asterism of stars Eta and Zeta Aurigae and brilliant Capella. The last minimum for Epsilon Aurigae was around 2010, and the next one will occur in 2037.

DECEMBER — ALGOL

One of the most famous variable stars in the sky, Beta Persei, was given the name Algol, the "Demon Star," by Arab astronomers. Did they note its tempestuous variable nature under clear desert skies and name it accordingly? Algol waxes and wanes from magnitude 2.1 to 3.4 – a threefold change in brightness – once every three days, and its dip lasts for about ten hours. Today, we know that Algol is an eclipsing variable star, a pair of stars that happen to orbit each other edge-on along our line of sight. In the case of Algol, the system includes 3- and 0.7-solar-mass stars in a tight orbit, about 0.6 AU (astronomical units) apart. We see the full brightness from both stars when they're at right angles to our line of sight, then the dip in brightness occurs when they're one in front of the other.

These are just a small sample of the thousands of variable stars that await the observer, any time of the year. Visit *aavso.org* to learn more. ✷

David Dickinson is the author of The Backyard Astronomer's Field Guide.

The charts are courtesy of AAVSO.

CREATING THE "PHASE-STACKED" MOON

By Jai Shet and Neil Shet

For the last few years, we had been traveling the United States capturing stunning images with our cameras. We are passionate about astronomy, and combining this with photography compelled us to do astrophotography in dark-sky places across the country. Being homeschooled made it easier for us to pursue this hobby. We have visited 38 out of 62 U.S. National Parks so far, some in which we stayed overnight to photograph the night sky. We have taken wide-angle shots of the Milky Way and have spent hours creating time-lapses. Our most stunning image is a 200-image Milky Way panorama which was published in the September 2020 edition of the *Reflector*.

We were at the height of our adventures after traveling almost every month in 2019. We looked forward to 2020 as we planned to continue our travel and astrophotography, but the pandemic made that an unviable option. We were heartbroken because living in the Houston area ruled out any possibility of photographing the Milky Way. Even worse was that we did not have good equipment for deep-sky imaging. The quarantine meant that the farthest we could travel was our backyard. In desperation, we sought out new ways to pursue our interests. Looking up at the night sky, the Moon was the only object that appeared to look back at us. Everything else seemed drowned out by the bright city lights of Houston, so we resorted to photographing the Moon for a lack of anything better.

We attempted lunar imaging on several nights but were frustrated with the quality of our images. Our equipment produced a low magnification which was not enough for imaging craters in detail. Luckily, one day, when a fellow amateur astronomer was preparing to move to another state, he offered to give away his vintage Celestron 8-inch Schmidt-Cassegrain telescope for free. We immediately seized the opportunity with high hopes that the telescope would keep us busy during the pandemic. Even though the telescope was from the 1980s, it meant a great deal to us because it produced an exceptionally high magnification, which would allow us to take better lunar images.

We had a blast imaging the multitude of Moon craters using the new acquisition and our Canon EOS R camera. We learned new imaging techniques in the process, one of which was to take multiple images and stack them together. This reduced the blur caused by the Earth's turbulent atmosphere and made craters look sharper. The atmosphere could easily smear fine detail on the lunar surface if we took just a single image instead of stacking multiple images. But how could we accumulate the large number of pictures we needed? Taking individual pictures one at a time would have been time-consuming, so we took 1-minute Ultra HD 4K videos recording at 30 frames per second to provide us with 1,800 frames per video to stack. Stacking a large number of frames greatly improved the quality of our photographs. We also made use of the telescope's high magnification to take three- to five-image panoramas of the Moon.

We noticed that the most well-defined craters were always near the lunar terminator (the line that divides day and night on the Moon). Craters farther away from the terminator were not as clear, so we wondered if one could see all the craters of the Moon as clearly defined as those near the terminator. Even though the whole Earth-facing surface is visible when the Moon is full, the craters look two-dimensional and are hard to distinguish due to a lack of shadows. How, then, could we create an image of the full Moon with all the craters in depth? As quickly as we came up with the question, we realized the answer. Since each phase had some prominent craters, we could photograph all the phases, pick the clearest craters of each phase, then combine them together. This, we imagined, would produce a composite full Moon image exhibiting all the craters of the Moon in greater detail.

We experimented with this idea in January 2020, before the pandemic started. We had captured all the waxing phases and combined together the clearest craters of each phase. We lacked a telescope at that time and instead used a Sigma 150–600 mm f/5.6–6.3 lens. The result was fantastic, but the image's resolution did not satisfy us. The Schmidt-Cassegrain telescope we acquired during the pandemic made it possible to upgrade the resolution of that image, so we decided to do the project once more.

Our second try on that project, however, would turn out to be different. We could only see a small portion of the sky from our backyard, and most of the waxing phases would end up being blocked by trees. Looking through the "window," we determined that we could only capture all the waning phases this time. This led us to a difficulty which was worse than the trees: getting up in the middle of the night for two weeks! Despite this, we figured that it was our best opportunity, as the weather forecast was for clear skies.

We planned diligently to be sure of capturing all the phases. In doing our research, we found that there was a pattern in the times we had to wake up. On the first night, the 95 percent illuminated phase was visible at 11:30 p.m. The following night, the 90 percent phase appeared at midnight. Consequently, the 80 percent phase showed up in the sky at 1 a.m. The Moon heads toward the morning sky as the waning phases get smaller. In other words, if the full Moon (or 100 percent illuminated phase) is visible from our backyard at 9 p.m. and the smallest crescent phase is not visible until 6 a.m., every other waning phase would fall in between 9 p.m. and 6 a.m. That was why each consecutive waning phase appeared later each night.

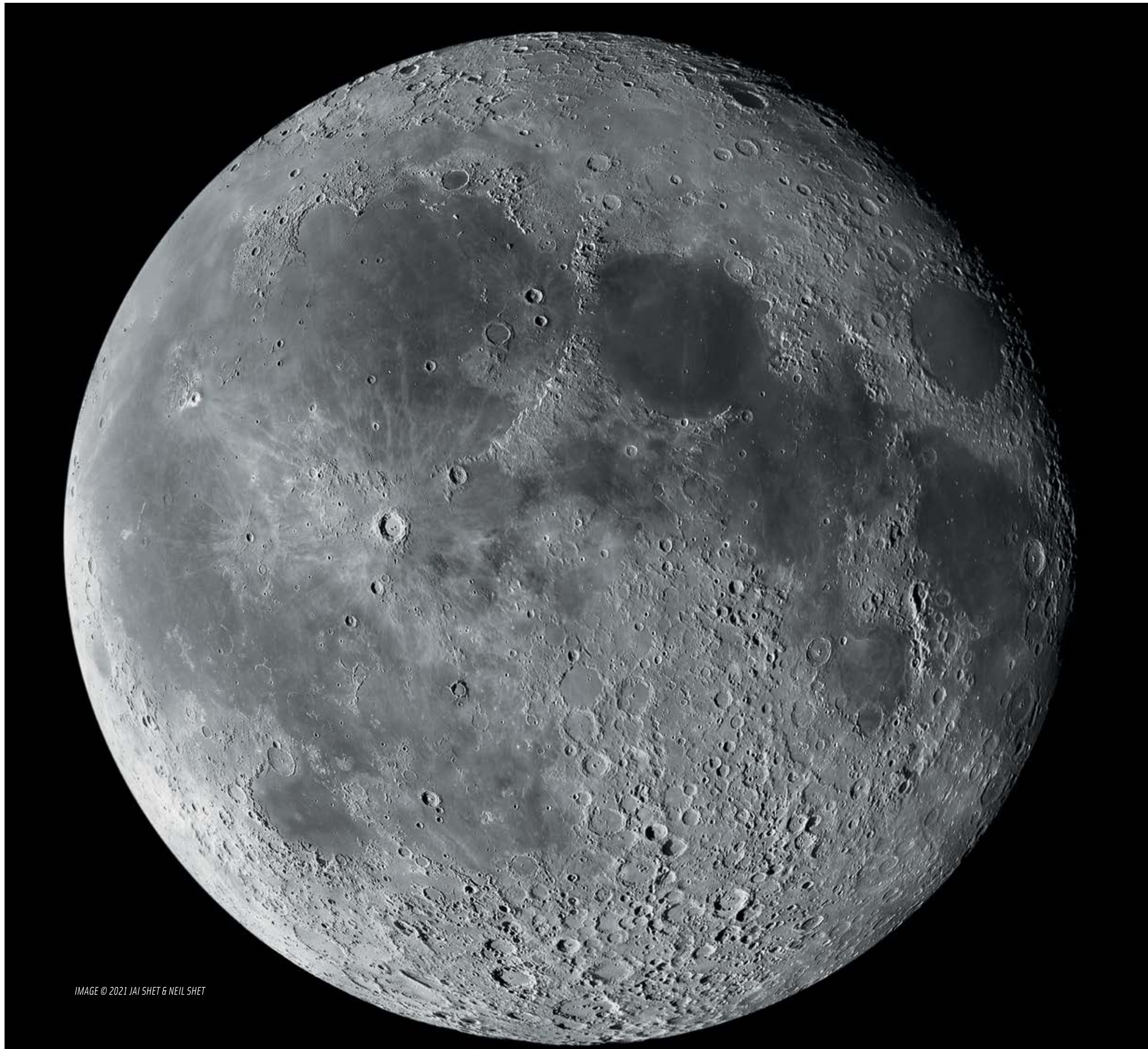
As if getting up early was not frustrating enough, getting up only to find cloudy skies was infuriating. We anxiously went to bed fearing that we would wake up under cloudy skies. We were fortunate not to miss a single phase. Even when clouds were present, we managed to make use of periods of respite. We used the video capture technique as it was fast and efficient, reducing the risk of clouds disrupting our session. We were relieved after successfully imaging for 12 nights, but our work was not over: processing and combining the phases would be the bulk of the project.

