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Terry Hancock and Tom Masterson (Western Colorado Astronomy Club) took this fantastic image of Comet C/2020 R4 (ATLAS) passing the Whale and the Hockey Stick galaxies (NGC 4631 and 4656 + 4657) from Grand Mesa Observatory using a Takahashi FSQ-130 with a QHY600 monochrome camera along with a Takahashi Epsilon-180 with a QHY410 color camera.

"He put a lot of thought into the content and layout of this little volume, and it shows. Every time I go out under the stars I appreciate Mr. Birren's labors that much more."

- Thomas Epps
in his blog *Of Reflected Starlight*



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M42 image captured with Stellina

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

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Reflector



Reflector

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To The Editor

In the June 2021 (vol. 73, no. 3) issue of the *Reflector*, there was an article titled "Finding Possibly Habitable Exoplanets With Machine Learning Algorithms" by Abhi Milind Gudipati.

In the article, the author states, "For my project, I used a machine learning algorithm to simply distinguish between possibly habitable and non-habitable exoplanets using the factors that determine habitability..."

Nowhere in the article does the author name the algorithm used. Can you supply that information? Thank you.

—Phil Cali

Fremont, California

Abhi Milind Gudipati answers:

The algorithm I used was the Gaussian Naive Bayes Classifier. It's a classifier that uses an initial prediction and uses previous answers to further fine tune the initial prediction. I used this classifier because it works better with smaller datasets, which was what I was working with in the project. I appreciate the question.

Star Beams

WHERE WE STARTED, WHERE WE ARE, AND WHERE WE ARE GOING

Twenty months ago, in January 2020, when the first COVID-19 case was recognized in the United States, who would have thought that our country would be basically shut down for a year or more?

I remember the various discussions we had with family members as well as with the leadership of the League and League groups. This was unknown territory. We had never experienced such a widespread occurrence. During the first few months, as many became essentially confined to their homes, and we cancelled our national convention, ALCon 2020, and regional conventions in response to scientific guidance, we in the leadership contemplated where we would go from that point.

In the fall of 2020, the Astronomical League received a generous offer from Scott Roberts and Explore Scientific to collaborate on a virtual "Global Star Party" each week. This joint venture

continues to be most successful, with our 18,000+ members and the astronomical community in general having access to high-quality speakers and astronomers across the globe via these virtual events. In addition, we have added a monthly Astronomical League Live event that is specifically focused on the League.

This spring, before vaccines were readily available, we once again had to postpone ALCon 2021 to 2022 in Albuquerque, and continue the moratorium on regional conventions, because of the pandemic still raging in many areas of the country.

With the success of these online initiatives, the leadership began to ponder how we could somehow schedule a virtual ALCon 2021. The answer came with the generous offer of Explore Scientific to provide the online technical expertise for a virtual event. Also, League secretary Terry Mann and vice president Chuck Allen (both former presidents) eagerly volunteered to co-chair a virtual event.

As part of ALCon 2021 Virtual, we asked member societies to promote themselves by providing a generous door prize. Each club is given publicity on the ALCon 2021 Virtual website, as well as a few minutes to talk about their society during the August event.

As this article is being written, we have received over \$7,000 in donated prizes from societies, to be given away during the event. Thanks so much for this outstanding response.

As the pandemic begins to subside, despite some flareups and new virus strains, societies are slowly returning to more normal operations, including returning to live public outreach activities. The Astronomical League's new normal includes a major expansion of our virtual offerings, including a new League YouTube channel (tinyurl.com/astroleaguevideo) where many of the virtual presentations are posted. Thanks to media officer and former president John Goss for making this all happen. When we return again to a physical ALCon in Albuquerque in 2022, I am fairly certain that our new virtual capabilities will be incorporated to further expand our reach.

Thanks to all for your support during this difficult time. With all the additional tools we have discovered and used during the pandemic, the best of the Astronomical League is yet to come.

—Carroll Iorg, President



Full STEAM Ahead

THE SOFTER SIDE OF ASTRONOMY

Women have played an important role in the early and continuing history of scientific observations, including in astronomy, despite many cultural roadblocks. Although great strides forward have been made, we still need to celebrate the countless extraordinary breakthroughs in this science and hobby that women have made in the past, despite the odds.

