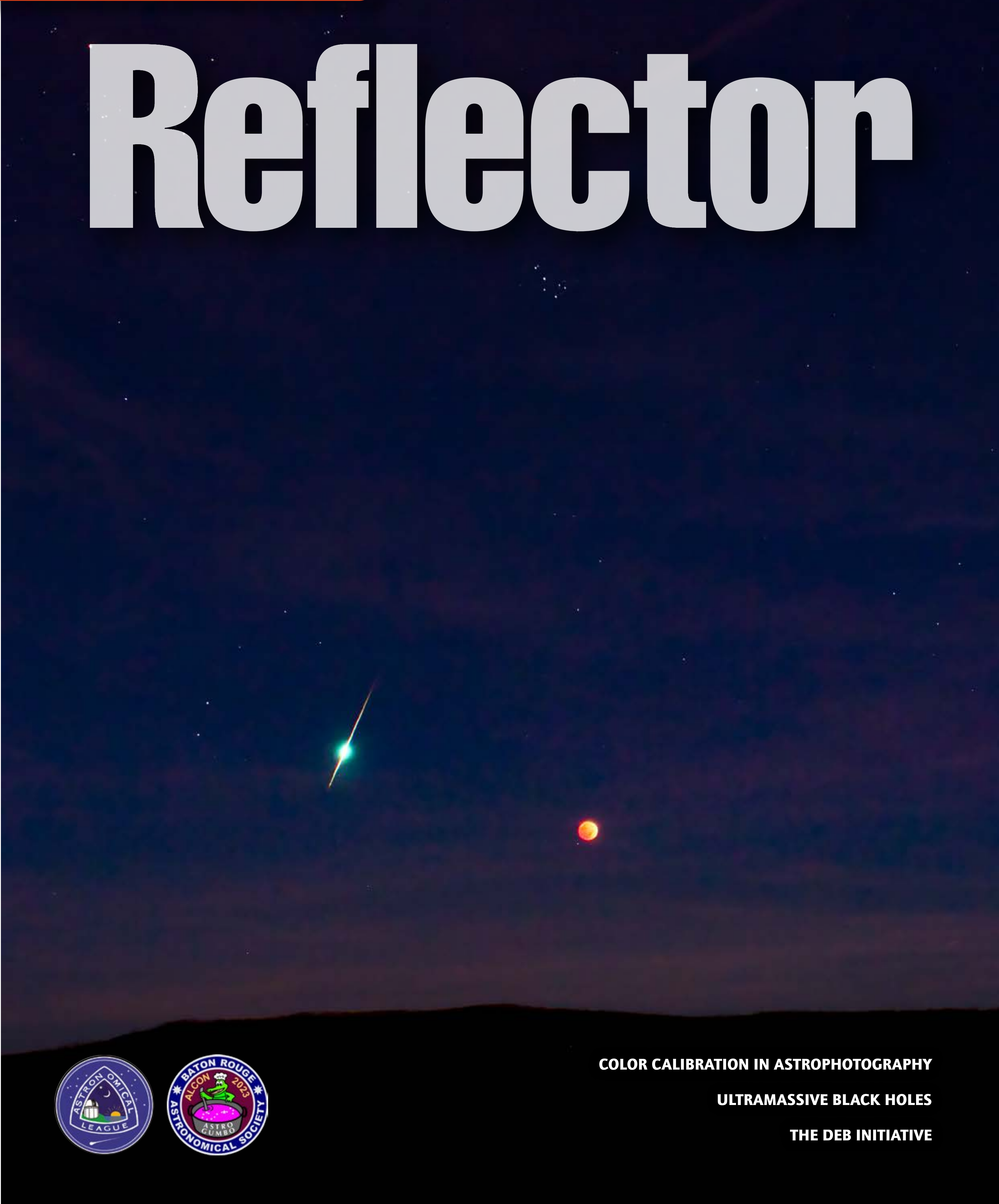
Published by the Astronomical League
Vol. 75, No. 2 MARCH 2023

Reflector



COLOR CALIBRATION IN ASTROPHOTOGRAPHY

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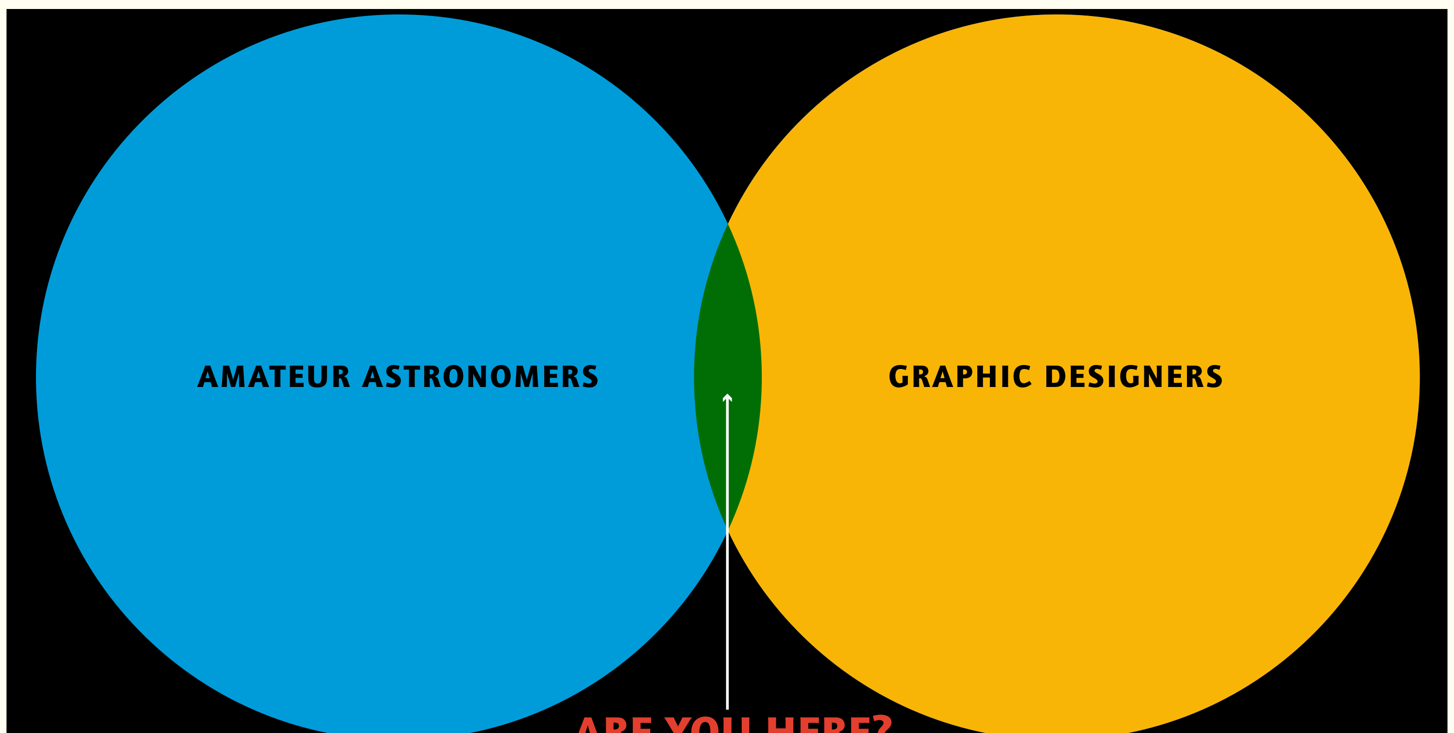

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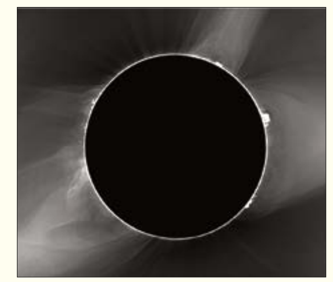
Contents

PAGE 8

PAGE17



PAGE 20

Michael Rosolina *(member-at-large) captured this view of the recent lunar eclipse, the Pleiades, and a Taurid meteor with a Canon T5i with an 18 mm lens.*

Reflector

The Astronomical League Magazine

Vol. 75, No. 2 • ISSN: 0034-2963 • MARCH 2023

A FEDERATION OF ASTRONOMICAL SOCIETIES
A NON-PROFIT ORGANIZATION
To promote the science of astronomy

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

Astronomical League National Office:
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April 29, 2023
50th anniversary

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For additional information, contact Gary Tomlinson Astronomy Day Coordinator gtomlins@sbcglobal.net

Reflector

QUARTERLY PUBLICATION OF THE ASTRONOMICAL LEAGUE

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

PAPER SUBSCRIPTIONS:

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***REFLECTOR* AND CLUB ROSTER DEADLINES**

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

To the Editor

On finishing the December 2022 issue, and having enjoyed this magazine for years, I feel compelled to send you a friendly note to tell you how much I love and enjoy your magnificent *Reflector* quarterly. I love reading every article in every issue, cover to cover. The brain just tingles with the flashing of synapses. Each article is thought provoking, fascinating, and inspiring, providing a glimpse of the unfathomable mysteries of the universe, spurring the imagination. I enjoy your broad range of topics, too. They inspire me to dig deeper and learn more. I also like how you lay out each issue. The quality, quantity, and arrangement of your photographs and figures scattered pleasingly throughout are both eye candy and brain candy, grabbing and focusing one's attention.

I am also writing praises to several of your contributors that provided email addresses as well. Thank you for bringing their articles to me!

Thank you so much, keep up the great work, and have a happy 2023.

Clear skies!

—Tom Derington
Von Braun Astronomical Society, Huntsville, Alabama

Nominations Due

Award and officer nominations are due by March 31. Please see the December issue for details; more information at *www.astroleague.org/al/awards/awards.html*.

Star Beams

My presidential travels during the last quarter of 2022 included a special October trip to the Omaha Astronomical Society to help them celebrate their 60 years as a society.

My wife, Betty, and I were warmly welcomed by society's president, Jon Larsen, and its members. It was my honor to present a 60-year plaque to commemorate this fine achievement. The OAS has always been quite active in outreach. Longtime member John Johnson was also recognized for his many years of service to the club and its outreach activities.

The society has a robust, successful Library Telescope program in place for their area. Mike Modrcin leads this effort. The Omaha Astronomical Society was the successful recipient of the 2022 Astronomical League Library Telescope for the Mid-States Region of the Astronomical League. A Library Telescope is given annually to one society in each region and to one member-at-large, for use through a library lending program in their communities.

In addition to being a strong astronomy club, the OAS for many years has cosponsored the Nebraska Star Party with the Prairie Astronomy Club in Lincoln, Nebraska. During its three decades, the star party has achieved national prominence as one of the premiere events nationwide. Merritt Reservoir State Recreation Area, the site of the star party, was recently designated an International Dark Sky Park by the International Dark-Sky Association.

Clear and dark skies!

—Carroll Iorg, President

International Dark-Sky Asssociation

UNDER ONE SKY 2022

IDA's third annual Under One Sky global conference took place over a 24-hour period starting on November 11, 2022. This virtual con-

ference had individual sessions scheduled so that participants from around the world could attend a session germane to their geographic location at a convenient local time, while all sessions were open for anyone willing to get up in the middle of the night to attend an interesting presentation or session. There were at least 649 unique live attendees from 54 countries who participated in 100,000 minutes of lively discussion. Speakers and panelists representing 17 countries shared their knowledge and passion for dark skies. Subjects covered were human and animal biology, art, history, and culture, and how they connect to the sky. These were woven into a general discussion of the importance of a dark sky.

A superb summary of conference highlights is available on the IDA website at *darksky.org/under-one-sky-2022-highlights*. This column will summarize a few notable highlights.

The global open session opened the conference with Kelly Beatty as master of ceremonies. This session featured the conference keynote address by Lisa Heschong, an architect and ecologist, who showed how day and night are different design considerations yet tied intimately to our human physiology. She explored how a healthy daytime environment influences healthier nights, and likewise how a healthier nighttime environment influences a healthier daytime environment. Basically, we are diurnal animals that are best adapted to high levels of light. Our metabolism is most active in the day, and nighttime is for sleep. Sleep is essential for dreaming, memory formation, growth, and immune system repair.

The first regional session – East and Southeast Asia, Australia, and New Zealand – followed the global open session. Nalayini Brito-Davies from IDA's board of directors hosted this regional session. There were simply too many good presentations and discussions in all the sessions to try to list or summarize them. Most not only addressed issues particular to their specific locales but offered much information applicable worldwide.

A community engagement workshop followed the first regional session. Panelists discussed ways to engage communities through outreach and education. This was hosted by Kerem Asfuroglu, a prominent lighting designer who uses art and creativity in his designs. It has been my experience that the best lighting designers almost universally support good nighttime lighting and control of light pollution.

The second regional session covered Europe, Africa, and India. There were speakers from Nepal, Saudi Arabia, and the United Kingdom. Biraj Nainabasti started off the session by talking about involving youth in the dark sky movement by showing the younger generations light pollution and its negative consequences. If dark sky movements around the world could capture the attention of younger generations and get them fully committed to tackling this problem, then we could expect a significant improvement in our skies within the next generation.

An International Dark Sky Places panel followed, featuring the application and certification process for the International Dark Sky Places program. An expert panel described how they obtained certification for their sites, outlining the challenges they overcame and the benefits they have seen since certification. Obtaining an International Dark Sky Places certification is an involved process requiring much work and coordination with IDA and one's local community. Just having a dark site by no means guarantees you can receive certification. The community must support such an effort by its commitment to replace any offending luminaires and by committing to use only dark sky friendly lighting, amongst other efforts.

The final regional session covered North, Central, and South America. It was hosted by Paulina Villalobos, a member of IDA's board of directors from Chile. The third and final engagement workshop followed this regional session and focused on how policy can be an instrument for change to reduce light pollution and promote awareness of the value of dark skies.

An awards reception and cocktail hour were held near the end of the Under One Sky conference. Award winners were announced and celebrated, and "virtual cocktails" were served where attendees separated into breakout groups to socialize and network. The global close reconvened everyone for a final session with Mike Simmons from IDA's board leading a conversation with astronaut Nicole Stott and actor and amateur astronomer Tim Russ. Their discussion covered what it means to look down on the Earth from space to gain new perspectives on our fragile world, realizing how we need to celebrate and protect it.

This brief summary of the conference cannot do it justice. There were too many fabulous speakers to list in this report, and I highly recommend you read about the meeting in more detail at *darksky.org/under-one-sky-2022-highlights.* Better yet, you can watch recordings of the meeting at *youtube.com/watch?v=KLl21uEW_OI.*

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

Night Sky Network

REVITALIZING CLUB MEETINGS

Do your club meetings need a bit of pizzazz? Has enthusiasm waned along with attendance over the past several years? Try shaking up your regular meetings to kick things back into gear! Even just one or two small tweaks to your meetings can help rejuvenate the experience for both your club's officers and members.

SHAKE UP THE SCHEDULE

What's your usual meeting structure? Have you been holding club business first, then member announcements, then speaker? It's a fine format, but consider trying a change if it feels stale. Maybe change the business session to officers-only for the first half, or attend to club business earlier than the main member meeting. Try starting the meeting at a different time. Was attendance sparse at 6 p.m.? Hold it at 7! Maybe Tuesdays don't work; what about Thursdays? The weekend? Members may find that regular meetings are a bit long. Try shortening them if they last for several hours. People enjoy getting a little time back, especially if that means more stargazing after the meeting!

BREAK THINGS UP

Perhaps holding one big meeting a month isn't the right fit for your group, especially if your club has a lot of members and interests. Maybe that business meeting with the officers can be held at an entirely different time and date than the regular member meeting. If your meetings have many attendees, having regularly scheduled breakouts during the meeting itself, where different committees and interest groups meet, can help liven things up and generate lots of good ideas and energy for future club events. Change up the location! Try an outdoor meeting during the summer at your group's preferred observing site or meet up for a movie night or ice cream social; new environments can inspire new and fun ideas.

NOVELTY!

Try new things, and don't be afraid to have a bad meeting once in a while. If meetings are a bit uninspiring try something very different. Hybrid meetings, where attendees can attend in-person or from home, have helped some members with long commutes or busy schedules reconnect and attend more meetings. Holding some meetings virtually when the weather is poor or business is light can also help, and don't forget to reduce the number of unnecessary meetings! Annual and recurring themes help planning meetings as well; member holiday parties, International Observe the Moon Night, equipment swaps, member contribution nights, speaker series, and new equipment workshop days can all be great potential meeting themes.