We used software called RegiStax to stack the images after accumulating nearly 75,000 frames from the 156 gigabytes of videos we shot. Then we got down to the trickiest part: combining the phases. We had to figure out a way to do this on our own because no specialized software or online tutorials existed for what we were trying to achieve.

It took two weeks, 20 hours of actively working on the computer, and dozens of attempts to combine the phases together in Photoshop. The Moon wobbles during its orbit around the Earth, which means all the phases never align perfectly. We tediously aligned every single crater using the tools in Photoshop to counter the wobble. Once alignment was complete, we retouched areas of the image to make it seamless. Surprisingly, despite the amount of work that ws involved, our computer never crashed. The result of our efforts is what we call the "phase-stacked" Moon.

However, we will never see the Moon like this in real life. As mentioned earlier, craters are hardly visible on a full Moon because they lack shadows which are necessary for perceiving depth, but every feature on the "phase-stacked" Moon has shadows. Even though the "phase-stacked" Moon is not a single true image of the Moon, it allows one to appreciate all the craters at once. Overall, we managed to improve the resolution of our original "phase-stacked" Moon and enjoyed the project every step of the way despite the challenges. We hope to continue pursuing our passion for astrophotography by creating opportunities instead of waiting for them. ✷

Jai Shet and Neil Shet are members of the Fort Bend Astronomy Club.



COMBINING BROADBAND AND NARROWBAND IMAGERY

By Stephen J. Maas

Emission and planetary nebulae are some of the most beautiful deep-sky objects sought out by astro-imagers, but their successful capture is often challenging. The surface brightness of many of these objects is low, often requiring long exposures to bring out their details. Unfortunately, long exposures can result in stars in the field surrounding the nebula appearing overexposed and bloated. Is there a way to have both bright, detailed nebulae and compact, natural-looking stars?

A possible solution comes from the way emission and planetary nebulae produce their light. High-intensity radiation from nearby stars, or collisions with the interstellar medium, cause a nebula's gases to glow. This light is emitted at specific wavelengths. For example, ionized hydrogen can emit light at 656.3 nm (H-alpha) or 486.1 nm (H-beta), while ionized oxygen can emit light at 500.7 nm (O III). These emissions give nebulae their characteristic colors.

Monochrome digital cameras equipped with the appropriate narrow-bandpass filters can capture the specific colors of nebulae. Long exposures using narrowband filters can record the detail of nebulae without overexposing the surrounding stars. Stars generally emit light in a nearly continuous spectrum, so imaging them with narrowband filters records only a small portion of their light. But, for this same reason, you generally can't combine narrowband images of stars and get them to come out in their correct colors.

So, how about a hybrid approach? Suppose you collected long exposures in the appropriate narrow bands to show the details of the nebula, but also shorter exposures in the standard broad bands (red, green, and blue) to produce sharp stars in their correct colors. If you could then combine them properly, the resulting hybrid image would display a bright, detailed nebula and sharp, point-like stars.

This has been attempted by many astro-imagers. The devil is in how you combine the various broadband and narrowband images. Often a degree of subjectivity is employed so that the resulting image "looks good." But what looks good to one person may not look good to another. Is there an objective method for combining these images that can produce a "true color" rendition of an object?

But first, what do I mean by a "true color" image? To me, a true color image is one that shows the object in the colors you would see if your eyes were sensitive enough to adequately respond to the levels of light emitted by the object. The Orion Nebula (M42) looks like a grayish wisp in a small telescope not because that is its true color, but because your eyes aren't sensitive enough to properly respond to it. Were your eyes more sensitive, the nebula would blaze with the red and pink colors that we know it has.

To illustrate the procedure, I'll use the example of the Dumbbell Nebula (M27). In 2015, I acquired 16-bit broadband (red, green, and blue) and narrowband (H-alpha, H-beta, and O III) imagery of it using a QSI 583 monochrome camera on an Orion EON 120 mm refractor. To capture the star field, I used broadband exposures of 1.5 minutes. To capture the nebula, I used narrowband exposures of 15 minutes.

I used standard image processing to align the individual images, apply dark and flat images, and correct for atmospheric extinction. The individual images were then stacked to produce "master" red, green, blue, H-alpha, H-beta, and O III images.

The first step in the hybridization process is to remove the stars from the master narrowband images. I used Straton *(zipproth.de/Straton)*, an inexpensive standalone package that generally does a good job. The results are master narrowband images that only contain the nebula.

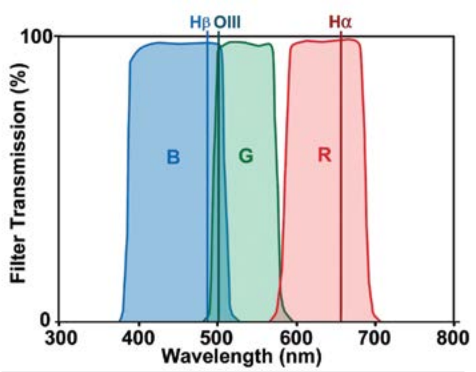


Figure 1. Bandpass characteristics of typical broadband and narrowband astronomical filters

Before we start combining images, let's look at the spectral characteristics of broadband and narrowband images. Figure 1 shows the spectral bandpass characteristics for the filters I used in the example. Where the narrowband filters lie with respect to the broadband filters will determine how we combine the images produced with them. The H-alpha filter lies entirely within the red broadband filter's bandpass, so images produced with those two filters should be combined. The O III filter lies within the green broadband filter's bandpass, and thus images produced with those two filters belong together. But it also lies in a portion of the blue broadband filter's bandpass. This mixture of blue and green produces the "teal" color characteristic of many planetary nebulas. So, we must combine the blue broadband image with not only the H-beta narrowband image but also the O III narrowband image. We can do this by adding the H-beta and O III narrowband images using image processing software to produce a single H-beta + O III image.

Now we have three pairs of images (Figure 2). The red broadband image goes with the H-alpha narrowband image, the green broadband image goes with the O III narrowband image, and the blue broadband image goes with the H-beta + O III narrowband image.

Before we combine the images, there's one thing we need to do. We usually assume that "empty space" is black, but some of the light that we capture with our images doesn't come from space but actually comes from atmospheric sources, primarily light pollution and airglow. This is often referred to as "skylight" and it can affect the color balance of our imagery. Using image processing software, I collected digital number (DN) values for pixels in the "empty spaces" between stars in the images. This is indicative of the skylight

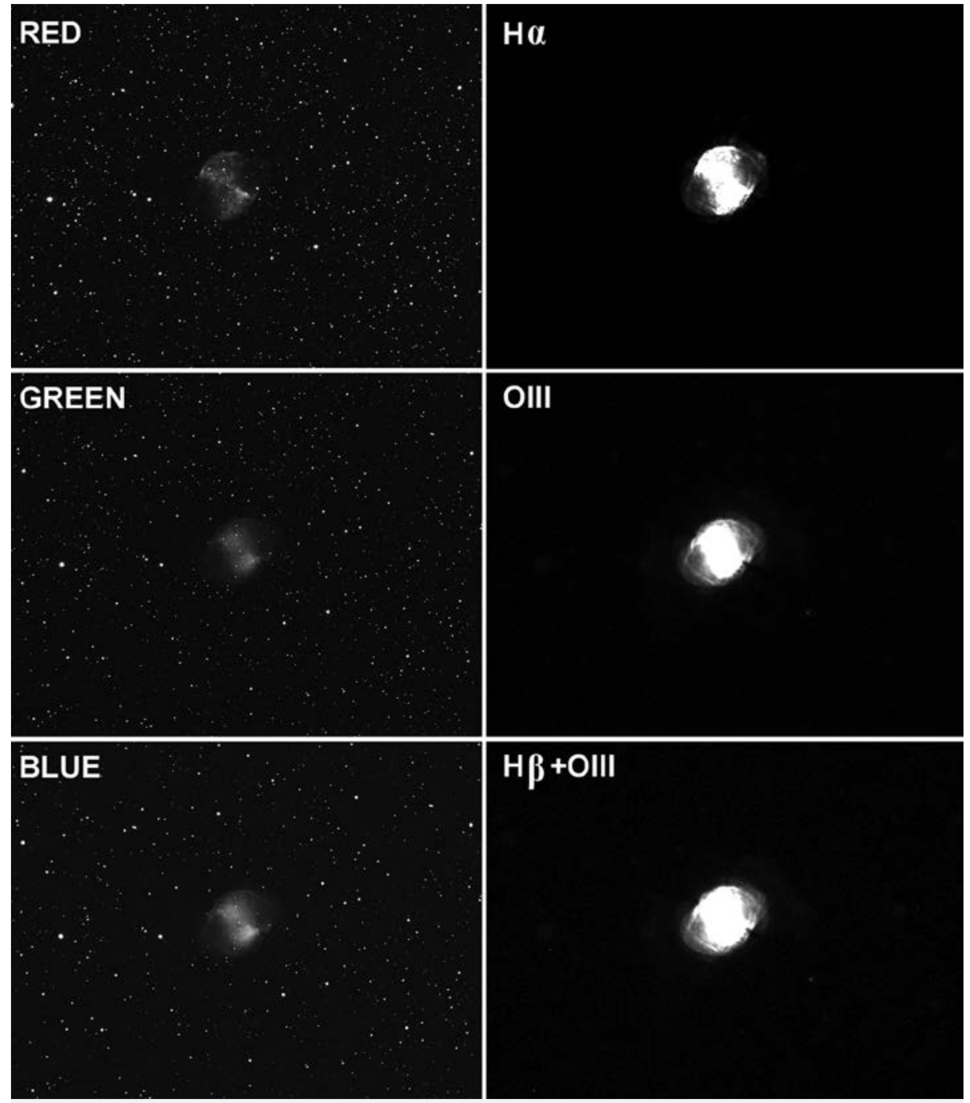


Figure 2. Master broadband and narrowband images

Figure 3. "True color" image of M27 resulting from this procedure

brightness. Objects in the image also contain the effects of skylight, but it's easier to quantify this effect by looking at the "empty" portions of the imagery. Averages are listed below for the images in Figure 2. Note that the average value for the H-beta + O III image is about twice the values for the other images. In adding the H-beta and O III images, we also added their skylight values.