This year, the League introduced a new imaging award, called the Williamina Fleming Imaging Award for women 19 years and older. This came about after I met a young lady from the AAVSO, Molly Wakeling, whom I contacted for the 75th anniversary session on women in astronomy. She shared her love of imaging and introduced me to the group, STELA – Striving to Engage Ladies in Astrophotography – an international organization of imagers ([instagram.com/we.are.stela](https://www.instagram.com/we.are.stela)). She shared that the group ranges in age from early twenties through fifties. I asked why I had not found any female imagers while hunting for imagers for the AL calendars over the past four years. Unfortunately, it appears that in certain circles, women do not feel welcomed, are talked down to, and feel intimidated by the current imaging community.

I had no idea of their plight, so in response I changed my idea about having famous national telescopes as the theme of the 2022 calendar, instead deciding to highlight women imagers. I forged ahead with the award and the executive committee made it happen. I am therefore proud to introduce the AL 2022 calendar, celebrating the women who make, made, and are making great strides in all facets of astronomy.

Once I had decided on the theme, Molly contacted STELA and shared the opportunity, and within a day, I was being emailed by women I had never met. In the past I have had some difficulty in finding enough images for the calendar; enter Marie Lott of the Charlie Elliott Chapter of the Atlanta Astronomy Club and her large list of AstroBin lady friends. Marie set out to wrangle some imagers for me, including some out of the country and some that are League members. Problem solved! Some even sent in images for the Williamina Fleming Award. The 2022 Astronomical League Calendar, Celebrating Women Imagers, also includes trivia on women in and of astronomy. It features astrophysicists, educators, comet and minor planet hunters, high school exoplanet

discoverers, and even celestial objects named after women. The dates of meteor showers, eclipses and moon phases, oppositions, elongations, equinoxes, and solstices are still included.

As a result of working on this project, I learned a lot about discoveries that I never knew were made by women. These include a comet discovered by Maria Winkelmann Kirch before Caroline Herschel; her husband took credit so that it would be able to be submitted to the scientific community. The first Einstein Ring, the Ring Nebula, and NGC 2360 were all discovered by women. One of the founders of Mt. Wilson Observatory was, you guessed it, a woman. Most astronomers know about the role of women in stellar classification, but did you know the developer of asteroismology (in 1966) was also a woman?

I hope this calendar will offer a more well-rounded view of the history of astronomy and fill in the gaps that have been glaring at us for many years. Although I am not an imager, I do find images compelling to behold, not only as an astronomer but as an artist. Thank you in advance for your support of this calendar, as I am highly confident something like this has never been done before.

The icing on the cake is that of the first Williamina Fleming Imaging Award winners, first-place winner Molly Wakeling has an image on the cover of the calendar, and the third-place winner, Terry Mann, contributed an image for the month of October.

The calendars are available in the League Store for \$13, and here again, any profits will go toward telescope making for the ALCon Jr. conference in summer of 2022.

Full STEAM ahead!

—Peggy Walker

Night Sky Network

ASTRONOMY THEME DAYS

Planning your outreach events can sometimes be a bit difficult. Will we be observing? Will there be a presentation? Should we have any activities – and if so, which ones? Astronomy “holidays” can make planning a bit easier, since these special days usually have specific themes, like International Observe the Moon Night, or Yuri’s Night! We’ll take a quick minute to list an assortment of popular astronomy “holidays” (including Astronomy Day, of course!) to help you plan ahead.

This list does not include events like eclipses,

meteor showers, planetary conjunctions and such, but those occasions are of course great for outreach, and lend themselves easily to theming and activities. You can also take inspiration from events like Black History Month (February) and Women’s History Month (March) and include some of the important contributions and discoveries made by women and people of color to astronomy.

Please note: the dates of some of these holidays vary from year to year, so please check their official sites for details. This is not an exhaustive list, just a few highlights to get you started!

