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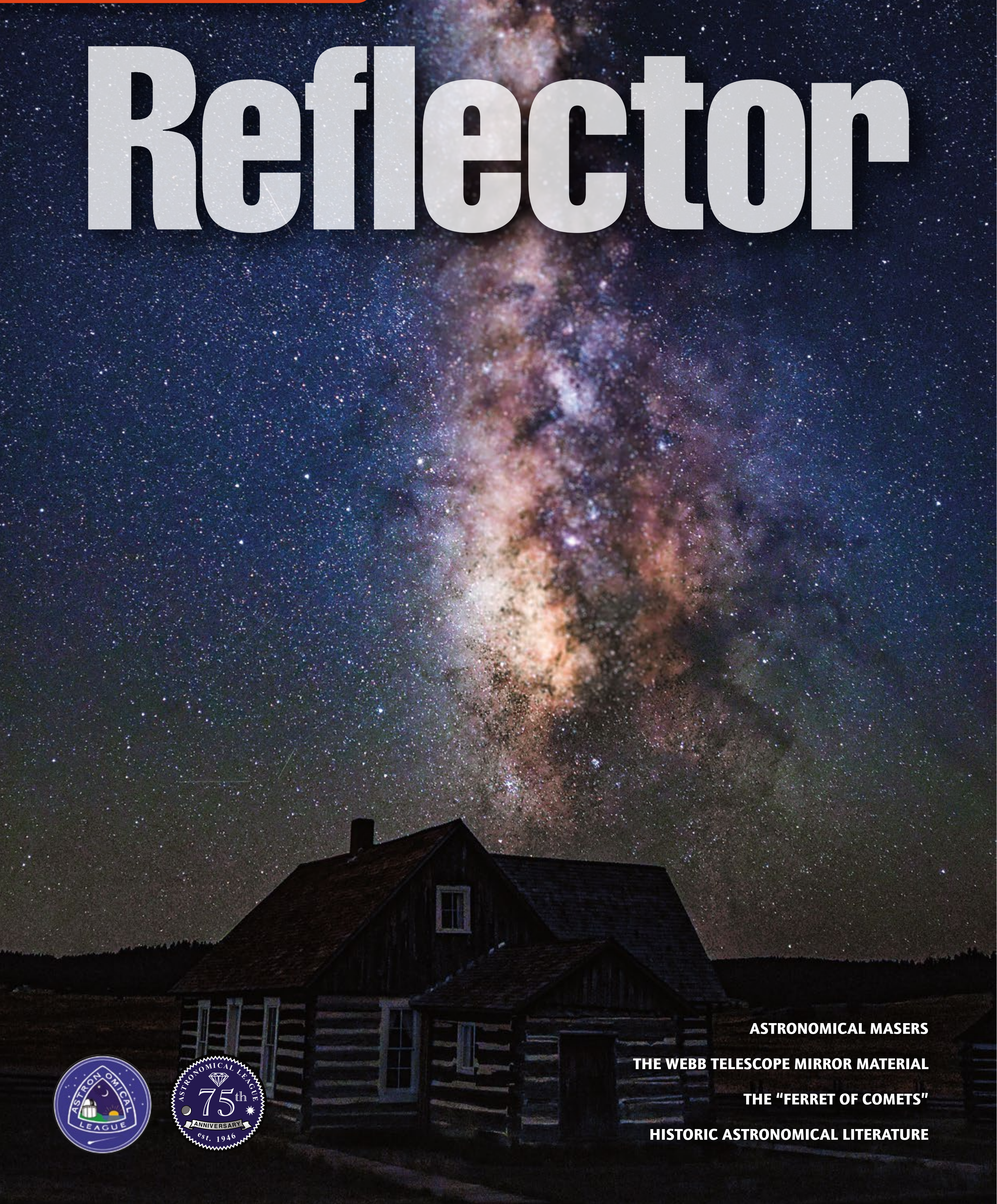
Reflector



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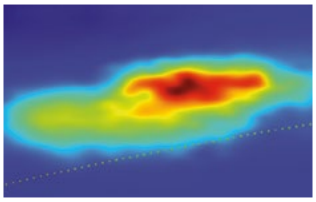

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Mark Harter (Colorado Springs Astronomical Society) captured this image of the Milky Way and the Hornbeck Homestead from the Florissant Fossil Beds National Monument in Colorado – a recently certified International Dark Sky Park. This is a single 13-second exposure using a Nikon D5600 DSLR with a Sigma 20 mm lens at f/1.8.

Reflector

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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.

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Reflector

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***REFLECTOR* AND CLUB ROSTER DEADLINES**

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

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To the Editor

I enjoyed the article by Jai Shet in the March *Reflector*. Jai (and Neil) Shet submitted a Milky Way panorama image assembled from exposures taken from Texas and New Zealand in June 2020. This was shortly after I read about them in the June 2020 *Reflector* (page 12). As the leader our local club's imaging group, I've seen a lot of images. I had only seen an image like this once, several years before.

I reached out to Jai and Neil to get more information. I found that they had planned on giving a presentation in person at their local club but COVID-19 shut it down. With our club going to Zoom meetings, I invited them to give the presentation to our imaging group. Zoom allowed us to attract a lot of great speakers from across the country but Jai and Neil were definitely the highlight of the year. Their presentation to our group can be found at *youtu.be/dYx_xi_m-WQ*.

I wish Jai and Neil continued success and I hope it includes a career in science.

—Dan Crowson
Astronomical Society of Eastern Missouri (ASEM)

Thank you for Bob Kerr's wonderful article "The Artist and the Eclipse," about D. Owen Stephens' work for the Hayden Planetarium-Grace Expedition to Peru to study the June 1937 eclipse. Bob's impressive research and elegant writing blended science, history, and biography to bring Owen Stephens' experience and the work of the expedition to life.

I would like to echo Bob's note at the end of the article:

"Anyone with knowledge of Stephens or his paintings is asked to contact the author at *kerr_comm@hotmail.com*."

And, could you also contact me: *lstarrvt@gmail.com?*

I am Owen Stephens' granddaughter, and my family, with the help of the Rose Valley Museum at Thunderbird Lodge, is cataloguing Owen's paintings and writings. We would love to find out where more of his paintings have *ended up*.

By a fascinating coincidence, *American Fine Art Magazine* has also recently published an article on Owen Stephens, by James D. Balestrieri, in their January/February 2022 issue:

"Into the Night – The art of little-known painter D. Owen Stephens explores the beauty of the night skies" *(americanfineartmagazine.com/issues/61/into-the-night)*. Mr. Balestrieri notes that he is a member of the Astronomical League.

With thanks and appreciation,

—Loring Starr
East Montpelier, Vermont

Star Beams

NEW AND IMPROVED WEBSITE

As I write this article, we are finishing up final testing of the new WordPress software for the Astronomical League's website. Soon we expect to be able to begin sharing news, including the specifics of the new and improved options. We hope our website visitors will find it to be an attractive and useful tool.

UPDATES FROM OUR REGIONS

Our regions are an integral part of the Astronomical League. Two officers of each region, the chair and the representative, are members of the Astronomical League Council, the governing body of the League.

Several of our regions are quite active, with regular communication to the League members in their regions, and conventions when COVID is not an issue. I would like to announce that the League's executive committee has now lifted the restriction on in-person regional conventions. This is consistent with the resuming of our national ALCon conventions after two years of no in-person events, but with a most successful ALCon 2021 Virtual.

We hope to start revitalizing the regions that have been largely dormant in recent years. If you would like to be a part of this effort in your region, please email me at *president@astroleague.org.* My goal is to schedule some online individual regional meetings and discuss options for breathing new energy into these vital parts of the Astronomical League.

On March 24, I was honored to appoint Mike Humphrey as the new chair of the Northeast Region of the Astronomical League. Mike is a member of the Buffalo Astronomical Society, and we look forward to working with him. Welcome, Mike!

ALCON 2022 IS COMING SOON

After postponing the national convention for two years, our third attempt is a go. The convention committee of the Albuquerque Astronomical Society has been courageous in standing with us, and I know they will host a fabulous convention. Whether it is the special reception with the astronaut, a visit to one of the society's observatories, one of the fabulous speakers, the youth award winner speakers, the Saturday night awards banquet, or a visit to the Very Large Array, there is something for everyone at the event.

GENEROUS BEQUESTS THE PAST FEW MONTHS

We were blessed to receive two bequests from former AL members during the past few months. It is refreshing to see that there is interest in giving back to the League through estate programs. If other members wish to remember the League in this manner, please contact me at *president@astroleague.org* for more information.

ANNUAL SOLAR ECLIPSE IN 2023, TOTAL SOLAR ECLIPSE IN 2024

The annular eclipse occurs on Saturday, October 14, 2023, on a narrow path from Oregon to Texas, then to Central America and northern South America. Parts of Utah, New Mexico, and Texas are the preferred locations for observing this, based on historical weather data.

The total eclipse happens on Monday, April 8, 2024. The path extends from the northeastern part of the country, extending down into Texas and then Mexico. Preferred locations for viewing, based on historical weather patterns, are Texas and Mexico. However, regardless of the weather odds, it is preferable to get yourself as close to the center line as possible, where totality will have a maximum duration of almost 4.5 minutes.

The League will announce plans for these two events in the next few months. We also plan to offer eclipse glasses for sale soon.

LEAGUE MEMBERSHIP AT AN ALL-TIME HIGH

During the pandemic, and continuing as the pandemic abates, our membership has reached approximately 21,000 members, an all-time high. The demand for telescopes and related accessories remains high. Even during the pandemic, members were out observing in substantial numbers.

Keep looking up!

—Carroll Iorg
President

International Dark-Sky Association

INTERNATIONAL ASTRONOMICAL UNION (IAU)

Founded in 1919, the International Astronomical Union (IAU, *iau.org*) is the internationally recognized body for professional astronomers and national astronomical societies. Its individual members are professional astronomers from all over the world who are active in research, education, and outreach in astronomy and related sciences. The IAU has more than 12,000 active professional astronomers from more than 100 countries. The IAU is, amongst other things, the recognized authority for the naming of astronomical bodies, such as comets and asteroids, and surface features on planets and minor bodies beyond Earth. The modern definitions of constellations and demarcations of their borders were established by the IAU in 1930.

There is a growing threat to the night sky from satellite constellations. The IAU issued a press release on February 3, "Selection of the New IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference" *(iau.org/news/pressreleases/detail/iau2201)*. SKA Observatory (SKAO) and National Science Foundation's (NSF) NOIRLab will co-host the new IAU Centre.

SKA (now SKAO) is the Square Kilometre Array project, an international effort to build the world's largest radio telescope, with eventually over one square kilometer of collecting area *(skatelescope.org)*. It is an intergovernmental organization headquartered in the United Kingdom with powerful networks of radio telescopes in Australia and South Africa.

NSF's NOIRLab, the National Optical-Infrared Astronomy Research Laboratory, is the United States's center for ground-based nighttime optical and infrared astronomy *(noirlab.edu/public)*.

The IAU supports the principle of a dark and radio-quiet sky as essential for advancing our understanding of the Universe, for preserving the cultural heritage of humanity, and for the protection of natural fauna and flora. The increasing number of launched and planned satellites and in low Earth orbit significantly threatens our skies. If all the proposed satellites were actually launched in the next decade, there may be no place on Earth, even Antarctica, where there would be a dark sky or a radio-quiet zone.

The IAU Centre's mission is to coordinate efforts and unify voices across the globe for the protection of the dark and quiet sky from satellite constellation interference. It is designed to bring together astronomers, satellite operators, regulators, and the public to act as a bridge between satellite stakeholders and the astronomical community so the needs of the satellite operators can be fulfilled without endangering the night sky.

To quote from the IAU website: "The staff members for the Centre are distributed over two main locations: Tucson, Arizona, USA, and Jodrell Bank, near Manchester, United Kingdom. The director is Piero Benvenuti, former IAU General Secretary, and the co-directors are Connie Walker (NSF's NOIRLab) and Federico Di Vruno (SKAO). A number of organizations have pledged to provide additional support to the Centre.

"Debra Elmegreen, IAU President, notes 'The new Centre is an important step towards ensuring that technological advances do not inadvertently impede our study and enjoyment of the sky. I am confident that the Centre co-hosts can facilitate global coordination and bring together the necessary expertise from many sectors for this vital effort.'"

The IAU initiative is most important for protecting our skies. Light pollution is a significant problem in all urban areas worldwide. There is some escape from it if you travel to distant suburbs and rural locations. We need to continue our all-out battle against this threat to the dark sky, but the threat of uncontrolled satellite constellations is an order of magnitude greater threat than we have faced heretofore.

—Tim Hunter
Co-founder, International Dark-Sky Association, Inc. (IDA)

Night Sky Network

WELCOMING GIRLS AND WOMEN TO OUTREACH EVENTS

A Girl Scout looks through a Dobsonian scope. Photo credit: Girl Scouts of Northern California

Look around your club. If you notice that women and younger members are missing, your club is not alone. The "graying" of astronomy clubs is noticeable; across the country, more than 80 percent of club members are men. There are a few clubs where this is less of an issue. What is it about the culture of those clubs that promotes more diversity?

Girl Scouts of Northern California observe the Sun through solar glasses. Photo credit: Girl Scouts of Northern California

Amateur astronomers have been talking for decades about having more women in astronomy clubs. The Night Sky Network has heard you, and is sharing a few easy-to-implement tools for making your public engagement friendlier to women and girls.

We looked at all the latest research on girls engaging with astronomy during a grant we worked on called "Reach for the Stars: NASA Science for Girl Scouts." Led by the SETI Institute, the primary purpose of the grant was to create space science merit badges for the Girl Scouts, which we did. You can find more about those at *bit.ly/astroall.* In each badge, we included a step to connect with your local astronomy community. To prepare amateur astronomers for the influx of Girl Scouts attending events, we created a workshop called "Confidence and Curiosity: Girls at the Telescope" to share the latest best practices with our community.

Over 300 participants attended the Confidence and Curiosity workshops, and we all learned a lot! We explored subjects such as dealing with misconceptions, asking and answering questions, telling diverse stories at the telescope, and growth mindset, among other topics. More than 90 percent of the participants said the workshop was "useful" or "very useful" for their public outreach.

Here are a few quotes:

"I found this to be a very useful workshop for understanding how to expand my outreach to include Girl Scouts of all ages."

"A wonderful opportunity to connect with professionals around the topic of engaging Girl Scouts in astronomy and feel plugged into a bigger network."

"The workshop opened me up to really good concepts, techniques and skills that weren't even on my radar."

Did you miss these workshops, or want to share what you learned with your club? We wondered what we could do to get these tools into the hands of more astronomy enthusiasts. We distilled some of the main points of these workshops into five short videos.

You can explore these videos and other tips and tricks at *go.nasa.gov/3GDseZz.* We'll discuss two of them here.

DEALING WITH MISCONCEPTIONS

At our public events, we often hear misconceptions about astronomy, so often that we may start to be annoyed, like when people mix up astrology and astronomy for the third time that night! However, it's the first time for that person in front of you who is trying to make a connection. Don't immediately jump onto how they are wrong, wrong, wrong! I try to see the correct ideas beneath the misconception – they are always there. In our example, I may say, "Astrology gave astronomers so much information about the positions of the planets! Astronomers needed that data to understand the rules of planetary orbits." Then redirect their attention to what you are doing. "Would you like to see Saturn through the telescope?"

This simple formula of noticing what's right, making a gentle correction and returning to what you are doing together is so encouraging to our visitors.

Kind responses can mean so much when someone is new to the hobby.

WELCOMING BEHAVIORS

You may have heard of "microaggressions" and that exploring our biases is important work. But have you also heard of micro-affirmations? These are small actions that make people feel included and welcomed. When someone is attending a club meeting or event for the first time, say hello! Learn their name and how to pronounce it. Look them in the eye and nod when you agree with them. Recognize the achievements of beginners – learning the sky can be challenging, so let people know when they are doing well.

These are probably behaviors you do naturally when you are with friends and family, so make an effort to extend these welcoming gestures to people who are newer to you. Also, don't assume their knowledge level, ask! They may have their own telescope, have moved from a club in a different location, or even work in the field. You may already have a lot to talk about together.

Space can be exciting to everyone, regardless of age or gender. Practice these simple tips to make your public engagement more girl-friendly, too!

—Theresa Summer

Theresa J. Summer is the astronomy educator and diversity coordinator for the Astronomical Society of the Pacific. Her secret mission in life is to help people to understand that science is not just for crazed geniuses in lab coats, but is for everyone, and is an important part of being an active citizen in today's world.

Full STEAM Ahead

PAINTED PETROGLYPHS

A two-week road trip that included ALCon 2011 provided the opportunity for many enjoyable petroglyph sightings. This experience began with the summer solstice watch at Chaco Canyon and continued to the darkest skies (in my humble opinion) of Monument Valley, included Grand Canyon south and Grand Canyon north, then

continued on to Zion National Park, Bryce Canyon, and lastly Arches National Park. Along the way, in conjunction with all the picture taking, two excellent booklets, *Easy Field Guide to Southwestern Petroglyphs* and *Easy Field Guide to Rock Art Symbols of the Southwest,* were purchased from American Traveler Press *(americantravelerpress.com).* In addition, the Chaco Canyon Cultural Center made available a free informational pamphlet, *Petroglyph Trail: Pueblo Bonito to Chetro Ketl,* that provided a great narrative of why the Chaco culture made rock carvings and the cultural information that could be deciphered by analyzing the petroglyphs *(archive.org/details/PetroglyphTrailPuebloBonitoToChetroKetl).*

In March, these resources were extracted from the archives of my file cabinet and a hands-on activity was born. As a team/teacher member of the Broken Arrow Virtual Academy in Oklahoma, I plan a monthly meet-up focused on astronomy, with a hands-on activity for a dozen students. In this activity I introduced the students to the world of petroglyphs and archeoastronomy, pigment making techniques, and symbol communication/language development.

Information from the Chaco Canyon brochure was shared, and we discussed how these civilizations relied on these carvings for information on animal migration, weather, farming, hunting, and lodging, and the techniques used to make and sharpen tools and preserve the carvings. A worksheet was made that represented many of the symbols related to the cosmos, weather, and time, including symbols for the sun, solar eclipse, moon phases, comets, supernovae, stars, meteors, rain, lightning, clouds, morning, night, and more. These were reviewed as a group and the students guessed which word represented each symbol. It was fun as they yelled out their answers, and exciting when a few got 17 out of 18 correct.