RED	*381*
GREEN	*356*
BLUE	*376*
H-ALPHA	*313*
O III	*343*
H-BETA + O III	*653*

The easiest way to fix this problem is to normalize the skylight brightness among the images. We can do this separately for the broadband images and the narrowband images. To normalize the broadband images, I first noted that the green image had the lowest DN value (356). Using AIP4Win *(willbell.com/aip4win/aip.htm)*, I subtracted 25 DN from each pixel in the red image and 20 DN from each pixel in the blue image. This resulted in each broadband image having approximately the same skylight brightness. For the narrowband images, the H-alpha image had the lowest average skylight brightness (313). I subtracted 30 DN from each pixel in the O III image and 340 DN from each pixel in the H-beta + O III image. This normalized the skylight brightness among the narrowband images. This process not only corrects the color balance of the "empty" portions of the images but also the color balance of the objects in the image.

We're now ready to combine images. Instead of simply adding images, we'll use the "maximize" function found in many image processing software packages. I used MaxIm DL *(diffractionlimited.com/product/maxim-dl)*. This function looks at each pixel location in two images and determines which has the greater DN value; it then writes this value into the corresponding pixel location of a new image. Since the narrowband images don't contain stars, the stars for the new image will come from pixels in the broadband images. And since the nebula is brighter in the narrowband images than in the broadband images, the nebula for the new image will come from pixels in the narrowband images. Exactly what we wanted!

We now have "hybrid" red, green, and blue

Figure 4. "True color" image of NGC 2174 resulting from this procedure

images created from our pairs of broadband and narrowband images. These can be combined to produce the final color composite image. Since this was a 16-bit image, I had to do some contrast-stretching using Photoshop to convert it to an 8-bit version that could be saved as a JPG image.

Figure 3 (previous page) shows the results. In this image, the stars display a natural range of colors without strongly saturated cores or bloating. The nebula is bright yet still shows a lot of detail. Most importantly, the nebula's colors are realistically rendered, from the soft teal of the O III emissions from the nebula's interior to the intense red of the H-alpha emissions along the nebula's shock fronts.

Figure 4 shows another example, NGC 2174, the Monkey Head Nebula. This is an H II star-forming region. As such, most of its light is due to ionized hydrogen and, in contrast to planetary nebulae, little is due to ionized oxygen. Thus, the nebula glows in the reds of hydrogen emissions.

Keep in mind that this approach is totally objective. All the information used in it came from the images themselves. Prior to contrast stretching of the final result, there was no subjective "fidgeting" with the images to produce a desired appearance. While this approach might not appeal to those who want a more artistically creative result, it does a good job of rendering realistic views of what many astronomical objects actually might look like. ✷

Stephen J. Maas is president of the South Plains Astronomy Club.

The Big Bang: Space Science Education for the Next Generation

By Cecilia Detrich

This is an interesting time in science education for our young students in the United States. Forty-four states have now embraced, in some version, the national Next Generation Science Standards *(ngss.nsta.org)* introduced in the 2013–2014 school year. This science education program covers four domains: physical science, life science, Earth and space science, and engineering. Opportunities for students to explore connections between the domains are woven into the standards so that students will develop a practical understanding of how to think and work like a scientist or engineer.

The astronomy community has a generous tradition of outreach and is always eager to share the wonder of the cosmos. We can enhance our support of young scientists and their teachers if we understand the science curriculum that is taught in our public schools. This article examines science standards that specifically address the space science standards that are taught in kindergarten through 12th grade. With this information, astronomy outreach opportunities can be planned to supplement what our students are learning in school, either by supporting their current learning or providing experiences that explore ideas beyond the scope of the standards.

The space science standards are titled "Earth's Place in the Universe." They cover two disciplinary core ideas (DCIs) that deal explicitly with space science: *The Universe and Its Stars* (ESS1.A) and *Earth and the Solar System* (ESS1.B). Within these core ideas, students explore the space science standards through crosscutting concepts that are common in all domains of science. These concepts are used to inform teachers and students how to interact with the standards. The concepts include patterns; scale, proportion, and quantity; systems and systems models; and energy and matter.

Our youngest students are introduced to space science in first grade *(nextgenscience.org/sites/default/files/dci-arrangement/1.ESS1June2017_0.pdf)* when they investigate Earth's place in the universe and look for patterns and cycles in the sky. These young scientists can benefit from our guidance on observing and predicting the movement of the Sun, Moon, and stars across the sky (Standard 1-ESS1-2). Students at this age are also asked to observe and compare relative amounts of daylight during the seasons of the year to discover patterns in this phenomenon (Standard 1-ESS1-2). Varied experiences with

these core ideas will provide the students with a foundation for more in-depth learning in later grades.

The next grade that students receive explicit instruction in space science is fifth grade *(nextgenscience.org/sites/default/files/dci-arrangement/5.ESS1June%202017.pdf)*, and these standards are packed with information to process and synthesize! Our fifth-grade students continue to explore observable patterns in the Solar System. Additionally, these standards introduce the concepts of scale, proportion, and quantity in space. Our students are expected to complete fifth grade with the ability to support an argument that observable differences in the brightness of the Sun and other stars occur because the Sun is relatively close to Earth and other stars are very far away (Standard 5-ESS1-1). Students are also asked to observe and communicate the daily patterns of sunlight and shadows and the yearly cycle of visible stars and other natural objects in the night sky due to movement within the Sun-Earth-Moon system (Standard 5-ESS1-2). This is a good time to make sure students can differentiate between the meanings of rotate, revolve, and orbit.

Middle school students build upon their elementary foundational space science lessons with standards that explore more comprehensively the two core ideas of the *Universe and its Stars* and *Earth and the Solar System (nextgenscience.org/sites/default/files/MS%20ESS%20SS%2004.08.14.pdf)*. Patterns, as well as scale, proportion, and quantity, continue to be focus concepts for these standards, with the addition of systems and system models. In order to more fully understand the relationships and mechanics of the Sun-Earth-Moon system, students are asked to describe and model the observable patterns and cycles of Earth's seasons, lunar phases, and eclipses (Standard MS-ESS1-1). Continuing with this theme of motion in space, our middle school students investigate the role of the force of gravity within solar systems and galaxies (Standard MS-ESS1-2). This can also include the role of gravity in ocean tides, particularly in U.S. states that have ocean coastlines. We can also assist our young astronomers in comprehending the incomprehensible – the enormity of the universe! Middle school students need guidance on how to examine and analyze data, gathered from Earth- and space-based instruments, about scale properties of objects within our Solar System including orbital radii, structure, and surface features (Standard MS-ESS1-3). A hands-on scale model of the Solar System activity is a perfect activity aligned with this standard.

Finally, in high school, the concepts of energy and matter are added to the concepts of scale, proportion, and quantity to provide direction for high school students to explore the core ideas of the *Universe and Its Stars* and *Earth and the Solar System*. Supporting these core ideas of space science are two core ideas from the physical science domain: Energy in Chemical Processes and Everyday Life and Electromagnetic Radiation *(nextgenscience.org/sites/default/files/HS-SS%205.6.13With%20Footer.pdf)*. The connections between these four core ideas are evident to us, but our young scientists may need our assistance to make them apparent. Spectroscopy is an example of a concept that unites all four areas.

There are four high school space science standards, loaded with information that builds upon the learning that began in first grade while looking for patterns in sky phenomena. Our high school scientists need to be able to use evidence to model the life of a star and describe the process of energy transfer from nuclear fusion in the Sun's core to energy received on Earth as solar radiation (Standard HS-ESS1-1). This is a good place to review energy transfer in terms of conduction, convection, and radiation. Investigating the theory of the Big Bang is the basis for the next standard on the high school list. Students can demonstrate an understanding of this theory by citing astronomical evidence about matter in the universe and the motion and light spectra of distant galaxies (Standard HS-ESS1-2). This would be an appropriate time to introduce the significant scientific contributions of the women astronomers of Harvard Observatory during the time of Williamina Fleming, Henrietta Leavitt, and Cecilia Payne-Gaposchkin. Students further explore the energy and lifecycle of stars, specifically to communicate how stars produce the elements in our universe (Standard HS-ESS1-3). Finally, students are introduced to Newton and Kepler through their mathematical representations of the laws of gravity and orbital motions (Standard HS-ESS1-4). Students are not required to do calculus for this work, but certainly may if they are ready for it.