These are just a few suggestions; we'd love to hear your own tips. Share how you have reenergized your meetings by sending us a message at *nightskyinfo@astrosociety.org.* And if you haven't found your club yet, go to *nightsky.jpl.nasa.gov* to find one near you!

—David Prosper

Full STEAM Ahead

BETTER THAN A GIMBELS STORE WINDOW

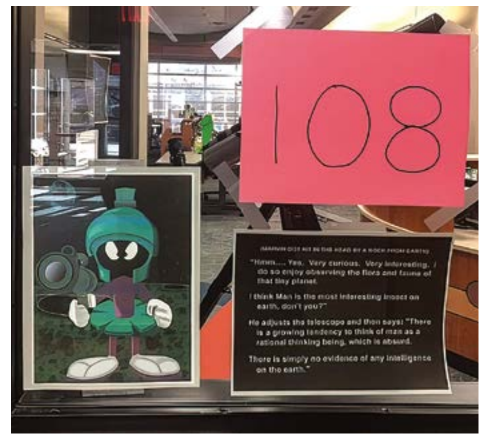
The Broken Arrow, Oklahoma, School System has an elementary school that has held STEM nights for many years, partnering with the Broken Arrow Sidewalk Astronomers from the beginning. Rhoades Elementary School received the International STEM Award about six years ago for the STEM activities they hosted at their school.

At the beginning of the 2022–23 school year, BASWA was contacted by the new principal, Mr. Akehurst, for his meet and greet event: he wanted a telescope and activity for the families that would stop by for his "Principal and Popsicles." After the event, he stated that they were planning a STEM Night for the spring, and I added that we are available to do classroom sessions and solar observing as well. Mr. Akehurst said that he wanted to connect me with Eric, the librarian, and added that we would hit it off quite well. Immediately upon meeting Eric I understood the reason for this connection. I was in the presence of a science nerd and tech-savvy guy. His office was full of science fiction and superhero posters and figurines on the desk and shelves. It was not just Marvel characters, but he rolled old school, with models and figurines from *Star Wars, Star Trek,* and *Doctor Who.* Oh my!

He was having an open house and wanted a display in front of the library windows. I was given two tables and free rein. Jupiter and Saturn were the topic, and a small Bushnell scope we use with a Sun Funnel was on display, along with *Sky & Telescope* booklets, club information, and *skymaps.com* handouts. My large tactile Jupiter cloud system was a hit as well as the Saturn CD activity with gravel moonlets in the yarn ring system, Jupiter moon "word find," and crossword puzzles. The windows were covered with my PowerPoint slides on moons, ring systems, cloud systems, and weather. The printed images were not all facing into the library; some faced the hallway since that is a major walkway for the students and teachers and the very first thing one sees when passing through the school's main doors.

In December, the large windows were reset for the Mars display. Its large size and the looks from students and teachers passing by gave it the feeling of a Christmas window display from Gimbels – one of the largest department stores at the turn of the 20th century. I kept the two tables with the scope and handouts. A topical map with the locations of landers and rovers noted had adjoining pages on each of those missions. Again, the pages from my Mars PowerPoint were taped on the windows and displayed on the tables, showing weather, surface features, polar caps, rocks, a labeled atlas, a list of future missions, and astronomers involved in Mars research. Two books by Jim Bell – *Postcards from Mars,* a large photo filled book, and his *Mars 3-D: A Rover's-Eye View of the Red Planet* – were also displayed. The latter has a flap that has the 3-D glasses embedded in it and the book is viewed by holding the book and flipping the pages downward. At the writing of this article, both are still available online.

Eureka! I found a Mars ball in a file which I did not know existed, and a 3-D Valles Marineris paper model kit from Kristal Educational Inc., purchased a long time ago and sadly no longer available. Both had to be extricated from the dark corners of the closet and dusted off. A small box of rock samples similar to what could be found on Mars was added to the display, but would only be brought out when Eric would talk about them or if the teachers wanted to use them in their classrooms. Another resource that no longer has an active link to it was a manual downloaded from NASA/JPL and Arizona State University, called *Mars Activities: Teachers' Resources & Classroom Activities.*



On the table is a tray with the cover of this book in an acrylic display and a note to the teachers to feel free to copy the activities and leave the original for their fellow teaching staff. The manual had 24 classroom activities that I stapled together that talk about Mars's size, rover simulations, surface core samples, volcanoes, fundamentals for life, edible rovers and spacecraft, meteorites, investigations below the surface, mathematics of Mars, Mars bingo, craters, and a Mars Pathfinder model.

The images were facing both directions, but this time included a section dedicated to the science fiction writers and movies that feature the planet Mars, including authors like Ray Bradbury, H.G. Wells, Gene Roddenberry, and Michael Crichton. I told the librarian what I did and how he could talk about science fiction with the students, which made him crack a smile.

Of course, no Martian display would be complete without our dear friend Marvin the Martian, who famously stated that there is no intelligent life on Earth.

Due to the no-longer-active link for that NASA booklet, if you cannot find it and would like a copy, please contact me (astroleague_steam@cox.net) *and I will send it to you.*

—Peggy Walker
STEAM and Jr. Activities Director

Wanderers in the Neighborhood

IS THE SOLAR SYSTEM STABLE?

What if you looked up in the sky where Jupiter should be and found that it was halfway across the sky? We expect the planets and asteroids to move in an orderly fashion around the Sun, and they do. We are able to predict solar eclipses into the future and compare them to eclipse observations in the distant past. While the Solar System is stable in the short term (astronomically speaking), how stable is it over much longer periods?

As with much research in astronomy, the stability of the Solar System is studied using computer modeling. These models of the Solar System require high-precision information on the planets, Sun, and Moon. This includes their initial positions and velocities, as well as their masses and shapes. Models have become more accurate as observations have improved our knowledge of the Solar System.

Before the advent of electronic computers, calculating the positions of the planets was done by hand, using formulae that were created in the 1890s. The resulting ephemerides (lists of the positions of an object at certain times) were published each year in almanacs. *The Astronomical Almanac* comes from a long line of almanacs starting back when they were crucial for naval navigation, long before the advent of GPS.

These nautical almanacs provided positions of the Sun, Moon, and planets to facilitate computing a ship's position based on sightings (altitude and azimuth) of celestial objects. Combined with the accurate time, the ship's latitude and longitude could be determined and would allow the captain to keep the ship on course. *The Astronomical Ephemeris and Nautical Almanac* has been published by the United States Naval Observatory (USNO) since 1852. In 1981, the USNO joined with Her Majesty's Nautical Almanac Office (HMNO) in the U.K. to coproduce the book, which was renamed *The Astronomical Almanac.*

These books included information about the planets, their moons (especially our Moon), and minor planets. These were all hand computed until electronic computers started to become available in the 1940s. With this additional computing power, the formulae used to produce the ephemerides were updated to include Einstein's relativistic corrections to the orbits.

The Jet Propulsion Laboratory (JPL) started producing its Developmental Ephemeris (DE) in the 1960s to guide its spacecraft and distributed the ephemeris on magnetic tape. The motions of the Sun, Moon, and planets were integrated on UNIVAC mainframes in the 1970s. The resulting tables were transformed into Chebyshev polynomial coefficients that were fit to 32-day intervals. They could be used to compute positions quickly without a large computer. The DE is available from JPL over the Internet (*ssd.jpl.nasa.gov/horizons*).

Versions of the Developmental Ephemeris are differentiated by a number. For example, DE69 was released in 1969. As observations have improved our knowledge of the Solar System, JPL has released new ephemerides. The latest version, DE441, was released in June 2020.

In building Solar System models, the initial conditions are crucial to matching the results with observations. Very small errors can accumulate over time to produce inaccurate results. To compound the problem, weak gravitational effects between the planets can also corrupt the final result. To minimize this effect, as many Solar System objects must be included in the model as possible. This means including the larger minor planets and moons in the model, but there is a limit imposed by the time it takes to calculate each step in the model. The more objects in the model, the more time it takes to calculate the gravitational effects between each pairing of the objects. To model the Sun, planets, 205 moons, 9 dwarf planets, and 35 minor planets larger than 160 miles across would require calculating 33,153 interactions for each step.

Modeling has revealed some scenarios that could destabilize our Solar System. For example, a resonance exists between periodic changes in the closest approaches of Mercury and Jupiter to the Sun (technically speaking, in the precession of their perihelia). As a result, Jupiter's gravity could pull Mercury out of its orbit in three to four billion years, sending it into the Sun, Venus, Earth, or Mars or ejecting it from the Solar System. Another potential instability is the possibility that Earth's polar axis could start to shift due to tidal interactions with the Moon (1.5 billion or more years from now).

Resonances between Neptune and Pluto (3:2 orbits) could make Pluto's location in its orbit unpredictable in a few hundred million years, even though the orbit itself will be stable. The Jovian moons have resonances as well, with Io and Europa (2:1) and Europa and Ganymede (2:1) interacting in unpredictable ways. Tidal stresses from the Io-Europa interaction produce volcanic activity on Io.

Finally, if a massive object from outside the Solar System were to pass by, its gravity could destabilize the Solar System. It would certainly alter the orbits of objects in the Oort Cloud. At least a dozen stars could approach us in the next few million years, however, an approach close enough to affect the major planets is unlikely to occur for a hundred billion years.

To study the stability of the Solar System on a shorter time scale, Angel Zhivkov and Ivaylo Tounchev of Sofia University in Bulgaria produced a model with simplifying assumptions that allowed them to run the program on a workstation in a reasonable amount of time. The run covers the next 100,000 years. During that time, the major planets' average distances from the Sun and the eccentricities of their orbits vary by less than one percent. This indicates that our Solar System will be stable over that time period.

Zhivkov and Tounchev believe that with a more powerful computer they can extend the model run to a million years. The algorithm could be modified to include relativistic effects, the fact that the planets are not point masses, and smaller bodies in our Solar System. Their work shows that, at least in the short run, the planets in our Solar System will continue their stately motion around the Sun, barring the arrival of an interloper from outside our system. You can read a technical preprint of their methodology at *arxiv.org/abs/2206.13467.*

—Berton Stephens

Deep-Sky Objects

COMPACTING GALAXIES

In 1982 Paul Hickson (1950–), an American-born astronomer with the University of British Columbia, published a catalog of 100 compact galaxy groups. A compact galaxy group is a tight collection of galaxies visible in our sky. Not only does each span a very small region of the celestial sphere, but they are also extremely close to each other in three-dimensional space. In many cases they are gravitationally interacting with each other. The most famous Hickson compact group is HCG 92, otherwise known as Stephan's Quintet. All Hickson Compact Groups contain four to seven galaxies. The galaxies are typically much fainter than can be seen in an 8-inch telescope. However, the group covered here, Hickson 44, is bright enough to see with an 8-inch scope and is easy to find due to its position in the constellation Leo.

Compact galaxy groups represent physically related galaxies that are in the process of merging. Astronomers hypothesize that when galaxies merge, whether they are spiral galaxies or elliptical galaxies, a single larger elliptical galaxy is created. These compact groups are relatively short-lived compared to the age of the universe. Mergers are thought to occur within a billion years.

The Milky Way Galaxy, M31, and M33 are not a compact group. But as these three galaxies, and possibly others in the Local Group, get closer together, they may someday be considered a compact galaxy group.

Hickson 44 contains four galaxies: NGC 3185, 3187, 3190, and 3193. Hickson 44 resides on the back of the Lion's neck. To find it, look for the stars Algeiba (Gamma Leonis) and Adhafera (Zeta Leonis). These two stars are on the east side of the curved region of the Sickle of Leo asterism (the backwards question mark in the sky). Hickson 44 lies on a line connecting these two stars, just north of the midpoint.

I captured an image of Hickson 44 (shown here) using a 10-inch f/6 Newtonian with a Paracorr 2 coma corrector yielding f/6.9. The total exposure was 260 minutes using 10-minute subframes with an SBIG ST-2000XCM CCD camera. In the image north is up and east to the left.

What appears to be two bright stars at the upper left of the image is actually a star and an elliptical galaxy. The star is a magnitude 9.5 G5 (Sun-like) star 72 light-years away. The elliptical galaxy is NGC 3193. It has an integrated magnitude of 11.05 and it is 79 million light-years away. The galaxy is around 2.2 arcminutes in diameter. Which of the two looks bigger and brighter in your telescope?

Just above the center of the image is the nearly edge-on spiral galaxy NGC 3190. This galaxy is magnitude 10.9 and measures 3.6 by 1.2 arcminutes. The galaxy has a huge central bulge and a prominent, distorted dust lane. Of course, all of the galaxies in Hickson 44 are about the same distance from Earth.

To the upper right of NGC 3190 is NGC 3187. This is a barred spiral galaxy that looks as if two spiral arms have been unwound. The galaxy is magnitude 13.3 and, not counting the unwound arms, measures 2.2 by 0.7 arcminutes. The unconventional spiral structure of NGC 3187 and the warped spiral disk of NGC 3190 result from a close interaction between these two galaxies and perhaps another in the compact group.

The final galaxy in the group, located on the lower right side of the image, is NGC 3185, a magnitude 12.1 spiral galaxy measuring 2.1 by 1.2 arcminutes in size. It's a little farther away from the other three galaxies and shows no sign of a close interaction with the others. All of the other galaxies in the image are background objects and are too faint to be seen in most amateur telescopes.

Hickson 44 is also known as Arp 316. It was the 316th of 388 entries in the *Atlas of Peculiar Galaxies* published in 1966 by Halton Arp (1927–2013). Arp was an American astronomer who spent the last 30 years of his life with the Max Planck Institute for Astrophysics in Munich, Germany.

If NGC 3190 looks familiar, it may be because it was the desktop image on MacOS 10.8, Mountain Lion, when it was released in 2012. If you haven't seen it, hop over to it this spring while hunting galaxies in Leo. You'll capture four galaxies for the effort of one.

—Dr. James Dire

IMAGING THE NEWEST OF MOONS

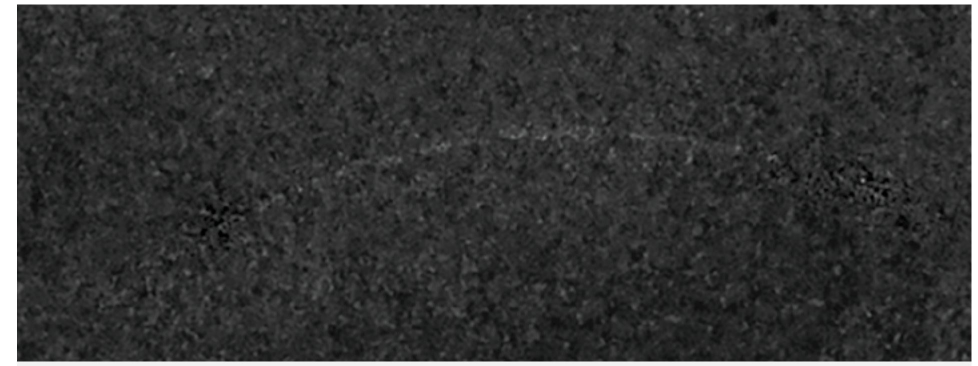
By Anas Sawallha

I'm 35 years old, live in Jordan, and work as an endodontist/dentist. Since my childhood, I've had a strong passion for science, especially astronomy and history.

When I was a kid, I used to spend hours at home looking at the sky wondering about the names of stars or where constellations were located. At that time, the only constellation I could recognize was Orion. I was also obsessed with seeing any meteor, to the degree that I still remember them clearly even now. I can't count the hours I spent just to see one meteor. Finally, my patience was rewarded when the 1999 Leonid storm came, and it was a sensation. I could not believe my eyes.

Many years went by without owning a telescope until 2017 when I was working in Saudi Arabia. I got my first scope on my birthday. It was a small 70 mm refractor which I pointed at Saturn, the first celestial object I ever saw through a telescope. What a birthday present!

Then I bought a 5-inch Celestron telescope with a manual mount, which taught me a lot. I started learning the sky and in 2019 I completed observing the Messier catalogue along with many other deep-sky objects and double stars.