SOLAR WEEK

Generally held in **March**, this week of Sun-themed events showcases resources and activities celebrating the Earth-Sun connection.

multiverse.ssl.berkeley.edu/Solar-Week

GLOBAL ASTRONOMY MONTH

Astronomers Without Borders coordinates this sprawling annual **April** event with a range of outreach events and space-themed activities the world over, and overlaps with a few other events here. From arts to observing to research, there is something to pique everyone’s astro-interest. my.astronomerswithoutborders.org/programs/global-astronomy-month

INTERNATIONAL DARK SKY WEEK

Held in **April**. Celebrate the wonder and cultural heritage of dark, starry skies – and spread awareness about light pollution and how you can help mitigate its effects. idsw.darksky.org

YURI’S NIGHT

Held on **April 12** each year, celebrating the launch of the first human into orbit – Yuri Gagarin – on April 12, 1961, and the first Space Shuttle launch, on April 12, 1981, Yuri’s Night inspires space-exploration parties around the world. yurisnight.net

BLACK HOLE WEEK

Everyone loves black holes – these famous yet mysterious celestial objects. NASA’s **April** Black Hole Week features many strange and colorful guides that introduce folks to the intriguing science of black holes. imagine.gsfc.nasa.gov/bhw

ASTEROID DAY

Held on **June 30** each year, Asteroid Day is a UN-sponsored education program to spread information about asteroids, including their role in solar system formation, possible resource use, and of course, impact events – and how we may be

able to defend ourselves from them.
asteroidday.org

ASTRONOMY DAY

October 9, 2021. Astronomy day celebrates all things astronomy, across the world, in spring and fall each year. For a free handbook, go to astroleague.org/al/astroday/astrobook.html

WORLD SPACE WEEK

October 4–10, 2021. Celebrating the benefits that advances in space science have brought humanity as a whole, the UN declared World Space Week in 1999, and it is held every October 4–10, with a new theme every year. For 2021, the theme is “Women in Space.” worldspaceweek.org

INTERNATIONAL OBSERVE THE MOON NIGHT

October 16, 2021. Celebrate our nearest neighbor! The date changes each year. This event is generally held in late September or October and is generally when the Moon is around first quarter phase. moon.nasa.gov/observe-the-moon-night

GLOBE AT NIGHT

Measure the quality of your skies with this worldwide community science project! Globe at Night campaigns run **every month**, making it a handy opportunity to add studying and mitigating light pollution to any of your regular outreach efforts. globeatnight.org

—David Prosper

International Dark-Sky Association

IDA FIXTURE SEAL OF APPROVAL

IDA's Fixture Seal of Approval (FSA) program was started in 2002 to provide certification for dark sky friendly lighting to minimize glare, reduce light trespass, and keep light pollution to a minimum. Recently, I searched the internet for “dark sky friendly” fixtures to help my step-daughter and son-in-law chose a light for a new mailbox they are having built. I was amazed at the number of poorly designed fixtures claiming to be dark sky friendly. If they have not been officially approved by IDA, they may well not be dark sky friendly as claimed. Buyer beware.

Even with the current global pandemic, which I hope at the time of this writing (June 2021) is receding, new companies continue to join the

IDA Fixture Seal of Approval program. The Fixture Seal of Approval program provides objective, third-party certification for lighting that minimizes glare, reduces light trespass, and does not contribute significantly to light pollution. IDA does not sell lighting; it lists dark sky friendly lighting in its FSA database (“Residential” section: tinyurl.com/darkskyproducts).

IDA also has a Dark Sky Retailers webpage: tinyurl.com/darkskyretailers.

To become a participating IDA Dark Sky Retailer, a retail outlet must

- ▶ have a dedicated landing page for Dark Sky Approved products,
- ▶ provide content that educates customers on what it means to be dark sky compliant,
- ▶ offer products that comply with IDA's Fixture Seal of Approval standards, and
- ▶ work with IDA to ensure product offerings are accurate and honest.

A fixture submitted to IDA is evaluated by an independent set of lighting experts. The fee for the evaluation and the fees for a company to register as having dark sky friendly products are listed on the IDA webpage (www.darksky.org/our-work/lighting/lighting-for-industry/fsa/apply-fsa). The fees IDA charges for the dark sky evaluation process range from \$250 per product family to \$2,500 for a one-time company registration. These are set to cover IDA's costs and are not designed to be a profit center. IDA otherwise makes no monies on fixtures approved and sold. Please check out this important IDA program and certainly make use of it should you consider buying or installing outdoor nighttime lighting.