After 12 years of science education grounded in the Next Generation Science Standards, our young adults should be ready for a lifetime of involvement in the sciences, either as future scientists or as scientifically literate and active participants in science as citizens of Earth. Members of community astronomy organizations have so much to offer our young people to help them achieve these objectives. Our expertise, access to astronomy equipment, and passion for astronomy, combined with our understanding of the scope and sequence of the national space science standards will enable us to develop even more meaningful outreach programs and presentations for the next generation. ✷

Cecilia Detrich is a member and board member of the Springfield Telescope Makers.

Photos are by the author.

Williamina Fleming

A Pioneering Woman In Astronomy

By Dr. W. Maynard Pittendreigh

When astronomer Williamina Fleming died in 1911, it was said that she had been able to get her chance to rise to prominence in an essentially male-dominated science when her boss told his assistants in frustration, "My maid could do better than you." Mrs. Fleming was that maid who became one of the most important astronomers of the late 19th and early 20th centuries.

Fleming discovered the Horsehead Nebula through the then-new science of astrophotography in 1888. That alone would have earned her fame that any current member of the Astronomical League would love to claim. More than that, she developed ways to classify stars, observed the first white dwarf, and discovered over 50 gaseous nebulae, 10 novae, and over 300 variable stars. She was frequently highlighted in newspapers in the early 20th century in human-interest articles about the successful woman working in what was then often described as a man's world.

As to whether or not her boss actually told his staff "my maid could do better than you," and how she proved him right, it is good to recall what Mark Twain once said: "Interesting if true. And if not true, still interesting." This story was related in an article that appeared in several newspapers late in 1906, but more reliable sources described her first job with Professor Edward Pickering as a copyist. The maid story was, however, one that helped endear her in the hearts of early 20th-century Americans and again later in the 21st century through a stage play about the lives of women astronomers, "Silent Sky."

Williamina Paton Stevens Fleming was born in Scotland in 1857. She was familiar with overcoming adversity at a young age. Her father died when she was seven, and her mother a few years before that.[1] She attended public school, where she demonstrated academic excellence. She was employed as a teacher at the age of 14. While the position of "pupil/teacher" was not common, it was by no means unheard of in Scottish schools in the 19th century. Accomplished students were paid to teach younger students while continuing their own studies.

At the age of 20, she married James Fleming and a year later the young couple sailed to Boston, Massachusetts. They were soon looking forward to the birth of a child. However, before their son was born, James deserted his family, leaving Fleming with more adversity to overcome.

She continued to find strength and resourcefulness to survive and thrive. The 23-year-old single mother found employment from Edward Pickering, who taught astronomy at Harvard and worked as the director of Harvard College Observatory. She may have started as a maid or housekeeper, but most sources describe her first position as his "copyist."[2] She kept that position only a few months before Pickering hired her to serve as a "computer." Those who have read the book or seen the film *Hidden Figures* will recall that the term "computer" sometimes referred to mathematicians who were hired to do complex calculations. In the case of the Harvard computers, the term was also applied to those who analyzed photographic plates and spectra.

She began to work with the vast library of astrophotography images and in 1899 was given an official position with Harvard as the curator of the library of 200,000 images. Newspapers, reporting on this seven years later, said that in the then-250-year history of Harvard, no other woman had held an official position at the university.[3] Serving as the curator of these images was no simple task. A colleague described Fleming's work: "Each photographic plate may be likened to the only existing copy of a valuable book, and, being very fragile, must be safely stored, and at the same time must be accessible, so as to be consulted readily at any moment."[4]

Williamina Fleming. Credit: Special Collections, Fine Arts Library/Harvard University

Writers of newspaper articles about Fleming clearly admired her for her work, but they also reflected the sexism of the times. One writer said, "It is interesting to know that the strain of intellectual and scientific pursuits has not destroyed that other side – the purely feminine side – of her life." Fleming was quoted as saying, "Ah! I don't mind housework, and I can cook as good a little dinner as half of the women installed in our kitchens. I'm never scared if the maid is sulky or threatens to give notice." Fleming was also quoted as saying, "While we cannot maintain that in everything a woman is man's equal, yet in many fields of work her patience, perseverance and methods make her his superior."[5] Early in her life, Fleming made it a practice to publish her findings under the name W.P. Fleming so that her gender would not hinder her work.[6]

When asked by one writer in 1906 what she had been doing lately, Fleming responded, "Doing? Why I have been to the tailor for a suit. I wish it might be a genuine tailor suit, too. Here they have made me a 'Fellow' of Wellesley, and a 'Fellow' of Radcliffe, and a 'Fellow' of two or three colleges where I am doing a man's work with a woman's pay. I'd like a fellow's clothes and salary if it were possible."[7]

Some organizations struggled to accept a woman in a prestigious scientific position. One story tells of a "certain scientific society" in which the clerk decided to list her as a "member" rather than a "fellow," but that society eventually corrected that error. This may have been a reference to the Royal Astronomical Society, which in 1906 made her a "member" and then soon after a "fellow." At the time, she was only the third woman to be granted that position, and the first American.[8] By this time, she had become a naturalized citizen of her adopted country.

Fleming's father, Robert Stephens, had a scientific mind that clearly nurtured his daughter's young mind.[9] He was the first in their home of Dundee, Scotland, to take a practical interest in daguerreotype photography. This was an early type of photography that was invented in 1839 and was widely used by the public in the 1840s and 1850s. To make the image, a daguerreotypist would polish a sheet of silver-plated copper to a mirror finish, treat it with fumes that made its surface light-sensitive, and then expose it in a camera. The exposures were often long by our standards, taking a few seconds in an outdoor setting with full sunlight, or much longer in dark settings. Developing the image involved exposing the latent image to mercury vapor fumes and chemical treatment.

Daguerreotype was almost completely replaced by cheaper and easier photographic processes by 1860. However, because the newer methods of photography caused a slight distortion, astronomers continued to use daguerreotype for many years because of its accuracy. Much of Fleming's work involved daguerreotype. While she was only seven years old when her father died, it is very possible that he influenced his daughter's interest in photography.

Williamina Fleming is in the center of this image; Pickering stands on the left. Credit: Special Collections, Fine Arts Library/Harvard University

Harvard College Observatory colleague Annie Cannon wrote Fleming's obituary in the *Astrophysical Journal* and described her process of analyzing the spectra of stars, the results of her classification published as the first edition of the "Draper Catalogue," which classified the spectra of 10,351 stars. She also discovered 10 novae and over 300 variable stars. Cannon concluded the description of Fleming's work by commenting that "her industry was combined with great courage and independence."[10]

Only a few months before her death, the Astronomical Society of Mexico presented her with the Guadalupe Almendaro medal for her discovery of new stars. She was a member of the Astronomical and Astrophysical Society of America and of the Société Astronomique de France.

At the age of 54, Fleming, who had been suffering from declining health for a few years, entered the hospital and was diagnosed with pneumonia. She died on May 21, 1911. She left one son, Edward P. Fleming, who graduated as a mining engineer from the Massachusetts Institute of Technology in 1901. At the time of his mother's death, he was working as the chief metallurgist for a large copper company in Chile.

Mrs. Fleming was described as having a charismatic personality, an attractive appearance that was "enlivened by remarkably bright eyes," and an ever-charming Scottish accent. While her focus was generally on scientific studies, she had a broad range of interests. She had a zest and joy for life. One colleague reflected on Fleming at the time of her death that "there was no more enthusiastic spectator in the stadium for the football games, no more ardent champion of the Harvard eleven."[11]

From a 14-year-old teacher, to an astronomer's maid or assistant, to a human computer, to the curator of the world's largest collection of astrophotographs, to the discoverer of novae, nebulae, and variable stars, Fleming served as an inspiration to young women at a time when women were not allowed to vote in America. As one who never earned a degree in astronomy, Fleming remains an inspiration today to citizen scientists of all genders. ✷

Notes

1. "Mrs. Williamina P. Fleming Dead," *The Boston Globe,* Boston, Massachusetts, 22 May 1911, p. 16.
2. "Woman Astronomer Discovered Six Out of Nine New Stars," *The Boston Globe,* Boston, Massachusetts, 26 Aug. 1906, p. 51.
3. "Woman Astronomer," *The Journal,* Huntsville, Alabama, 20 Sept. 1906, p. 2.
4. Dava Sobel, *The Glass Universe: How the Ladies of the Harvard Observatory Took the Measure of Stars* (New York: Penguin Books, 2017), p. 47.
5. "Woman Astronomer," *The Journal,* Huntsville, Alabama, 20 Sept. 1906, p. 2.
6. "A Famous Astronomer – Mrs. Williamina Fleming is a Brilliant Scientist," *Miami News,* Miami, Florida, 16 Nov. 1906. p. 11.
7. "Woman Astronomer Discovered Six Out of Nine New Stars," *The Boston Globe,* Boston, Massachusetts, 26 Aug. 1906, p. 51.
8. "English Scientific Society Elects Lady Astronomer to Membership," *The Decatur Weekly News,* Decatur, Alabama, 29 Sept. 1906, p. 1.
9. There is some confusion about the name of Williamina Fleming's father. Newspaper articles in Massachusetts reported in 1906 that his name was Robert Stevens, as did her obituary by fellow astronomer Annie Cannon in *The Astrophysical Journal* (Nov. 1911), v. 34, no. 4, p. 314–317. On the other hand, birth records in Scotland report his name as Henry Howard Stephens.
10. *The Astrophysical Journal* (Nov. 1911), v. 34, no. 4, p. 314–317.
11. Ibid.