A crop from one of Mr. Sawallha's images. The faint crescent is relatively easy to see in the RGB electronic image, but processing it for ink on paper was a challenge for our production artist, requiring several software manipulations to make it (we hope) visible here. Some dust-speck artifacts were also retouched out.

Several months ago, I became a member-at-large of the Astronomical League and completed the Lunar and Comet (Silver) Observing Programs. Nowadays, I'm finishing the Double Star and Lunar II Programs.

I started astrophotography thanks to Mr. Mohammed Odeh, director of the International Astronomical Center. He asked me to image the crescent Moon every first Hijric month (Islamic calendar) as a member of the Islamic Crescents Observation Project (ICOP), lending me a telescope with a computerized mount and camera. With this equipment, I began my journey exploring the realm of astrophotography. However, I am and always will be a visual observer.

On February 1, 2022, I imaged the crescent at 07:21 UT from my home in Irbid, Jordan. This photo was taken 95 minutes after the geocentric conjunction. The crescent was about 4.55 degrees from the Sun.

Then, on August 27, 2022, I imaged the crescent at exactly the time of geocentric conjunction (first of Safar of the year 1444 according to the Hijric calendar). I also took this photo from Irbid, and the crescent was 4.6 degrees from the sun.

Before I proceed with imaging, I get the date of the conjunction from International Astronomical Center *(astronomycenter.net)*, and then I get the coordinates of the crescent from a computer program called *Accurate Times* developed by Mr. Odeh.

Using a Solar filter, I point the telescope to the Sun so I can focus it. Next, I slew to the Moon, mount a baffle that occludes the Sun's rays from the objective lens of the telescope, and begin image acquisition with SharpCap. I usually take 500 images and 200 flats which I process using MaxIm DL software. This technique also helped me image Venus's ring before the inferior conjunction.

Equipment that I use in my imaging includes an Explore Scientific ED80 telescope, an iOptron MiniTower altazimuth mount, an Imaging Source DMK 21AU04 15 frames-per-second monochrome camera, and an Astronomik ProPlanet 742 infrared-pass filter.

I would like to thank the Astronomical League for making my observations tidier, for orienting me to new observing targets, and for the wonderful pins they send me. Also, special thanks to Mr. Chuck Allen for the opportunity to write this article. ✶

League News

ALCON 2022 SUMMARY

ALCon 2022 was held in Albuquerque, New Mexico, at the Embassy Suites Hotel from July 27 to 30, 2022. There were 110 single registrations, 38 couples registrations, and nine student/youth registrations for a total of 195 registrants.

ALCon 2022 was planned and executed by a committee of 13 members of the Albuquerque Astronomical Society. The committee was augmented during the conference by 15 volunteers. There were 15 speakers, four AL President's Panel members, and ten workshop presenters.

There was one Platinum Sponsor ($2,100), the American Association of Variable Star Observers (AAVSO), and two Silver Sponsors ($500), the Baton Rouge Astronomical Society (BRAS) and Lowell Observatory.

Each registrant, speaker, and volunteer was provided with an attendee bag that contained a program, name badge and lanyard, logo pin, and items supplied by the AAVSO, BRAS, and the Albuquerque Convention and Visitors Bureau.

The lead-off speaker on Thursday was Glenn Chaple from *Astronomy* magazine who spoke about observing variable stars and the Astronomical League's Variable Star Observing Program. Other Thursday speakers were Tom Prettyman of NASA's *Dawn* mission who discussed asteroid research, Dennis Webb of Johnson Space Center Astronomical Society and Fort Worth Astronomical Society who talked about things he learned creating the *Annals of the Deep Sky* books, Scott Harrington who spoke about observing with binoculars, Mark Boslough of Los Alamos National Lab and the University of New Mexico who gave a talk titled "Deluge of Fire: The Anatomy of an Asteroid Airburst," and Rick Fienberg of the American Astronomical Society who spoke on pro-am collaboration. Also on Thursday was a workshop on progress at New Mexico observatories.

Astronomical League vice president Chuck Allen, supported by Scott Harrington, started Friday with a presentation on the scale of the observable universe. They were followed by Dr. Kerry Magruder of the University of Oklahoma who gave the talk "The Sky Tonight Project: What Stories Do Historic Star Atlases Tell Us?" and freelance science writer Ann Finkbeiner who spoke about the book *A Grand and Bold Thing*. The final session on Friday was the AL President's Panel that discussed the topic "Diversity is Our Strength." Also on Friday was a workshop on astrophotography. The first part of the workshop about how to use the ZWO ASIAIR PRO and Plus was standing room only.

The highlight of the conference was the VIP reception and dinner with Apollo 17 astronaut Harrison H. Schmitt. Schmitt signed copies of his book *Return to the Moon* for each of the VIP reception attendees and then gave a talk titled "Apollo 17: 50 Years and Counting" to the dinner attendees. His presentation was followed by a lively question session that provided a superb ending for a very enjoyable event.

Michael Bakich, retired *Astronomy* magazine senior editor, started the Saturday presentations with a talk called "Solar Eclipses: The Cool, the Bizarre, the Wonderful." He was followed by G.B. Cornucopia who spoke about the astronomies of Chaco Canyon, Larry Crumpler of the New Mexico Museum of Natural History and Science who spoke about rovers on Mars, and Jennifer Owen-White of Valle de Oro National Wildlife Refuge who spoke about the refuge, IDA's first Urban Night Sky Place. Also on Saturday was a workshop on photometry.

The final event of the conference was the awards banquet. The keynote talk from Dr. Seth Shostak of the SETI Institute was "Why Haven't We Found the Extraterrestrials?"

Tours and trips provided during the ALCon were:

- UNM Museum of Meteoritics tour
- Star parties at the General Nathan Twining Observatory on Wednesday and Thursday
- Rainbow Park tour
- A star party at the Valle de Oro National Wildlife Refuge
- Tours to the Karl Jansky Very Large Array (VLA) and a visit to the Astronomical Lyceum in Magdalena, a dinner, and an observing session near Pie Town with a 40-inch Dobsonian telescope

—James Fordice, Chair

MORE ON ALCON 2022

The Albuquerque Astronomical Society were excellent hosts for ALCon 2022. Jim Fordice and most of the convention committee members stayed on board throughout the almost five years from start to end, with COVID-19 getting in the way and delaying the event for two years. We were honored to present Jim the League's 2022 G.R. Wright Service Award for special service to the League.

One thing we learned during the period of active COVID was that we can extend the reach of the League and the ALCon conventions tremendously through online means. Thanks to Scott Roberts and Explore Alliance for generously inviting the League to join them on the weekly Global Star Parties that began in the early days of COVID. Also, this has developed to include a monthly *Astronomy Live,* ably produced by Terry Mann, our AL liaison with Explore Scientific. We invite our members to tune into these events on Facebook.

The tremendous help from Scott Roberts and his groups also extended to the Virtual ALCon 2021, capably chaired by Terry Mann and Chuck Allen, and then ALCon 2022. We envision building on the many interviews and the live awards ceremony coverage that Explore Alliance provided for ALCon 2022. We have received positive feedback on these efforts, and plan to expand this at ALCon 2023, July 26–29 in Baton Rouge, Louisiana. Very possibly, this will include an online registration with a nominal fee for those unable to attend in person.

—Carroll Iorg, Astronomical League President

PLANNING AHEAD FOR ASTROCON AT BRYCE CANYON

2025 ASTROCON BRYCE CANYON-UTAH DARK SKIES ROCK!!!

AstroCon 2025 will be held June 25–28, 2025, under the spectacularly dark skies of Bryce Canyon National Park in southern Utah. The venue will be Ruby's Inn and Convention Center a few miles from the park entrance. A special area a few miles east of the convention center will be available for evening viewing plus astrophotography and digital imaging workshops.

The convention's goal is to offer enhanced personal viewing experiences and opportunities to learn astrophotography skills. We are still in the planning stage and we welcome your input on how daytime or evening presentations and workshops can best achieve these goals. Ideas that our committee is considering include:

- Setting up personal observing programs
- Astronomical League Observing Programs
- Observing tips
- Using star charts (digital and paper)
- Creating observing lists for different types of objects
- Understanding eyepiece selection
- Using filters for visual and photographic work
- Sketching workshop
- Observing log workshop
- Astrophoto/digital imaging workshops (novice and advanced)

Please contact me at *bolide@cisna.com* if you wish to offer a presentation or coordinate a workshop. We are starting our planning early, but we learned from AstroCon 2017 at Casper, Wyoming, held during the total solar eclipse, that advance planning is important for this type of event. We look forward to hearing from you.

—Lowell Lyon
AstroCon 2025 Chair

CONFESSIONS OF AN OBSERVING PROGRAM COORDINATOR

Paging through a 2010 issue of the *Reflector* magazine, my attention was drawn to an article, "Observing Coordinators Needed," by National Observing Program Director Aaron Clevenson.

Although I had fallen in love with astronomy in my boyhood and finished a 6-inch mirror in high school, my time with the hobby diminished after college and a stint in the army. But in 2004, my interest rekindled, I joined a local club. I hadn't found any particular direction for observing, which consisted mostly of checking out past favorite objects or locating things I had read about in books and magazines.

I was introduced to the Astronomical League and its Observing Programs (at that time called "clubs") by watching fellow club members receive observing awards and hearing talks about the benefits of the programs by Greg, our ALCor (Astronomical League Correspondent). He was an enthusiastic participant in the programs, and I recall being impressed by the weighty, pin-laden cap he passed around.

I thought the programs sounded worthwhile and decided to try one to see whether their structure would help reenergize my involvement in the hobby. I began with the Double Star Club, since I had always enjoyed observing doubles and was already familiar with a handful on the observing list. It seemed like a good jumping off point to experience how the clubs worked. It would also finally accord me a reason to give my 20-year-old mirror an overdue cleansing, upgrade the tube components, and tune up its equatorial mount.

As I completed several more, it turned out I really liked participating in these well-organized programs. The observing lists were thoughtfully prepared and some were accompanied by descriptive guidebooks to assist me along the way. I finally felt a purpose to my observing and found myself eagerly planning my next night at the eyepiece. There was also a sense of accomplishment when my observing efforts were recognized with an award certificate and attractive pin. These can either be mailed directly to the member or presented at a club meeting. Greg was now presenting awards to me!

By the time I read Aaron's article, I had invested in a new scope and eyepieces and completed a number of additional programs. I had been impressed with the helpful roles played by the encouraging observing coordinators I had encountered. If I could assist others, as I had been assisted, I wanted to do it, so I contacted Aaron.

After several email exchanges and a phone conversation, I found myself assigned as coordinator for one of the League's foundation programs, the Globular Cluster Observing Program, initiated in 2004. I was very pleased by this, as I had completed this program several years earlier and discovered the surprising diversity of these beautiful, somewhat enigmatic objects.

Now, thirteen years later, I value my role as a coordinator more than ever. Along the way, I've had the opportunity to author the Binocular Double Star and Advanced Binocular Double Star Observing Programs. The former has proved extremely popular, as League members love binoculars and their fine performance on double stars.

Coordinating an observing program requires commitment to the Astronomical League and fellow members. Good organizational skills and attention to detail are necessary, including maintaining records, carefully reviewing observing submissions, timely issuing and mailing of awards, and reporting quarterly activity for publication in the *Reflector* and the online database. But that commitment is small compared to the benefits I receive from being a coordinator.

A key reward I did not anticipate is that it's a marvelous opportunity to become involved in broad-based astronomy outreach. There are occasions to assist others better understand and enjoy the hobby, and, in turn, coordinators are enriched by getting to know highly experienced, knowledgeable observers from across the country and abroad. Occasionally, there are chances to help foster relationships between individual observers with similar interests or geographic commonalities, particularly in support of members-at-large, who are extremely active in the programs.

Over the years, I have had the privilege of making the acquaintance of members whom I will never personally meet. Long after completing one of my programs, I take pleasure in someone updating me concerning their ongoing observing activities.

However, my greatest reward is not only the thoughtful thanks I often receive for being a coordinator, although these are much appreciated. The true reward is reading reports of individual member experiences slipped into their emails and log notes. These indicate to me the ways, in addition to receiving a certificate and pin, that these programs contribute to members' personal fulfillment and how much amateur astronomy enhances their lives:

"Nice taking a break from chasing faint fuzzies with the 14-inch. Fun to relax with my trusty 20×80s in a comfy camping chair to check out these gems."

"It took me three tries to split this close pair, but I finally steadied myself against a tree and there they were! Yippee, cocoa time!"

"I pretty much looked at the same globs every time I got out the scope. Never knew about how many there actually are & how really different they look. Good stuff!"

"Tonight I finally bagged NGC 5466 – feel kind of proud. Wish dad could have been here."

As the number of Astronomical League Observing Programs grows every year, so does the necessity of having dedicated members step up to become Observing Program coordinators. Enrich your commitment to amateur astronomy. Aaron would love to hear from you!

Clear Skies!

—Bob Kerr

The Obsessed Astronomer And Her Husband: Chasing the Occultation

By Jerelyn and Paul Ramirez

The hype of the Moon–Mars occultation was something I was telling my friends and colleagues about, including my family and non-astronomy friends. After eagerly awaiting this moment for nearly a year, December was finally here.

I checked the weather forecast for my area daily, and it showed the expected conditions to be less favorable every time I checked. It looked as though I was going to miss this rare cosmic event. The forecast looked grim: clouds, rain, and fog for most of Kansas. I live in northeast Kansas near Topeka.

Watching the radar on December 7, the clouds and rain were coming from the southwest, swirling clockwise near the Kansas–Nebraska border towards Missouri. Yes, we were totally socked in.

My husband, Paul, called at 3:30 p.m. as he clocked out at work while I was monitoring the radar. I floated the idea of driving north to Nebraska to see the occultation. He was all for it. We planned to drive north towards Lincoln, Nebraska. At that moment, it was clear there and the edge of the clouds was staying near the Kansas–Nebraska border.

As Paul was driving home from work, I gathered up a small f/4 4.5-inch reflector on a Dobsonian mount and two pairs of binoculars, and got my cold weather gear and a change of clothes so we could stay the night in Lincoln, a 2.5-hour drive north from our house.

Paul and I went to a local diner after he got home to get something to eat and plan our strategy before heading north to Nebraska. We would get to Lincoln with an hour to spare before first contact of the occultation.

The clouds were relentless. I kept watching the radar on my phone as Paul drove. An hour into our drive, the swirl of clouds started to migrate north. We could see clear skies to our north and west, with clouds overhead in the twilight. I could see the light from the full Cold Moon illuminating the clouds, but nothing more. The clouds started to break up a little at the edge between clear skies and clouds. The Moon started to intermittently peek through for a few moments as we headed north, but the clouds followed us all the way to Lincoln.

The altocumulus deck began to break up a little more until I could see Mars intermittently through the clouds, just below the Moon. We still had an hour before first contact. We could see clear skies to the north, but we couldn't drive fast enough to get out from under the clouds. We pushed on west from Lincoln and ended up in Milford. Time was running out. We pulled over near a construction site and watched the Moon move closer and closer to Mars through our binoculars between the clouds.

We brought some low-power binoculars with us, 8×42 and 10×42, for steady handheld views. They did rather well. Because of the clouds moving east in front of the Moon, it gave the optical illusion of Mars appearing to chase the Moon, getting ever so close. It was an interesting effect as it gave it the appearance of motion.

We had first contact at 8:53 p.m. Central Standard Time near Mare Orientale, and second contact followed one minute later. Wow, we saw the Moon pass in front of Mars through the altocumulus clouds! We were excited. Now we waited for Mars to reappear.

We then drove back to a gas station we had passed to get some coffee, since we had to wait about an hour for third contact. The temperature outside was 27 degrees.

We parked where we could see the Moon from the front of the car. About 15 minutes before third contact, we set the little tabletop telescope on the hood of the car. The rubber feet kept it from sliding off the hood. The Zhumell telescope has a small 2-inch lunar portal in the dust cover to limit the light from the full Moon from entering the telescope. The portal is on axis so even the secondary mirror blocked some of the light from the Moon. It is a great lunar filter. We used a zoom eyepiece that would go from 8 to 24 mm. I targeted the Moon through the red-dot finder, got it in focus, and zoomed to a comfortable magnification. We were ready.