—Tim Hunter
Co-founder IDA

Wanderers in the Neighborhood

THE FUZZY CORE OF JUPITER

NASA's Juno spacecraft has been orbiting the planet Jupiter since July 5, 2016, returning spectacular images of the very top of the atmosphere of the “King of the Planets.” The instruments this probe carries are designed to study Jupiter's gravitational and magnetic fields. The spacecraft is in a highly elongated polar orbit that stretches from 2,600 miles above the cloud tops out to 5,000,000 miles from the planet. The orbit is designed in part to keep Juno out of Jupi-

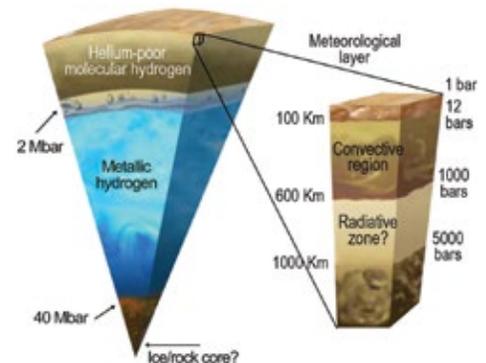
ter's shadow so its solar panels can continuously produce electricity.

Jupiter is surrounded by intense radiation belts held in place by its strong magnetic field. The energetic particles trapped in the belts can penetrate the spacecraft, striking atoms in the transistors of the electronic systems. This slowly degrades each transistor until enough hits cause it to fail. Since most electronics in Juno are critical, this can bring an abrupt end to the mission.

The most intense radiation belts are near the planet but well above the cloud tops. The highly elliptical polar orbit allows Juno to spend most of its time out of the intense radiation, far from the planet. As it heads inward, it passes through the weaker radiation near the polar region and drops into the lower-radiation gap between the cloud tops and the bottom of the radiation belts. This gets the spacecraft's instruments close enough to take data near the cloud tops without exposing the spacecraft to the intense radiation.

The orbit also allows Jupiter's interior to be studied using its own gravity. The spacecraft would feel slightly different gravitational pulls, depending on Jupiter's interior composition. As Jupiter's gravity tugs on the spacecraft, its speed changes. As the spacecraft transmits its signals to Earth on a specific frequency in the X band (8404.135802 MHz), the spacecraft's speed relative to Earth changes the frequency received by the Deep Space Network (DSN) due to the Doppler effect.

The Doppler effect is familiar to most people when applied to sound. When a car blows its horn, it will be heard as having a higher pitch as it is coming toward you; as it passes, the horn will have its normal pitch, and as it recedes away from you, the horn will have a lower pitch. By measuring the exact frequency that the DSN receives



A cross section of Jupiter's interior as it was thought to be before the Juno mission. The most active region is located at the very top of the atmosphere. Below that is a layer of helium-poor molecular hydrogen with a transition layer to the metallic hydrogen layer. Finally, at the very core is the rocky material that was the nucleus of the proto-Jupiter whose gravity drew in all the hydrogen that formed this gas giant.

Credit: NASA/JPL-Caltech/SwRI



An artist's rendering of the impact of a protoplanet with the proto-Jupiter around 4.5 billion years ago. This impact scattered the rocky material throughout the central half of Jupiter. It is thought that it will take many billions of years for the rocky core to reform. Illustration by K. Suda and Y. Akimoto/Mabuchi Design Office, courtesy of Astrobiology Center, Japan