The session segued into generating pigments, and the students were shown the many rocks and minerals that were crushed to generate the various colors. To make red ochre, one needs red clay, iron oxide, and hematite, whereas charcoal almost exclusively was used for the black pigment. To create green, arsenic and plant life were the main sources, as well as chromium and copper. Cadmium yields a variety of yellow, orange, and even red hues, while lapis lazuli, cobalt, malachite, azurite, cinnabar, berries, and flowers created shades of blue. Earthy shades (browns, grays, cream) would be made from various clays and barks. Last but not least, white was made from chalk, lead, seashells, titanium, and zinc. There are many YouTube videos on how to make your own pigments from rocks that would make a great STE(A)M activity.

The highlight was sharing a box of stones I collected from Australia. Although I did not know the specific area each of the rocks came from, the students were provided pictures of Victoria Falls, Bridal Veil Falls, Minnehaha Falls, and Wentworth Falls from the Blue Mountain Range in Katoomba, New South Wales, Australia. Eyes got big as I let the students pick their own special rock and then their reaction when they realized there were no paint brushes, but sharpened sticks with yellow ochre paint in the small plastic condiment containers.

I encouraged them to design their own symbol of their favorite astronomical object, or they could copy any of the symbols from the worksheet they had been given. During the painting stage of the lesson, several members of the administration from the Broken Arrow Virtual Academy walked among the students and reacted to the sharpened sticks. The students told them the rocks were from Australia which made them hang around to see the outcome. The feedback from the parents and conversations days later was positive. I was thanked for the creative and imaginative way I presented the history and traditions of ancient cultures. For their part, the students gave me an A+ for my session.

For more information on how to plan a session like this for your students, feel free to contact me at *astroleague_steam@cox.net.*

—Peggy Walker

Wanderers in the Neighborhood

WHAT IS A PLANET?

Science is based on observations as part of the scientific method. Observation initiates the formulation of a hypothesis. This leads to the development of experiments that can support the hypothesis, reject the hypothesis, or modify it based on the results. The final piece of the process is the ability of other scientists to reproduce the experiment and get the same results.

But science also rests on an understanding of the world using the same terminology, where a word always has the same scientific meaning. These definitions underpin the language of science, an agreed upon understanding of a concept. A word that has a history of meaning is "planet."

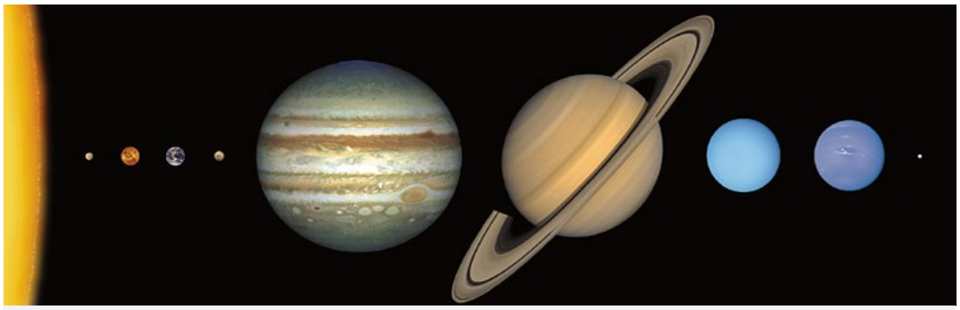
In a portrayal (shown here cropped) by Félix Parra painted in 1873, Galileo Galilei explains his ideas to a Franciscan friar at the University of Padua. With a compass in his left hand, he measures on a celestial globe or armilla. Behind him is a bookcase containing books by Aristotle, Plato, and Copernicus. Galileo's observations with his improved telescope moved the Sun to the center of the Solar System, displacing the Earth. His other discoveries in the fields of mathematics, physics, and engineering were also groundbreaking. Image credit: Museo Nacional de Arte, Mexico

Millennia ago, the definition of planet was simple: planets were pinpoints of light in the sky that moved relative to the background of stars. The very name "planet" means wanderer. Mercury and Venus would never wander far from the Sun, while Mars, Jupiter, and Saturn could be found at any distance from the Sun, but always along the narrow path called the ecliptic.

With Galileo's improvement of Hans Lippershey's telescope, these points of light revealed themselves as tiny disks whose aspects changed, revealing them to be spheres like the Earth. Galileo also discovered the moons of Jupiter and realized that these moons orbited Jupiter just as Jupiter orbits the Sun. This was in direct contradiction to the geocentric model of the Solar System where all celestial objects orbit the Earth. The phases of Venus that he observed confirmed that the planets orbited the Sun and his observations started moving other astronomers toward the heliocentric model of the Solar System.

Galileo saw the Jupiter system as planets orbiting a larger planet. He did not differentiate Io, Europa, Ganymede, and Callisto as moons, but called them planets. His concept was that a planet is a geologically active body in space. This grew out of his telescopic observations of the Moon. Seeing mountains on another body in space just like the mountains on Earth allowed him to extend this geological definition of a planet to all the other objects he could see.

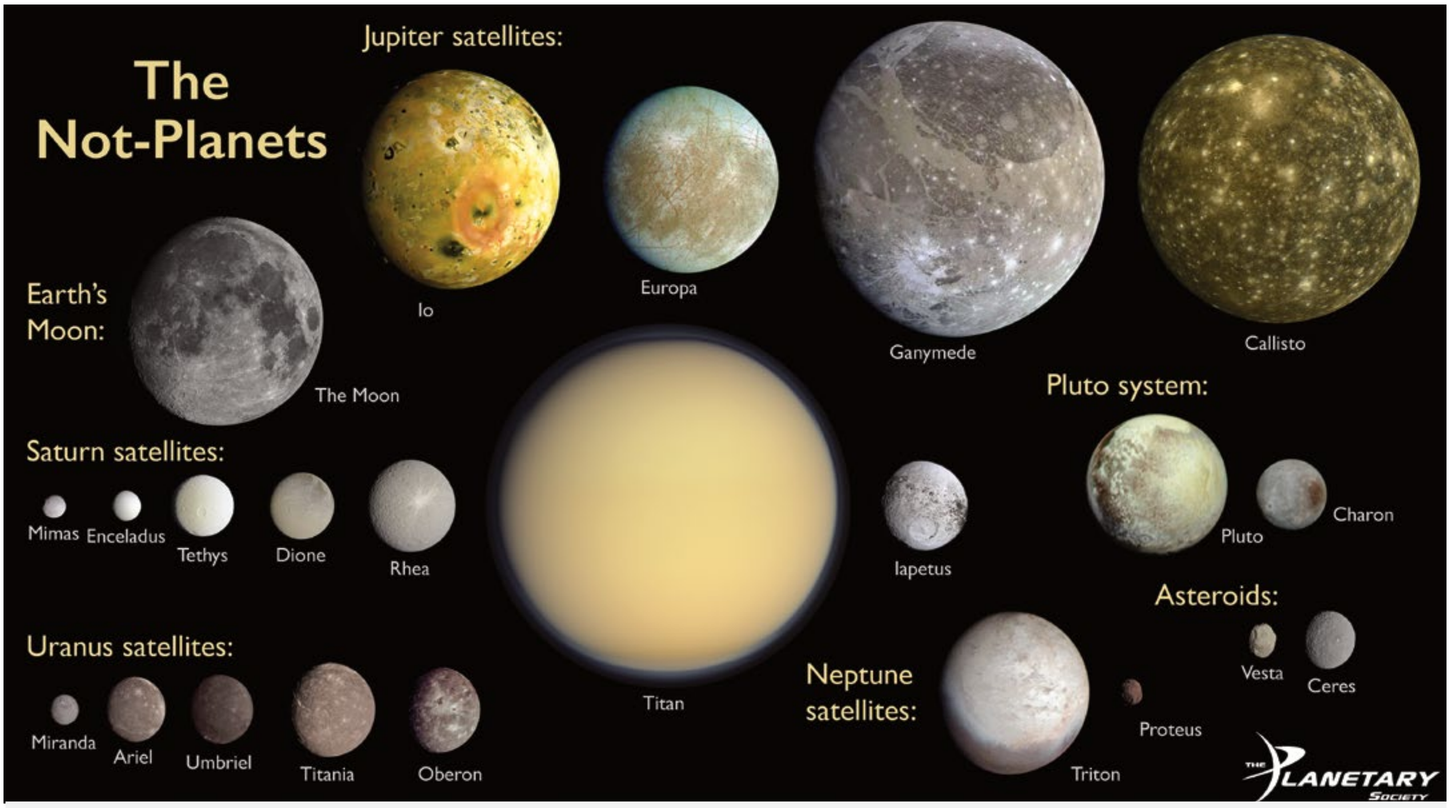
This definition of a planet was in common use from its inception in the 1600s until the early 1900s. Starting around 1910, astronomers became more interested in stellar astronomy than planetary astronomy as the tools for studying the stars become more effective. The number of scientific papers on planetary astronomy declined, according to a bibliographic study undertaken by a group of researchers headed by Phillip T. Metzger of the University of Central Florida in an article in the journal *Icarus.*



The planets in our Solar System shown at the same scale. Jupiter and Saturn are the two largest planets and along with Uranus and Neptune form the gas giants. Mercury, Venus, Earth, and Mars are the rocky planets. Pluto is a dwarf planet that was the first of the Kuiper Belt objects to be discovered. The planets are not shown at their appropriate distances from the Sun. Source: NASA/Lunar and Planetary Institute

Almanacs had become popular in the late 1700s and continued to be popular into the early 1900s. They provided weather predictions based on planetary positions. Meanwhile, astrology relied on the positions of the major planets as well. In both cases, satellite planets and minor planets obscured their simple prediction systems. They needed a small and fixed number of planets to work with.

With the popularity of astrology and almanacs, the notion of only eight planets (nine with the discovery of Pluto) crept into the popular lexicon as the public become more scientifically aware. The knowledge that the Earth and planets orbited the Sun merged with the astrological definition of planets. This is when satellite planets were demoted to a lower status of moons in everyone's mind, even astronomers, as the geological definition of a planet faded.



Large, round, non-planet objects in our Solar System that have been visited by spacecraft. These objects are in hydrostatic equilibrium – they are round. They might have been called planets under the current definition if they orbited the Sun and had cleared their orbital neighborhoods. Many of them would be planets under Galileo's geophysical definition of a planet. Images from Galileo (Jupiter's moons), Cassini (Saturn's moons), Voyager 2 (Uranus and Neptune's moons), New Horizons (Pluto), Dawn (asteroids). Data from NASA/JPL/HUAPL/SwRI/UCLA/MPS/DLR/IDA processed by Ted Stryk, Gordan Ugarkovic, Emily Lakdawalla, and Jason Perry. Earth's Moon photo by Gari Arrillaga. Montage by Emily Lakdawalla, The Planetary Society, blog@planetary.org*; image text modified by* Reflector *staff.*

The 1960s brought the space program, reigniting interest in the planets as the United States and the Soviet Union launched probes to the other planets in the Solar System. The flood of data allowed scientists to produce more planetary papers, but while a few scientists used Galileo's original definition, most scientists were influenced by the newer notion that moons are not planets. While some moons were as interesting as the planets they orbited, the concept of moon brought forth the image of a cold, dead object like our Moon. Meanwhile, new objects were being discovered in our Solar System at a prodigious rate.

By the time the International Astronomical Union (IAU) voted to demote Pluto to a dwarf planet in 2006, virtually all astronomers wanted to keep the number of planets in the Solar System small (after all, schoolchildren had to memorize them). Satellites were not planets, even though Jupiter's satellite Ganymede is slightly larger than Mercury. To emphasize that point, the IAU passed a separate resolution that there were eight planets and enumerated them.

The definition of a planet that the IAU accepted states that the object must be in orbit around the Sun, in hydrostatic equilibrium (spherical), and have "cleared the neighborhood" around its orbit. The last requirement is somewhat problematic. It eliminated both the (dwarf) planets Ceres and Pluto from the list of planets. But it also depends not only on the physical characteristics of the object, but its location. If Mars orbited farther out, in the Kuiper Belt, it too would be eliminated from the list of planets, since it does not have enough mass to clear an orbit in that region.

Metzger points out, "But if, for instance, a star passes by and disrupts our solar system, then planets are not going have their orbits cleared anymore." Other astronomers have noted that Earth, Mars, Jupiter, and Neptune have not cleared their zones either. Minor planets accompany the first three while Neptune has Pluto in its orbital space.

This definition only applies inside our Solar System. The rapidly expanding number of objects discovered orbiting other stars (exoplanets) are not governed by this definition. The IAU has yet to define an exoplanet or modify the current definition so it applies all across the universe. Metzger says he'd like to see the IAU create a new definition based on the geophysical characteristics of planets, and that the scientific use of the geophysical-focused definition be reflected in textbooks. Perhaps we would then be able to identify an object as a planet when we come out of warp into a new star system.

REFERENCES

Metzger, Philip T., et al. March 1, 2022. "Moons are Planets: Scientific Usefulness Versus Cultural Teleology in the Taxonomy of Planetary Science." *Icarus* 374: 114768. *sciencedirect.com/science/article/pii/S0019103521004206*

Wells, Robert. Dec. 8, 2021. "Planet Decision That Booted Out Pluto is Rooted in Folklore, Astrology, Study Suggests." *phys.org/news/2021-12-planet-decision-booted-pluto-rooted.html*

Deep-Sky Objects

GLOBULAR STAR CLUSTER M80

Star clusters come in two flavors: open star clusters and globular star clusters. Open star clusters are small and contain anywhere from dozens to thousands of stars. Small groups that are less gravitationally bound are called star associations. Globular star clusters contain many more stars: tens of thousands to a million stars. The one thing common to all star clusters is each was formed out of a giant molecular gas cloud. So all the stars in a cluster share a common chemical origin.

Open star clusters are usually found in the plane of the Milky Way, hence they are also called galactic star clusters. These clusters are young and contain stars of all stellar classes. There are not enough stars for their combined gravity to hold these clusters together indefinitely; their stars will eventually disperse. That is why there are no old open star clusters. Our Sun was formed in an open star cluster that has long-since broken up, leaving our Sun a lone star paving its own path through the Milky Way. Astronomers have identified other stars with very similar composition to the Sun and think they were born in the same star cluster.

Globular star clusters are very old, almost as old as the universe itself. They have enough mass to keep their stars gravitationally bound forever. They contain no large stars of spectral classes O, B, and A. These stars have lifespans much shorter than the age of most globular star clusters. If formed in these clusters, O, B, and A stars have long since died out. The stars in globular clusters are mostly early generation stars in that they do not contain many materials ejected from dying stars. These clusters do not orbit the Milky Way in the galactic plane, but orbit randomly in a fairly uniform spherical halo around the galaxy. Astronomers are not sure how these large clusters formed and ended up in a halo around the galaxy. There are somewhere between 150 and 200 globular clusters in the Milky Way. We find them in other nearly galaxies, that is, galaxies close enough that their globular clusters can be resolved. M31 has thousands of them!

Sagittarius contains the most globular star clusters of any constellation. But Scorpius is not far behind. When gazing at these constellations from our vantage point two-thirds of the way from the center of the Milky Way to the edge, we are looking towards the center of the galaxy, and beyond it, above and below the galactic plane. That is why so many globular clusters are found in those constellations.

This month I'll focus on globular cluster M80, which is located about halfway between the stars Antares (Alpha Scorpii) and Graffias (Beta Scorpii). M80 is easily seen in binoculars in dark skies. M80 shines at magnitude 7.3 and is 32,600 light-years away. That's 6,600 light-years farther than the center of the Milky Way. It is currently 20,000 light-years north (galactic coordinates) of our galaxy's spiral plane.

M80 has an apparent diameter of 10.0 arcminutes, corresponding to an actual diameter of 95 light-years. It contains several hundred thousand stars, making it one of the most densely packed globular clusters in our galaxy. The cluster is estimated to be 13.5 billion years old.

Charles Messier discovered M80 in 1781. He was unable to resolve the object and distinguish it from a tailless comet, except that M80 did not move with respect to the stars. William Herschel was probably the first astronomer to resolve M80 into stars using his 18.7-inch Newtonian. He described it as "one of the richest and most compressed clusters of small stars I remember to have seen."

M80 is more than four times farther away than M4, a globular cluster located adjacent to Antares. Were M80 as close as M4, it would be slightly bigger and noticeably brighter due to its denser core. At that distance, it would even rival M22, the finest globular cluster visible from mid-northerly latitudes.

An 8-inch telescope at high magnification will provide superb views of M80, resolving it into countless stars and revealing its dense unresolved core. I imaged M80 using an 8-inch f/8 Ritchey–Chrétien with 0.8× focal reducer/field flattener with a SBIG ST-2000XCM CCD camera. The 40-minute exposure was perfect for capturing the cluster.

In the image of M80, the bright star to the upper left of the cluster is SAO 184288 and shines at magnitude 8.44. While the star appears brighter than the cluster, the integrated magnitude of the cluster is brighter. SAO 184288 is a foreground star to the cluster. The second brightest star in the image, below the cluster, is a double star with a magnitude 8.7 yellow primary and a magnitude 10.6 white companion.

There is a nice optical double consisting of a red star and a white star to the lower right of M80 on the image. The red star is magnitude 10.6 while the white star is an easily resolvable double star of magnitude 9.5. Centering the eyepiece on this pair will bring a nice triple star into the view a few arcminutes south of this pair (not captured in this image). The trio has an 8.4 magnitude yellow primary flanked by two 12.8 magnitude white companions.

Because of its location near the ecliptic, occasionally the Moon occults M80. It happened this year on March 22 at 11:20 p.m. CDT. It will not happen again in dark skies for several years.

—Dr. James Dire

From Around The League

GLOBULAR CLUSTER OBSERVING CHALLENGE

The distribution of globular clusters in our galaxy is often described as resembling "bees buzzing around the galactic hive," with clusters moving every which way, circling the galactic center. (At its center lurks a supermassive black hole – the queen bee, perhaps?)