By now the sky had completely cleared all around the viewing area. We could see Orion and the star Aldebaran in Taurus. I was watching through the eyepiece of the telescope waiting for Mars to make a showing. And there it was, the Moon gave birth to a red Mars pimple at 9:55 p.m. right next to Mare Australe. A minute later, Mars was free from the Moon's limb.

We drove 154 miles to see the Moon–Mars occultation, but it was definitely worth it! This was the second occultation I have witnessed during my amateur astronomy journey. The first was on November 30, 2001, in Rose Hill, Kansas. I had just bought my first telescope, an f/8 4.5-inch reflector on an altazimuth mount. I saw Saturn disappear behind the full Moon at around 6:42 p.m. CST. Saturn and the Moon were in the constellation Taurus. At the time I didn't know this was a rare event. It was serendipity. ✶

THE ELUSIVE PROPELLER IN GLOBULAR CLUSTER M13

By Roger Ivester

During the summer, the great globular cluster M13 is located high overhead for observers in the northern hemisphere, allowing for excellent viewing. Observing this cluster back in 1977 with my 4¼-inch f/10 reflector, the most I could see was a moderately bright ball of unresolved stars.

While observing M13 with that small reflector, I was unaware of the three dark lanes cutting into the southeast edge of the cluster, called the propeller. I'd never heard of the propeller at that time, and this scope was far too small to reveal this very faint feature. However, 32 years later, in May 2009, using a much larger telescope, I saw it. A 10-inch telescope might be considered the minimum aperture required to see this most unique shape. If you have plans to observe the elusive propeller, the optimum magnification seems to be around around 200×.

Lord Rosse mentioned three dark rifts in the 1850s, and T.W. Webb in *Celestial Objects for Common Telescopes* noted that the lanes were seen by Buffham, using a 9-inch reflector. The propeller challenge became popular due to Walter Scott Houston, writer of the monthly "Deep-Sky Wonders" column, which ran in *Sky & Telescope* magazine from 1946 to 1994. Houston first wrote about the dark lanes in the July 1953 column. And although he brought it up several more times throughout the years, the propeller has gained much attention in the amateur astronomy community only recently.

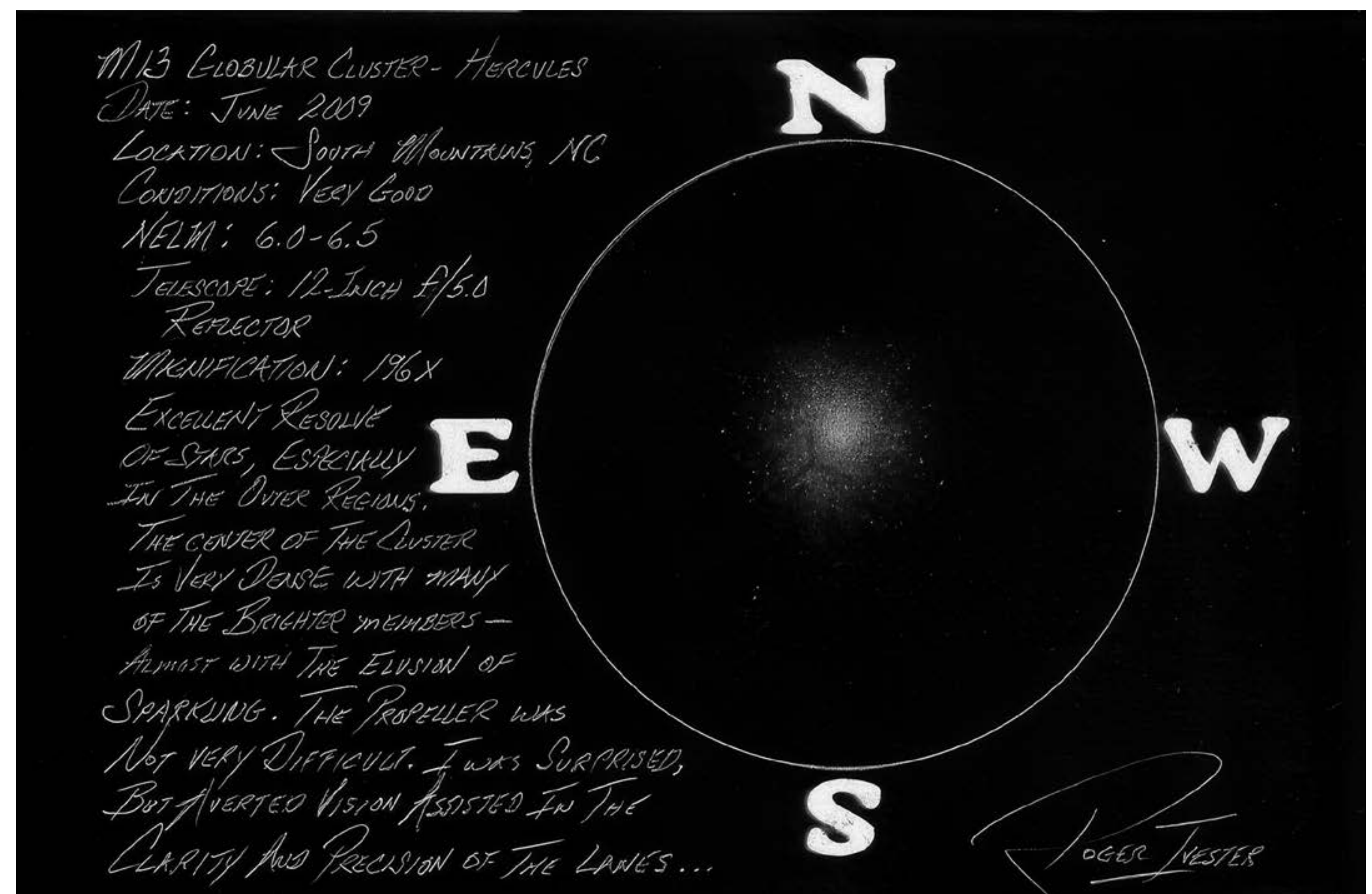
John Bortle saw the lanes in 1980 using a 12.5-inch Newtonian reflector at 176×. During the 1981 Stellafane Convention, Dennis di Cicco was surprised by how easily the lanes were seen with the 12-inch f/17 Porter turret telescope at about 180×. Both Bortle and di Cicco commented on the importance of magnification.

In May 2009, I was able to observe the propeller with 10- and 12-inch reflectors. My observation of the cluster with the 12-inch came from the southern rim of the South Mountains in North Carolina. I would rate this site as very good with a naked-eye limiting magnitude of 6.5, and maybe even better on an excellent night.

The propeller was fairly easy to see with the 12-inch f/5 reflector from the dark site. Seeing it, however, proved very difficult using a 10-inch f/4.5 reflector from my moderately light-polluted backyard with a limiting magnitude of about 5.0 or slightly less.

The following sketch was made using a 12- inch f/5 reflector at 190×, with nothing more than a No. 2 pencil and a blank 5×8 note card. The colors were inverted using a scanner. ✶

Further Reading: *Deep-Sky Wonders* by Walter Scott Houston, selections and commentary by Stephan James O'Meara. Sky Publishing Corporation, Cambridge Massachusetts.



ULTRAMASSIVE BLACK HOLES

The first direct visual image of a black hole shows the one at the heart of M87. The image was captured by the Event Horizon Telescope, a planet-scale array of radio telescopes collaboratively gathering precisely synchronized data. The dark central area is the shadow cast by the blak hole, about 2.5 times larger than the black hole's actual event horizon, which is more than three times the mean diameter of Pluto's orbit. For more information, see note at the end of this article. Credit: Event Horizon Telescope Collaboration.

THE MOST MASSIVE MYSTERIES IN THE UNIVERSE

by Dave Tosteson

The sensory organs of our bodies have an amazing range of diversity and sensitivity. Retinal cones detect wavelengths of light from the deep blue to the far red, and its rods can detect a single photon. Nerve cells in our skin feel the warmth of infrared radiation, and ultraviolet light triggers pigment cells to produce melanin that tans and protects us. I felt the gentle tingle of electricity ascending through my hiking boots when caught on a bare mountaintop in a thunderstorm's lightning strike that was, thankfully, just far enough away. We can even indirectly detect gravity or, more precisely, the effect it has on our body through our inner ears, joints, and circulatory system.

Our senses have evolved and adapted to living in Earth's environment, so there has been no need or survival advantage over the millennia to detect most types of radiation. Starting with Galileo's amplification of visible light in the early 1600s, to the nineteenth century's discoveries of different wavelengths of electromagnetic radiation, to the findings of neutrinos in underground observatories and those of sophisticated space telescopes, humans have multiplied their sensory capabilities by orders of magnitude. In 2015, the culmination of over half a century of work detected gravitational waves from black holes for the first time, by positional shifts in space smaller than the diameter of a proton.

Black holes are thought to come in four types. Primordial black holes may have formed immediately after the Big Bang, but none have yet been detected. Stellar mass black holes such as Cygnus X-1 were the first type identified, and attain up to about a hundred solar masses. The gravitational wave telescopes LIGO and VIRGO proved that black holes grow larger through merging. The third species is intermediate mass (IMBH), with a range of a few hundred to a few hundred thousand times solar. They proved elusive, but a number of them have recently been identified. Their higher gravities with increased speed of accretion produce hard X-rays, allowing them to be seen in galaxies to distances of tens of millions of light-years. I have observed the hosts of several IMBHs, including the 300,000 solar mass core of the dwarf Seyfert galaxy NGC 4395.

The final type is those with over a few hundred thousand, some say over a million, solar masses. They are called *supermassive* black holes (SMBH), the most massive objects known. Nearly all spiral and elliptical galaxies have been found to host such a gargantua in their centers, as well as some dwarf galaxies as M32. Irregular galaxies often lack central black holes, and there is a likely correlation, because the origin and continuation of a spiral pattern from the central SMBH anchor maintains the integrity of the rotation. Without it, asymmetric, spiralless structures such as the Small Magellanic Cloud or IC 10 may form. In galaxies that are gravitationally interacting, such as the Mice (NGC 4676) or the Antennae (NGC 4038 and 4039), this pattern is disrupted, and the central black holes may wander about the newly forming elliptical galaxy, eventually merging or being ejected.

One of the great current mysteries of our universe relates to the size of black holes at the center of galaxies. The first stars that formed a few hundred million years after the Big Bang (ABB) were thought to have attained very high masses, up to a few hundred times that of our Sun. They quickly burned through their fuel to go supernova, leaving black hole cores that were large compared to those made by the less massive stars of today. These first-generation stellar mass black holes were up to one hundred times the Sun's mass. In that dense early environment, they were surrounded by the gas of their nurseries, and formed accretion disks of swirling matter upon which they fed. The friction and energy of this infalling matter heated them and caused their central portions to glow in visible, ultraviolet, and X-ray radiation, making them small scale congeners of their SMBH cousins that became active galactic nuclei (AGN). If the viewing angle toward us is tipped, their accretion disk will be seen from Earth as a quasar. If they are partially or completely obscured from our vantage by the dusty torus that surrounds the disc, we will note a Seyfert or an ultraluminous infrared galaxy, respectively.

In the last few decades, careful studies with instruments able to weigh the mass of these galactic cores have discovered a problem: *ultramassive* black holes with masses over *ten billion* solar that were too large to have formed in the time given by the processes now understood. Ton 618 has the highest known mass, suggesting an enormous value of sixty-six billion solar masses. This is greater than that of all the stars in the Milky Way (64 billion), and sixteen thousand times more than our galaxy's central black hole, Sagitarius A*, which has four million solar masses.

Studies have found quasars at a redshift of 7 (only one billion years ABB) with SMBHs of a billion solar masses or more. The brightest quasar in the early universe was SDSS J043947.08+163415.7. It had a luminosity of 600 *trillion* times solar, and the Atacama Large Millimeter Array (ALMA) in Chile determined it to be a compact ultraluminous infrared galaxy with a central SMBH of a few hundred million masses. Much larger central black holes would form just a few billion years later. With the theoretical restrictions of how fast they should have been able to grow, there should not have been enough time since they were formed to attain such a high mass. The constraints on growth stem from what is called the Eddington limit, named for the British astronomer Arthur Eddington. There is a balancing point where the energy generated by the infalling matter equals that of the gravity pulling it in. This is similar to what keeps a main-sequence star at a stable size. As often happens in science, this "That's odd!" moment caused theorists to don their thinking caps to explain the conundrum.

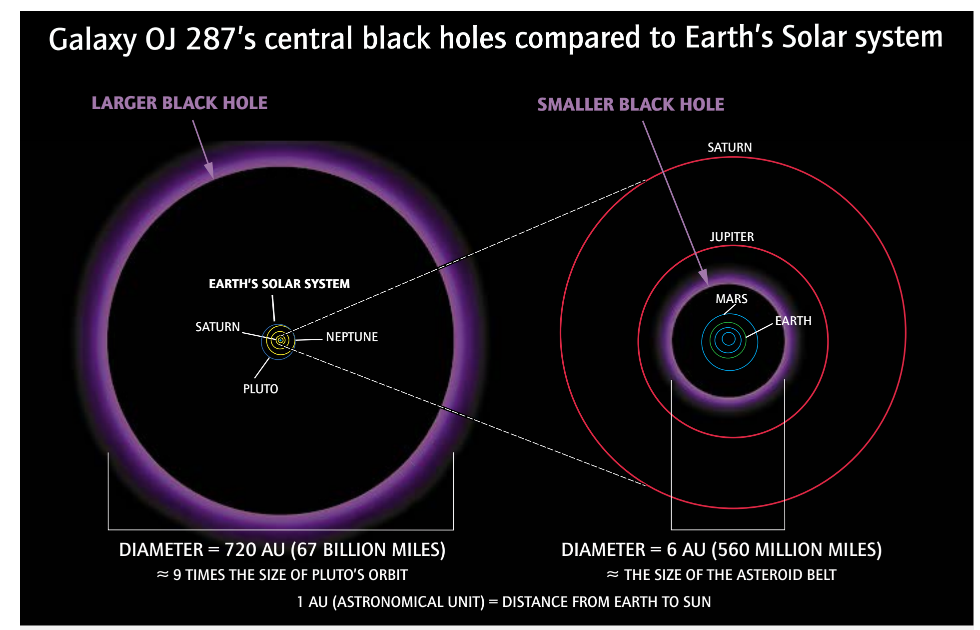
The literature was soon rife with ideas on how rapid growth of black holes may have occurred in the early universe. Mergers of massive stars, mergers of stellar mass black holes, dark matter accretion, new disk-dynamics, and even direct collapse of both stars and giant molecular gas clouds with thousands of solar masses into black holes without first forming a star were all proposed. In 2015, a star with 25 times the mass of the Sun that should have gone supernova vanished without a trace in the spiral galaxy NGC 6946, just 22 million light-years from us. Enough examples of this shady behavior have been found to estimate that 10 to 20 percent of massive stars may collapse directly into black holes.

The usual restrictions on the growth potential of central black holes may not be universal. The late Israeli astronomer Tal Alexander published a 2014 *Science* article suggesting a process he called "supra-exponential growth" may have allowed rapid increase of black hole mass in the early universe, paving the way for SMBH formation in that epoch. At redshifts greater than 15, or only two hundred million years ABB, the density of the universe was high and its angular momentum was low. This may have inhibited the usual formation of accretion disks around the "equator" of some black holes, allowing direct flow of matter onto a larger portion of their spheres. Alexander and his team suggested this hypothetical process allowed SMBHs to grow to tens of thousands of solar masses in just ten million years.

Computer simulations offered intriguing ideas on solving the growth problem. John Regan of Dublin City University in Ireland heads the SmartStars project, which attempts to show how supergiant stars could seed early SMBHs. He thinks that black holes up to 250,000 solar masses could form by 200 million years ABB. Muhammad Latif of the United Arab Emirates University in Abu Dhabi is the principal investigator of the FIRSTBHs project, and his simulations agree that seed black holes of "hundreds of thousands of solar masses" are large enough to account for SMBHs of up to a billion solar masses in a "small time frame." He felt that fairly specific criteria were needed to achieve this, including higher densities and amounts of hydrogen and helium in small volumes, and accretion rates of at least 0.1 solar masses annually.