A Funny Thing Happened in Solar Physics

(And a New Opportunity for Backyard Observers)

—By John Briggs

Twenty years ago, it was my privilege to serve as a site survey engineer for what became the Daniel K. Inouye Solar Telescope on the island of Maui in Hawaii. The three-year survey gave my family and me the opportunity to live and work at the National Solar Observatory in Sunspot, New Mexico. My daughter, Anna, thus came into this world as a "Sunspot baby." We now look back fondly on our time in that remarkable scientific community high in the Sacramento Mountains. My friend at nearby Apache Point Observatory, Bruce Gillespie, had a background in hands-on solar physics. He said, "everyone should do a site survey once in his life," and I agreed with him.

Maui was chosen for the mighty new telescope, an awesome 4-meter clear-aperture reflector that now leads the world in ground-based solar astronomy. Its design and construction were done by a large team of specialists over many years at a cost of over $340 million. Having played "cog in a wheel" early and briefly in this big-science project, I followed its progress with the insight and appreciation that my flirtation with the solar community allowed me. The magnitude of the effort – in cost, time, and talent – always left me in awe.

Flash forward to 2016, and a meeting of the American Astronomical Society's Solar Physics Division in Boulder, Colorado. This was the professional forum where the final construction progress for the amazing new telescope could be reported and celebrated. In a press conference on June 1, 2016, four of the "hottest topics in solar physics at the moment" were selected for special presentation to journalists. Naturally, recent progress of the multimillion-dollar Inouye telescope was included. But, in an evolution beyond anything I could have dreamed, another of the four reports featured an instrument in my own backyard, using an objective lens that had cost me about $5! It was just a fleeting event, but, to me, it was a little surreal.

Credit for the moment was due entirely to solar specialist Dr. Leif Svalgaard of Stanford University. In brief, Dr. Svalgaard had recognized that important eighteenth-century solar sunspot records needed to be better calibrated. A way to do this was to re-observe the Sun now using eighteenth-century instruments or reasonable reproductions of them, and then compare those observations with modern standard sunspot counts.

The matter is important because sunspots are an index of the underlying magnetic activity cycle of the Sun that relates in many ways to the "space weather" experienced by Earth. Proper interpretation of the historical record is very important, and initial results based on data from a small team from the Antique Telescope Society allowed Dr. Svalgaard to propose a significant correction factor. The other observers in our team included Ken Spencer and Walter Stephani.

The observations are simple daily sunspot drawings using a single-element refractor via eyepiece projection. The focal length of the lens can be 20 to 40 inches or so, with a clear aperture of 0.5 to perhaps 1 inch. My own replica of an eighteenth-century telescope uses a 1-meter focal length simple lens stopped to about 15 millimeters aperture. It's glued to a large steel washer that, in turn, is glued to a cardboard mailing tube. To make my tube appear distinguished, I gave it a spiral wrap of copper tape that I had handy. That flourish was unnecessary, but in my case it set the stage for a taped-on Crescent wrench that facilitated balance in declination on a microscopic old Edmund equatorial mount. The mounting might just as well have been a very simple altazimuth.

This simple homemade single-element refractor with a $5 objective purchased from Surplus Shed was one of three telescopes used by members of the Antique Telescope Society to collect simple sunspot data. The project allowed specialist Dr. Leif Svalgaard to propose a significant correction in the interpretation of eighteenth-century sunspot records. As solar activity now increases, additional observers are especially welcome in the project. Photo at the Stellafane Clubhouse by J. W. Briggs.

The eyepiece for solar projection onto a small sheet of white paper is not critical, but I chose the simplest and most primitive one in my optical junk pile. In fact, heat could damage a fancy multi-element eyepiece. The key is to devise a projected solar diameter of about three inches. The images will then be similar in scale to ones recorded in the 1700s. I prepare sheets of paper ahead of time with a circle drawn using a particular jar lid. Recording the exact positions of sunspots is not required – it's simply a matter of recording the approximate positions of ones clearly seen. Experience teaches that only a few major spots are typically seen with such primitive telescopes.

As solar activity is now increasing, recording spots is becoming more interesting, and Dr. Svalgaard would greatly appreciate additional observers. Some observations have been recorded with true eighteenth-century telescopes, but most potential observers just commit to using homemade reproductions. What is truly surprising is how *engaging and enjoyable* the simple ritual of basic observation becomes, even in this modern world of $340 million solar telescopes! With additional data, solar specialists can become more confident that the historical correction factor now suggested by Dr. Svalgaard should indeed be applied to the early solar records. And in so doing, the project and its observers may again be amused to find themselves attracting attention – even shoulder-to-shoulder with those building and running the grandest instruments of our modern time.

A related web page describing the project with instructions and encouragement will be online at the AAVSO's Solar Section as this article goes to press. See also Dr. Svalgaard's most recent presentation for the Antique Telescope Society, linked here: *leif.org/research/Sunspots-with-Ancient-Telescopes-for-SC25.ppt.* ✷

John Briggs is a member of the Springfield Telescope Makers, and is associated with the FOAH Observatory and The Astronomical Lyceum in Magdalena, New Mexico.

NEVER LOOK AT THE SUN DIRECTLY WITH THE NAKED EYE OR THROUGH ANY UNFILTERED OPTICAL DEVICE!

GALLERY

MEMBER ASTROPHOTOGRAPHS

This page:

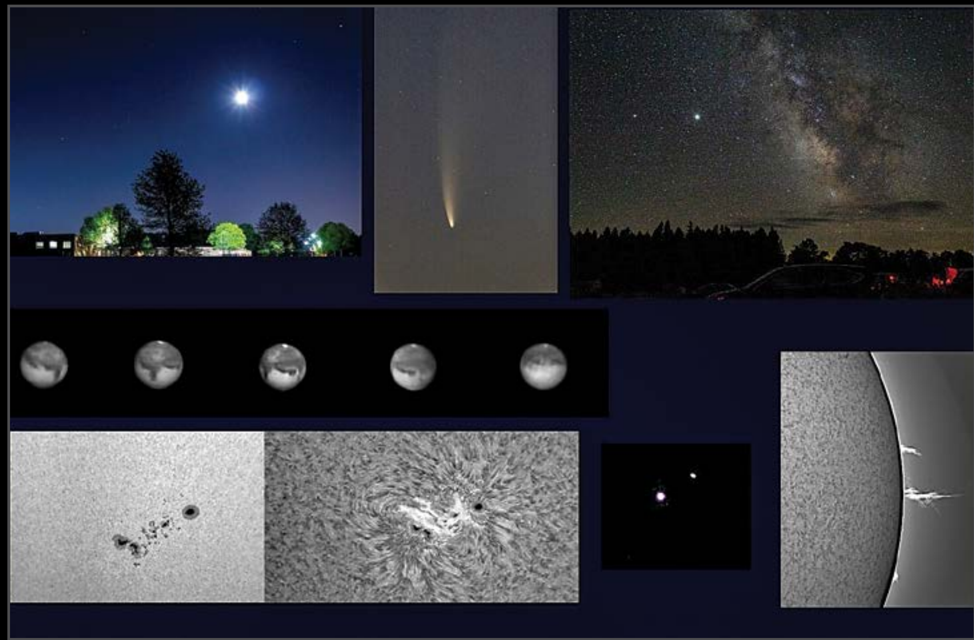
Top: Tom Nolasco (Delaware Valley Amateur Astronomers) shared this composite of his year in imaging.