Sketches by Cindy Krach,
12.5-inch reflector, various magnifications

This perception gives the impression that all globular clusters are alike, just as all the busy worker bees are alike. That is not the case. Globulars come in different sizes, and contain different stellar concentrations and distributions; some are not really concentrated and compact, but more dispersed.

June through September are the most convenient months to spy the largest number of these grainy globes of light before midnight. In "light" of this, the Astronomical League is issuing a Globular Cluster Observing Challenge for this summer. Simply observe and note any twelve or more globular clusters on the list in the Ophiuchus/Sagittarius region of the sky. Share your quarry with someone who normally wouldn't give these galactic bees a second thought.

Astronomical League members who complete the challenge will receive a certificate through email commending their achievement.

astroleague.org/content/al-observing-challenge-special-observing-award

LIBRARY SCOPE GIVEAWAY

Each year, the Astronomical League gives away up to 11 Library Telescopes for placement in local libraries around the country. League member societies and members-at-large may apply. One applicant society in each of the League's ten regions will be selected in random drawings, and one applicant member-at-large will also be selected.

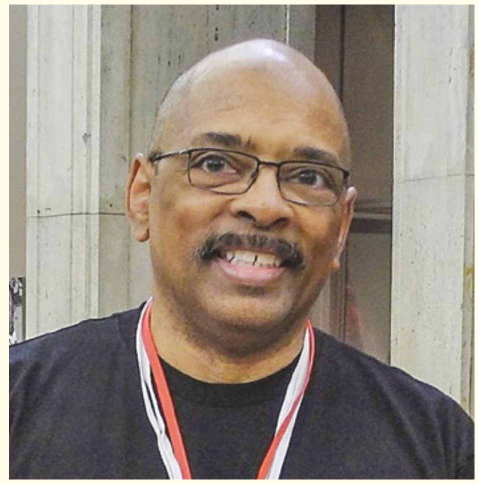
Clubs across the country have discovered that the Library Telescope Program publicizes their organizations and places telescopes in the hands of people in their communities who are exploring the night sky for the first time. The program offers benefits to everyone involved: to libraries, to library patrons, and to the sponsoring clubs. Library Telescope placement also makes an ideal club project.

Last year, we had several regions with no applicants, so a club in each of those regions missed an excellent opportunity to receive a valuable

Library Telescope and participate in this wonderful public service project.

To enter the drawing, go to the League website at *astroleague.org,* click on "Library Telescope Program" in the menu, and open the link to the application form. The application must be emailed per instructions on the form no later than June 30, 2022.

WELCOME TO MIKE HUMPHREY, OUR NEW NERAL CHAIR



We are pleased to introduce the newly appointed chair of the Northeast Region of the Astronomical League, Mike Humphrey.

Mike doesn't remember when he was first interested in the stars, but he does recall, when very young, taking a telescope (refractor) and eyepiece apart to figure out how they worked. The challenge was getting them back together before his parents found out! (Happily, they didn't.) He was brought up on NASA and the early U.S. space program, which fueled his early interest in astronomy. As he obtained improved scopes and a better understanding of space, he found that each answer brought more questions.

Mike joined the Buffalo Astronomical Association in 2010 and served as editor of its newsletter, *Spectrum*, from 2014 to 2019. In 2017, he received an Achievement Award from the BAA College of Fellows. He also served as BAA vice president and was elected president of the club in 2018. Under Mike's leadership, the club is thriving, with approximately 120 members and virtual meeting attendance in the 50-member range! Mike loves doing outreach and works hard to provide audiences with the most informative and entertaining events possible. A tinkerer at heart, he has rebuilt several telescopes including his ETX125 travel scope and a 12-inch LX200-GPS that he uses at home.

Mike received an A.A.S. and certification in medical laboratory technology and began working for Somerset Laboratories. He left this Buffalo-based facility to pursue a management position with Ortho Diagnostics System and later returned to Buffalo to take a position with the American Red Cross managing regional hospital accounts. He later left the Red Cross to work with Time Warner supervising regional accounts. Mike retired from Time Warner and now divides his time among his wife, four big kids, two grandkids, astronomy, computer building, and car repair.

OFFICER CANDIDATE BIOS

CARROLL IORG, CANDIDATE FOR PRESIDENT

Greetings, members of the Astronomical League!

I am a candidate for president of the League. Also, I am a member of the Astronomical Society of Kansas City and a past president.

I would like to review where we have been these past two years, the progress we have made, and what we hope to accomplish in the next two years.

The opening line of Charles Dickens' *A Tale of Two Cities* perhaps sums up quite well: "It was the best of times, it was the worst of times."

About two years ago, the League made the difficult decision to cancel an ALCon (2020) for the first time since World War II. At about the same time we prohibited regional conventions as well. We also postponed the live ALCon 2021 until 2022.

As our country continued to shut down the functions we had believed would be always open – including schools, many businesses, and restaurants – we had to make some more difficult decisions as an organization.

Team Attainments:

• Zoom was introduced to keep in contact with our various associates.

• Began a collaboration with Scott Roberts, CEO of Explore Scientific, with the weekly Global Star Party and monthly Astronomical League Live. We enthusiastically embraced this bold idea. Members of the executive committee and others rotated to represent the League at each of these weekly Zoom meetings. Thanks to Terry Mann, who functions as the liaison with Explore Scientific.

• We have been fortunate this past year in receiving two most generous donations from estates.

• ALCon 2021-Virtual was a success, with Scott Roberts challenging us to engage more technologically. There was a massive online reach across the world, door prize support by many member societies, and the keynote speaker joined us virtually from the United Kingdom.

• The League's 75th anniversary celebration this past year has recaptured much history that had not been seen for a while. Thanks to Peggy Walker, John Goss, and others who made all of this happen.

• The website update from Drupal to WordPress is scheduled to be finalized in just a few weeks. We are so excited. Many of the updates we have needed for several months are now on the verge of being realized. It is designed to make the site work much better for our members and clubs in a more efficient manner. It was an expensive project, but one that will pay rewards for many years.

• John Goss was appointed as media officer and has set up the League's YouTube channel and greatly enhanced the content of our other social media avenues including Facebook. This accomplished another one of our goals from two years ago.

Future goals:

• Strengthen the regions.

• Continue to improve our relationships internationally. A joint convention is being planned with the Royal Astronomical Society of Canada in Toronto in 2024.

• Constantly find new opportunities to improve the visibility of the new website and make it even more useful to our site visitors.

• Improve the diversity of our membership and League council.

• Continue the active digitizing of League records.

The third time is a go for ALCon 2022 in Albuquerque. The society was patient in hanging with us for these many years. Please plan to attend if at all possible. An excellent program is planned.

Thanks for your tremendous support these past two years, and I would appreciate your vote for president.

CHARLES E. ("CHUCK") ALLEN III, CANDIDATE FOR VICE PRESIDENT

Chuck is currently League vice president and has prior service as League president (1998–2002), vice president (1994–1998), secretary (2019–2020), and Great Lakes Region chair (1991–1998). A League Lifetime Member, he founded the National Young Astronomer Award in 1991, received the G. R. Wright Award in 1998, and holds the League's Master Outreach Award with 1,100 hours logged. He is a Master Observer Gold with 42 programs to his credit including

Herschel Society Silver. Chuck served as co-chair of ALCon 2021 Virtual and has coordinated the League's Solar System, Lunar, and Lunar Evolution Observing Programs since 2020. He chairs the League's bylaws revision committee and is actively promoting joint activities with the Royal Astronomical Society of Canada.

Chuck is program director of the Evansville Astronomical Society and past president of the Louisville Astronomical Society. He is also a former lead judge in earth and space science for the Intel International Science and Engineering Fair and a past director of the Louisville Regional Science Fair.

Chuck graduated from Duke University in 1970, served as a U.S. Air Force officer (1970–1974), and graduated from the University of Kentucky College of Law in 1977. He was a partner in Kentucky's largest firm where he worked for 27 years.

An amateur astronomer from the age of 7, Chuck attended his first ALCon in 1965, and, that same year, earned the League's Advanced Junior Certificate and became president of the Louisville Junior Astronomical Society.

MAYNARD PITTENDREIGH, CANDIDATE FOR EXECUTIVE SECRETARY

I am currently serving as the executive secretary of the Astronomical League and would like to continue to serve one more term. I believe there

are three qualifications that an officer of the Astronomical League should have: being an avid observer, active in outreach, and experienced in the leadership of the AL.

As an active observer I hold the Master Observing Award, reaching the gold level. I have earned over 100 observing awards (I must note I've been working on these programs for over 30 years).

In terms of active outreach, I have a steady presence in some of our local schools, libraries, and scouting organizations. As the League's national coordinator for our Outreach Award, I enjoy helping some of our local clubs discover ways they can organize astronomy outreach in their communities.

I have been involved with the AL since I was 16 years old, and over the years have been a member of several different local clubs. I have served as an officer of local clubs and in various positions in the AL. In addition to serving as executive secretary since 2019, I am the coordinator of the Outreach, Youth Astronomer, and Beyond Polaris Observing Programs. I am one of the five members of the National Observing Program Directors who oversee the work of our many observing programs. I was the chairperson of the 2019 ALCon. I am currently a member of the Brevard Astronomical Society, the Central Florida Astronomical Society, and a Lifetime Member of the League.

LESLIE C. PELTIER AWARDS COMMITTEE REPORT

The heart of amateur astronomy is observing. We can read all we want about astronomical phenomena, but the real joy in astronomy is going out under the night sky and observing the objects about which we have read. But while most of us are casual observers of the sky, looking at the same few objects over and over, a few amateur astronomers develop their observing skills to the ultimate degree. They then use these skills to make careful observations of the sky and record them for scientific analysis.

Whether the observation is made with a photometer, CCD, spectroscope, or just the human eye, the ability to find an object and record scientifically useful detail is an uncommon trait. To recognize the amateur astronomer who is not only able to do this, but has contributed their observations to an ongoing observing program, the Astronomical League presents the Leslie C. Peltier Award. The Peltier Award was created in 1980, awarded posthumously to Peltier in the autumn of that year, and first was presented in 1981.

The Peltier Award Committee tried to assume some form of normalcy despite the COVID pandemic and mailed the awards to the recipients for 2020 and 2021. In August 2021, they were honored remotely at ALCon 2021 Virtual. We now hope human contact can resume and our in-person annual meetings can continue.

What follows is information about the 2021 honoree.

DON MACHHOLZ, OUR 2021 RECIPIENT

Don was born in Portsmouth, Virginia, October 7, 1952, and became interested in astronomy at age 8. He received his first telescope, a 2-inch refractor, in October 1965. Later he received a 6-inch Criterion Dynascope and found all the Messier Objects in one year (1969–1970).

Then Don spent some time doing astrophotography (1972–1974), having a few photos published in small astronomy magazines. After his time in the Army, he embarked on a comet hunting program, which he began on January 1, 1975. He found his first comet on September 12, 1978, after 1,700 hours of searching. His second find took an additional 1,742 hours. He has now spent 8,800 hours comet hunting, during which he has discovered a total of 12 comets that bear his name. Don is the number one living visual comet discoverer.

On August 30, 1975, Don was one of many who reported the new Nova Cygni (1975) to the Central Bureau for Astronomical Telegrams.

In 1990, Don, his late wife Laura, and son Matthew moved from San Jose, California, to Colfax, California, where they lived for nearly 30 years. From there he visually discovered eight comets and held numerous public star parties, taught at a local junior college, and conducted classes at a local science center.

In 1978, Don was one of the independent inventors of the Messier Marathon, an attempt to find and view all 110 galaxies, clusters, and nebulae in one night. In the last 40 years he has completed over 50 Messier Marathons and has written two books on the subject.

On the night of April 3, 1981, Don located and observed 599 deep-sky objects, averaging 52 seconds to star hop to each one. The objects were from both the Messier Catalog and from his own list of bright galaxies, clusters, and nebulae. This became known as the Massive Marathon.

From 1978 until 2000 Don wrote a monthly column called "Comet Comments," designed for astronomy club newsletters and interested individuals worldwide. Between 1988 and 2000 Don was the Comets Recorder for the Association of Lunar and Planetary Observers.

Don continues his visual comet hunting and Messier Marathons from Arizona, where he lives with his wife Michele.

Don has a weekly podcast: "Looking Up with Don," found on most podcast platforms.

His website is *donmachholz.com.*

We are now in the process of preparing for our 2022 honoree. It is hard to believe that this Astronomical League tradition is 42 years old. We owe Scott Roberts and Explore Scientific a great deal for their sponsorship of the Peltier Award.

—The Peltier Award Committee

Dr. Roger Kolman, Chair; Barry Beaman, Russ Maxwell

The Stellafane Convention

Experience the ***original*** star party, held since 1926 at the storied home of the Springfield Telescope Makers!

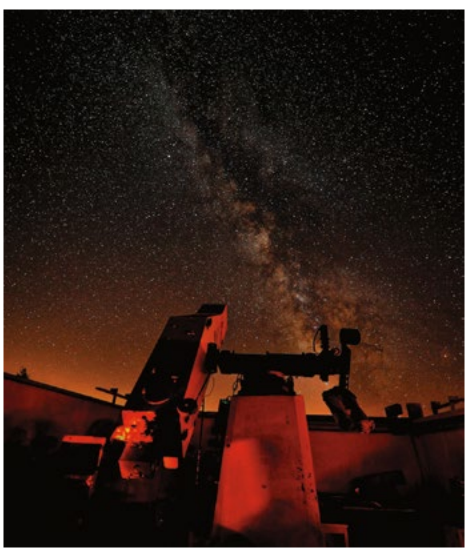
KEYNOTE ADDRESS

"Building the Glass Universe" by Dava Sobel, author of *Longitude, Galileo's Daughter, A More Perfect Heaven, The Planets,* and *The Glass Universe*.

"SHADOWGRAM" TALK

"Holding up Half the Sky: Women in Astronomy" by Dr. Kristine Larsen

FINE OBSERVING from our dark Vermont hilltop, with your telescope, the legendary **Porter Turret Telescope,** the McGregor Observatory's **13" Schupmann Telescope,** the Simoni Observatory's **Hale Spectrohelioscope,** and other modern and historic instruments on our campus.



TELESCOPE COMPETITION

Built a telescope? Show it off in front of the historic Stellafane Clubhouse in our mechanical and optical competitions. In the ATM world, nothing beats a blue ribbon from Stellafane!

A WIDE RANGE OF **TALKS, DEMONSTRATIONS, & WORKSHOPS** FOR AMATEURS FROM BEGINNER TO EXPERT

FULL **FOOD SERVICE** ON SITE

FANTASTIC RAFFLE PRIZES

NON-COMMERCIAL SWAP TABLES

OBSERVING OLYMPICS

TEEN ROBOTICS WORKSHOP ON THE WEBB SPACE TELESCOPE'S TECHNOLOGY

CAMP ON SITE OR STAY IN LOCAL HOTELS & B&BS

The Hartness House Workshop

After a 2-year break, the Hartness House Workshop will return as part of the Stellafane Convention on Thursday, July 28. The theme this year will be

Eclectic Astronomy

—the Workshop will offer high-quality presentations on a range of astronomical subjects, with an opportunity to mingle with the speakers and other attendees at the historic Hartness House Inn.

The **Hartness/Porter Museum of Amateur Telescope Making** will be open during the day, and the unique **Hartness Turret Telescope** will be available for night-time observations, if the skies are clear. **Dava Sobel** will give the keynote presentation (a distinctly different presentation to her keynote at the Convention on Saturday). Separate day and evening programs: the evening program includes dinner and keynote. Registration is separate from Convention, with additional fees. See the web page at the link below for registration information.

The 86th Convention of Amateur Astronomers and Telescope Makers will be held atop Breezy Hill in Springfield, VT, Thursday July 28 – Sunday, July 31, 2022 • Learn more and register online at ***stellafane.org/convention/2022/index.html*** • **Register early for best rate!**

photo credits: keynote panorama, Tom Spirock; telescope competition, Richard Sanderson; Hartness House, Tyler Goodrich via Wikimedia Commons; Schupmann Telescope, Dennis di Cicco.

The Quantum Chemistry of Astronomical Masers

By Stephen Tzikas

Astronomical masers can be observed in the radio frequency band. The term maser is an acronym for microwave amplification by stimulated emission of radiation. The oxygen-hydrogen (OH) or hydroxyl molecule emits electromagnetic radiation in the radio spectrum that can be observed by amateur and professional astronomers when they target OH-source astronomical masers. But what makes masers so special, allowing for their observation, and what else can be gathered from them?

Students and amateurs have a powerful tool available to them for radio astronomy observing. It is Skynet's 20-meter radio dish. I provide demonstrations of this radio telescope annually at the Society of Amateur Radio Astronomers (SARA) summer conference at the Green Bank Observatory in West Virginia, which is where the 20-meter dish is located. Members of SARA have access to the 20-meter if they meet the National Science Foundation grant requirements, including being a U.S. citizen.

Barry Turner classified OH masers according to emission frequency, distinguishing between those sources which radiate most strongly at 1,665 or 1,667 MHz (found in H II regions) and those which radiate most strongly at 1,612 or 1,720 MHz (predominantly with infrared stars). The difference between the two classifications concerns the physics of the pumping processes.

Radio receivers and antennas are sensitive to the random motions of electrons (thermal radiation), the motions of electrons in magnetic fields (synchrotron radiation), atomic transitions (hydrogen at 1,421 MHz), and molecular transitions.

The last of these includes hydroxyl (OH) molecular transition spectral lines occurring at:

1,720 MHz (weak/satellite)
1,667 MHz (strong/main)
1,665 MHz (strong/main)
1,612 MHz (weak/satellite)

ELECTRONIC, VIBRATIONAL, AND ROTATIONAL INFORMATION

When molecular transitions are present, they are comprised of three factors that make up a total wave function, as it is called in quantum chemistry. These are the electronic, vibrational, and rotational points of a molecule, and are often represented by energy level diagrams in books related to inorganic or quantum chemistry. Jumps between energy levels are responsible for spectral lines. These energy levels have letters to denote their energy states. The angular momentum of vibration of a diatomic molecule (such as OH) is an integral multiple, J, of the energy of rotation. The Greek letter Pi represents the rotational state of the molecule. An electronic interaction between the electrons and the proton depends on the quantum number F. One last parameter to note is that the two states of Pi and J represent a doublet (called the lambda doublet) which depends on the value of J. This doublet represents a quantum system with two possible spin states.