Observations attempting to confirm some of these theories include findings of AGNs in dwarf galaxies at a higher prevalence (3 to 16 percent) than previously thought. These small galaxies are the building blocks of large spirals. ALMA saw a thick ring of gas and dust around a SMBH in a distant galaxy. In August 2019, the X-ray telescope Chandra saw a "cloaked black hole" growing rapidly only 700 million years ABB. The James Webb Space Telescope may have the power to spot seed black holes, and the European Space Agency's Athena mission scheduled for the early 2030s will study them at high energies.

What will amateur observers be able to see of these distant behemoths? Fortunately, the ones powering accretion discs and quasars are the most energetic objects known. The gravitational and hydrodynamic forces surrounding SMBHs can cause material to be ejected along their rotational axes. These jets proceed at nearly the speed of light and a few are visible in amateur telescopes, such as ones I have seen in M87, Centaurus A, and 3C 273. In the ever-changing pantheon of the largest or the brightest, here are three current contenders for the title of most massive



Two supermassive black holes are locked in an orbital dance at the core of the distant galaxy OJ 287. This diagram shows their sizes relative to the Solar System. The larger one, with about 18 billion times the mass of our Sun (left), would encompass all the planets in the Solar System with room to spare. The smaller one is about 150 million times the mass of our Sun (right), which would be large enough to swallow up everything out to the asteroid belt, just inside the orbit of Jupiter. Credit: redrawn by Reflector *staff after diagram by NASA/JPL-Caltech/R. Hurt (IPAC); caption also theirs.*

SMBH. In the first corner is S5 0014+81, a 16.5-magnitude blazar in northern Cepheus. This object has its jet pointed straight at us, maximizing its brightness. Its redshift of 3.66 gives it a light travel time of 12.1 billion years. It was discovered in 1981 and was the largest known SMBH for several decades. With forty billion solar masses, it has the same mass as all the stars in Messier 33. It carries an absolute magnitude of −31.5 and has a luminosity 300 *trillion* Suns, or 25,000 times that of the Milky Way. Its event horizon is eight times larger than our Solar System's Kuiper belt. I observed it at the 2017 Okie-Tex Star Party using my 32-inch reflector with Tim Parson and Barbara Wilson. It was stellar.

Next up is MS 0735.6+7421, a 17.7-magnitude quasar in Camelopardalis. It's famous as the site of the (former) most powerful explosion ever seen. Studies found that its central AGN was active for over a hundred million years, and produced the equivalent energy of *hundreds of millions* of gamma ray bursts (10^{55} Joules). Astronomers calculated that the MS 0735 black hole accreted six hundred million solar masses to produce this event. Its SMBH weighs in at 51 billion solar masses, and a 20-inch telescope should be able to spot its stellar-appearing quasar that is relatively near at 2.6 billion light-years away. Showing the ephemeral nature of supremacy, a more powerful explosion called NeVe1 was uncovered in 2016 near the host supergiant elliptical galaxy in the heart of the Ophiuchus Supercluster. This similar event (that has now quieted down) was five times more powerful than that from MS 0735, and manifested as a "dent" in the X-ray envelope of the central galaxy. I was able to see its central cD galaxy with difficulty, as it sits behind the plane of the Milky Way, using my 32-inch telescope from my home in 2022.

The current heavyweight champion for ultramassive black holes, Ton 618, is a true monster. It was discovered in 1957 at the Tonantzintla Observatory, southeast of Mexico City near the town of Puebla. The site name was derived from a native Nahuatl female deity, and its survey for faint blue stars was performed by Braulio Iriarte and Enrique Chavira using a 0.7-meter reflector. Spectroscopy done at McDonald Observatory in west Texas confirmed that it was a high redshift (2.218) QSO/AGN, placing it 10.8 billion light-years away. Its apparent magnitude is 15.9, and its absolute magnitude of −30.7 makes it a little less luminous than S5 0014 above, but still 140 trillion times that of our Sun. In the last several years there is data that a *gargantua* near or exceeding 10^{11} solar masses exists at the core of the Phoenix cluster, within its central galaxy called Phoenix A. Stay tuned.

Ton 618 and its ultramassive, distant brethren can be used as lighthouses to probe intergalactic space between them and Earth. Their energetic radiation can be used to study details of the intervening material, including molecular clouds, dark matter galactic halos, and even imprints of primordial sound waves from the early universe. On the evening of April 28, 2022, just before midnight, light from this most massive single object known in the universe entered my 15-inch reflector in west Texas and was focused onto my left retina. Its few photons made an indelible impression on the rest of me. ✶

DATA

S5 0014+81: 00h 17m 08.5s, +81d 35m 08s.
MS 0735.6+7421: 07h 41m 50.2s, +74d 14m 51s.
Ton 618: 12h 28m 24.9s, 31d 28m 38s.

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Dye et al.: arXiv, *1707.09975, 23 Oct. 2017.*
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NOTES ON THE FIRST DIRECT BLACK HOLE IMAGE

The Event Horizon Telescope image at the beginning of this article is the first direct visual evidence of the supermassive black hole in the center of Messier 87.

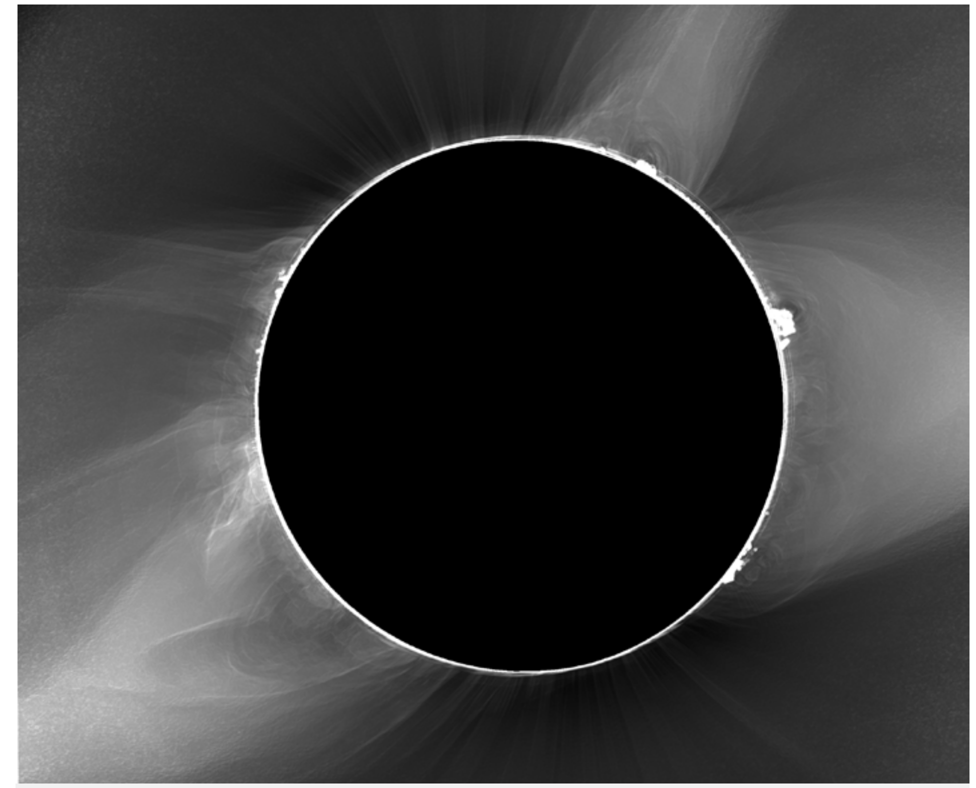
The shadow of a black hole seen in the image is the closest we can come to an image of the black hole itself, a completely dark object from which light cannot escape. The black hole's boundary – the event horizon from which the EHT takes its name – is around 2.5 times smaller than the shadow it casts and measures just under 40 billion km across. While this may sound large, this ring is only about 40 microarcseconds across – equivalent to measuring the length of a credit card on the surface of the Moon.

Although the telescopes making up the EHT are not physically connected, they are able to synchronize their recorded data with atomic clocks – hydrogen masers – which precisely time their observations. These observations were collected at a wavelength of 1.3 mm during a 2017 global campaign. Each telescope of the EHT produced enormous amounts of data – roughly 350 terabytes per day – which was stored on high-performance helium-filled hard drives. These data were flown to highly specialised supercomputers – known as correlators – at the Max Planck Institute for Radio Astronomy and MIT Haystack Observatory to be combined. They were then painstakingly converted into an image using novel computational tools developed by the collaboration.

Find more information at *eventhorizontelescope.org*

—The Event Horizon Telescope Collaboration (edited)

The DEB Initiative



High dynamic range image results from the 2017 Citizen CATE Experiment show fine details in the inner corona. The DEB Initiative's equipment will provide an even wider field of view.

By Matt Penn

The last two years have brought us four wonderful lunar eclipses. Now we enter a season of solar eclipses. There will be total and annular solar eclipses in both 2023 and 2024. With that in mind, who's ready for some eclipse science?

More than 215 million Americans watched the 2017 total solar eclipse. The highly successful 2017 Citizen CATE (Continental-America Telescopic Eclipse) Experiment organized and trained over 280 volunteers to operate 70 observing sites and capture 90 minutes of white-light images of the inner corona. The team published heliophysics science results on the acceleration of coronal mass materials and made data and software publicly available, and in the years following the eclipse, the team published exoplanet observations and ran other projects using the telescope equipment.

Scan this QR code to visit the DEB Initiative website.

Now a new citizen science eclipse project is underway. The DEB Initiative is led by Matt Penn, also the principal investigator and project lead for Citizen CATE in 2017. DEB stands for the **Dynamic Eclipse Broadcast**. The project will follow in the footsteps of the CATE Experiment while adding some ambitious new goals. We are hoping that some of you will join us.

The DEB Initiative will include observing sites inside and outside the path of totality in April 2024. Similar to 2017, observing sites will be evenly spaced along the path of totality. Teams within totality will gather data-quality images of the Sun's inner corona. Researchers will use this data to measure the velocity and acceleration of material in the inner corona, including any coronal mass ejections.

Observing teams outside the path of totality also play a key role in this research. They will monitor the Sun's surface, or photosphere. Interactions between the photosphere and the inner corona are poorly understood. Simultaneous data from both the corona and the photosphere is vital when it comes to exploring how structures in the corona arise. With the 2024 total solar eclipse being close to solar maximum, there should be lots of activity to look at!

You might be wondering why we can't simply use images from other sites or space-based observatories such as the Solar Dynamics Observatory (SDO), Solar and Heliophysics Observatory (SOHO), or even the Parker Solar Probe. The SDO does not experience total solar eclipses because of its specific orbit. SOHO is only designed to observe the outer corona and Parker can only focus on small regions at a time. Also, as with any good science experiment, controlling variables is key. Having all observing sites using identical equipment greatly reduces the complexity of analyzing the data.

Yes, you read that right: you may be able to help us collect data that is not accessible by NASA satellites.

Citizen CATE involved 70 observing sites strictly inside the path of totality. Totality will last longer in 2024, requiring fewer sites along the path of the Moon's shadow. The goal is approximately 40 observing sites using updated equipment, evenly spread along the eclipse's path, and another 40–60 sites outside of totality, spread across the rest of the continent.

The DEB Initiative has already been working for two years to establish a new equipment

Matt Penn, seen here training Sienna High School students during the 2017 Citizen CATE Experiment, is also leading the DEB Initiative for 2023–2024. Many observing sites in 2017 were run by teachers and students.

package, which will be less expensive, faster, and better than the system used in 2017. It should function as an excellent introductory setup for new astronomy enthusiasts, and it will be an excellent guide scope upgrade for veteran astro-imagers. There are plans to test this package in Australia during the April 20, 2023, total solar eclipse.

The annular solar eclipse on October 14, 2023, in the United States will be the first large-scale test for the DEB Initiative. While there is not as much solar science to accomplish during an annular eclipse, the team will examine the ability to measure structures along the lunar limb using parallax, made possible by widely separated observers. It will also be a wonderful opportunity for public education and outreach.

All of this adds up to great science and an enjoyable experience for those involved, but you may notice that none of it explains the project's name. This will be a Dynamic Eclipse Broadcast, meaning that images from all the observing sites will be broadcast live during the eclipses this October and in April 2024. Images from each site will be loaded onto a map once each minute. Anyone will be able to use the DEB Initiative's website to see the eclipse in progress at all observing sites simultaneously.

This is a citizen science project, so we hope a number of you will join us. The DEB Initiative is looking for both participants and financial contributions. Many members of the CATE Experiment in 2017 were high school and college teachers working with their students, and we hope that will be the case again in 2023 and 2024. Many astronomy clubs are active in astronomy outreach and lament how few young people are active in their clubs. We hope you will consider sponsoring a site or partnering with a local school. You will be trained on how to use the equipment and there will be follow-up projects involving solar, exoplanet, asteroid, and variable star observations, giving everyone the ability to continue to participate in citizen science after 2024.

If you are interested in learning more or signing up as a participant, visit *DEBinitiative.org* for details or contact Matt Penn at *debinitiative@gmail.com*. ✶

QUESTIONS ABOUT LIGHT THAT KEEP ME AWAKE AT NIGHT

By Jai Shet

The nature of light gives me spine-tingling chills. The more questions we ask, the stranger our answers seem to get. Why is light both a wave and a particle? Can light travel any faster? How is light affected by gravity? Generations of people came up with explanations more eccentric than the questions themselves. These questions keep me awake at night, and I hope they interest you, too.

IS LIGHT A WAVE, A PARTICLE, OR BOTH?

Light behaves like a particle in some experiments and a wave in others. Sir Isaac Newton (1642–1727) pondered the idea of light as a particle during a time when the nature of mundane things – such as why things fall toward the ground – was taken for granted. He observed that light traveled in straight lines and theorized that it was packed into tiny corpuscles of energy. On the other hand, Christiaan Huygens (1629–1695) believed light was instead a wave emanating from its source. Later, a British scientist named Thomas Young (1773–1829) tested Huygens' theory of light by devising the now famous double-slit experiment. The British physicist shone filtered light through a piece of cardboard with two slits cut into it. Young observed a diffraction pattern on the projection screen, one that could only emerge from wave interference. This discovery challenged Newton's corpuscle theory of light and sparked heated debate within the scientific community. Many refused to believe Newton was wrong on this aspect of light. After all, it took only a piece of card with two slits to prove that light was a wave.

These discoveries are the very basis of a scientific tool called photoelectron spectroscopy. Much of the universe may have remained a mystery if not for spectroscopy. Astronomers now use it to analyze the chemical compositions of planets, stars, and more. Spectroscopy works because light carries signatures that mark the identity of the elements we observe. When light passes through the atmospheres of exoplanets, we can study their signatures – dark bands in the spectrum – and determine their chemical compositions. Each element has a unique dark-line signature on the spectrum which helps us study the chemistry of heavenly bodies and much more.

However, the paradox of light did not end there. The photoelectric effect showed that light could be a particle, too. In 1887 German physicist Heinrich Hertz first demonstrated this effect; shining ultraviolet light on a metal plate generated sparks, as electrons were knocked out of the metal's atoms. The surprising aspect was that a brighter beam of light produced more electrons but they didn't have more individual energy, while increasing the frequency of the light resulted in the same number of electrons carrying more energy each. Albert Einstein (1879–1955) revisited the photoelectric effect and discovered that a wave model of light could not properly explain why it caused electrons to fly from the metal. He concluded that light must also have particle-like properties to justify this behavior, and for this discovery Einstein won the Nobel Prize in Physics in 1921. But much earlier work, the treatise *A Dynamical Theory of the Electromagnetic Field* by James Clerk Maxwell (1831–1879) had rigorously explained how light behaved in terms of mathematics. These equations related the speed of light and properties of electricity and magnetism, giving birth to the term electromagnetic radiation.

WHAT COLOR IS THE SUN?

The seemingly obvious answer to this question is unsettlingly wrong despite its intuitiveness. We cannot look directly at the Sun to determine its color, so why bother asking if it appears yellow in our peripheral vision? It turns out the Earth's atmosphere alters our color perception of the Sun. Our atmosphere preferentially scatters green, blue, and violet wavelengths while allowing more red, yellow, and orange wavelengths to pass through, giving white light from the Sun its warm tint. If we go to outer space, the Sun appears colorless. View any International Space Station camera and you will see that this is true. Earth's atmosphere has been deceiving us all along! Then why are photographs of the Sun taken with telescopes often a deep shade of red, yellow, or orange? Often, this is due to narrow-band filters, such as hydrogen alpha filters (red) in Solar telescopes. Photographers also may digitally add color to monochrome images to match our cultural perception of the Sun as a warm-colored star, matching what our eye expects to see. Despite Earth's atmosphere, we are deceiving ourselves after all!