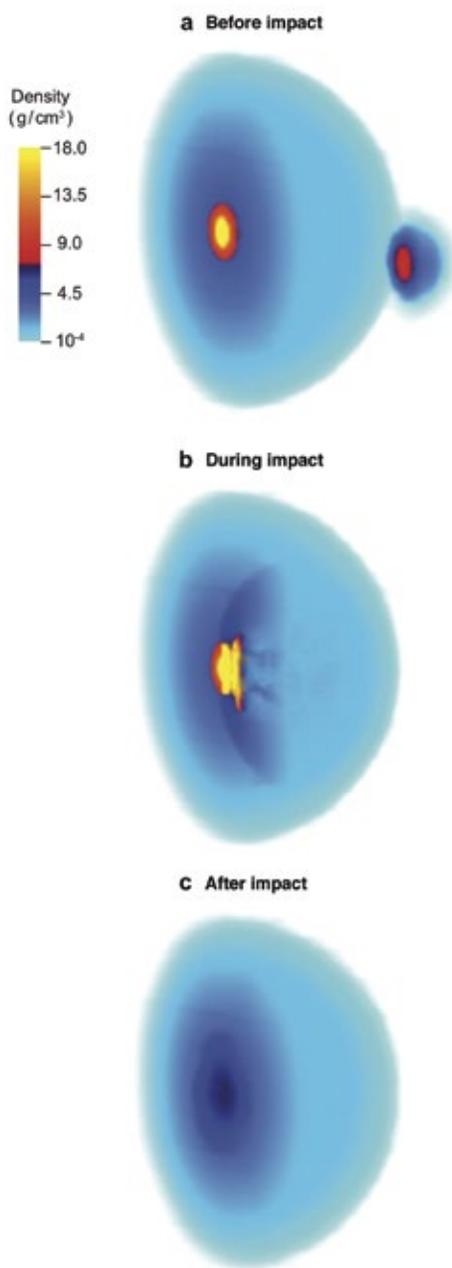
from Juno, the speed of the spacecraft relative to Earth can be computed. By taking many measurements of the Doppler-shifted radio signal, the exact shape of Jupiter's gravitational field can be calculated. The shape of the field reveals clues to Jupiter's interior.

The calculated map of Jupiter's gravitational field is compared to the field that would be generated by different models of Jupiter's interior. Before Juno, it was assumed that Jupiter had a rocky and icy core at its center. This would have been the initial rocky material that was the earliest part of the proto-Jupiter, accreting material like any other rocky planet. Above the core, metallic hydrogen would occupy two-thirds of the radius of the planet. Floating on top of that up to the cloud tops is a region of helium-poor molecular hydrogen with some trace elements. When astronomers modeled the gravitational field this structure would generate, it did not match Juno's observations.

Since the standard model did not match the observed field, astronomers tried a number of different models. The only model that matched the observed gravitational field is a core of mixed rocky material and metallic hydrogen taking up about half the center of the planet. This is a surprising result, since the rocky core was supposed to be the nucleus of the proto-Jupiter that pulled in hydrogen from the primordial cloud to build Jupiter into the massive object it is today.

The original structure had a clear boundary between the rocky core and the metallic hydrogen above it. In the new model, there is no hard boundary, but a fuzzy boundary between the metallic hydrogen and rocky material mixture and the higher parts of the atmosphere.

Armed with a model that matched the gravitational field shape, astronomers now needed to create a scenario that would result in a fuzzy core.



The interior structure of Jupiter as observed by NASA's Juno spacecraft does not have a rocky core, but the heavier materials are scattered through the central half of the planet. This would not be expected from classic planetary-formation models. A novel hypothesis has a ten- to twenty-Earth-mass protoplanet striking the proto-Jupiter head-on, disrupting its core and scattering the material from both objects throughout the central area of Jupiter. Illustration by Shang-Fei Liu/Sun Yat-sen University

None of the standard evolutionary models would produce it. Astronomers needed a new scenario.

Shang-Fei Liu from Sun Yat-sen University in China and an international team of colleagues put forward a hypothesis that the proto-Jupiter was struck head-on by a rocky protoplanet with a mass of ten to twenty Earths. The impact would have disrupted both Jupiter's rocky core and the interloping protoplanet. Their combined material would have been scattered throughout the region around the planet's center. Modeling showed that even if it happened 4.5 billion years ago, the fuzzy core would still persist for many billions of years.

While it seems that such a collision would be unlikely, the early Solar System was a violent place with frequent collisions. Jupiter's mass would contribute to the likelihood of a collision by pulling in protoplanets. Its gravity would modify a protoplanet's orbit, bringing it closer and closer to Jupiter until it finally collided with the massive planet.

While there is no way to go back in time and observe this major collision, this model has withstood all the tests applied to it thus far. Data are still coming in from the Juno spacecraft that may help confirm or refute this hypothesis. In the meantime, it is a fascinating view of our largest local planet and the violent nature of the early Solar System.

Read more about the impact model here: news.rice.edu/2019/08/14/young-jupiter-was-smacked-head-on-by-massive-newborn-planet.