These quantum parameters can be presented and placed into the context that make the four spectral lines possible. Although this article's intent is not to teach you quantum chemistry, the terminology I am presenting allows you to explore the subject further.

The 20-meter dish at Green Bank, available to members of the Society of Amateur Radio Astronomers through Skynet. Credit: NRAO/GBO/AUI.

TYPES OF CHART DATA

It is the four spectral lines presented above that can be observed using the 20-meter radio telescope. Let's have a deeper look into this. There is a molecular cloud, called W3, some 6,200 light-years away in Cassiopeia. The W designation notes that it is part of the Westerhout Radio Catalog. W3 is associated with the Heart and Soul Nebula, where it is the brightest part of the Heart Nebula (IC 1795). I will present two radio maps I created of W3 later in the article. First, it's important to state a few more properties of astronomical masers to fully appreciate them. Depending on how your observational data is collected, certain information can be gleaned:

Spectral Lines and Frequency Spread – If a layer of gas were stationary, each line would have a width determined by the temperature of the gas. If the gas is moving with different mass velocities, absorption and emission will not occur at a single frequency, but over a range of frequencies due to Doppler shifts. The shape of a chart could also be influenced by different amounts of emission or absorption.

Time Variations – Hydroxyl masers vary in time. In certain types of variable stars, the outer atmosphere is ejected during pulsation peaks. This ejected mass condenses with distance forming molecules such as water and dust grains. The water molecules can be split by ultraviolet light to form hydroxyl molecules. The heat from the warm dust excites the hydroxyls causing maser emission at 1,667 and 1,612 MHz. The intensity of the maser follows the changing brightness of the star as it pulsates.

Polarization – Astronomical masers are usually circularly polarized: the electromagnetic field has a constant magnitude, and it rotates at a constant rate in a plane perpendicular to the direction of the wave. The electric field vectors of a traveling circularly polarized electromagnetic wave can be left handed (LH) or right handed (RH) and are related by the right-hand rule to the direction the wave is moving. The right-hand rule is a concept you may have learned in high school physics.

Components – The radiation at 1,665 and 1,667 MHz from hydroxyl masers is usually almost completely circularly polarized, either RH or LH. The 1,612 MHz radiation may also be nearly completely polarized. The observations of the 1,720 MHz hydroxyl radiation are less clear. It is almost always found that the number of distinct component sources is appreciably greater for one transition than for the three others in a hydroxyl maser.

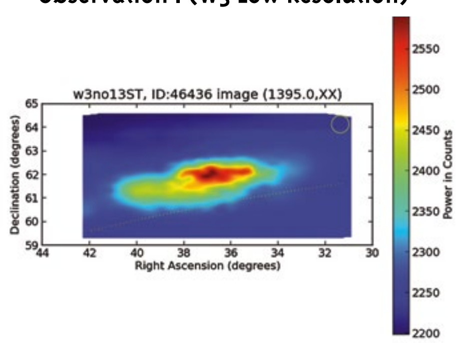
PUMPING SCHEMES

Masers are pumped by the radiation from an associated thermal energy source, such as an H II region or an infrared star within the shell of the maser. An important concept in pumping is called population inversion. Consider an incoming photon that causes a molecule to emit two photons of the same frequency, phase, and direction. This can only happen when there is a population inversion: that is, more atoms have electrons in a higher excited energy level than a lower one. If the incoming photon has the exact frequency of the difference in these two energy levels, then it can stimulate this system to drop to a lower energy level. Thus, the original photon plus an extra photon have now been emitted in the same frequency, phase, and direction. As the process repeats, an exponential amplification of this process occurs, hence the maser acronym. The molecules that are pumped to an excited state will decay (relax) non-radiatively (vibrationally) to a metastable state where a population inversion is created, before it fully decays to the ground state. There are some subtleties in that earlier term that I mentioned, the lambda doublet, that determine which spectral line transitions occur. For 1,667/1,665 MHz spectral line emission to occur, the lambda doublet must be inverted and the pumping mechanism does not discriminate between levels with different values of quantum number F. For 1,720/1,612 MHz spectral line emission, but where the lambda doublet is not inverted, the pumping process does distinguish between different values of F. However, if the lambda doublet is inverted, stimulated emission may occur in both the satellite and main line transitions. Which lines predominate can depend on the astrochemistry and energy sources of the surrounding environment. In pulsating circumstellar star environments, 1,612 MHz masers can predominate. In interstellar star-forming regions, 1,665 MHz masers can predominate.

FEATURED OBSERVATIONS

As examples of the capability for the 20-meter radio telescope, I present three of my observations. One is a low-resolution raster map of W3, one is high resolution raster map of W3, and one is a tracking observation of W49, another molecular cloud with radio maser sources. By following the links with each observation, detailed information can be reviewed for the input parameters I chose for these observations.

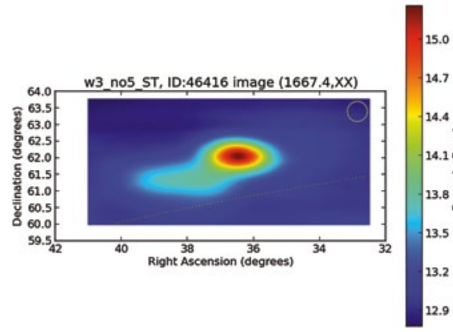
Observation 1 (W3 Low Resolution)



This observation is located at gb.nrao.edu/20m/peak/W3NO13ST/Skynet_59086_w3no13ST_46436_56008.htm.

This is a raster map with a low-resolution H I filter (1,355 to 1,435 MHz) with a 1,395 MHz center frequency at approximately 18 minutes, mapped at 6 by 6 beam widths. Note that while this frequency bandwidth is somewhat broad, it is not in the frequency range to detect the OH spectral lines. This demonstrates that the W3 molecular cloud is comprised of much more than just the maser components.

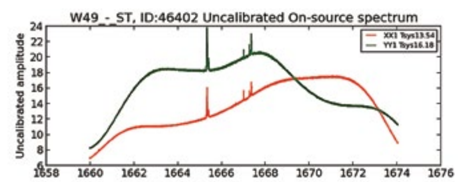
Observation 2 (W3 High Resolution)



This observation is located at: gb.nrao.edu/20m/peak/W3_NO5_ST/Skynet_59081_w3_no5_ST_46416_55990.htm

This is a raster map with a high-resolution filter with a center frequency of 1,665.402 MHz and a secondary frequency of 1,667.359 MHz. The observation time was approximately 18 minutes, mapped at 6 by 6 beam widths. In this observation I centered the frequencies on the maser spectral lines. This observation had a narrower frequency bandwidth of approximately 1,660 to 1,675 MHz.

Observation 3 (W49 Chart)



This observation is located at gb.nrao.edu/20m/peak/W49_-_ST/Skynet_59078_W49_-_ST_46402_55973.htm.

This is a tracking chart of 120 seconds duration with a center frequency of 1,665 MHz and a secondary frequency of 1,667 MHz, with a 15.625 MHz bandwidth. In this observation note the two polarization curves for the two frequencies. Note the main spectral lines around 1,665 and 1,667 MHz and the Doppler shifts.

I presented observations for the strong/main spectral lines, but I have observed the weak/satellite spectral lines as well. My observations for the weaker 1,612 MHz spectral line for Masers OH808–19 and OH2606+06 are found at these two links for your exploration: *gb.nrao.edu/20m/peak/OH808-19/Skynet_57499_OH808-19_19305_20196.htm and www.gb.nrao.edu/20m/peak/OH2605+06/Skynet_57273_OH2605+06_15315_16234.htm.*

An observation of W49 by another person for a Doppler-shifted 1,720 MHz spectral line (and the 1,665/1,667 MHz lines) is at *gb.nrao.edu/20m/peak/W49-023/Skynet_57574_W49-023_22171_22226.htm.* →

One can also view a large assortment of Skynet's publicly available 20-meter radio observations at *gb.nrao.edu/20m*. Click the "Log of 20m results" link. See the chronological log of observations and the hyperlinks in each observation for continuum and spectra data, data file descriptions, ASCII files, and other process data views shown for the observation. Also search for observations by Frank Ghigo (Observer fghigo_2839), one of the scientists at the Green Bank Observatory. He, too, has several observations of W3.

When making your maser observations, don't forget to check your target's size against the right ascension and declination of the raster scan. There is a lot of H I in every celestial direction. The intragalactic dust and gas are especially concentrated in the galactic plane. This is "comparable" to light pollution in optical observing. In radio observing, it can make you think you are observing your target although you are actually observing dust and H I. Additionally, chart intensities must be put in the context of frequencies received, as well as the instrument's noise and telescope's system temperature at the time of observation.

FURTHER LEARNING

Alan Cook's book *Celestial Masers* (1977; Cambridge University Press) is the best, in my opinion, for astronomical masers. It has many charts that are helpful for planning targets of observations. In this publication, Professor Cook presented a radio map of W3, which I used as the basis for my own observational radio map. If you purchase the book, note that the coordinates of the maser have shifted slightly, as one would expect over many decades. This change is almost entirely due to the precession of equinoxes. W.G. Laidlaw's *Introduction to Quantum Concepts in Spectroscopy* (1980; Robert E. Krieger Publishing Co.) is excellent for a more thorough overview in quantum chemistry. It was the basis for a 1981 Atomic and Molecular Dynamics course I took at Rensselaer Polytechnic Institute while pursuing my chemical engineering degree. It's a 240-page book that I still use for reference.

Finally, have a look at two good maser websites. Maserdb *(maserdb.net/search.pl)* provides many maser properties including flux density, velocity, and spectral data. The Maser Monitoring Organization *(masermonitoring.com)* is also a good informative website. ✶

A Rainy Night With Professor Arp

In *Reflector* vol. 74, no. 1, p. 4–5, Boris Starosta suggests that H. C. (Chip) Arp was "typically limited to smaller telescopes" in looking for evidence for non-cosmological redshifts. This isn't necessarily bad: searching for large-scale things requires adequate fields of view (Shapley used to say that Hubble missed recognizing clusters of galaxies because his telescopes were too big). It also isn't entirely true. How do I know?

I was there.

Dateline: Palomar Mountain Observatory, December 1966.

It was the last evening of a three-night run. I was the observer assigned to the 48-inch Schmidt telescope (no, not the first woman to receive allocated time at Palomar, that was Vera Rubin; I was only the second, and, as is probably well known, Margaret Burbidge had made excellent use of time assigned to her husband, Geoff, who often took charge of cutting plates and developing them). My task was to attempt to calibrate fluxes coming from the Crab Nebula in various emission lines. The 200-inch observer was Arp, wanting to image at high angular resolution some of the (often peculiar) galaxies that he thought had higher-redshift objects associated with them. But by sunset, rain was pouring down.

Early to bed? Well, no. You don't casually abandon observing time on the world's foremost telescopes. Rather, we sat over a fire in the lounge of the "monastery" (as the living quarters were known) discussing, of course, astronomy.

Arp already had a number of 200-inch images from earlier observing runs (and yes, he got more later). These were the sort of prints on paper from photographic plates, showing the sky white, stars as black dots, and various pieces of diffuse nebulae, galaxies, and so forth as wispy shades of gray. And, of course, we were hoping the clouds would clear.

Arp told me that he thought something very interesting was going on with these assemblages of nearby galaxies and more distant objects, but he wasn't quite sure what. What did I think? I thought, and said, that the patterns indeed looked interesting and that he should publish them, inviting his colleagues to provide interpretations, and go back to what he had been working on before.

Was the distinguished senior astronomer going to take the advice of a third-year (female at that) graduate student? No, of course not, though in later years I have occasionally wondered how the outcome, for astronomy, for his career, and all, would have been different if he had.

The story dribbles out here; my thesis advisor, not happy at the idea of my spending an entire rainy night with Chip Arp, drove up the mountain, arriving at midnight or thereabouts, and drove me back to Pasadena.

Material from the first two nights of that 48-inch Schmidt run and a couple of later ones eventually made their way into my PhD dissertation ("Motions and Structure of the Filamentary Envelope of the Crab Nebula"). Contrary to old stereotypes of women scientists, I did not marry my thesis advisor; Chip eventually married Marie-Helene Demoulin Ulrich and moved to the European Southern Observatory with her; and we all lived happily ever after, I guess. The ESO telescopes of the time were indeed smaller than the Palomar 200-inch, though their VLT is a current record-holder.

—Virginia Trimble

Professor of Physics and Astronomy, University of California, Irvine, past president of the Division of Galaxies and the Universe of the International Astronomical Union.

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• THE DREAM CONTINUES •

Development of the Mirror Material for the James Webb Space Telescope

James M. Marder

The James Webb Space Telescope is easily recognized in any photograph or drawing by the visual impact of the 18 gold-plated hexagons of its primary mirror. It is quite appropriate that the Webb Telescope is identified by its primary mirror since that is one of the key components that will allow it to do its intended work of vastly expanding our knowledge of the universe. I was privileged to play a part in developing O-30 beryllium, the material of which the mirrors are made. O-30 took years of extraordinary technological innovation to develop. I was project manager for optical material development programs at Brush Wellman, the company that produced the beryllium components used in the James Webb.

Designing any high-performance structure demands attention to an incredible number of seemingly minor details. In aircraft and other manufactured objects that are not supported by the ground, there is typically a balance between operational performance and weight. I have heard that jet engine designers are willing to sell their mothers for an idea taking a pound out of a part on the drawing board. That's probably an exaggeration, but not much of one. A few earthbound applications, such as wind turbine blades, generate similar priorities. In spacecraft, saving ounces or grams drives an even greater level of innovative urgency.

However, the Hubble Space Telescope provided an example of how a seemingly insignificant oversight could jeopardize a multi-billion dollar, multi-decade, high public profile project. A 3-millimeter error in positioning the main mirror, probably caused by a thin washer left in place after ground testing but not part of the flight hardware, resulted in disappointing images, NASA embarrassment, and million-dollar missions to correct the problem. The crucial role to be played by the Webb mirrors led to an enormous effort to assure that there would be no last-minute surprises. New technologies undergo proof of concept testing, laboratory performance verification, sub-size component testing, and full-sized component testing, followed by detailed analyses and overall program review to assure that they fit in with the rest of the vehicle to complete the mission. The years of testing and analysis it takes to qualify a mirror is aimed at making certain that best balance of weight and optical performance is achieved and that nothing that can be foreseen is overlooked. This has to be done with many critical eyes watching because no one wants a repeat of the effects of some "inconsequential" detail. Selecting a material for any satellite component is not done lightly. Working with NASA, Perkin-Elmer, Hughes Aircraft, and other contractors involved in developing and producing the optics for the Webb Telescope drove home the idea that small differences can make big differences in spacecraft performance.

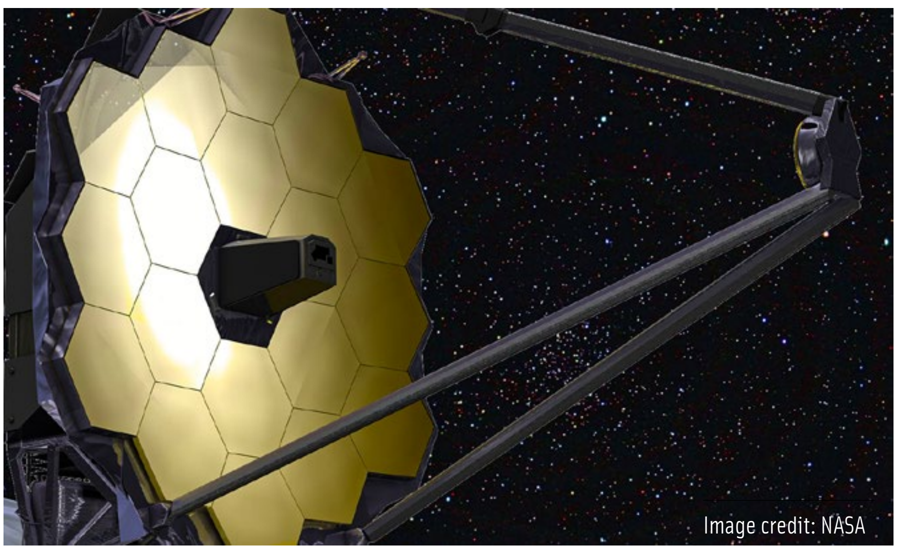


Image credit: NASA

The Webb reflectors are actually made of gold. It is easy to polish, very efficient at reflecting infrared light, and is easily cooled to cryogenic operating temperatures because of its very high thermal conductivity. There are a few drawbacks to using gold in satellites. The first, of course, is weight: gold objects are heavy. The second is that it is weak and flexible rather than strong and stiff. Low density, high strength, and high stiffness are primary measures of the efficiency of any aerospace structure. Gold is remarkably poor in these three categories. Cost is another issue, and gold fails in that respect as well.

Optical designers have found a way to use gold without having to deal with its shortcomings. A base material of high strength and stiffness, the substrate, is shaped to the right geometry and polished. A very thin coating of gold, 1,000 angstroms thick, is used for the Webb, and its total weight over the entire 25 square meters of mirrors is 48.25 grams, about a tenth of a pound. Because the gold comprises such a thin layer, the surface features of the underlying material "print through" the coating. The quality of the surface under the gold coating determines the perfection and accuracy of the reflective layer.

Two materials are the most common candidates for large infrared mirrors: glass and beryllium. Glass has been used as a mirror for centuries, and for space mirrors since satellites were first launched. Beryllium is a relative newcomer and has only been proven in a small number of relatively recent orbiting observatories. Other aerospace materials, including aluminum, titanium, and magnesium, have been considered. Aluminum and titanium are too heavy. Magnesium is light but it has very poor stiffness and thermal conductivity. Ultra-low expansion (ULE) glass is used in the Hubble and many other satellites. Beryllium was first used in the Infrared Astronomical Satellite (IRAS) launched in 1983 and is currently the reflector in the Spitzer Space Telescope.