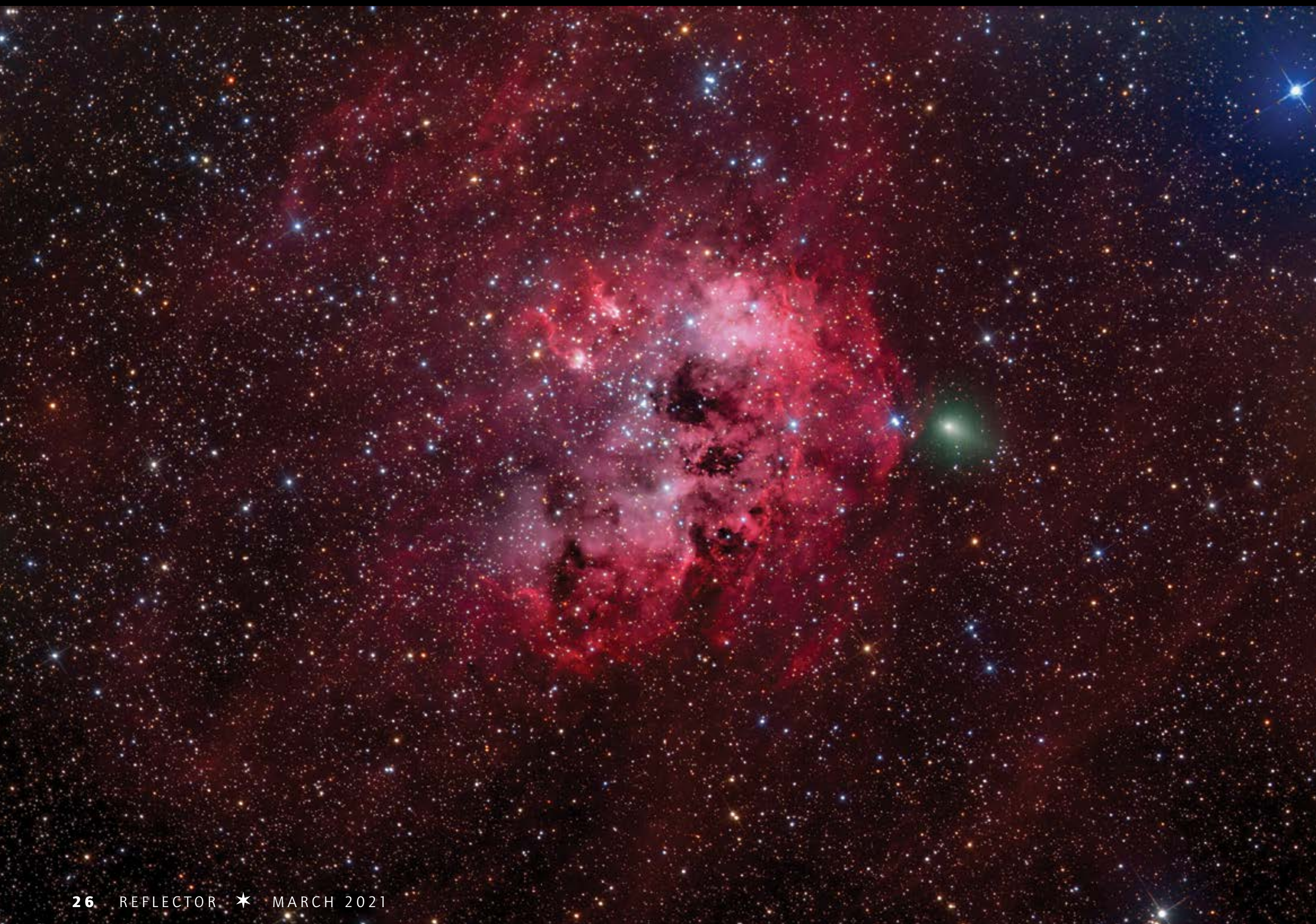
Bottom: Gregg Ruppel (Tucson Amateur Astronomy Association) captured this image of NGC 1893 as comet C/2020 M3 ATLAS passed through from his remote observatory at DSNM in Animas, New Mexico, with an ASA 10N f/3.8 Astrograph with a SBIG STL-11000M CCD camera.

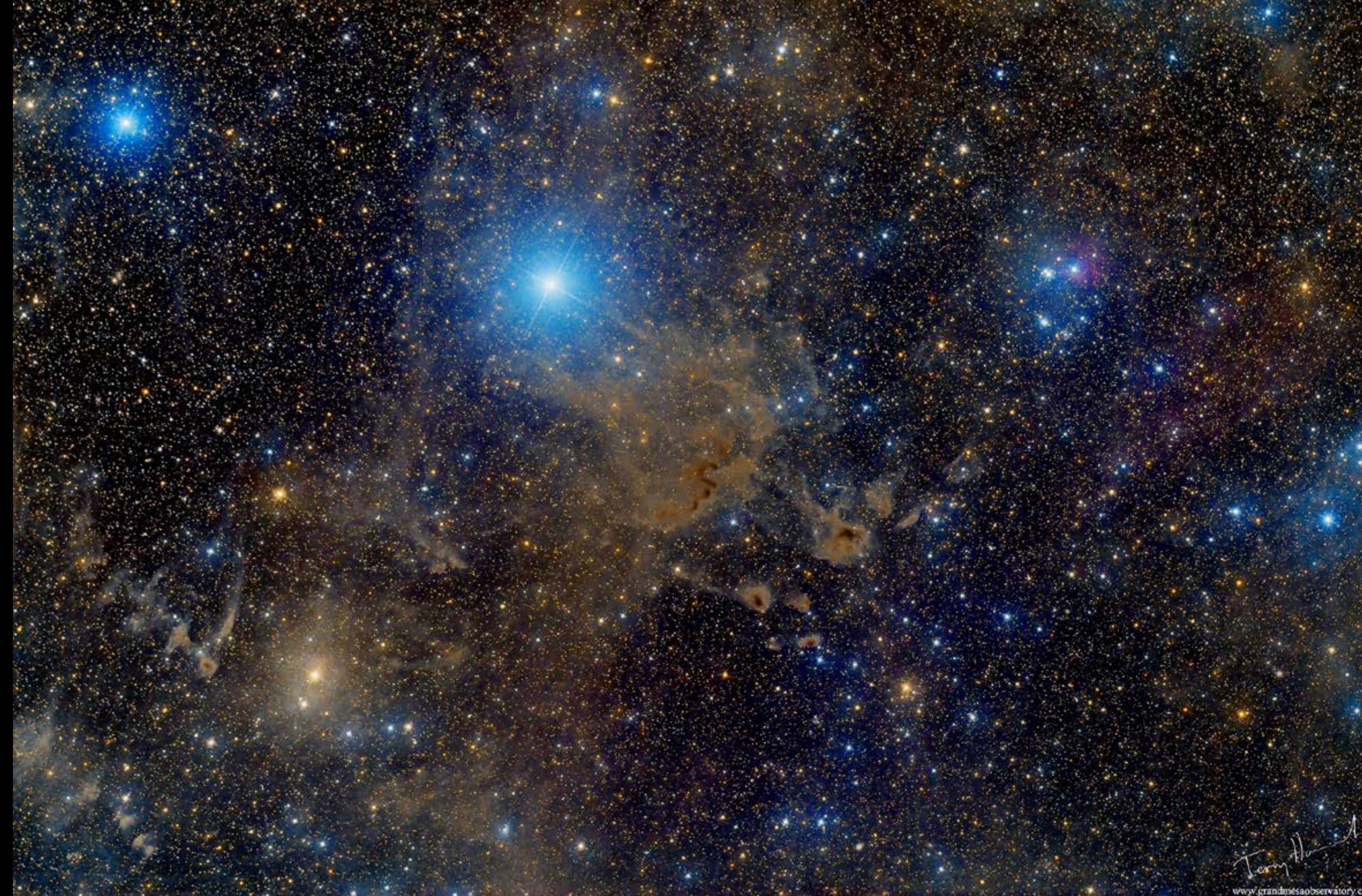
Opposite page:

Top: Terry Hancock (Western Colorado Astronomy Club) captured this fantastic image of bright and dark nebulae in Cepheus from the Grand Mesa Observatory using a Takahashi E-180 Astrograph with a QHY410C color CMOS camera.

Bottom: Bob Fugate (Albuquerque and Magdalena Astronomical Societies) created this composite view of the Jupiter and Saturn conjunction from Albuquerque on December 21, 2020, with a Meade 7-inch Maksutov telescope and a Nikon D850 camera.







ALCON 2021

ALBUQUERQUE NEW MEXICO

August 5 – 7

EMBASSY SUITES HOTEL

1000 Woodward Pl. NE
Albuquerque, New Mexico 87102
https://alcon2021.astroleague.org/
(Website available by January 1, 2021)

TAAS The Albuquerque Astronomical Society

Hosted by:

The Albuquerque Astronomical Society

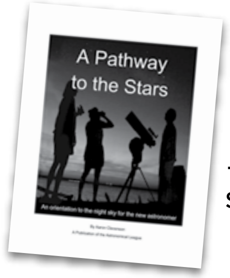
www.TAAS.org

one-stop astronomy shopping

ASTRONOMICAL LEAGUE BASEBALL HAT
EMBROIDERED LOGO, ADJUSTABLE; ROYAL BLUE, MAROON, KHAKI, NAVY; $18 PLUS $5 S&H

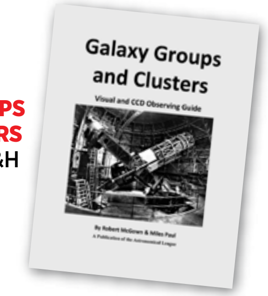
ASTRONOMICAL LEAGUE SPORTSMAN'S BUCKET HAT
EMBROIDERED LOGO, ONE SIZE; KHAKI ONLY
$22 PLUS $5 S&H

THE HERSCHEL II OBSERVING PROGRAM
$18, PLUS $7 S&H

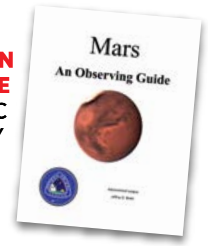


A PATHWAY TO THE STARS
THIS MANUAL IS A GREAT INTRODUCTION TO ASTRONOMY FOR THE NEW ASTRONOMER.
$10 PLUS $4 S&H

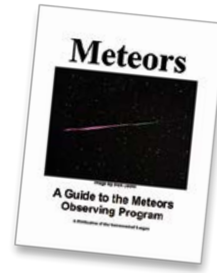
UNIVERSE SAMPLER
A JOURNEY THROUGH THE UNIVERSE FOR THE BEGINNER
$13 PLUS $5 S&H



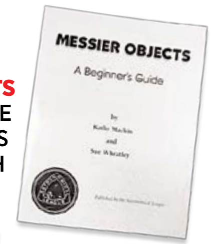
GALAXY GROUPS AND CLUSTERS
$20 PLUS $7 S&H