CAN LIGHT TRAVEL FASTER THAN THE COSMIC SPEED LIMIT?

Light travels at a constant 670,616,629 miles per hour in the vacuum of space. That is the cosmic speed limit. Travel any faster than that, and you violate the laws of physics. Rest assured there are no cosmic authorities ready to give you a speeding ticket if you happen to travel faster than light. It's just that no object can travel faster through the vacuum of space on its own. However, our universe is expanding at ever increasing speeds. This means there are areas in space expanding faster than the speed of light relative to other areas. Contrary to our intuition, the expansion of space itself does not cause light to slow down or speed up. Instead, the wavelength of light simply stretches or compresses. When a galaxy moves away from us at a high speed, its light stretches and becomes redder – it redshifts. If a galaxy moves toward us, its light compresses and gets bluer – it blueshifts. The expanding fabric of the universe merely affects the wavelength of light but not its speed. Not even light can ride the expanding universe and break the cosmic speed limit.

ARE BLACK HOLES LIKE VACUUM CLEANERS?

Light gets stranger still. From Newton's laws of physics, we know that gravity attracts anything with mass. But if light is massless, how does it get trapped by a black hole? According to Einstein's general theory of relativity, black holes warp the fabric of space-time, causing light to follow a curved path. In other words, they distort the space around them, much like a bowling ball would do to a trampoline if placed on it. The cloth around the bowling ball would bend, causing, for example, a plastic ball to roll into the divot. This is how a black hole works, except that light strangely behaves like our plastic ball, following the curves of spacetime. But black holes do not simply suck in light like a vacuum cleaner; they only distort the area around them.

Conservation of momentum helps to explain why a black hole cannot immediately suck in all matter in its vicinity. Objects moving through space have momentum, and tend to continue their motion unless acted upon by an independent force. This is similar to why the planets orbit our Sun instead of falling into it. Black holes are surrounded by accretion disks, gas and dust particles trapped on a merry-go-round, but one in which the horses interact with each other, creating friction. These particles initially revolve around the black hole instead of immediately getting sucked in, but over time the orbits of the individual particles decay, and the black hole accretes material, increasing its mass. So, black holes are not like sharks roving through the universe, and are only "dangerous" if they exist in your immediate neighborhood.

WHAT IS THE LARGEST KNOWN TELESCOPE?

The largest telescope is not China's Five-Hundred-Meter Aperture Spherical Telescope (FAST) or Russia's 576-meter RATAN-600 radio telescope, it is one that uses the effects of gravitational lensing to magnify distant objects. Sometimes we see gravitational lensing effects in images of massive galaxy clusters. The combined mass of these clusters creates a gravitational field so strong that they magnify distant objects like a lens. This profound discovery helped prove that light's path can bend due to gravity, as in the case of the black hole–trampoline analogy I discussed earlier. In fact, researchers found a gravitational lens in a galaxy cluster composed of thousands of individual galaxies named Abell 2218 that magnifies a faint galaxy 13.4 billion light-years away. If only we could somehow shift our perspective to point this "gravity-scope" in different directions—what a telescope that would be!

CAN WE LOOK BACK IN TIME?

Could we travel faster than the speed of light and look back in time? This question has kept me wide awake at night because I cannot help but think about this possibility. Imagine traveling from Earth and you surpass the cosmic speed limit. You reach a point in space where you can observe streams of photons that left the Earth 65 million years ago. These photons carry information from when the dinosaurs were alive. If you had an infinitely powerful telescope allowing you to observe Earth in high resolution from 65 million light-years away, then you could observe the dinosaurs roaming our planet! Similarly, if you teleported 4 billion light-years away (assuming you had the technology to observe Earth from that distance), instead of seeing Earth as the blue planet it is today, you would have seen a mostly volcanic Earth. Maybe faraway aliens have not communicated with us because all they see is Earth as it was billions of years ago. When we look at stars in the night sky, we are observing the light they radiated a long time ago. Some of those stars may even be gone by now, but we are oblivious because their dying light has yet to reach us. If you want to look back in time, peer up at the night sky.

THERE ARE MORE QUESTIONS THAN ANSWERS

Just when we think light could not get any stranger, Einstein's special theory of relativity predicts a concept known as time-dilation: time slows down for a person traveling near the speed of light as measured by a slower moving observer. Questions like these and related mysteries can keep astronomers awake at night, some of us more than others. Sometimes a vivid imagination is all you need to set you on the path to making a great discovery. Einstein was kept awake by the question of how the universe looked to someone riding on a beam of light, and the result was a brand-new way of looking at our universe. Ask strange questions and let strange science guide you. ✶

DID YOU KNOW?

Solar flares play a prominent role in numerous episodes of the BBC sci fi series *Doctor Who*, ranging from "The Ark in Space" (1975) to "Time Heist" and "In the Forest of the Night" (2014).

THE VERMONT ACADEMY CAVE

By Bob Kesler

Miscellaneous equipment in the observatory at Vermont Academy before the Cave's restoration

Astronomy has always been a fascination for me. I was lucky to have an uncle who ground his own mirror and built a telescope, and that must have sparked my interest.

Fast forward 50 years and there I was with my first telescope: a Meade LX50. I thought bigger was better but, alas, that was not the case for me, as it was almost too heavy to move around and set up. I can still see myself at my first star party in Hawaii at Dillingham Field. I arrived in my Ford Ranger with this giant plywood shipping crate, unloaded and set up my instrument with little knowledge and zero experience. There must have been some chuckles from the other members who all had smaller, more portable, but effective telescopes. I don't remember seeing anything that night except for the kind Hawaii Astronomical Society member who helped me not look so ridiculous.

After a few years I realized the futility of my efforts and picked up another Meade: a 10-inch Meade LX200 GPS. I was over the moon with delight and had some wonderful viewing in my own backyard in Hawaii. I was on my way to enjoying a hobby of astronomy, astrophotography, and astronomy outreach with my local astronomy clubs in Germany and later with the Harford County Astronomical Society in Maryland.

Little did I know that in a few years I would play a small part in an astronomical makeover in Vermont.

In 2016, my stepdaughter, Christine Armiger, was teaching environmental science and sustainability at Vermont Academy, a private boarding school in Saxtons River. She was keenly interested in astronomy, having grown up watching and listening to Carl Sagan eloquently chat about the billions and billions of stars. After we had visited a few times from Maryland, she asked if I would be interested in bringing my gear up to Vermont and setting up a star party for her students. I had seen Vermont Academy's roll-off roof Observatory, and it was impressive. However, it had not been used in years. We set up a student clean-up party and went about sweeping and dusting and de-cobwebbing the inside. There were telescope parts, tripods, tubes, eyepieces, cases, and sundry parts lying about on the floor and against the walls. Because I had my own roll-off roof observatory, I was able to figure out how to operate the winch system and the Wi-Fi and, voila, it worked! We had ourselves an observatory! I hung posters borrowed from HCAS and arranged displays from NASA for the students to enjoy. I set up my 10-inch Meade Schmidt-Cassegrain tube on my Losmandy G-11 mount and we were off to a great start tracking and observing planets, the Andromeda Galaxy, globular clusters, and more.

I kept noticing some miscellaneous parts in one corner of the observatory that seemed to go together. I wasn't sure what they were but knew it was some kind of old telescope and mount. I asked the administration if I could take them home to Maryland and they agreed. Well, they sat in my basement for years until I was back at Vermont Academy in 2021 for a star party in the observatory. The new head of school, Jennifer Zaccara, participated and was so interested and engaging that I knew I had to complete the reassembly and restoration of the pile of junk I had discovered back in 2016. I contacted my close friend Buddy Kling who agreed to help me with the electronics restoration – a job in itself! Oh, did I mention that the pile of parts was actually a 1970-ish Cave Astrola 10-inch Cassegrain? A splendid engineering design and beautiful to look at! My friend took the electrical components and I started the restoration with the glass cleaning, cleaning, priming, painting, machining, and replacing all the rusted steel cap screws with stainless steel. The three finderscopes were removed and carefully cleaned. The heavy-duty right ascension and declination bearings were cleaned and regreased, and the 1-rpm 120-volt drive motors were reconnected to their solid aluminum drive housings and brass gear drives. Cleaning and waxing the optical tube assembly and cleaning up all the painted surfaces, priming, and painting was soon completed. Finally reassembling the beast and rough collimation was accomplished with help from HCAS club members. Buddy and I replaced the electrical components and, thanks to his skill, it all worked! Only one little rubber drive coupling had to be replaced.

The author, with a student at the eyepiece of the refurbished Cave Astrola 10-inch Cassegrain

So, in October 2022, six years after seeing that pile of parts, we delivered a freshly restored Cave Astrola 10-inch Cassegrain back to its rightful home in Vermont, into the hands of astronomy teacher Christine Armiger. I was amazed at the excitement and enthusiasm associated with the return of the Cave; it was very gratifying to experience.

The Vermont Academy observatory now has new life and there is even an astronomy class being offered. The students actually seem eager to set down their mobile devices, just for a moment, and brave the clear, cold nights of Vermont to look skyward. I believe they, too, are trying to grasp the meaning and vastness of it all; I just hope it doesn't take them 50 years! ✶

IMAGE COLOR CALIBRATION

Extinction Coefficients and Weight Factors

Figure 1. Image of NGC 5139 without (left) and with (right) atmospheric transmissivity calibration

Stephen J. Maas

With the availability of good telescopes and digital cameras, astro-imaging has become very popular. The Internet is replete with spectacular images of galaxies, nebulae, and star clusters. Interestingly, if you browse through the many collections of images, you'll notice that the appearance of objects can be quite different from site to site. On one site, a particular nebula may appear more bluish, on another more greenish. Artistically, "beauty is in the eye of the beholder," but you might wonder, "What's the *real* color of that object?"

This is where image calibration comes in. By calibrating the raw imagery from your camera, you can correct its color balance so that it displays a realistic representation of the imaged object. This works for both monochrome and color cameras. With a monochrome camera, we use color filters to acquire images in the red, green, and blue spectral bands. With a color camera, the raw color image can be demosaiced or debayered into separate red, green, and blue images that can then be handled the same way as images from a monochrome camera. In either case, the red, green, and blue images need to be calibrated so that, when combined, the resulting color image has the correct color balance.

Color calibration attempts to correct for two factors: the effects of the atmosphere and the characteristics of your imaging equipment. The atmospheric effect is quantified by the atmospheric transmissivity factor, *A*. The light from an astronomical object directly overhead (at the zenith) traverses the shortest optical path through the atmosphere to get to you. As the object gets lower in the sky, its light traverses a longer optical path through the atmosphere resulting in more scattering and absorption. So, the value of *A* decreases as the angle between the object and the zenith increases and we observe that the object gets proportionately dimmer. The rate at which the object dims is controlled by the extinction coefficient, *k*. The atmosphere affects some wavelengths of light more than others – blue light gets scattered the most and red light the least (that's why the sky is blue and the setting sun is red). Thus, the value of *k* will differ for the three spectral bands. As an object approaches the horizon, not only does it get dimmer but also *its color balance changes.*

The value of *A* doesn't change much around the zenith, so if you restrict your imaging to when an object is high in the sky, the resulting atmospheric effects will be relatively small. Sometimes, though, you don't have a choice. In April 2016 I imaged the spectacular globular cluster NGC 5139, Omega Centauri, using a QSI 583 monochrome camera with Baader RGB filters on an Orion 120 mm EON refractor. At my latitude of 33.6°N, this object doesn't get higher than nine degrees above the horizon. **Figure 1** shows two versions of the processed image with and without calibration for atmospheric transmissivity. Like the setting sun, the stars in the uncalibrated version are strongly reddened by their light passing through the atmosphere. This effect has been corrected in the calibrated version, where the cluster appears as if it were directly overhead.

For color calibration, the characteristics of your imaging equipment (camera, filters) are quantified by the weight factor, *W*, sometimes called the "white balance." The amount of signal generated by the sensor in your camera for a given number of photons falling upon it, its "quantum efficiency," is a function of wavelength. Modern camera sensors tend to be most sensitive in the green wavelengths, but the specific spectral response varies among sensors. *W* is also affected by the filters you use with your monochrome camera. This includes the spectral transmissivity of the filters (how much light they pass) and their spectral bandwidth (what wavelengths of light they pass). The same is true for the array of tiny color filters on top of the sensor chip (the "Bayer pattern") in a color camera. Thus, the value of *W* will be different for the three spectral bands and *will be unique for your choice of camera and filters.*

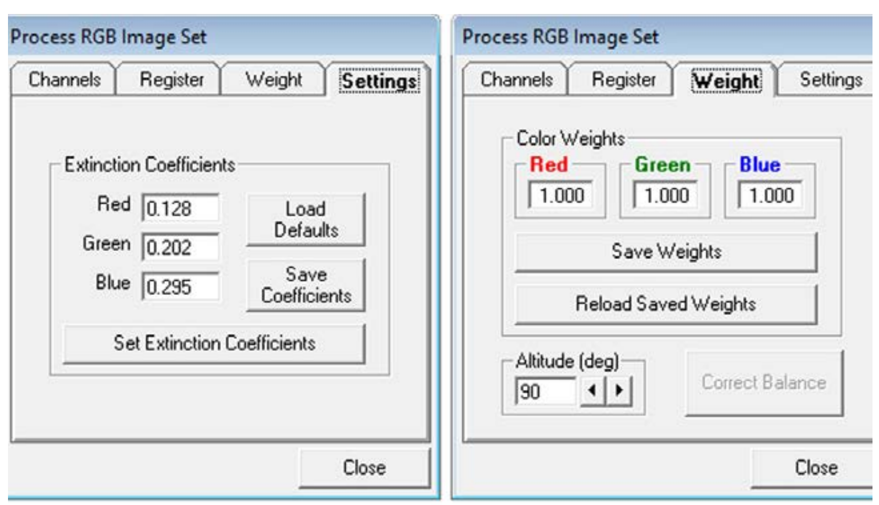


Figure 2. "Settings" and "Weight" tabs from AIP4Win showing default values for *k* and *W*

I've written software that applies values of *k* and *W* to color calibrate my imagery, but most astro-imagers rely on commercially or freely available image processing software. Most of these software packages provide default values for *k* and *W* that you can use in calibrating your imagery. For example, **Figure 2** shows the "Process RGB Image Set" panel from AIP4Win, software that is freely available through the American Association of Variable Star Observers *(aavso.org/aip4win-no-longer-requires-registration).* Under the two tabs, you can see the default values for *k* and *W*. If you want, you can enter your own values for these factors and save them. However, using the default values will usually get you reasonable-looking images that you can later manually adjust to your liking in Photoshop.

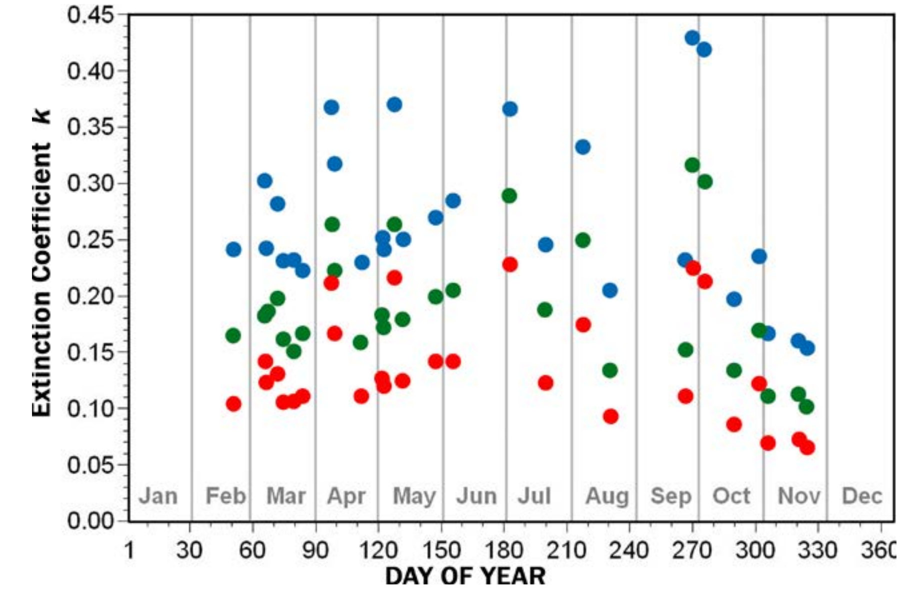


Figure 4. *W* values for the red, green, and blue spectral bands from data collected on 28 clear nights in 2015 and 2016.