Had the Webb primary been designed using ULE glass, it would have been too heavy to be launched by any vehicle. An obvious strategy for weight reduction is to use a low-density material, remembering that it must also have all of the characteristics of a high-precision optical reflector. This is where material performance and weight trade studies begin. ULE glass has a density of 2.21 grams per cubic centimeter (g/cc). The density of O-30 beryllium is 1.85 g/cc. A beryllium mirror will weigh only about 85 percent as much as a glass mirror made using an identical blueprint. Even greater weight reductions were made possible by using beryllium's advantage in strength and stiffness. My job was to understand what the optics experts and the structural designers needed, translate that into changes in the way beryllium was used for mirrors, and help coordinate the work being done by experts all over the country. Since most of the development was done before the internet, even before conference calls were common, I plied the airways from Cleveland and Elmore, Ohio, where the beryllium billets were made, to the satellite designers at Hughes Aircraft in El Segundo, California, Perkin-Elmer in Danbury, Connecticut, Tinsley Labs in Richmond, California, where the final polishing would be done, and Speedring Systems in Cullman, Alabama, where the beryllium blocks would be machined into shape before they were polished. Development came in spurts.

The Webb Telescope's optics are designed to gather and focus light with wavelengths in the range of 0.6 to 28.5 microns, the near infrared. Infrared noise, consisting of heat from the telescope itself, has to be minimized and eliminated if possible. That is why the mirror is cooled to –200°C (–327°F). Without cooling, the telescope would have as much chance of seeing extraterrestrial objects as you would of seeing the light from a birthday candle that was 10 miles away while a 500-watt light bulb was shining into your eyes from 10 feet away. Cooling a satellite and its supporting structure does not sound complicated, but it is. As the temperature of most materials is reduced, they shrink, and as temperature is raised, they expand. This is not usually important in everyday life. However, large temperature changes in structures that require dimensional precision cannot be ignored. As an example, SR-71 Blackbirds were notorious for leaking fuel when they were on the ground. The leaks came from the seams of the fuel tank halves that were not tightly closed. However, at the high temperature generated by Mach 3+ flying, the tank halves expanded towards each other and became tightly joined. Had the seams been tight when the Blackbirds were on the ground, thermal expansion would have caused the tank halves to push against each other, buckle, and then leak. The Lockheed designers, and probably the flight crews, preferred fuel leaks before and after a mission rather than during one.

Since it is hard to convince the people who polish mirrors to work at –200°C, cryogenic telescope mirrors are shaped and polished at room temperature. Grinding produces the shape, the figure, that focuses the light. After grinding, the mirror is polished with fine abrasives to produce its smooth reflective surface. Designers reduce the thermal expansion related errors in the figure by grinding an incorrect figure at room temperature that becomes correct at the operating temperature. This is called "null figuring." The smaller the coefficient of thermal expansion (CTE), the value that shows the change in length for a 1°C change in temperature, the easier it is to get the proper room temperature figure.

ULE glass has the lowest CTE, 0.031 ppm/°C, and is the best in keeping its shape as it cools. That isn't surprising, since ultra-low expansion glass was developed and named for precisely that characteristic. The value for beryllium is 11.7 ppm/°C, greater than that of ULE glass but about half the value of most metals. ULE glass is better from this standpoint, but cooling has another facet: thermal conductivity. This is the property that governs the temperature uniformity of the mirror. A mirror operating with nonuniformities in temperature poses design problems that are probably unsolvable.

The entire mirror system must be uniform in temperature even though it is gathering and concentrating infrared radiation, which is heat. High thermal conductivity allows heat to flow between locations within the structure. The Hubble operates at 21°C. It was not primarily designed for infrared observation, although it does carry an infrared camera. Maintaining that temperature is not a simple task in space, but it does not require the effort needed by the Webb operating at –200°C. The thermal conductivity of beryllium is about 200 times that of ULE glass, and left ULE far behind in the competition to be the Webb mirror.

These are just a few of the issues involved in the selection of the material for an infrared space telescope mirror. Among the other factors are the stiffness and ability to be polished. Beryllium is equal to ULE glass in its ability to take a polish, and far superior to any material in its specific stiffness. The stiffness of a material is its elastic modulus – how much it grows when it is pulled in tension. The specific stiffness is the ratio of its elastic modulus to it density, showing its growth under its own weight. Specific stiffness is important because it governs performance characteristics such as gravity release, the change in shape when the mirror goes from Earth's gravitational field to weightlessness in space. The specific stiffness of beryllium exceeds that of any metal by a factor of 6. In addition, the Webb mirror segments have their shape adjusted by mechanical actuators to get the most refined image possible. These adjustments are on the order of millionths of a meter. The greater the stiffness, the more precise the control over the adjustment can be.

The message is that there are more factors that go into a design than you can imagine until you are faced with actually designing a high-precision system. The studies done for the Webb gave the go-ahead for beryllium as the optimum mirror substrate. It is not the best in all of its characteristics, but when all factors are accounted for, it has the best combination of properties.

Having made the decision that beryllium is the right choice, the question became, "How do we make it better?" The IRAS was successful, but figuring and polishing revealed shortfalls that could be addressed. That was the state of beryllium mirror technology when

I arrived at Brush Wellman, and meeting the challenges highlighted by IRAS was perhaps the most satisfying aspect of my career. The innovations in beryllium technology directed specifically toward space-based mirrors over a period of approximately 15 years culminated in the development of grade O-30. The O stands for optical, and 30 refers to the maximum beryllium oxide content allowed, 0.3 percent. As a materials scientist by training, I had to be schooled by the experts in optics, structures, and the technical idiosyncrasies of beryllium itself in order to define and produce the characteristics that would make the best mirror. O-30 was the result of a technical collaboration between Brush Wellman, the Air Force Manufacturing Technology Division at Wright-Patterson Air Force Base, and all of the supporting expertise that could be brought to bear by the aerospace community.

Beryllium ore is mined and refined in Utah, then converted into metal in Elmore, Ohio. In the conventional process used since the 1940s, it is cast to produce an ingot, similar to any other metal. Cast ingots of beryllium do not have very good strength (among several other drawbacks) so they are ground into particles of powder which are then compacted into solid blocks called billets. The compaction method used for the powder was vacuum hot pressing. The powder is poured into a press, similar to a cider press used for apples, heated to a temperature in excess of 1,000°C and pressed to become a solid. The equipment is enclosed in a vacuum chamber to prevent oxidation. As with most powder metallurgy products, the typical pressing has a very small proportion of voids remaining between particles. The size of the voids is on the order of a few microns. This is unimportant for most applications. In a mirror, however, grinding and polishing will intersect the voids and leave them as imperfections in the surface. Imperfections scatter light instead of focusing it, reducing the image quality. The void-sealing technique we developed for beryllium was a variation on a process used to seal pores in cast jet engine turbine blades and to achieve superior properties in other metal powder products.

Hot isostatic pressing (HIP) can completely eliminate voids. The powder is placed into a steel container that is sealed after all of the air is removed by vacuum pumps. The container is placed into a chamber that is filled with argon and pressurized between 15,000 and 30,000 pounds per square inch and heated to a typical temperature of 900–1,200°C. The heat and pressure compress the powder into a solid billet. The tremendous force and energy of HIP may be understood from the failure of a HIP unit in Andover, Massachusetts: the hot, pressurized argon threw the 4,000-pound lid of the pressure chamber a quarter of a mile, and the blast was heard 25 miles away. It happened at 1 o'clock in the morning, and fortunately no one was injured. The HIP unit was filled with turbine blades that were scattered over the eastern Massachusetts countryside.

Hot Isostatic Pressing was developed in the 1940s by Battelle Memorial Laboratories in Columbus, Ohio. In 1981, as part of a government-sponsored mirror development program, engineers at Battelle tried to HIP beryllium powder. I witnessed their process as an invited guest. They were unsuccessful; there was still porosity after HIP. I combined my experience at Pratt with what I learned about beryllium at Brush Wellman, and I knew what had gone wrong. They were not completely evacuating the steel container before it was sealed. Water vapor bonded to the powder surfaces decomposed at high temperature. The freed oxygen formed beryllium oxide and the hydrogen formed bubbles. I did a trial in my Cleveland lab, heating the canister to a few hundred degrees Celsius and taking extra care in the evacuation step. We were stunned by success on the first try. We had taken the first step, an important one, on the path to making the Webb mirrors as good as they needed to be.

The second area that IRAS highlighted for improvement concerned the inadvertent alignment of the beryllium powder particles, producing nonuniform properties. All metals except mercury are composed of microscopic crystals; iron, copper, aluminum, and all the others are crystalline. Crystalline means that each atom has a place in a simple pattern which is repeated millions of times in all directions, not that they are transparent. Beryllium crystals have the hexagonal close packed arrangement, with slightly different properties in different directions within the crystal. The elastic modulus, thermal conductivity, and thermal expansion values previously cited are averaged values and good enough for most applications. Conventionally ground beryllium powder particles are relatively flat flakes whose faces have the same crystal orientation. The particles behave like crackers in a box with the flat faces packing on top of one another. When the flat faces of many powder particles stack up to produce large regions with similar properties, adjacent regions with somewhat different orientations behave slightly differently. The differences in thermal expansion between two particle stacks can result in surface rumpling during cooling. To truly randomize the properties, spherical powder particles are needed. Spheres do not have flat surfaces that correspond to crystal directions so they cannot form large areas with a common orientation, making the mirror more uniform.

Spherical particles are produced by gas atomization, similar to a perfume atomizer. Instead of liquid perfume, powder atomization starts with molten beryllium in a vacuum chamber. The metal is poured into a tundish, essentially a ceramic kettle, and drops through a nozzle to form a stream of liquid. Jets of high-velocity, high-purity argon break the stream into fine particles. Surface tension pulls the droplets into spheres and the high-purity gas prevents oxidation. An atomizer was constructed at the Brush Wellman Elmore plant as part of an Air Force Manufacturing Technology program. This powder not only randomized crystal orientation, it also reduced the beryllium oxide content.

At the Brush Wellman production facility in Elmore, we solved the kind of problems that always arise with a new process. One of these was as simple as metal freezing the nozzle rather than flowing through it. We solved that by pre-heating the nozzle, wrapping it with an electrical resistance heater made from wire similar to what is used in an electric toaster. Changes have been made to make nozzle heating more efficient and increase the quantity of powder produced in each atomization run, but the concept was proven as part of the earliest development of beryllium atomization. Trial billets of atomized and HIPed beryllium powder were sent out for optical processing and evaluation using the expertise of Perkin-Elmer and Tinsley Laboratories. It performed exactly as we had hoped. We had an unequalled beryllium mirror material in hand.

Those are the changes used to produce beryllium ideally suited for space-borne observatories. The James Webb Space Telescope is the benefactor of long-term development programs and the experience gained with other satellites. Most of us take for granted details such as the mirror material. Even with my experience, I take the details of the other, equally vital systems for granted. What is not said often enough is that any successful technical project, such as the Webb, is the result of the innovative work and cooperation of many individuals and organizations. Relatively anonymous engineers and scientists working in the background for many years provide the backbone of projects such as the JWST. My involvement was exhausting and fulfilling and it was a privilege to be part of that group.

As of March 2022, the telescope and the NASA control team are batting 1.000 so far. As an individual watching this so-far perfect performance, I am enormously pleased that we will soon be talking about JWST's observations and their implications for humanity's understanding of our huge neighborhood. Being part of this exciting undertaking has filled me with pride and with gratitude for everyone who worked to make the mirrors and the entire project a success. As an engineer, I cannot be complacent about success. I would advise the NASA operators to be careful not to forget any small detail until the mission is complete. That's my mirror, take good care of it! ✶

REFERENCES

1. Gossett, E.W., Jr., J. Marder, R. Kendrick and O. Cross, "Evaluation of Hot Isostatic Beryllium for Low Scatter Cryogenic Optics," Proc. SPIE 1118, Space Optical Materials and Space Qualification of Optics (1989), 50.

2. Gildner, D.A, and J.M. Marder, "Creation of Aspheric Beryllium Optical Surfaces Directly in the Hot Isostatic Pressing Consolidation Process," Proc. SPIE 1485, Reflective and Refractive Optical Materials for Earth and Space Applications (1991).

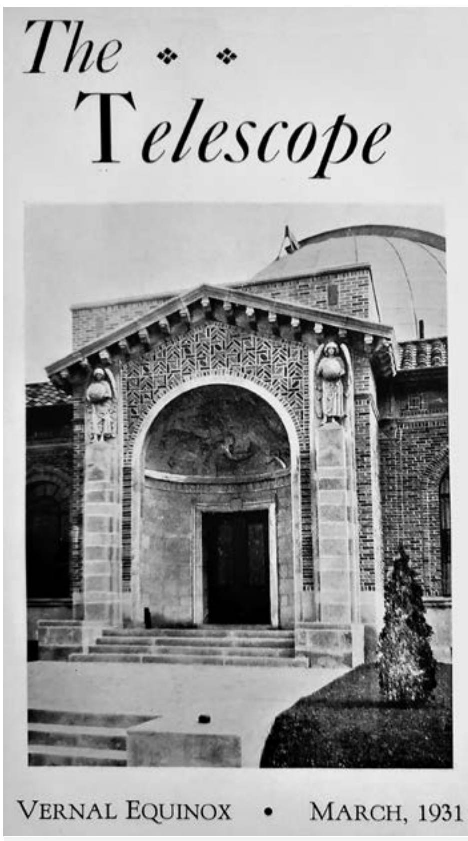
3. Hashiguchi, D. and J. M. Marder, "Spherical Beryllium Powder," WL-TR-91-8017, Wright Laboratory, Air Force Systems Command, Wright Patterson AFB, OH, 45433 (Oct. 1991).

Dr. Marder retired as the director of operations, k-Technology Division of Thermacore, Inc., a company that designs and fabricates thermal management systems for spacecraft such as the Perseverance Rover. He previously held the position of director of technology, Beryllium Products, Brush Wellman, Inc. (now Materion). He has published over 50 technical articles and is named as the inventor on ten U.S. patents. Dr. Marder received a BS degree in metallurgical engineering from the Polytechnic Institute of Brooklyn (now New York University Tandon School of Engineering), an MS in metallurgy from the University of Connecticut, and a PhD in materials science from Case Western Reserve University, where he is an adjunct faculty member.

Connecting with Astronomy Through Its Amazing Literature

By John W. Briggs

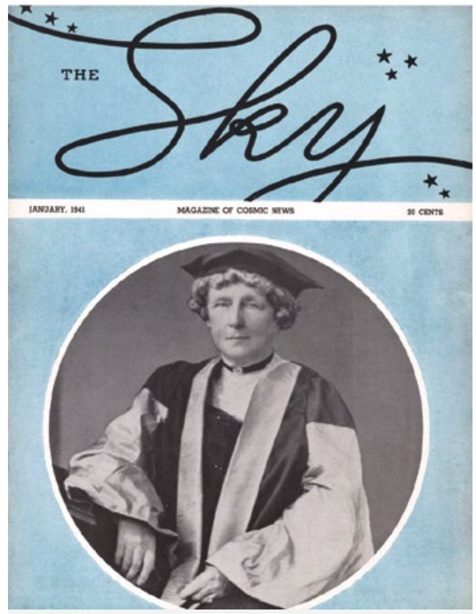
Explaining and sharing the wonder of the deep sky that inspires so many of us in astronomy is harder than it was decades ago. This is because, given light pollution, the beauty of the sky is not so obvious to most people now. In a somewhat analogous situation, I fear that fewer people currently have a chance to encounter the vast and amazing literature of our astronomical forebears. This is because astronomical libraries are expensive to house and maintain, both at colleges and universities and especially at historic research observatories and other institutions, many of which are having to redefine themselves to survive.



Even the most long-time readers of *Sky & Telescope* are unlikely to have ever seen this especially rare issue of *The Telescope* — the very first one published in March 1931, at Perkins Observatory in Ohio. The magazine evolved into a second series that merged with *The Sky* to create *Sky & Telescope* starting in November 1941.

It's a fact, however, that retracing the key progress of astronomy through its original literature can be darn near as *wondrous* as a fabulous observing session under a dark sky. How can that be? Well, if you can, imagine a figure in the history of astronomy who seems especially heroic to you. Depending on your experience, the individual could be any of a vast number of people. I like to think of astronomers like Hale or Barnard, or instrument makers like Clark and Brashear. We can't directly *know* historic figures. Most of the time, we can merely read *about* them. But the possibility remains to read their own words – their explorations, explanations, and, especially in a case like Hale's, even their *aspirations.* Further, we can read their errors and misunderstandings. The progress of science has been a very human enterprise and often a matter of blood, sweat, and tears. These details can be extremely interesting and humbling, and they are not always well conveyed in, say, a typical homework problem! Many students of science must thus be reminded of the humanity of their subject.

I had a lucky break discovering *Sky & Telescope* magazine as a young teenager. Another break came a little later, when I discovered a complete bound set of *Sky & Telescope's* predecessor, *Popular Astronomy,* in the basement of a college observatory. This journal was published in 59 volumes between 1893 and 1951 by Goodsell Observatory of Carleton College. Skimming though those old books proved amazing! There were papers by people like Barnard and his peers, often beautifully illustrated. The volume and breadth of the information, and of the effort and the scientific



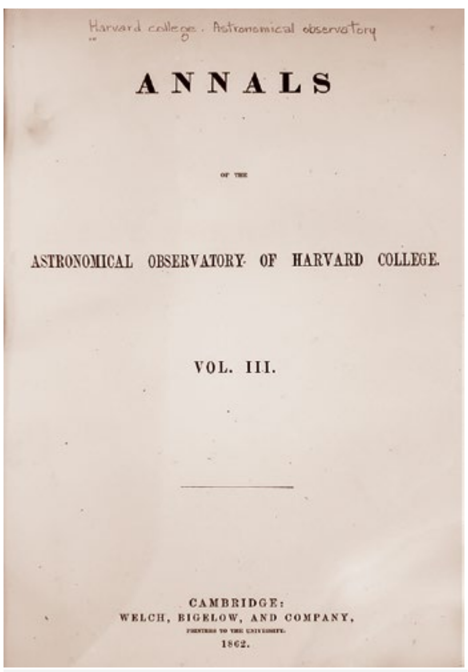
An early issue of *The Sky* magazine featured pioneering American stellar spectroscopist Annie J. Cannon on the cover. *Sky & Telescope* resulted from the merger of *The Sky* and *The Telescope* to become among the most familiar journals of astronomy in the United States.

community it all represented, were irresistibly engaging to me. I found topics of great interest, serendipitously, volume by volume. I could never have engaged so well with the material using online files and scans. There is something about having an actual, printed, original *volume* in your hand. The material is as the author themselves had known it and prepared it. Experiencing the material, physically – as originally printed – strengthens a connection between you as reader and your forebear.