MARS – AN OBSERVING GUIDE
A SYSTEMATIC PROGRAM STUDY OF THE RED PLANET.
$18 PLUS $6 S&H

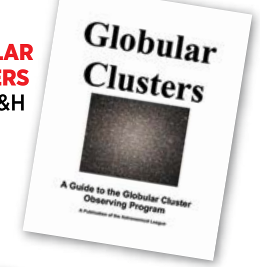


METEORS—
A GUIDE TO THE METEORSOBSERVING PROGRAM
$11 PLUS $4 S&H

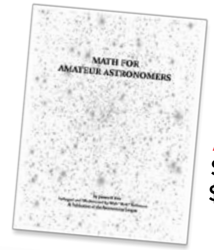


MESSIER OBJECTS
A BEGINNER'S GUIDE
$8 PLUS $3 S&H

PLANETARY NEBULAE
$19 PLUS $6 S&H

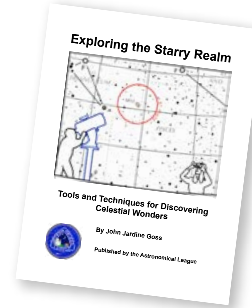


GLOBULAR CLUSTERS
$16 PLUS $5 S&H



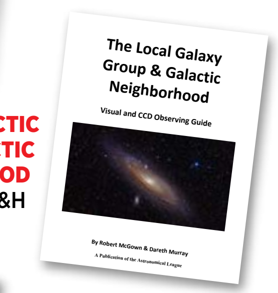
MATH FOR AMATEUR ASTRONOMERS
$14 PLUS $5 S&H

ASTRONOMICAL LEAGUE VISUAL ASTRONOMICAL OBSERVING JOURNAL
$16 PLUS $6 S&H



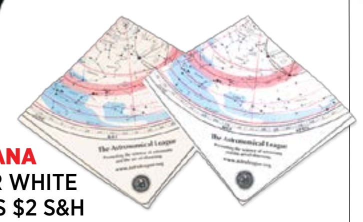
EXPLORING THE STARRY REALM
TOOLS AND TECHNIQUES FOR DISCOVERING CELESTIAL WONDERS
$14 PLUS $5 S&H

ASTRONOMICAL LEAGUE TOTE BAGS
NYLON (LEFT) OR CANVAS
$12 PLUS $6 S&H



THE LOCAL GALACTIC GROUP & GALACTIC NEIGHBORHOOD
$23 PLUS $8 S&H

ASTRONOMICAL LEAGUE TRAVEL MUG
$10 PLUS $4.50 S&H

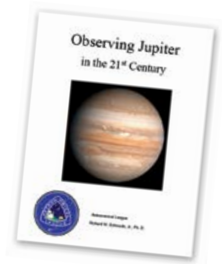


ASTRONOMICAL LEAGUE BANDANA
NATURAL OR WHITE
$13 PLUS $2 S&H

CARBON STARS
A GUIDE TO THE CARBON STAR OBSERVING CLUB
$12 PLUS $4 S&H

HERSCHEL 400
NOW REVISED AND EXPANDED
$15 PLUS $5 S&H

ASTRONOMICAL LEAGUE WINTER KNIT CAP
NAVY/GRAY, PURPLE, BLACK, MAROON, ROYAL BLUE, GRAY, GREEN; $20 PLUS $5 S&H



OBSERVING JUPITER IN THE 21ST CENTURY
$12 PLUS $4 S&H

SECURE ONLINE ORDERING FROM STORE.ASTROLEAGUE.ORG
Or order by mail at Astronomical League Sales, 9201 Ward Parkway, Suite 100, Kansas City, MO 64114.
Enclose check for price and S+H charges as shown.

Observing Awards

Advanced Binocular Double Star Observing Program
No. 36, **Charles E. Allen III**, Evansville Astronomical Society; No. 37, **W. Maynard Pittendreigh**, Lifetime Member; No. 38, **Jerelyn Ramirez**, Kansas Astronomical Observers

Alternate Constellations Observing Program
No. 2, **Charles E. Allen**, Evansville Astronomical Society; No. 3, **Rob Ratkowski**, Haleakala Amateur Astronomers; No. 4, **Aaron Clevenson**, North Houston Astronomy Club; No. 5, **Rodney Rynearson**, St. Louis Astronomical Society; No. 6, **W. Maynard Pittendreigh**, Lifetime Member

Arp Peculiar Galaxies Northern Observing Program
No. 101-I, **John Sikora**, Lifetime Member; No. 102-I, **Jack Fitzmier**, Member-at-Large; No. 103-I, **Robert Stan**, Mohawk Valley Astronomical Society

Arp Peculiar Galaxies Southern Observing Program
No. 19-V, **Charles E. Allen III**, Evansville Astronomical Society

Asterism Observing Program
No. 61, **Stephen L. Snider**, Albuquerque Astronomical Society; No. 62, **Brad Payne**, Northern Virginia Astronomy Club; No. 63, **Bernard Venasse**, Member-a-Large; No. 64, **Kim Balliett**, Richland Astronomical Society; No. 65, **Paul Harrington**, Member-at-Large

Asteroid Observing Program
No. 67, **Roland Albers**, Gold, Tri-Valley Stargazers

Astronomy Before the Telescope Observing Program
No. 2, **Brad Young**, Astronomy Club of Tulsa

Beyond Polaris Observing Program
No. 40, **Salil Kulkarni**, Houston Astronomical Society; No. 41, **Eric Edwards**, Minnesota Astronomical Society; No. 42, **Kevin C. Carr**, Minnesota Astronomical Society; No. 43, **Amanda Zagata**, Member-at-Large

Binocular Double Star Observing Program
No. 166, **Michael Stephens**, Member-at-Large; No. 167, **Thomas Gazzillo**, Chesmont Astronomical Society; No. 168, **Tom Van Buskirk**, Member-at-Large; No. 169, **W. Maynard Pittendreigh**, Lifetime Member; No. 170, **William A. Loder**, Member-at-Large; No. 171, **Michael Phelps**, Atlanta Astronomy Club; No. 172, **Jim Hontas**, Cincinnati Astronomical Society; No. 173, **Jenny Stein**, Houston Astronomical Society; No. 174, **David Wickholm**, San Antonio Astronomical Association; No. 175, **Mark Davis**, Lowcountry Stargazers; No. 176, **Andrew Corkill**, Member-at-Large

Binocular Messier Observing Program
No. 1203, **Andrew Jaffe**, New Hampshire Astronomical Society; No. 1204, **Aaron Roman**, Kalamazoo Astronomical Society; No. 1205, **Ethan Karn**, Member-at-Large; No. 1206, **Michael J. Caba**, Member-at-Large; No. 1207, **David Berish**, Greater Hazleton Area Astronomical Society; No. 1208, **Michael McShan**, Oklahoma City Astronomy Club; No. 1209, **Andrew Corkill**, Member-at-Large; No. 1210, **Eric Edwards**, Albuquerque Astronomical Society; No. 1211, **Rick Ginanni**, Greater Hazleton Area Astronomical Society

Binocular Variable Star Observing Program
No. 45, **Lewis Cason**, Lowcountry Stargazers; No. 46, **John L. Goar**, Olympic Astronomical Society; No. 47, **Michael Stephens**, Member-at-Large; No. 48, **Lisa Wentzel**, Twin City Amateur Astronomers

Carbon Star Observing Program
No. 118, **Brad Payne**, Northern Virginia Astronomy Club; No. 119, **Michael McShan**, Oklahoma City Astronomy Club; No. 120, **Rodney R. Rynearson**, St. Louis Astronomical Society; No. 121, **Larry Farrington**, Mt. Shasta Star Gazers; No. 122, **Matt Orsie**, Tri-State Astronomers

Citizen Science Observing Program
William Castro, Central Florida Astronomical Society, Variable Stars, Observational Silver; **Richard Krahling**, Richland Astronomical Society, Galaxy Zoo Mobile, Active Silver; **Richard Krahling**, Richland Astronomical Society, Galaxy Zoo Mobile, Active Gold Class 1; **Richard Krahling**, Richland Astronomical Society, Star Notes, Active Bronze; **Richard Krahling**, Richland Astronomical Society, SuperWASP Variable Stars, Active Bronze; **Richard Krahling**, Richland Astronomical Society, Mapping Historic Skies, Active Bronze; **Richard Krahling**, Richland Astronomical Society, Mapping Historic Skies, Active Silver; **Richard Krahling**, Richland Astronomical Society, Mapping Historic Skies, Active Gold Class 1; **Al Lamperti**, Delaware Valley Amateur Astronomers, Nova, Observational, Bronze; **Al Lamperti**, Delaware Valley Amateur Astronomers, Galaxy Zoo Star Notes, Active, Gold, Class 15; **Michael Hotka**, Longmont Astronomical Society, NEO, Observational Gold, Class 3

Comet Observing Program
No. 117, **John Skillicorn**, Silver, Tucson Amateur Astronomical Association; No. 118, **Charles E. Allen III**, Silver, Evansville Astronomical Society

Constellation Hunter Northern Skies Observing Program
No. 252, **Kevin Carroll**, Member-at-Large; No. 253, **Albert Smith**, Member-at-Large; No. 254, **Michael Stephens**, Member-at-Large; No. 255, **Michael Harang**, Texas Astronomical Society; No. 256, **Doug Lively**, Raleigh Astronomy Club; No. 257, **Eric Edwards**, Albuquerque Astronomical Society

Deep Sky Binocular Observing Program
No. 419, **Stephen Hildenbrandt**, Miami Valley Astronomical Society; No. 420, **Hans de Moor**, Member-at-Large

Double Star Observing Program
No. 661, **Preston Pendergraft**, Member-at-Large; No. 662, **Ron Ziss**, Naperville Astronomical Association; No. 663, **Don Kolb**, Member-at-Large; No. 664 **Andrew Corkill**, Member-at-Large; No. 665, **Glynn Germany**, Rio Rancho Astronomical Society