—Berton Stevens

Deep-Sky Objects

THE LITTLE DUMBBELL NEBULA

During the end of a Sun-like star's life it will eject layers of gases. These hot gases will glow for thousands of years forming spherical structures around the star. From our perspective these shells of glowing gas appear as circular or oval-shaped rings. A one-solar-mass star may lose half its mass through this process. These gaseous objects are called planetary nebulae. Of course they are not planets, but in low-power views some do resemble gas giant planets. Thus the name has stuck. Many have blue and green glows not that much different from the planets Uranus and Neptune (for example, NGC 4563 or NGC 7662). Others may appear more like Jupiter and Saturn, such as the Ghost of Jupiter Nebula (NGC 3242) or the Saturn Nebula (NGC 7009).

One of the most interesting planetary nebulae is M76, commonly called the Little Dumbbell Nebula. It has also been known as the Cork Nebula and the Barbell Nebula. Pierre Méchain discovered M76 in 1780 and reported it to Charles Messier for inclusion in his famous catalog. William Herschel thought M76 was two overlapping nebulae, which resulted in M76 receiving two NGC numbers. NGC 650 is the southwestern part of the nebula and NGC 651 is the northeastern part.

Shining at magnitude 10.1, M76 is one of the faintest Messier objects. But it is relatively easy to find. Starting at the magnitude 3.6 yellow star Upsilon (51) Andromedae, hop 2.25 degrees north-northeast to the magnitude 4.0 blue-white star Phi Persei. Fifty arcminutes due north of Phi is an orange star of magnitude 6.7 (SAO 22551). M76 is 13 arcminutes west of SAO 22551.

M76 does not have the typical ring structure of a planetary nebula, so it took a long time for astronomers to determine its true nature. Isaac Roberts studied images he took of it in the year 1891 and determined that M76 was indeed a single nebula. It wasn't until 1918 that astronomer Heber Curtis correctly classified it as a planetary nebula.

The nebula has a cylindrical-shaped bar running from north-northeast to south-southwest that is about 87 arcseconds long and 47 arcseconds wide. The ends of the bar are much brighter than the center. Surrounding the bar is a faint halo consisting of two lobes, one on the northwest side and one on the southeast side.

The entire structure is 2.7 by 1.8 arcminutes in size. The nebula is thought to be 2,544 light-years away, making it about two light-years in diameter.

The central star of M76 has a visual magnitude of 15.9 and a photosphere temperature of 88,000 K, much hotter than our 5,700 K Sun. This high temperature is consistent with a star that is in the planetary nebula phase. Over billions of years, the star will eventually cool into a white dwarf.

I took the accompanying image of M76 with an 8-inch f/8 Ritchey-Chrétien Cassegrain telescope with a TeleVue 0.8× focal reducer/field flattener yielding f/6.4. The telescope was on a Paramount MYT German equatorial mount, and an SBIG ST-2000XCM self-guiding single shot color CCD camera was employed. The exposure was 240 minutes using 10-minute subframes. Darks and flats were used. The subframes were registered and stacked using ImagesPlus 6.5 and the final image processing was completed in Adobe Photoshop. In the image, north is up and east is to the left.

The bright star on the left side of the image is the aforementioned SAO 22551. The image captured the nebula's bar with its central star not quite drowned out by the middle of the bar. The outlines of the northwest and southeast lobes were also captured. The faintest stars in the image are slightly brighter than magnitude 18.

The bar-shaped portion of M76 is clearly visible in an 8-inch telescope. Astronomers believe the bar is really a nearly edge-on dusty torus

around the star. The optical emissions are thought to be from oxygen IV (triply ionized oxygen atoms). Regardless of the processes that formed M76, the planetary nebula is a great find with any size telescope on a clear autumn night.

— Dr. James R. Dire

Kauai Educational Association
for Science and Astronomy

Observing Program Showcase

DARK SKY ADVOCATE PROGRAM

This important activity-based award is unlike any other that the League offers. If you have wanted to do something about a topic so important to our hobby – the loss of our dark skies due to light pollution – this is a way you can help. Here is a great opportunity for you to make a positive, dramatic impact on your community that will be long-lasting and far-reaching. Ambitious? Perhaps, but can you imagine any better way you can influence the future?