In older times, it was, in fact, quite common for leading observatories to publish their own journals. A major activity at many observatories was thus editorial work. The accumulated result, even just in the English language, is vast and is like a Milky Way of astronomical literature. For example, starting in 1856, there began a very long series, *Annals of the Astronomical Observatory of Harvard*

One collection of historical literature is housed at the Astronomical Lyceum in Magdalena, New Mexico. Its most unusual elements came from the closed Sproul Observatory of Swarthmore College.

College. It was here that pioneering works of stellar photometry, photography, and spectroscopy were published, including by authors like Annie J. Cannon, so famous for her massive effort in stellar spectral classification, and by



Harvard college. Astronomical observatory

ANNALS

OF THE

ASTRONOMICAL OBSERVATORY OF HARVARD COLLEGE.

VOL. III.

CAMBRIDGE:
WELCH, BIGELOW, AND COMPANY,
PRINTERS TO THE UNIVERSITY.
1862.

The *Annals of the Observatory of Harvard College* was a very famous and important journal in the 19th and early 20th centuries, but few students of astronomy are familiar with it or its allied publications today. This leading page is for volume III published in 1862, a volume that was dedicated entirely to the great Comet Donati of 1858.

many other authors familiar to us. But also, there is some of the most beautiful published astronomical *delineation* – astronomical illustration from before the advent of detailed astronomical photography. The records are as much amazing works of art as they are of science.

I was lucky to have an astronomical mentor, Dorrit Hoffleit, who showed me the Harvard *Annals* just after I graduated from high school in 1977. At the same time I started learning about other publications like them. By no means did I become an expert in such things, nor am I to this day! But it was immediately inspiring to at least learn they existed and to begin building a curiosity, including for examples that were more obscure.

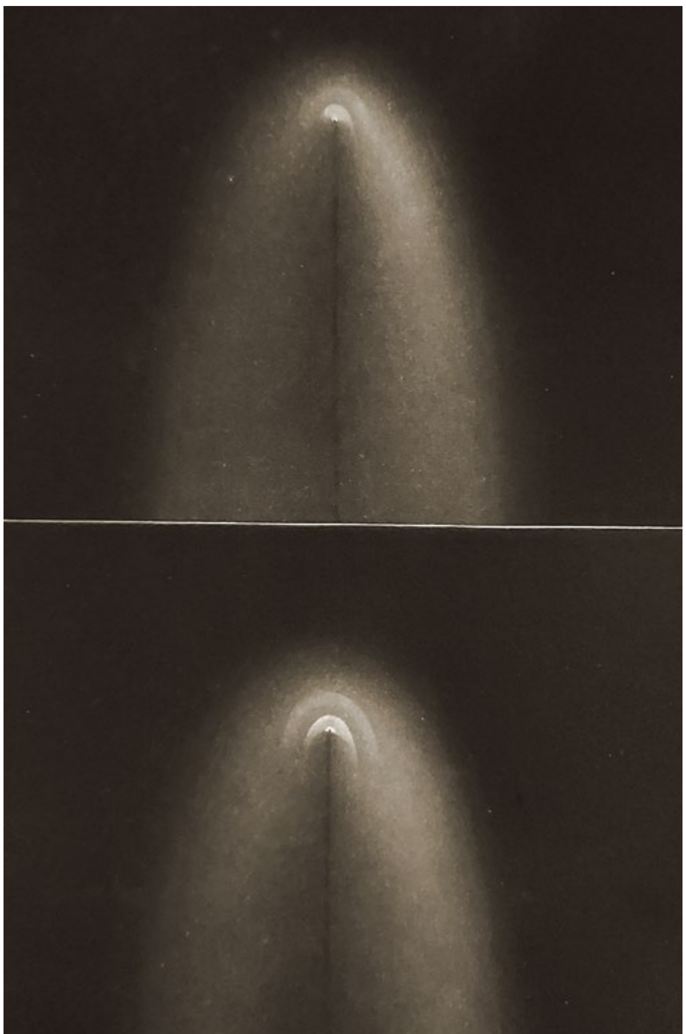
Returning to the thought of deep-sky objects, most of us understand that to appreciate the fainter targets, it's as much an exercise of the mind as it is of visual perception. A few months ago, for example, I got a view of the famous galaxy cluster, Stephan's Quintet, in Pegasus. I hadn't seen it in quite a few years. And although the view through James Totoritis's new 40-inch f/3.5 reflector in Pie Town, New Mexico, was surely the best of my life, the marvelous wonder of the experience was based not just on the view, but also on the knowledge – as we can now nearly take for granted – that most of the galaxies seen in the group are about 250 million light-years away. It was necessary to try to imagine that fact to glean a full impact from the experience.

Like viewing the deep sky, to fully appreciate things we experience in the astronomical literature can require some thoughtful contemplation. But that's at the core of the fun!

Consider a modest three-page paper that, like the *Annals,* was published by Harvard College Observatory, but in this case, in *another* long-running set of volumes, arguably more obscure ones, entitled the *Circulars.* The *Circulars* were relatively brief papers, and it seems clear that the goal was rapid dissemination of new results and observations. They were bound together into volumes, and we are lucky to have a full set of them at a facility we call the Astronomical Lyceum in New Mexico. The volume containing *Circulars* 151 to 200 was published in 1917. *Circular 173* was issued on March 3, 1912, and it's titled *Periods of 25 Variable Stars in the Small Magellanic Cloud.* The title is not unusual for material typical of the *Circulars.* A reader could thus easily overlook it and its modest three pages. To most people it would appear unappealingly arcane. Who would know that these three pages, written by a 44-year-old woman, readable by anyone, first revealed a key observation that unlocked a huge step outward in observational cosmology, enabling humanity to set the scale of the Universe around us? The three-page paper, in fact, lucidly describes Henrietta Swan Leavitt's discovery of the period–luminosity relationship of Cepheid variable stars, to this day a critical rung in our cosmic distance ladder.

The paper begins, "The following statement regarding the periods of 25 variable stars in the Small Magellanic Cloud has been prepared by Miss Leavitt." In 1912, it was common and normal for most results from observatories to be reported by observatory directors. Thus the article concludes with the signature, "Edward C. Pickering." But from the first sentence, there is no question that the story and the results were Miss Leavitt's. In fact, they were developed from her greater and more fundamental effort cataloging 1,777 variables published in an earlier volume of the *Annals*. It's a moving experience to carefully read through the short report, following the logic and explanation of the author, and studying her graphics. There is no question that she and her director fully understood the significance of the discovery.

She wrote, "A remarkable relation between the brightness of these variables and the length of their periods will be noticed." The relationship was suggested in the work leading to the earlier catalogue of 1,777 stars, but as Leavitt explains, "at that time it was felt that the number was too small to warrant the drawing of general conclusions." A key statement is, "Since the variables are probably at nearly the same distance from the Earth, their periods are apparently associated with their actual emission of light, as determined by their mass, density, and surface brightness." Leavitt continues, "It is to be hoped, also, that the parallaxes [distances] of some variables of this type may be measured." The first effort in that direction was indeed undertaken soon, by the famous Danish astronomer, Ejnar Hertzsprung, in a step toward calibration of the relationship, refinements of which continue to this day. Leavitt looked forward, writing, "The facts known with regard to these 25 variables suggest many other questions with regard to distribution, relations to star clusters and nebulae, differences in the forms of the light curves, and the extreme range of the length of the periods. It is hoped that a systematic study of the light changes of all the variables, nearly two thousand in number, in the Magellanic Clouds may soon be undertaken at this Observatory."



Historical literature is often illustrated in a remarkable fashion for its time, as in this one of many delineations of hood structure in Comet Donati by George P. Bond in volume III of the Harvard *Annals*.

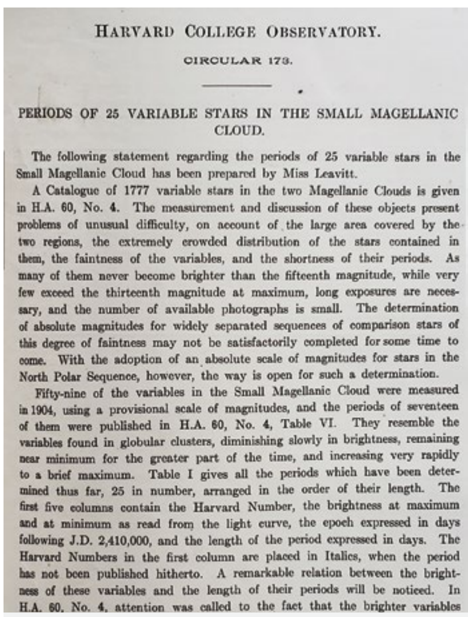
The great Mount Wilson astronomer Walter Baade reviewed the period-luminosity relation of the Cepheids in 1956, writing in *Publications of the Astronomical Society of the Pacific* (yet another journal of great interest in our collective literature), describing its "far-reaching influence on the further development of astronomy" and the many more involved considerations that followed. J. D. Fernie of the David Dunlap Observatory wrote a later historical review of the relation, again in *PASP,* in 1969. He began drolly, "In some ways astronomers are like small children. The high adventure, the furor and excitement they create among themselves is not greatly cared about or understood outside, at least in any immediate way." Fernie went on to describe the complex efforts to properly calibrate and apply the relation by leading astronomers through the 20th century. The details quickly became the realm of specialists, but given the recognition of occasional major errors and their eventual resolution, it's interesting to follow the historical review as best as a non-specialist can, however convoluted the progress became.

The Astronomical Lyceum in Magdalena, New Mexico, started as a collection of instrumentation and related artifacts. But the library has grown to become equally interesting. The brown volumes behind the famous 16-inch Dilworth Relay Telescope are among the most prized, the *Contributions from the Mount Wilson Solar Observatory.*

Fernie makes it entertaining, as he himself was entertained by earlier papers. "The definitive study of the herd instincts of astronomers

A fragile, oversized fold-out sheet from volume III of the Harvard Annals *demonstrates the challenge of conveying the contents of some historical literature by scans posted online. The remarkable sketches by George P. Bond show the changing near-nucleus structure of Donati's Great Comet of 1858.*

has yet to be written, but there are times when we resemble nothing so much as a herd of antelope, heads down in tight parallel formation, thundering with a firm determination in a particular direction across the plain. At a given signal from the leader we whirl about, and, with equally firm determination, thunder off in quite a different direction, still in quite parallel formation."



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 173.

PERIODS OF 25 VARIABLE STARS IN THE SMALL MAGELLANIC CLOUD.

The following statement regarding the periods of 25 variable stars in the Small Magellanic Cloud has been prepared by Miss Leavitt.

A Catalogue of 1777 variable stars in the two Magellanic Clouds is given in H.A. 60, No. 4. The measurement and discussion of these objects present problems of unusual difficulty, on account of the large area covered by the two regions, the extremely crowded distribution of the stars contained in them, the faintness of the variables, and the shortness of their periods. As many of them never become brighter than the fifteenth magnitude, while very few exceed the thirteenth magnitude at maximum, long exposures are necessary, and the number of available photographs is small. The determination of absolute magnitudes for widely separated sequences of comparison stars of this degree of faintness may not be satisfactorily completed for some time to come. With the adoption of an absolute scale of magnitudes for stars in the North Polar Sequence, however, the way is open for such a determination.

Fifty-nine of the variables in the Small Magellanic Cloud were measured in 1904, using a provisional scale of magnitudes, and the periods of seventeen of them were published in H.A. 60, No. 4, Table VI. They resemble the variables found in globular clusters, diminishing slowly in brightness, remaining near minimum for the greater part of the time, and increasing very rapidly to a brief maximum. Table I gives all the periods which have been determined thus far, 25 in number, arranged in the order of their length. The first five columns contain the Harvard Number, the brightness at maximum and at minimum as read from the light curve, the epoch expressed in days following J.D. 2,410,000, and the length of the period expressed in days. The Harvard Numbers in the first column are placed in Italics, when the period has not been published hitherto. A remarkable relation between the brightness of these variables and the length of their periods will be noticed. In H.A. 60, No. 4, attention was called to the fact that the brighter variables

The modest title page of *Harvard College Observatory Circular 173,* with the article's short and concise text, does not convey that it represents, in 1912, one of greatest breakthroughs of observational astronomy – Henrietta Swan Leavitt's discovery of the Cepheid period-luminosity relationship.

Fernie also observed, "Nothing is as dead as yesterday's literature, however, and … facts [can be] long forgotten." Don't misunderstand: this was not a remark to disparage historical literature. It was just the opposite, an appeal for astronomers to remember it!

My short article here, highlighting one historical paper, however key the paper may have been, can no better do justice to the greater historical literature than a view of an open cluster can hint at the full grandeur of the Milky Way. Nevertheless, I do hope readers will consider tuning in to older journal runs, however they can find them; exploiting subject indices and exploring publications, however randomly initially, to discover their content and flavor. It might take a trip to a local college or university library. Much of the literature will prove nearly hopelessly specialized. But older volumes, even of Hale's *Astrophysical Journal,* are wonderfully readable, enlightening, and relevant to the interests of many modern astronomers, amateur and professional. Even with all the burden already upon students, it's important also that they have a chance to discover the older literature, including scientific biography. Many of them need our help, direction, and encouragement to do so, as our mentors encouraged many of us. ✶

REFERENCES:

Baade, W. (1956). "The Period–Luminosity Relation of the Cepheids." *Publications of the Astronomical Society of the Pacific. 68* (400): 5.

Fernie, J.D. (December 1969). "The Period–Luminosity Relation: A Historical Review." *Publications of the Astronomical Society of the Pacific. 81* (483): 707.

Leavitt, Henrietta S.; Pickering, Edward C. (1912). "Periods of 25 Variable Stars in the Small Magellanic Cloud." *Harvard College Observatory Circular. 173:* 1–3.

John W. Briggs serves on the board of the American Association of Variable Star Observers, headquartered in Cambridge, Massachusetts, and recently became the first secretary of the new Alliance of Historic Observatories. He is curator of the Astronomical Lyceum, in Magdalena, New Mexico, and a member of the Springfield Telescope Makers.

THE "FERRET OF COMETS"

THE LIFE OF CHARLES MESSIER

By Larry McHenry

Charles Joseph Messier was born on June 26, 1730, in the small village of Badonviller, located in the Lorraine region of France. Charles was the tenth of twelve children born to his father Nicolas and mother Françoise. Nicolas was a court usher for the state princes, which allowed his family to enjoy a comfortable lifestyle in a large home. Still, six of Charles' siblings died while he was young, and Charles also had a close call when, as a child, he fell out of an upper story window and broke his leg. In 1741, his father Nicolas died. Due to the family's financial constraints, Charles had to leave formal school, and finished his education at home.

While a teenager, Charles developed an interest in astronomy by the appearance of the six-tailed Comet of 1744, and a few years later, in 1748, an annular solar eclipse that was visible from his hometown. From this spark, Charles began observing the stars.

Charles Messier, painting by Ansiaux, public domain

In 1751, at the age of 21, Charles left home to look for work in Paris. With help from a family friend, Charles was able to get an interview with Joseph Delisle, the official astronomer of the French Navy. Delisle found Charles' fine handwriting and drawing skills particularly useful and hired him as an assistant at the Royal Navy observatory located on top of the Hôtel de Cluny in Paris. Messier's job was to keep careful records of Delisle's observations and copy maps and charts for use at the observatory. He was also instructed in using its various telescope instruments. Delisle took it upon himself to teach Charles elementary astronomy and precise record keeping and position measuring. Messier excelled at the work he was given, and in 1754, was promoted to a clerk of the Depot of the Navy.

The Hôtel de Cluny "observatory" was originally a medieval townhouse built in 1334. On the roof of the house's tower was built a pyramidal wooden structure with large side windows. Inside were kept the portable observatory telescopes that could be positioned to point out of whichever window the observer preferred. The concept of interchangeable telescope eyepieces was not yet common in Messier's time; most of the telescopes that he used were small objective refractors with a fixed eyepiece and magnification. For the majority of his observing, Messier preferred to use a small 100 mm (4-inch) refractor. Today's modern small refractor or reflector will therefore easily outperform the best of Messier's telescopes.

Charles Messier's first documented astronomical observation was that of the transit of the planet Mercury visible from Paris in May 1753. Delisle was impressed by Messier's skill at recording the transit, along with Messier's knowledge of the observatory and its equipment. In 1757, Delisle decided to assign Messier the task of searching for the first predicted return of Halley's Comet. On the night of January 21, 1759, Messier swept up the faint glow of Halley's Comet, and became one of the first to recover the famous comet. Messier went on to make a successful observation of the 1761 transit of Venus, after which Delisle retired and Messier was placed in charge of the observatory where he could now dedicate himself to what Charles thought was his life's purpose, hunting for comets!

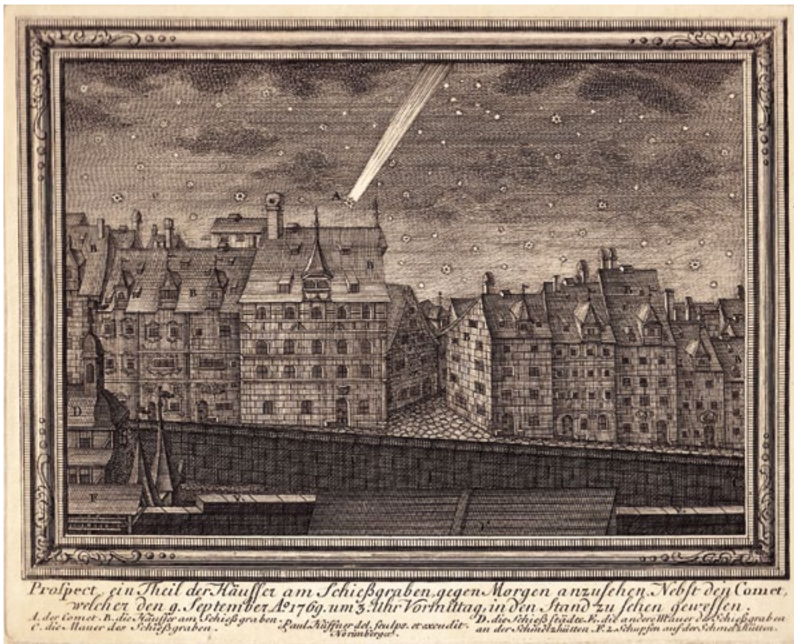
Before long, in late 1763 and January 1764, Charles discovered his first two comets using the observatory's telescopes. He followed that up in 1766 by discovering a naked-eye comet that had been missed by other observers. But it was during his dark-of-the-moon comet hunting that Messier began noticing a recurring problem, false comets!