Foundations of Imaging Observing Program
No. 1, **Gregg Ruppel**, Tucson Amateur Astronomy Association; No. 2, **Dan Crowson**, Astronomical Society of Eastern Missouri

Galaxy Groups and Clusters Observing Program
No. 48-DA/I, **John Skillicorn**, Tucson Amateur Astronomy Association

Galileo Observing Program
No. 63, **Charles E. Allen III**, Binoculars, Evansville Astronomical Society; No. 64, **W. Maynard Pittendreigh**, Binoculars, Lifetime Member; No. 65, **Robert Togni**, Binoculars, Central Arkansas Astronomical Society; No. 66, **Antone Gregory**, Binoculars, Minnesota Astronomical Society

Globular Cluster Observing Program
No. 357-V, **Patrick Peak**, Lifetime Member

Herschel 400 Observing Program
No. 621, **Don Gazdik**, Minnesota Astronomical Society; No. 622, **Robb Chapman**, South Plains Astronomical Club; No. 623, **James Bruce McMath**, Central Arkansas Astronomical Society; No. 624, **Scott D. Sudhoff**, Wabash Valley Astronomical Society; No. 625, **Hans de Moor**, Member-at-Large

Hydrogen Alpha Solar Observing Program
No. 50 Imaging, **Peter K. Detterline**, Member-at-Large; No. 51, **Vincent Michael Bournique**, Lifetime Member

Library Telescope Award
No. 9, **Alfred Schovanez III**, Silver, Eastern Missouri Dark Sky Observers; No. 10, **Jerelyn Ramirez**, Silver, Kansas Astronomical Observers

Lunar I Observing Program
No. 1120-I, **Steve Boerner**, Member-at-Large; No. 1121 and 1121-B, **Bruce Scodova**, Richland Astronomical Society; No. 1122, **Kyle Penning**, Ancient City Astronomy Club; No. 1123 and 1123-B, **Andrew Corkill**, Member-at-Large; No. 1124-B, **Debra Wagner**, Member-at-Large; No. 1125-B, **Peter K. Detterline**, Member-at-Large; No. 1126 and 1126-B, **Mark Davis**, Lowcountry Stargazers; No. 1127 and 1127-B, **Jason Wolfe**, Member-at-Large; No. 1128 and 1128-B, **Conal Richards**, Youth Member-at-Large

Lunar II Observing Program
No. 113, **John Strebeck**, St. Louis Astronomical Society

Lunar Evolution Observing Program
No. 8-I, **Steve Boerner**, Member-at-Large; No. 9, **Vincent Michael Bournique**, Lifetime Member

Mars Observing Program
No. 7, **Brad Payne**, Northern Virginia Astronomy Club; No. 8, **Peter K. Detterline**, Imaging, Member-at-Large

Messier Observing Program
No. 2843, **Marc Machin**, Regular, Member-at-Large; No. 2836, **Eric Edwards**, Honorary, Albuquerque Astronomical Society; No. 2842, **Scott Cadwallader**, Honorary, Baton Rouge Astronomical Society; No. 2844, **Kendall Bonds**, Regular, Member-at-Large; No. 2845, **Stephen Pavela**, Honorary, La Crosse Area Astronomical Society; No. 2846, **Rick Ginanni**, Regular, Greater Hazleton Area Astronomical Society; No. 2847, **Raymond L. Bradley**, Honorary, Roanoke Valley Astronomical Society

Meteor Observing Program
No. 190, **Fred Schumacher**, 24 hours, Member-at-Large; No. 202, **Lauren Rogers**, 6 hours, Escambia Amateur Astronomers Association; No. 191, **Gregory T. Shanos**, 18 hours, Museum Astronomical Resource Society

Multiple Star Observing Program
No. 1, **Terry Trees**, Amateur Astronomers Association of Pittsburgh; 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-I, **David Douglass**, East Valley Astronomy Club; No. 6, **Al Lamperti**, Delaware Valley Amateur Astronomers; No. 7, **Michael Hotka**, Longmont Astronomical Society; No. 8, **Albert Smith**, Member-at-Large; No. 9, **John Raymond**, Richmond Astronomical Society

NEO Observing Program
No. 19, **Vic Grossi**, Intermediate, Member-at-Large; No. 20, **Vic Grossi**, Advanced, Member-at-Large; No. 21, **David Whalen**, Intermediate, Atlanta Astronomy Club

Nova Observing Program
No. 10, **Al Lamperti**, Gold, Delaware Valley Amateur Astronomers; No. 11, **Paul Harrington**, Gold, Member-at-Large; No. 12, **Aaron Clevenson**, Silver, North Houston Astronomy Club; No. 13, **Aaron Clevenson**, Gold, North Houston Astronomy Club

Open Clusters Observing Program
No. 90, **Jack Fitzmier**, Member-at-Large; No. 91, **Lisa Wentzel**, Twin Cities Amateur Astronomers

Outreach Observing Award
No. 1167-S, **Laurie V. Ansorge**, Member-at-Large; No. 1214-O, **Matt Orsie**, Tri-State Astronomers; No. 1218-M, **Patrick Peak**, Lifetime Member; No. 1219-O, **Janet Rush**, Delaware Valley Amateur Astronomers; No. 1219-S, **Janet Rush**, Delaware Valley Amateur Astronomers

Planetary Nebula Observing Program
No. 16, **Scott Sudhoff**, Advanced Imaging, Wabash Valley Astronomical Society; No. 17, **Mark L. Mitchell**, Advanced Imaging, Delaware Astronomical Society; No. 40, **Jeff Hoffmeister**, Basic, Olympic Astronomical Society; No. 84, **David Wickholm**, Advanced, San Antonio Astronomical Association; No. 85, **Stephen L. Snider**, Advanced, Albuquerque Astronomical Society; No. 86, **Robert Harrison**, Advanced, Patron Member

Radio Astronomy Observing Program
No. 29-B, **Vincent Michael Bournique**, Lifetime Member

Sky Puppy Observing Program
No. 67, **Gianna Buck**, Independent; No. 68, **Andrew Pu**, Independent; No. 69, **Joslyn Walkup**, Independent; No. 70, **O'Shae Simmat**, Independent; No. 71, **Kaelyn Jollymore**, Independent

Solar System Observing Program
No. 166-I, **Steve Boerner**, Member-at-Large; No. 167-B, **Robert Togni**, Central Arkansas Astronomical Society; No. 168, **Marc Machin**, Member-at-Large; No. 169, **Mike Titus**, Cincinnati Astronomical Society; No. 170, **Daryel Stager**, Lifetime Member; No. 171-B, **Peter K. Detterline**, Member-at-Large; No. 172 and 172-B, **Jenny Stein**, Houston Astronomical Society

Spectroscopy Observing Program
No. 1, **Aaron Clevenson**, North Houston Astronomy Club

Stellar Evolution Observing Program
No. 81, **Bob Scott**, Island County Astronomical Society; No. 82, **Mark L. Mitchell**, Delaware Astronomical Society; No. 83, **Antone Gregory**, Minnesota Astronomical Society

Sunspotter Observing Program
No. 197, **Vincent Michael Bournique**, Lifetime Member; No. 198, **David M. Douglass**, East Valley Astronomy Club

Universe Sampler Observing Program
No. 149-T, **Don Knabb**, Telescope, Chester County Astronomical Society; No. 150-T, **Scott Cadwallader**, Telescope, Baton Rouge Astronomical Society; No. 151-T, **Matt Orsie**, Telescope, Tri-State Astronomers; No. 152-T, **Eric Edwards**, Telescope, Albuquerque Astronomical Society

Urban Observing Program
No. 209, **Scott D. Cadwallader**, Baton Rouge Astronomical Society; No. 210, **Istvan Matis**, Member-at-Large; No. 211, **Rakhal Kincaid**, Haleakala Amateur Astronomers; No. 212, **Dave Osenga**, Twin City Amateur Astronomers; No. 213, **Andrew Wolfe**, Member-at-Large; No. 214, **Fred Schumacher**, Member-at-Large; No. 215, **Greg Scheiderer**, Seattle Astronomical Society; No. 216, **Bernard Venasse**, Lifetime Member

Variable Star Observing Program
No. 42, **Charles E. Allen III**, Evansville Astronomical Society; No. 43, **John L. Goar**, Olympic Astronomical Society; No. 44, **Bill Castro**, Central Florida Astronomical Society; No. 45, **Terry Trees**, Amateur Astronomers Association of Pittsburgh

Master Observer Progression

OBSERVER AWARD
Daryel Stager, Lifetime Member

MASTER OBSERVER AWARD
No. 241, **Bruce Scodova**, Richland Astronomical Society

BINOCULAR MASTER OBSERVER AWARD
Robert Togni, Central Arkansas Astronomical Society; **Peter K. Detterline**, Member-at-Large

ADVANCED OBSERVER AWARD
Alfred Schovanez, Astronomical Society of Eastern Missouri; **Stephen L. Snider**, Albuquerque Astronomical Society; **Brad Payne**, Northern Virginia Astronomy Club

MASTER OBSERVER AWARD – SILVER
Vincent Michael Bournique, Lifetime Member

Membership Secretary
Astronomical League
National Office
9201 Ward Parkway, Suite 100
Kansas City, MO 64114

NON-PROFIT
ORGANIZATION
U.S. POSTAGE
PAID
TUCSON, AZ
PERMIT #271