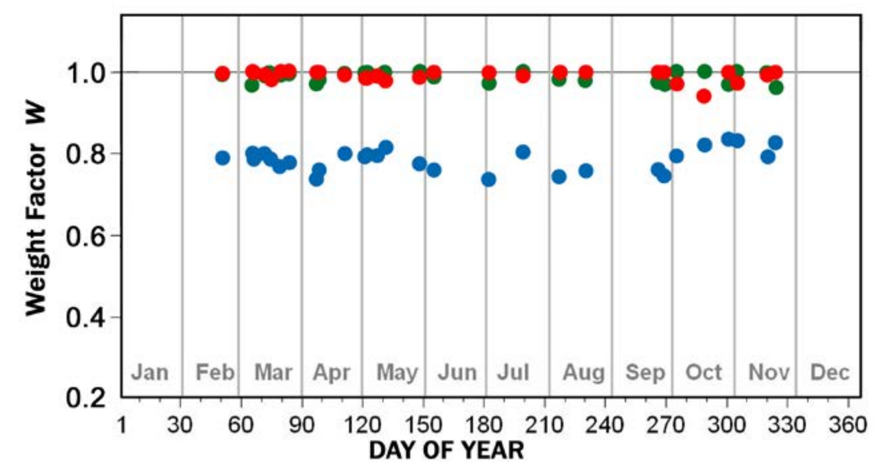


Figure 3. *k* values for the red, green, and blue spectral bands from data collected on 28 clear nights in 2015 and 2016

But if you want to do more than make "pretty pictures" and would like your images to show the true colors of astronomical objects, you'll need to avoid subjectivity in your image processing. This includes supplying your own values for *k* and *W* that represent the atmospheric conditions when you acquired your imagery and the characteristics of your imaging equipment. In an addendum to this article *(cat-star.org/pubs/addendum_2023.pdf)*, I describe how to use astro-imagery to evaluate *k* and *W*. It's not difficult, and it'll give you something to do on those nights where the moon is bright.

So, how much can the values of *k* and *W* vary? To get a handle on this, I evaluated these factors using data collected at my location near Lubbock, Texas, on 28 clear nights during 2015 and 2016, starting in February and running through November. My region has a continental climate and an elevation of around 1 km above sea level.

Figure 3 shows values of *k* for the red, green, and blue spectral bands plotted for the dates on which the data were collected (the color of each point indicates the spectral band). The values showed considerable variation over the course of the year. Larger values tended to occur during summer, when clear nights were typically warm and humid. Smaller values tended to occur in winter, when clear nights were typically cold and dry. But, beyond this seasonal variation, there can be large day-to-day changes in *k* associated with short-term changes in atmospheric conditions. This variability makes using default values problematic for objective color calibration.

Figure 4 shows values of *W* for the red, green, and blue spectral bands plotted in the manner of Figure 3. There is no systematic variation in the values over the course of the year, and day-to-day variations are generally small, not more than about 4 percent. Unlike *k*, it is probably sufficient to use a single, average value of *W* for each of the three spectral bands. If you use the same imaging equipment every time, then this set of *W* values should be okay for all your image processing. You'll still have to determine *W* one time but, after that, you should be able to use those values until you make a change in your equipment.

It's important to note that, because the object you're imaging is constantly changing its elevation in the sky during your imaging session, the value of *A* will be different for each of your raw images. Therefore, color calibration involving *k* should be performed on your images *before* they're stacked. In contrast, since your equipment presumably stays the same during the imaging session, color calibration involving *W* can be performed after image stacking.

So, with a little effort, it's possible to obtain the information to objectively calibrate the color balance of your imagery to show astronomical objects in their true colors without any subjective fiddling with Photoshop. They'll still be pretty pictures but, for a change, realistic. ✶

Press Release

LARGEST POTENTIALLY HAZARDOUS ASTEROID IN EIGHT YEARS DETECTED

An international team using the Dark Energy Camera (DECam) mounted on the Víctor M. Blanco 4-meter Telescope at Cerro Tololo Inter-American Observatory in Chile, a Program of NSF's NOIRLab (National Optical-Infrared Astronomy Research Laboratory), has discovered three new near-Earth asteroids (NEAs) hiding in the inner Solar System, the region interior to the orbits of Earth and Venus. This is a notoriously challenging region for observations because asteroid hunters have to contend with the glare of the Sun.

By taking advantage of the brief yet favorable observing conditions during twilight, however, the astronomers found an elusive trio of NEAs. One is a 1.5-kilometer-wide asteroid called 2022 AP7, which has an orbit that may someday place it in Earth's path. The other asteroids, called 2021 LJ4 and 2021 PH27, have orbits that safely remain completely interior to Earth's orbit. 2021 PH27 is the closest known asteroid to the Sun; during its orbit its surface gets hot enough to melt lead.

"Our twilight survey is scouring the area within the orbits of Earth and Venus for asteroids," said Scott S. Sheppard, an astronomer at the Earth and Planets Laboratory of the Carnegie Institution for Science and the lead author of the paper describing this work. "So far we have found two large near-Earth asteroids that are about 1 kilometer across, a size that we call planet killers."

"There are likely only a few NEAs with similar sizes left to find, and these large undiscovered asteroids likely have orbits that keep them interior to the orbits of Earth and Venus most of the time," said Sheppard. "Only about 25 asteroids with orbits completely within Earth's orbit have been discovered to date because of the difficulty of observing near the glare of the Sun."

Finding asteroids in the inner Solar System is a daunting observational challenge. Astronomers have only two brief 10-minute windows each night to survey this area and have to contend with a bright background sky resulting from the Sun's glare. Additionally, such observations are very near to the horizon, meaning that astronomers have to observe through a thick layer of Earth's atmosphere, which can blur and distort their observations.

Discovering these three new asteroids despite these challenges was possible thanks to the unique observing capabilities of DECam. The state-of-the-art instrument is one of the highest-performance wide-field CCD imagers in the world, giving astronomers the ability to capture large areas of sky with great sensitivity. Astronomers refer to observations as 'deep' if they capture faint objects. When hunting for asteroids inside Earth's orbit, the capability to capture both deep and wide-field observations is indispensable. DECam was funded by the U.S. Department of Energy (DOE) and was built and tested at DOE's Fermilab.

"Large areas of sky are required because the inner asteroids are rare, and deep images are needed because asteroids are faint and you are fighting the bright twilight sky near the Sun as well as the distorting effect of Earth's atmosphere," said Sheppard. "DECam can cover large areas of sky to depths not achievable on smaller telescopes, allowing us to go deeper, cover more sky, and probe the inner Solar System in ways never done before."

As well as detecting asteroids that could potentially pose a threat to Earth, this research is an important step toward understanding the distribution of small bodies in our Solar System. Asteroids that are further from the Sun than Earth are easiest to detect. Because of that these more-distant asteroids tend to dominate current theoretical models of the asteroid population.

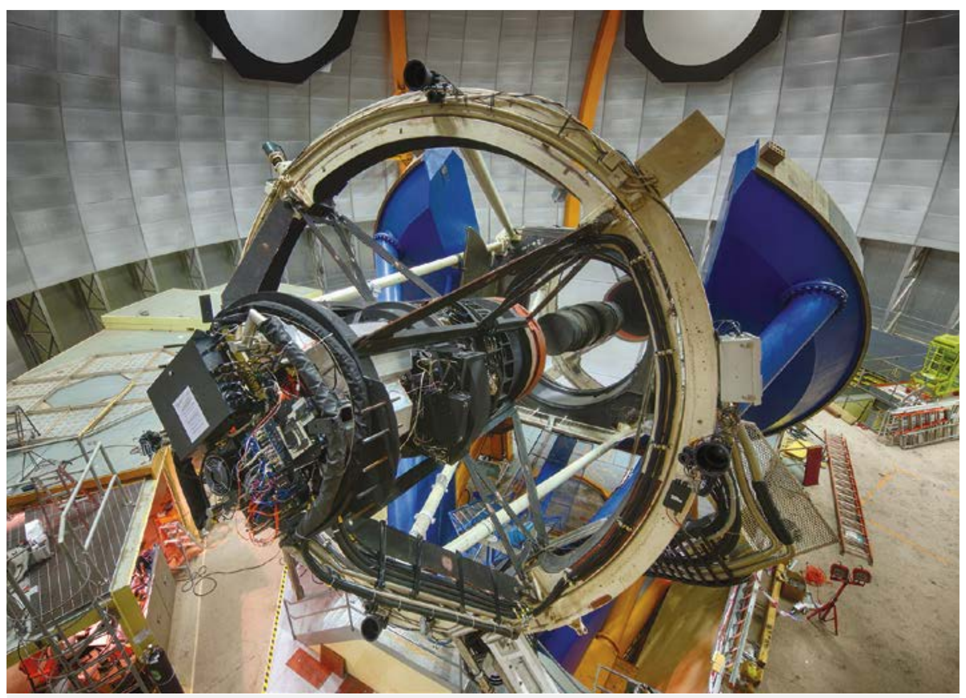
Detecting these objects also allows astronomers to understand how asteroids are transported throughout the inner Solar System and how gravitational interactions and the heat of the Sun can contribute to their fragmentation.

"Our DECam survey is one of the largest and most sensitive searches ever performed for objects within Earth's orbit and near to Venus's orbit," said Sheppard. "This is a unique chance to understand what types of objects are lurking in the inner Solar System."

"After ten years of remarkable service, DECam continues to yield important scientific discoveries while at the same time contributing to planetary defense, a crucial service that benefits all humanity," said Chris Davis, NSF Program Director for NOIRLab.

DECam was originally built to carry out the Dark Energy Survey, which was conducted by the DOE and the U.S. National Science Foundation between 2013 and 2019.

—Charles Blue
Public Information Officer, NOIRLab



The Víctor M. Blanco 4-meter Telescope has a 4-meter (13-foot) diameter mirror, which weighs 15,400 kg (34,000 lbs). It was designed in the 1960s. The Dark Energy Camera (black paint) is mounted at the prime (first) focus near the top of the Serrurier truss (white paint). The blue-painted structure is the large bearing that allows the telescope to move in right ascension. The telescope declination axis is located at the level of the middle of the right ascension bearing and is best seen on the left side of the large U-shaped notch. The primary mirror is located a few feet lower than the declination axis. Credit:DOE/FNAL/DECam/R. Hahn/CTIO/NOIRLab/NSF/AURA

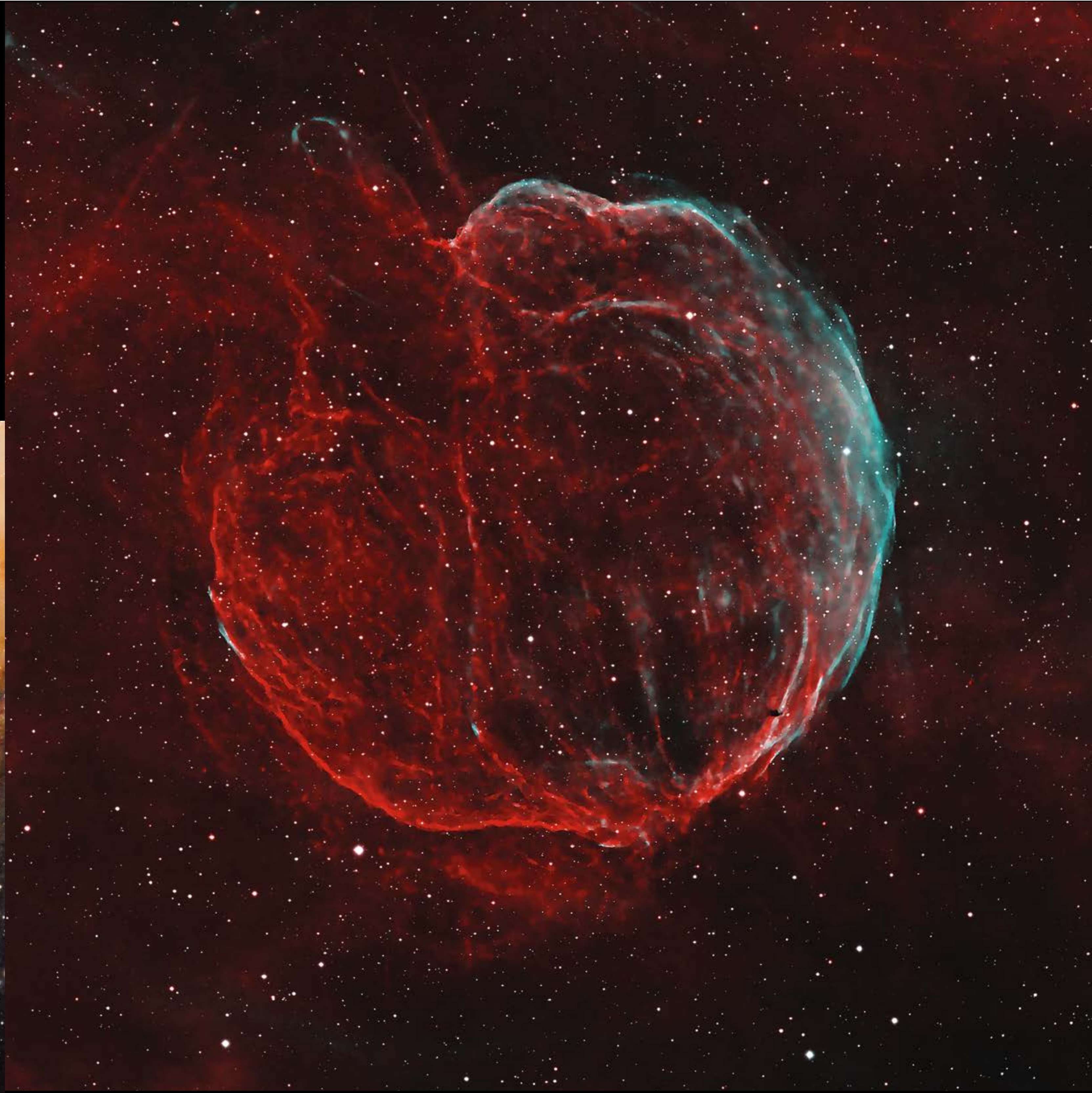
REFERENCE

Sheppard, S. Tholen, D., Pokorný, P., Micheli, M., and Dell'Antoniio, I., et al. (2022). *"A deep and wide twilight survey for asteroids interior to Earth and Venus."* The Astronomical Journal, 164, 168. *doi.org/10.3847/1538-3881/ac8cff*

GALLERY

All images are ©2022 or 2023 by their credited creators.

Jeffrey O. Johnson (Astronomical Society of Las Cruces) captured this image of NGC 206 from his backyard in Las Cruces, New Mexico, using a Takahashi TOA-130F refractor with a QSI 690WSG CCD camera.



M.J. Post (Longmont Astronomical Society) captured this image (shown cropped) of LBN 576 using a Celestron 11-inch RASA telescope with a ZWO ASI6200MM camera from his Dark Sky New Mexico observatory in Animas, New Mexico.

Bernard Miller (East Valley Astronomy Club) captured this image of IC 1396 using a PlaneWave 17-inch CDK telescope with an FLI 16803 CCD camera from his observatory in Animas, New Mexico.

Gallery images are processed by *Reflector* staff for better contrast and tonal range on the printed page.

Gregg Ruppel (Tucson Amateur Astronomy Association) captured this image of Sharpless 151 from his remote observatory at Dark Sky New Mexico, in Animas, New Mexico using an ASA 10N f/3.8 Astrograph with an SBIG STL-11000M CCD camera.