During his night sweeps, Charles kept finding faint dim objects that somewhat resembled comets. He would take the time to record their positions and watch for movement over several hours, sometimes for even most of an entire evening, only to finally realize he was wasting his time. The objects weren't comets but were dim nebulae or faint clusters of stars. In May 1764, Messier resolved to keep a list of these objects as he found them so that during future comet sweeps he could easily disregard them as not being comets. Charles decided to start making his list by re-surveying the 16 nebulae already known from antiquity. These included the ancient hazy clouds that we know today as the Andromeda Galaxy, Praesepe star cluster, and Orion Nebula.

Charles then expanded his research to more recently discovered objects by other astronomers over the last 150 years, such as Galileo, Lalande, Flamsteed, de Lacaille, and Bode, who had added additional "starry spots" such as the clusters in Scorpion's tail, in the middle of Auriga the charioteer, and the nebulous patches in Sagittarius the archer and Scutum the shield. Before the year was out, Messier had a put together an observed list of 40 objects, eighteen of which were newly discovered by him.

The first object in his list was the little nebula in Taurus that he had stumbled upon back in 1758 while searching for Halley's Comet. We know this object today as the supernova remnant M1, the Crab Nebula. The second object, M2, was a partly resolvable ball of stars in the constellation of Aquarius that we now know is a globular cluster. After several months, Messier, thinking he had finished his list of false comets to avoid, stumbled on a new one, M41, a faint cluster of stars in Canis Major, just below the bright star Sirius. In early 1769 Messier returned to his comet hunting sweeps and decided to write up his list of 41 "non-comet" objects, along with a description of what each one looked like and its position in the sky. But he decided to add a few more items to the list, including the already well-known Orion Nebula, Prasepe, and Pleiades to round the list off at 45.

But before he could publish the list, in August 1769, Charles discovered a new comet that became one of the great comets of the 18th century, developing a dazzling coma and a tail over 90 degrees long. Charles followed this up a year later in June 1770 with another extraordinary bright comet discovery that brought him worldwide recognition.



The Great Comet of 1769 as seen over Nurenberg. Engraving by Paul Küfner, Förderverein Kulturhistorisches Museum Nürnberg

It was at this point that the king of France, Louis XV, gave Messier the name "Ferret of Comets."

In 1771, Messier was finally able to publish the first edition of his *Catalog of Nebulae and Star Clusters* in the official journal of the French Academy. But soon after publishing his catalog, Messier found four more objects to add to the list. He soon added a fifth in 1772, two more in 1774, and another in 1777. Unfortunately, Charles didn't match his usual precision in recording some of the observations of these new objects, particularly M47 and 48, which led many future observers to mis-identify the objects.

Messier continued to find additional new objects, such that in early 1780, he published a new revised list of 68.

He then went on with help from fellow French astronomer and comet hunter Pierre Méchain to find another 32 faint "nebulae" by April 1781, bringing his list up to a new total of 100 false-comet objects. Right before Charles' new list of objects was to be published, Méchain sent in another three objects. Unfortunately, in his haste to get the new objects submitted in time to Messier, he ended up duplicating the second entry, M102, once again confusing future observers.

During this period, Charles Messier also discovered seven more comets in 1771, 1773, 1780, 1785, 1788, 1793, and 1798. Messier eventually discovered or co-discovered 21 comets and made observations of a total of 41 individual comets, including both new discoveries and previously returning comets. Of the 45 comets discovered between 1758 and 1801, Messier accounted for almost half the overall total.

During this time, Messier had planned on revising his 103-object catalog with additional searches. From an article in the *Connaissance des Temps* for 1801, Messier outlined plans to publish another updated version of his catalog, and that he had observed "still other" nebulous objects. But due to various distractions such as the injuries from an accident and the French Revolution, Charles never did move forward with his revisions.

Over the centuries, as missing documents and manuscripts from both Messier and Méchain have been found by astronomers and historians, the case was made to expand the list to 110 objects to include those that Messier was thought to have planned on including in his final revision. Today, most sources now include those last 7 objects, though there is still some doubt as to the actual identity of several, including M102, M108, and M109.

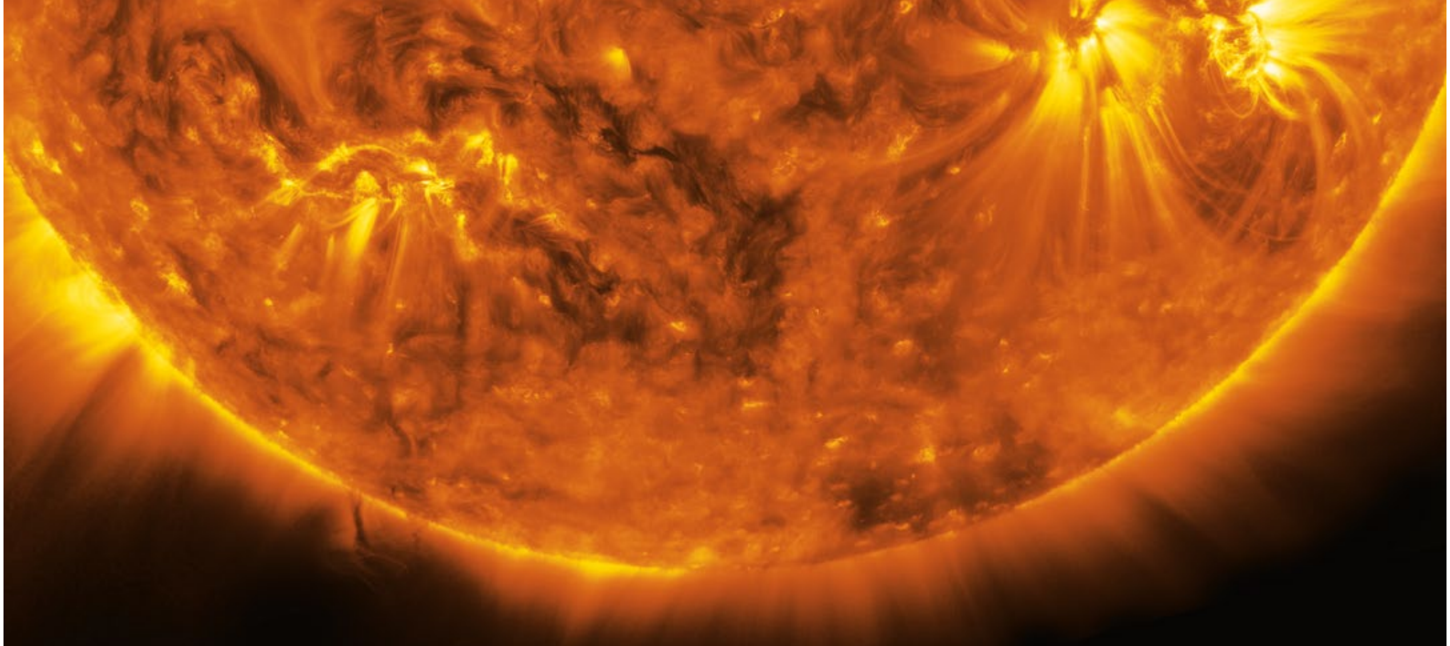
Though contested by some, M110 (satellite galaxy of M31) is generally considered to be the final object, for while Messier never listed it as an individual object, he did include it in his sketch of M31.

Messier himself had independently found 65 of the 110 objects. His friend and associate Pierre Méchain contributed 25 original discoveries. The remaining 20 objects came from prior earlier sources and observers. Of the 110 objects, today we know that 40 are galaxies, 29 globular clusters, 27 open star clusters, 6 diffuse nebulae, 4 planetary nebulae, 1 supernova remnant, and 3 miscellaneous objects: the star cloud M24, the double star M40, and the asterism of four stars M73.

Messier received many honors during his lifetime. In 1764, he was elected a fellow of the Royal Society of London (1764), a foreign member of both the Royal Swedish Academy of Sciences and the Berlin Academy of Sciences (1769), and to the French Academy of Sciences (1770). Messier suffered a stroke in 1815 that partly paralyzed him, then in the spring of 1817, at the age of 87, came down with a virus and, after a few days in bed, died on April 12.

Over the course of his lifetime Charles Messier discovered 21 new comets and is also credited with the first recovery observations of many previously found comets, including one of the first observations of Halley's Comet in 1759. But none of this is what Charles Messier is known for today. Instead, it is his list of fixed diffuse objects to avoid while comet hunting, his Catalog of Nebulae and Star Clusters, that today's modern amateur astronomers seek out, the bright showcase of some of the best galaxies, nebulae, and star clusters of the night sky. ✶

Larry McHenry's website is stellar-journeys.org



ENCOURAGING EYES ON THE SUN (SAFELY)

By Bob Anderson

I enjoyed Robert Berta's letter to the editor encouraging solar astrophotography in the December 2021 issue. I want to encourage visual observing as well. If you've seen warnings about not looking directly at the Sun with your eye, binoculars, or a telescope, believe them. Permanent damage can occur in an instant.

That said, there is a lot of fascinating observing that can be done, beginning with your naked eyes! I have enjoyed solar observing for over three decades. There is always something to see that wasn't there yesterday. I begin by checking the *spaceweather.com* website for news about sunspots, solar flares, and possible auroras. Next, I go outside and look at the sky, being careful to cover the Sun with my hand, a notepad, or even the edge of a building. I look for cloud and haze conditions and atmospheric phenomena, such as sundogs, pillars, and rings. If you have a pair of eclipse glasses from the 2017 eclipse, check them for pinholes or discoloration, and if none, you can use them to safely look at the Sun. Often, large sunspots can be seen with just this optical aid. Don't expect big dots; even the largest appear as tiny dots. Observing in the morning may give better views before the sunlight heats the atmosphere around you.

To directly view the Sun through a telescope, a solar filter specifically designed to cover the full aperture is needed. The Sun is far brighter than any other object in the sky, and some filters reduce the opening of the telescope (stop it down) to admit only the necessary amount of light. Small telescopes, two to four inches aperture, will show much detail. If your telescope came with a green filter marked "Sun" that screws on an eyepiece, throw it away. They can crack from the concentrated heat in your telescope. Buy a filter to go on the front. There are many available from telescope dealers on the web and they also advertise in the *Reflector* and *Sky & Telescope.*

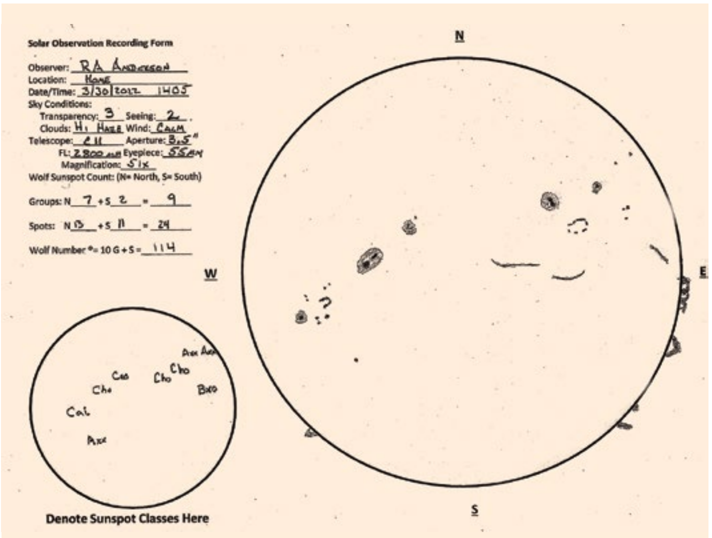
What can you see? Sunspots! A good source of information is the AL Sunspotter Observing Program. There are charts showing the morphology of sunspots and phenomena in the visible layer of the Sun, the photosphere. A magnification of only 50× will most likely show you the whole disk. You can zoom in on a group of spots and see more details. A magnification of 100× will suffice to see the dark center of a spot, called the *umbra,* and the lighter area surrounding it, called the *penumbra.* Brighter areas near spots called *faculae* are sometimes visible, as well as the rarer white-light flares. These only last 10–20 minutes, at most an hour, and then subside. If you can observe for several days, you can see the march of the spots across the face of the Sun. Spots rotate around from the east side of the Sun and disappear around the west side a few days later. Some spots suddenly appear in the middle of the face and develop as they march across. Others fade and disappear.

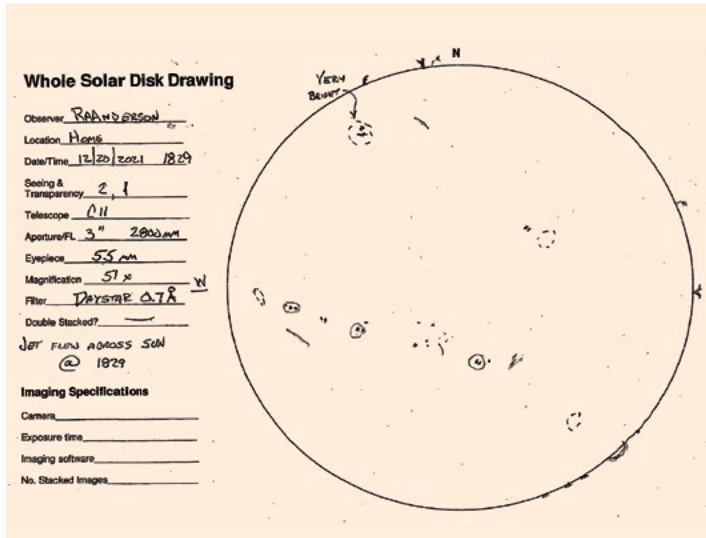
Sketch what you see each day, using the Sunspotter forms. You will develop your visual skill and soon see spots and features you didn't see at first. A good observation takes 20 to 30 minutes, but you can watch as long as you want.

Once you're hooked on solar observing, you may want to also try hydrogen-alpha observing. This requires a more specialized filter that passes only a narrow band of light emitted by the electron transitioning between the third and second lowest energy levels in a hydrogen atom. There are different manufacturers of these filters, and even dedicated solar telescopes are available. The narrow band of light, called the bandpass, is measured in angstroms. A 1-angstrom bandpass will allow you to see prominences on the limb of the Sun. These can last hours and constantly change. A filter that gives a bandpass of less that 0.5 angstroms shows fine detail in the chromosphere and is very exciting. To see both prominences on the Sun's limb and detail

Background image above: ESA & NASA/Solar Orbiter/EUI team; Data processing: E. Kraaikamp (ROB), modified by *Reflector* staff on the surface, a good compromise bandpass is 0.7 angstroms. I have a DayStar 0.7-angstrom filter that has a heater to warm the filter's coatings to allow light to pass between the grains of the coatings. I start out with the filter off and observe the sunspots and sketch them as I would in white light. No artistic skill is needed, just look at my sample log sheet! The purpose of sketching is for you to enjoy, have a record of what you saw, and sharpen your observing skill. After sketching the sunspots, I turn on the filter and allow it to come to operating temperature, and then add the hydrogen-alpha details to my drawing, including prominences, the bright areas around sunspots, and filaments. A sunspot near the limb may appear depressed in hydrogen alpha light, very much like a crater on th e Moon. The Astronomical League also has a Hydrogen Alpha Solar Observing Program, with lots of information on what you can see.

Solar activity is on the rise as a new sunspot cycle started in 2021. And, on April 8, 2024, just a little over two years from now, the Moon will once again eclipse the Sun over North America, but this time the path will run from Texas northward to Ohio and then eastward over New York. Now is the time to become familiar with the Sun and make your plans for the finest of solar events. ✶





LEAGUE OBSERVING PROGRAMS IN THE COLLEGE CLASSROOM

By Kristine Larsen

Shortly after starting as a faculty member in 1989, I set to work revising and expanding the suite of astronomy courses available at Central Connecticut State University, leading to the creation of an astronomy minor. One of my favorite courses has been Observational Astronomy, a starhopping-based fall semester course that introduces students to observing the night sky using the unaided eye, a variety of handheld and mounted binoculars, portable Newt-Dobs, and the observatory's 16-inch Cassegrain. Enrollment is limited to 12–15 students. Students enroll in the course either as part of the astronomy minor or to fulfill the general education laboratory science requirement for graduation.

The course includes two daytime 'lecture' periods and two nighttime 'lab' periods per week, the air quotes signifying that some sunny days are devoted to solar observing and cloudy nights are devoted to the planetarium, additional lectures, or other activities. One of my favorite among the last of these is a walking tour of campus to point out ever-increasing examples of light pollution. Over the past decade, our campus skies have significantly brightened (by at least a half a magnitude), thanks in large part to construction and a switch to bright LED outdoor lighting. Students had become increasingly frustrated in the course, finding it nearly impossible to see objects that had once been reasonable targets (e.g., M71 in Sagitta and the variable star Eta Aquilae). The fall 2021 semester was the first time the course was to be taught during the pandemic, thankfully completely on-ground and in-person; this was the perfect time to make a serious change in the course pedagogy.

In order to give more cohesiveness to the course and get fresh ideas of what observations and other related tasks I could reasonably expect given our deteriorated skies, I turned to the Astronomical League's Observing Programs *(astroleague.org/observing.html)*. Rather than base half of the course grade on their logbooks (documenting their observations – including sketches – of whatever random list of objects I cobbled together each night), they completed four observing 'portfolios,' each of which included a completed checklist of objects observed and activities completed along with ancillary evidence in their notebook and logbook. Two of these portfolios covered the binocular certification portion of the AL Lunar Observing Program *(astroleague.org/al/obsclubs/lunar/lunar1.html)* and the Beyond Polaris Observing Program *(astroleague.org/content/beyond-polaris-observing-program)*. A third was a subset (roughly 75%) of the items listed in the Dark Sky Advocate Observing Award *(astroleague.org/al/obsclubs/darkskyadvocate/darkskyadvocate.html)*, while the last was a list of objects selected from the Galileo, Solar System, Sketching, Double Star, Messier, and Variable Star Observing Programs.

Each observing night students were given a list of objects (by OP and item number, as appropriate) that they were expected to complete, for example a list of specific objects to find in the Lunar Program. Students were also directed to complete some specific observations on their own, for example sighting the "Old Moon in the New Moon's Arms" as part of their Lunar Program portfolio and documenting examples of light pollution in their neighborhood as part of their Dark Sky Advocate portfolio. Students were also alerted when we had covered a specific item during lecture so that they could circle back and include it in the relevant portfolio notebook. Examples include "Tell 2 mythical constellation stories" (A3) and "Explain lunar eclipses and solar eclipses and draw diagrams" (C4) from the Beyond Polaris OP.

As the sharing of eyepieces was problematic during COVID-19, students largely worked with their own individual instrument on a given night, but worked as a team in that they eagerly pointed out objects in the sky to each other and gave each other helpful hints as to how they found the target objects for that evening, or what type of distinguishing details to look for.

While I was satisfied as an instructor by the students' success in completing these assignments, the anonymous end-of-course opinion survey gave the students an opportunity to reflect on their own learning. I therefore end this article with a selection of the students' own words, presented here verbatim and with their permission, in the hope that others will integrate the AL Observing Programs into their own teaching.

"It offered a new realm of amateur astronomy I did not know existed. It also broadened my horizons with regards to the night sky. I can identify much in the night sky and it is fun to show others."

"Overall the portfolios boosted my confidence in terms of my observing skills. It also motivated me to do better."

"A good deal of the things we observed or things that were in the portfolio seemed to tie into what we were learning in class. As we went through the list each week I think I got better at navigating the night sky and learned reference points and familiar objects".

"I thought this was an amazing learning experience. I think the portfolios allowed for a lot of 'teach yourself' moments, and therefore made me more engaged with the material than I was expecting. I retained a lot of information that I can share with others."

"I felt that the portfolios were a good way to learn about the basics and essentials of observation. It offered a list of targets that had not only observations, but other tasks such as researching star party etiquette and local lighting ordinances. Of course, it is important to learn how to observe, but the other 'non-observational' tasks gave us the opportunity to gain a multifaceted understanding of astronomy and observation."

"The learning experience was fabulous! At first, I was intimidated by the amount of material due to my lack of knowledge. However, the observing programs made it so the material was easy to comprehend and fun! Finishing it was a breeze. My favorite class this semester."

✶

Kristine Larsen is an Astronomy Professor at Central Connecticut State University, the editor of the Reflector, *and a member and Trustee of the Springfield Telescope Makers.*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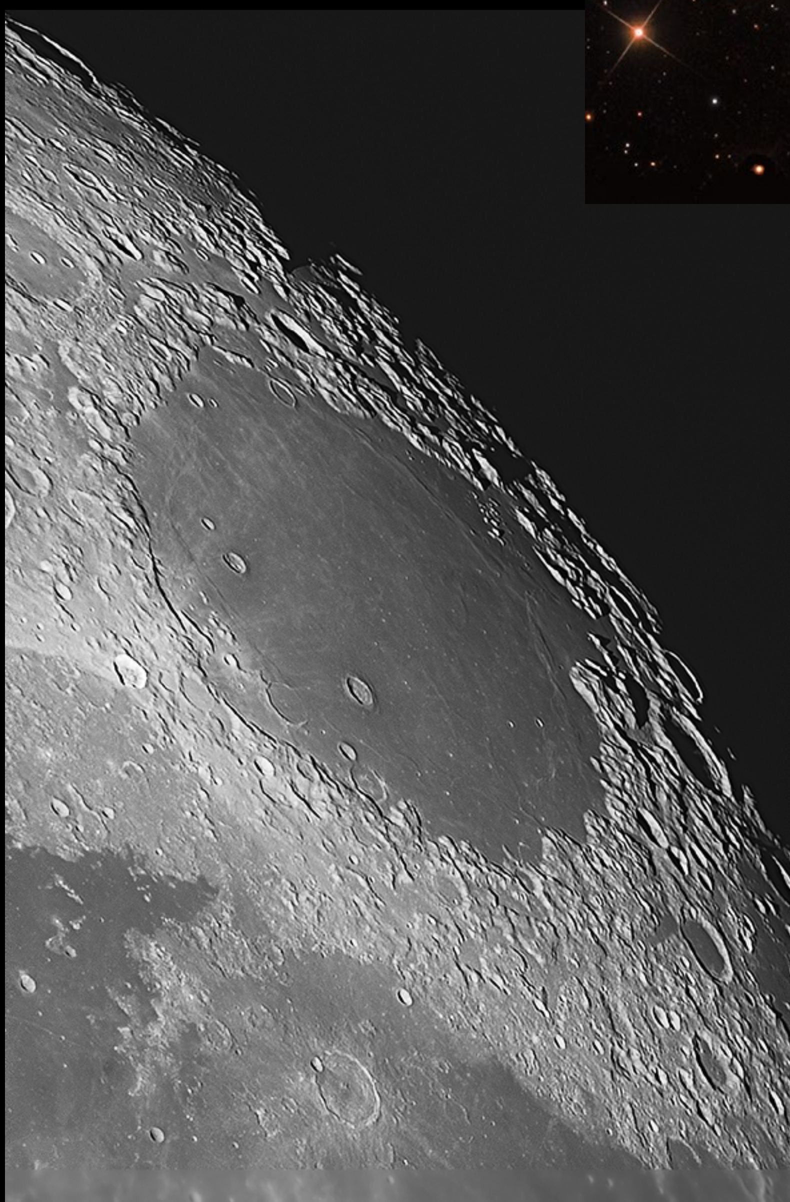

This page, above: Bernard Miller (East Valley Astronomy Club) captured this deep image of M82 with a PlaneWave 17-inch CDK with Apogee and FLI 16803 CCD cameras from his observatory in Animas, New Mexico. This image is the culmination of over 46 hours of exposures over several years.

This page, left: Dave Barnett (Astronomical Society of Long Island) captured this image of Mare Crisium using an Orion Mak 180 f/15 and a Celestron Skyris 236M camera.

Next page, top: Steven Bellavia (Amateur Observers' Society of New York) captured this image of the heart of the Heart nebula (IC 1805) using a TS-Optics PHOTOLINE 115 mm f/7 triplet apo and a ZWO ASI294MM Pro camera with H-alpha and O III filters.

Next page, bottom: Joe Ziha (Astronomical Society of Eastern Missouri) captured this image of M78 from his observatory in Animas, New Mexico, using a PlaneWave CDK14 with a ZWO ASI6200MM Pro camera.

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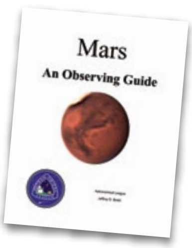

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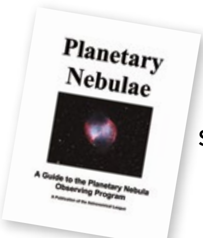

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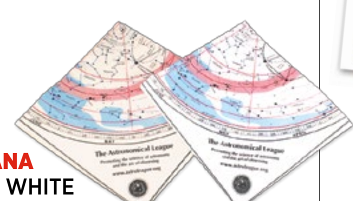

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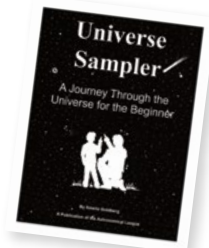

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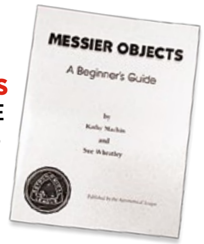

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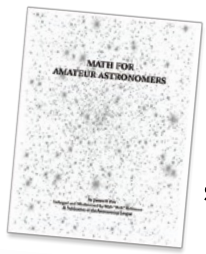

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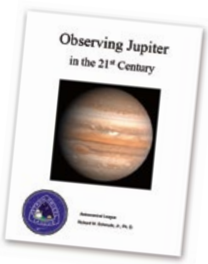

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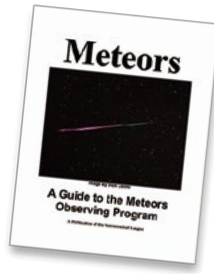

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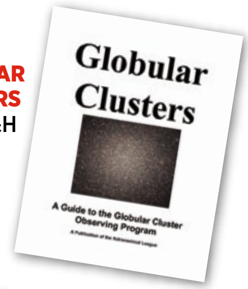

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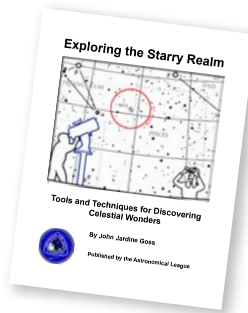

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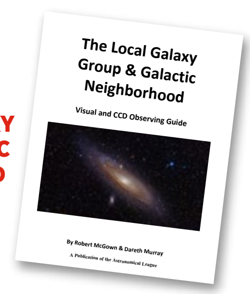

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Arp Peculiar Galaxies Northern Observing Program

No. 110-I, **Keith Kleinstick**, Lifetime Member

Arp Peculiar Galaxies Southern Observing Program

No. 21-I, **Terry N. Trees**, Amateur Astronomers Association of Pittsburgh

Asterism Observing Program

No. 71, **Lauren Rogers**, Escambia Amateur Astronomers Association

Beyond Polaris Observing Program

No. 50, **Anna Daly**, Kalamazoo Astronomical Society; No. 52, **István Mátis**, Member-at-Large; No. 53, **Carolyn Mirich**, Member-at-Large; No. 54, **Brett Belingheri**, Utah Valley Astronomy Club; No. 55, **Jeremy Horn**, Member-at-Large

Binocular Double Star Observing Program

No. 193, **Carlos Vicente**, Member-at-Large; No. 194, **Pete Hermes**, Tucson Amateur Astronomy Association

Binocular Messier Observing Program

No. 1231, **Glynn Germany**, Rio Rancho Astronomical Society; No. 1232, **Albert E. Smith**, Member-at-Large; No. 1233, **Veronica Lane**, Ancient City Astronomy Club; No. 1234, **Fred Schumacher**, Member-at-Large; No. 1235, **Ted Coyle**, South Jersey Astronomy Club; No. 1236, **Tom Pullman**, Member-at-Large

Binocular Variable Star Observing Program

No. 58, **István Mátis**, Member-at-Large; No. 59, **Brad Payne**, Northern Virginia Astronomy Club

Bright Nebula Observing Program

No. 30, **Alfred Schovanez III**, Advanced, Astronomical Society of Eastern Missouri

Carbon Star Observing Program

No. 133, **Jason Wolfe**, Member-at-Large; No. 134, **John Jardine Goss**, Roanoke Valley Astronomical Society; No. 135, **David Wickholm**, San Antonio Astronomical Society; No. 136, **Jack Fitzmier**, Member-at-Large

Citizen Science Special Program

Dan Crowson, Astronomical Society of Eastern Missouri, Active Asteroids, Active, Gold Class 14; **Dan Crowson**, Astronomical Society of Eastern Missouri, Variable Stars, Observational, Gold Class 39; **Al Lamperti**, Delaware Valley Amateur Astronomers, Star Notes, Active, Gold Class 63

Comet Observing Program

No. 58, **Terry N. Trees**, Gold, Amateur Astronomers Association of Pittsburgh; No. 59, **Charles E. Allen III**, Gold, Evansville Astronomical Society; No. 125, **Clayton L. Jeter**, Silver, Member-at-Large; No. 126, **Eric Edwards**, Silver, Albuquerque Astronomical Society

Constellation Hunter Northern Skies Observing Program

No. 281, **Kay Lehman**, Tucson Amateur Astronomy Association; No. 282, **Amanda Grzyb**, Member-at-Large; No. 283, **Todd Mitchel**, Ventura Astronomical Society; No. 284, **Paul Runkle**, Chapel Hill Astronomical & Observational Society

Dark Nebula Observing Program

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Deep Sky Binocular Observing Program

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Double Star Observing Program

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Flat Galaxy Observing Program

No. 44-V, **Michael Overacker**, Honorary, Star City Astronomy Network

Galileo Observing Program

No. 67-B, **Paul Harrington**, Member-at-Large; No. 68, **Dan Posey**, Hill Country Astronomers; No. 69-B, **Jim Hontas**, Cincinnati Astronomical Society; No. 70, **Paul Runkle**, Chapel Hill Astronomical & Observational Society; No. 71, **Eric Edwards**, Albuquerque Astronomical Society; No. 71-B, **Eric Edwards**, Albuquerque Astronomical Society; No. 72-B, **Brad Payne**, Northern Virginia Astronomical Society; No. 73, **Dave Tosteson**, Minnesota Astronomical Society; No. 73-B, **Dave Tosteson**, Minnesota Astronomical Society; No. 74-B, **Jeffrey Corder**, Ancient City Astronomy Club; No. 75-B, **Bernard Vanasse**, Lifetime Member

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Herschel 400 Observing Program

No. 643, **John Skillicorn**, Tucson Amateur Astronomy Association; No. 644, **Richard Tenney**, Utah Valley Astronomy Club; No. 645, **Viola Sanchez**, Albuquerque Astronomical Society

Herschel II Observing Program

No. 115, **Terry N. Trees**, Device-aided, Amateur Astronomers Association of Pittsburgh

Hydrogen Alpha Solar Observing Program

No. 57-V, **Eric Edwards**, Albuquerque Astronomical Society; No. 58-V, **Dave Tosteson**, Minnesota Astronomical Society

Jupiter Observing Program

Aaron Clevenson, North Houston Astronomy Club; **W. Maynard Pittendreigh**, Lifetime Member

Library Telescope Awards

No. 22, **Keith Lawrence**, Silver, Vermont Astronomical Society; No. 22, **Keith Lawrence**, Gold, Vermont Astronomical Society

Local Galaxy Group and Neighborhood Observing Program

No. 48-MV, **Thomas J. Flynn**, Member-at-Large; No. 49-MV, **Sean Smith**, Denver Astronomical Society

Lunar Observing Program

No. 1166, **John Galla**, Astronomical Society of Eastern Missouri; No. 1166-B, **John Galla**, Astronomical Society of Eastern Missouri; No. 1167-B, **Pamela Lowe**, Boise Astronomical Society; No. 1168-B, **Dave Tosteson**, Minnesota Astronomical Society; No. 1169, **Gene Riggs**, Salt Lake Astronomical Society; No. 1170-B, **István Mátis**, Member-at-Large; No. 1171, **Raymond David Whatley**, Northeast Florida Astronomical Society; No. 1172, **Michael Hutkin**, Roanoke Valley Astronomical Society

Lunar Evolution Observing Program

No. 20, **Michael A. Hotka**, Longmont Astronomical Society; No. 21, **Cindy L. Krach**, Haleakala Amateur Astronomers

Lunar II Observing Program

No. 125, **Christian Weis**, Tucson Amateur Astronomer Association; No. 126, **Juan Velasquez**, Denver Astronomical Society; No. 127, **Glynn Germany**, Rio Rancho Astronomical Society

Messier Observing Program

No. 2805, **Kiefer Iacaruso**, Honorary, Harford County Astronomical Society; No. 2864, **Jason Wolfe**, Honorary, Member-at-Large; No. 2866, **Mary Warren**, Honorary, Ancient City Astronomy Club; No. 2881, **John Cachel**, Honorary, Member-at-Large; No. 2882, **Veronica Lane**, Regular, Ancient City Astronomy Club; No. 2883, **Bryan Scott Wargo**, Honorary, Northeast Florida Astronomical Society; No. 2884, **Fred Schumacher**, Honorary, Member-at-Large

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NEO Observing Program

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Nova Observing Program

No. 20, **István Mátis**, Gold, Member-at-Large

Open Clusters Observing Program

No. 105, **Angele Mott Nickerson**, Rose City Astronomers, Advanced

Outreach Award

No. 258-S, **Thomas V. Schumann**, Lifetime Member; No. 1246-O, **Mark Grizzaffi**, Flint River Astronomy Club; No. 1247-O, **Mike Hutkin**, Roanoke Valley Astronomical Society; No. 1248-O, **John Spruhan**, Roanoke Valley Astronomical Society; No. 1249-O, **Jeffrey S. Moorhouse**, La Crosse Area Astronomical Society; No. 1250-O, **Al Ansorge**, Member-at-Large; No. 1250-S, **Al Ansorge**, Member-at-Large; No. 1251-O, **Pete Hermes**, Tucson Amateur Astronomy Association

Radio Astronomy Observing Program

No. 36-B, **Andy Walker**, Bronze, Astronomical Society of Eastern Missouri

Planetary Nebula Observing Program

No. 3, **Terry N. Trees**, Advanced, Southern Imaging, Amateur Astronomers Association of Pittsburgh; No. 21, **David Roemer**, Advanced Imaging, Huachuca Astronomy Club; No. 46, **Laura Hintz-Keller**, Basic, Indiana Astronomical Society; No. 96, **Rob Ratkowski**, Advanced, Haleakala Amateur Astronomers

Sketching Observing Program

No. 53, **Eric Edwards**, Albuquerque Astronomical Society; No. 54, **István Mátis**, Member-at-Large

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No. 193-I, **Gregory T. Shanos**, MARS Astronomy Club; No. 193-B, **Gregory T. Shanos**, MARS Astronomy Club; No. 194, **Glynn Germany**, Rio Rancho Astronomical Society; No. 195-B, **Brad Payne**, Northern Virginia Astronomy Club; No. 196, **Cindy L. Krach**, Haleakala Amateur Astronomers; No. 197; **Dave Tosteson**, Minnesota Astronomical Society; No. 197-B, **Dave Tosteson**, Minnesota Astronomical Society; No. 198, **John Zimitsch**, Minnesota Astronomical Society; No. 199, **Bruce Bookout**, Colorado Springs Astronomical Society; No. 200, **Stephen Pavela**, La Crosse Area Astronomical Society

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Universe Sampler Observing Program

No. 158-T, **Kiefer Lacaruso**, Telescope, Hartford County Astronomical Society

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