Observing Awards

Active Galactic Nuclei Observing Program
No. 31-I, **Eric Edwards**, Albuquerque Astronomical Society; No. 32-V, **Bill Hennessey**, Neville Public Museum Astronomical Society

Advanced Binocular Double Star Observing Program
No. 49, **Stephen Pavela**, La Crosse Area Astronomical Society; No. 50, **Dave Tosteson**, Minnesota Astronomical Society; No. 51, **Gus Gomez**, Tucson Amateur Astronomy Association; No. 52, **Brad Payne**, Northern Virginia Astronomy Club; No. 53, **Jeffrey S. Moorhouse**, La Crosse Area Astronomical Society

Alternative Constellation Observing Program
No. 15, **William Clarke**, Tucson Amateur Astronomers Association, Silver

Asterism Observing Program
No. 74, **Dave Tosteson**, Minnesota Astronomical Society

Asteroid Observing Program
No. 66, **Mike Conley**, Regular, Night Sky 45 Astronomy Club; No. 67, **Steve Boerner**, Regular, Member-at-Large

Binocular Double Star Observing Program
No. 203, **Clayton L. Jeter**, Member-at-Large; No. 204, **Jason Wolfe**, Member-at-Large; No. 205, **Andrew Jaffe**, New Hampshire Astronomical Society

Binocular Messier Observing Program
No. 1244, **Pete Hermes**, Tucson Amateur Astronomy Association; No. 1245, **Joe Kraus**, Denver Astronomical Society; No. 1246, **Claire Weaverling**, Minnesota Astronomical Society; No. 1247, **Richard Benson**, Rio Rancho Astronomical Society

Bright Nebula Observing Program
No. 32, **Cliff Mygatt**, Advanced, Olympic Astronomical Society; No. 33, **Daniel Beggs**, Advanced, Albuquerque Astronomical Society; No. 34, **David Babb**, Advanced, Member-at-Large; No. 35, **Viola Sanchez**, Advanced, Albuquerque Astronomical Society; No. 36, **Scott Sudhoff**, Advanced, Wabash Velley Astronomical Society; No. 37, **John Sayers**, Advanced, Member-at-Large

Caldwell Observing Program
No. 287, **Veronica L. Lane**, Silver, Ancient City Astronomy Club; No. 288, **Bruce Bookout**, Silver, Colorado Springs Astronomical Society; No. 288, **Jeffrey S. Moorhouse**, Silver, La Crosse Area Astronomical Society

Carbon Star Observing Program
No. 145, **Karl Schultz**, Central Arkansas Astronomical Society

Citizen Science Special Program
Richard Benson, Rio Rancho Astronomical Society, Disk Detective, Active, Bronze; **Andrew Corkill**, Lifetime Member, Observational, Variable Stars, Gold Class 1; **Dan Crowson**, Astronomical Society of Eastern Missouri, Active Asteroids, Active, Gold Class 25 & 30; **Dan Crowson**, Astronomical Society of Eastern Missouri, Supernova Hunters, Active, Gold Class 5 & 6; **Mike Hotka**, Longmont Astronomical Society, NEO, Gold Class 4; **Rich Krahling**, Richland Astronomical Society, Planet Hunters, Active, Bronze; **Rich Krahling**, Richland Astronomical Society, Galaxy Zoo, Star Notes, Active, Silver; **Al Lamperti**, Delaware Valley Amateur Astronomers, Galaxy Zoo, Star Notes, Active, Gold Class 160; **Al Lamperti**, Delaware Valley Amateur Astronomers, Active Asteroids, Active, Gold Class 83; **Brad Young**, Astronomy Club of Tulsa, Variable Stars, Observational, Gold Class 5

Constellation Hunter Northern Skies Observing Program
No. 291, **Debra Wagner**, Member-at-Large; No. 292, **Dana Bostic**, Raleigh Astronomy Club; No. 293, **Jeremy Mullican**, Lifetime Member; No. 294, **Richard Benson**, Rio Rancho Astronomical Society; No. 295, **Cindy Krach**, Haleakala Amateur Astronomers; No. 296, **John W. Bierman**, Miami Valley Astronomical Society

Dark Nebulae Observing Program
No. 38, **Viola Sanchez**, Albuquerque Astronomical Society

Deep Sky Binocular Observing Program
No. 442, **Jerelyn Ramirez**, Kansas Astronomical Observers; No. 443, **Brian McGuinness**, Northern Colorado Astronomical Society

Double Star Observing Program
No. 698, **Mike Titus**, Cincinnati Astronomical Society; No. 699, **Andrew Hall**, Member-at-Large

Foundations of Imaging Observing Program
No. 7, **Jack Fitzmier**, Member-at-Large; No. 8, **Peter K. Detterline**, Member-at-Large

Galaxy Observing Challenge
Brad Young, Astronomy Club of Tulsa

Galaxy Groups and Clusters Observing Program
No. 53-DA/I, **David Whalen**, Atlanta Astronomy Club; No. 54-M/V, **Paul Harrington**, Member-at-Large

Globular Cluster Observing Program
No. 387-V, **Rick Ginanni**, Greater Hazleton Area Astronomical Society; No. 388-I, **John Reed**, Member-at-Large; No. 389-V, **John Jardine Goss**, Roanoke Valley Astronomical Society; No. 390-V, **Jim Talbot**, Minnesota Astronomical Society; No. 391-I, **Val Ricks**, Houston Astronomical Society; No. 392-I, **David Babb**, Member-at-Large

Herschel 400 Observing Program
No. 652, **Mike Titus**, Cincinnati Astronomical Society

Herschel Society Observing Award
No. 19, **Paul Harrington**, Silver, Member-at-Large

Herschel II Observing Program
No. 117, **Marie Lott**, Device-Aided, Atlanta Astronomy Club; No. 118, **Robert Harrison**, Device-Aided, Crystal Coast Stargazers

Hydrogen Alpha Solar Observing Program
No. 65-V, **Matt Shulse**, Astronomical Society of Kansas City; No. 66-I, **Andrea Girones**, Member-at-Large; No. 67-V, **Bernard Venasse**, Lifetime Member; No. 68-V, **Ronan Kerr**, Austin Astronomical Society

Jupiter Observing Program
No. 1, **Peter K. Detterline**, Member-at-Large

Library Telescope Observing Award
No. 27, **Mike Veith**, Silver, River Bend Astronomy Club; No. 28, **Terry Menz**, Silver, River Bend Astronomy Club; No. 29, **Jeff Menz**, Silver, River Bend Astronomy Club

Local Galaxy Group & Neighborhood Observing Program
No. 54-M/V, **Mike Reitmajer**, Rose City Astronomers; No. 55-DA/I, **Daniel Beggs**, Albuquerque Astronomical Society

Lunar Observing Program
No. 1190-I, **Brad Payne**, Northern Virginia Astronomy Club; No. 1191, **Brent Knight**, Escambia Amateur Astronomers Association; Nos. 1192 and 1192-B, **Steve Condrey**, Omaha Astronomical Society; No. 1193, **Joseph Washburn**, Member-at-Large; Nos. 1194 and 1194-B, **Ernie Wright**, Howard Astronomical League; No. 1195-B, **William Clarke**, Tucson Amateur Astronomy Association; Nos. 1196 and 1196-B, **Bennett Staton**, Astronomy Club of Tulsa; No. 1197-B, **Joseph Washburn**, Member-at-Large; Nos. 1198 and 1198-B, **Mark Petersen**, Minnesota Astronomical Society

Lunar II Observing Program
No. 131, **Page Jennings**, Tri-Valley Stargazers; No. 132, **David Berish**, Greater Hazleton Area Astronomical Society; No. 133, **Karl A. Schultz**, Central Arkansas Astronomical Society

Lunar Evolution Observing Program
No. 24, **Douglas L. Smith**, Tucson Amateur Astronomy Association; No. 25, **David P. Rudeen**, Etna Astros; No. 26, **David Berish**, Greater Hazleton Area Astronomical Society; No. 27-I. **Eric Edwards**, Albuquerque Astronomical Society

Mentor Observing Award
Bryan Gibson, Colorado Springs Astronomical Society; **Ralph McConnell**, Barnard Astronomical Society; **Dave Warner**, Colorado Springs Astronomical Society; **Barry Young**, Colorado Springs Astronomical Society

Messier Observing Program
No. 2898, **Claude Plymate**, Regular, Bear Valley Springs Astronomy Club; No. 2899, **Bruce Lamoreaux**, Honorary, Longmont Astronomical Society; No. 2900, **Michael Phelps**, Honorary, Atlanta Astronomy Club

Meteor Observing Program
No. 205, **Michael Phelps**, 18 hours, Atlanta Astronomy Club

Multiple Star Observing Program
No. 19-V, **Eric Edwards**, Albuquerque Astronomical Society; No. 20-V, **David Tosteson**, Minnesota Astronomical Society; No 21-V, **Viola Sanchez**, Albuquerque Astronomical Society

Near Earth Objects Observing Program
No. 27, **Mark Simonson**, Intermediate, Everett Astronomical Society; No. 28, **Mark Simonson**, Advanced, Everett Astronomical Society

Open Clusters Observing Program
No. 110, **Scott Cadwallader**, Advanced, Baton Rouge Astronomical Society; No. 111, **Daniel Beggs**, Basic, Albuquerque Astronomical Society; No. 112, **Bruce Scodova**, Advanced, Richland Astronomical Society; No. 113, **Lauren Rogers**, Advanced Imaging, Escambia Amateur Astronomers Association

Outreach Special Program
No. 855, **Jay Ford**, Stellar, Fort Bend Astronomy Club; No. 1187, **Richard Wheeler**, Stellar, Northeast Florida Astronomical Society; No. 1189, **Ernest F. Jacobs**, Master, Buffalo Astronomical Association; No. 1199, **Mike Titus**, Stellar, Cincinnati Astronomical Society; No. 1238, **Mike Modrcin**, Stellar, Omaha Astronomical Society; No. 1244, **Kevin Habhegger**, Stellar, La Crosse Area Astronomical League; No. 1295, **Douglas L. Smith**, Outreach, Tucson Amateur Astronomy Association; No. 1296, **Adam White**, Outreach, Astronomical Society of Kansas City; No. 1297, **Sam Grommes**, Outreach, Rose City Astronomers; No. 1298, **Jason Christian**, Outreach, Cincinnati Astronomical Society; No. 1299, **Richard L. Benson**, Outreach, Rio Rancho Astronomical Society; No. 1300, **Ralph Reed**, Outreach and Stellar, Colorado Springs Astronomical Society; No. 1301, **Caitlin Mallory**, Outreach and Stellar, Colorado Springs Astronomical Society; No. 1302, **Margaret Sauer**, Outreach, Colorado Springs Astronomical Society; No. 1303, **James Keebaugh**, Outreach, Colorado Springs Astronomical Society; No. 1304, **Will Keebaugh**, Outreach, Colorado Springs Astronomical Society; No. 1305, **John Sauer**, Outreach and Stellar, Colorado Springs Astronomical Society; No. 1306, **David Koster**, Outreach, Colorado Springs Astronomical Society; No. 1307, **John Doryk**, Outreach, Colorado Springs Astronomical Society; No. 1308, **Mark Harter**, Outreach, Colorado Springs Astronomical Society; No. 1309, **Mike Babnick**, Outreach, Colorado Springs Astronomical Society; No. 1310, **Nate Babnick**, Outreach, Colorado Springs Astronomical Society; No. 1311, **Carolyn Mirich**, Outreach, Member-at-Large; No. 1312, **David Hasenauer**, Outreach, Stellar, and Master, Texas Astronomical Society of Dallas; No. 1313, **Joseph D. Kubal**, Outreach, Naperville Astronomical Association; ,No. 1314, **Mike Veith**, Outreach, Stellar, Master, River Bend Astronomy Club; No. 1315, **Thomas Conley**, Outreach, Fort Bend Astronomy Club; No. 1316, **Todd Dunnavant**, Outreach, Stellar, Fort Bend Astronomy Club; No. 1317, **Conrad Terrill**, Outreach, Stellar, Member-at-Large; **Shalaka Godse**, Outreach, Fort Bend Astronomy Club; No. 1319, **Lee Higgins**, Outreach, Fort Bend Astronomy Club; No. 1320, **Chris Morisette**, Outreach, Fort Bend Astronomy Club; No. 1321, **Elizabeth Prochnow**, Outreach, Fort Bend Astronomy Club; No. 1322, **Treavor Quinn**, Outreach, Fort Bend Astronomy Club; No. 1323, **Terry Menz**, Outreach, River Bend Astronomy Club; No. 1324, **Jeff Menz**, Outreach, River Bend Astronomy Club

Planetary Nebula Observing Program
No. 22, **Mark Simonson**, Advanced Imaging, Everett Astronomical Society; No. 23, **Daniel Beggs**, Advanced Imaging, Albuquerque Astronomical Society; No. 102, **Jonathan Cross**, Advanced, Manual, Seattle Astronomical Society

Radio Astronomy Observing Program
No. 28-S, **Dave Lacko**, Silver, Member-at-Large; No. 29-S, **Marie Lott**, Silver, Atlanta Astronomy Club

Sketching Observing Program
No. 58, **Preston Pendergraft**, Member-at-Large; No.59, **Lauren Rogers**, Escambia Amateur Astronomers Association

Sky Puppy Observing Program
No. 80, **Jamin Horn**, Youth Member-at-Large; No. 81, **Zachary Guise**, Independent

Solar Neighborhood Observing Program
No. 6, **Michael Stephens**, Eyes Only, Member-at-Large; No. 7, **Dave Tosteson**, Eyes Only, Minnesota Astronomical Society; No. 8, **Brad Young**, Eyes Only, Astronomy Club of Tulsa; No. 2, **Michael A. Hotka**, Binocular, Longmont Astronomical Society; No. 3, **William Clarke**, Binocular, Tucson Amateur Astronomy Association; No. 4, **Michael Stephens**, Binocular, Member-at-Large; No. 5, **Eric Edwards**, Binocular, Albuquerque Astronomical Society; No. 6, **David Tosteson**, Binocular, Minnesota Astronomical Society; No. 7, **Brad Young**, Binocular, Astronomy Club of Tulsa; No. 1, **Dave Tosteson**, Telescopic, Minnesota Astronomical Society; No. 2-I, **Terry Trees**, Telescopic, Amateur Astronomers Association of Pittsburgh

Solar System Observing Program
No. 206, **Ronan Kerr**, Austin Astronomical Society

Southern Sky Telescopic Observing Program
No. 63, **Christian Weis**, Tucson Amateur Astronomy Association

Stellar Evolution Observing Program
No. 94, **Alfred Schovanez**, Astronomical Society of Eastern Missouri; No. 95, **John Jardine Goss**, Roanoke Valley Astronomical Society; No. 96, **Jason Wolfe**, Member-at-Large; No. 97, **Randal Dean**, Texas Astronomical Society of Dallas; No. 98, **Jim Kvasnicka**, Prairie Astronomy Club; No. 99, **Richard Wheeler**, Northeast Florida Astronomical Society; No. 100, **Gerard J. Jones**, Minnesota Astronomical Society; No. 101, **David Babb**, Member-at-Large

Sunspotter Observing Program
No. 218, **Lisa Wentzel**, Twin City Amateur Astronomers; No. 219, **Pamela Graybear**, Rochester Astronomy Club; No. 220, **Bernard Venasse**, Lifetime Member; No. 221, **Trena Johnson**, Minnesota Astronomical Society

Two in the View Observing Program
No. 55, **Dave Tosteson**, Minnesota Astronomical Society

Universe Sampler Observing Program
Nos. 163-T and 163-N, **István Mátis**, Member-at-Large; No. 164-T, **Michael Stephens**, Member-at-Large; No. 165-N, **Richard Benson**, Rio Rancho Astronomical Society

Urban Observing Program
No. 235, **David Hasenauer**, Texas Astronomical Society of Dallas; No. 236, **Pete Hermes**, Tucson Amateur Astronomy Association

Master Observer Progression

OBSERVER AWARD

Viola Sanchez, Albuquerque Astronomical Society

MASTER OBSERVER AWARD

No. 254, **Clayton Jeter**, Member-at-Large; No. 255, **David Hasenauer**, Texas Astronomical Society of Dallas; No. 256, **Mike Titus**, Cincinnati Astronomical Society

ADVANCED OBSERVER AWARD

Cindy L. Krach, Haleakala Amateur Astronomers; **Viola Sanchez**, Albuquerque Astronomical Society

MASTER OBSERVER AWARD – SILVER

Lauren Rogers, Escambia Amateur Astronomers Association; **Douglas L. Smith**, Tucson Amateur Astronomy Association

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