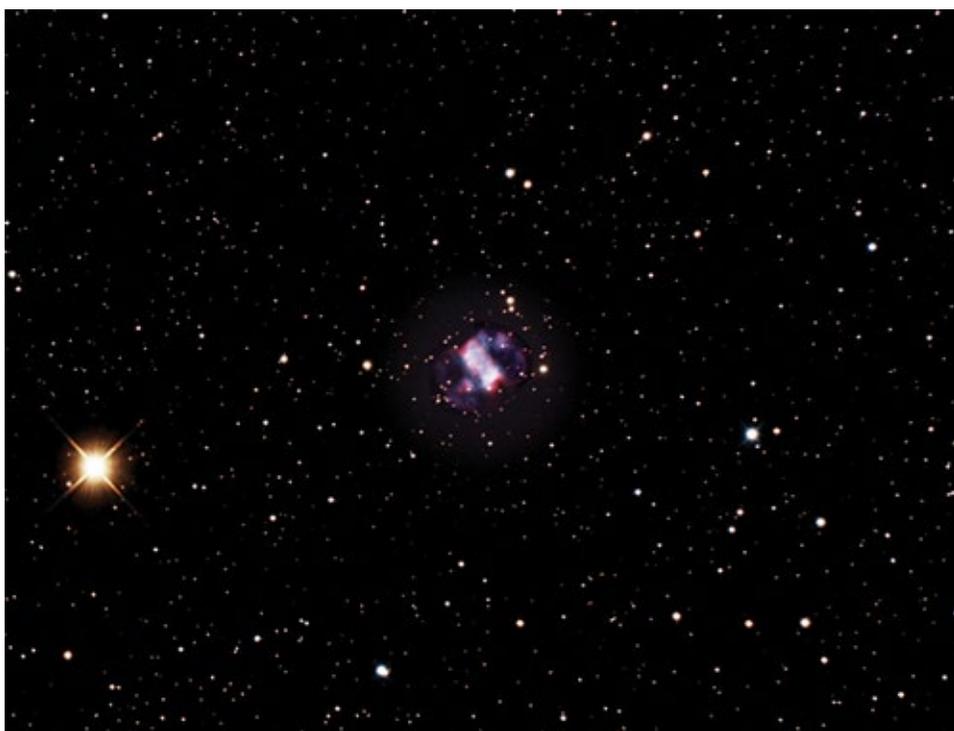
Light pollution and light trespass are two subtle but pervasive problems that degrade our quality of life and destroy our enjoyment of the night skies. Too many amateur astronomers have silently witnessed the unnecessary destruction of the night, first beginning in the cities, but now spreading to the remaining rural areas. We must not choose to ignore this problem.

This program is one of personal enlightenment and public awareness. It is divided into twenty activities spread across several categories that teach individuals how light pollution affects them personally and how it affects our society as a whole. Take the challenge at tinyurl.com/dark-skyadvocate. Confront light pollution!

—John Goss

ALTERNATE CONSTELLATIONS OBSERVING PROGRAM — EXPLORE THE SKY IN A NEW WAY

The Alternate Constellations Observing Program offers the chance to explore star groups as seen from around the globe and across 5,000 years of history. Using just your eyes or small binoculars, the program includes 50 observations of star groups from the cultures of six geographic regions. You also track down 40 obsolete constellations: these were invented beginning in the Renaissance but were discarded when the 88 official constellations were set. A set of additional



exercises completes the requirements of the program. You sketch your favorite “unofficial” star group and discover how location and precession affect the stars we see.

Along the way, you can learn much about other cultures and other times – for example, how the Polynesians used the stars to navigate the vast Pacific Ocean, from Indonesia to Hawaii and beyond.

You may be surprised by how ubiquitous the constellation symbols of other cultures are today in brands and icons all around you. Check out our YouTube video (tinyurl.com/youtube-alt-const) or visit the program’s web page (tinyurl.com/al-alt-const) for more information.

—Brad Young

MULTIPLE STAR OBSERVING PROGRAM

The multiple star systems in this Observing Program include three or more stars that appear from Earth to be close to one another in the sky. These systems are not considered asterisms. Many may be merely “apparent” star systems, in which case they are optical multiple stars (meaning that the stars may appear to be close to each other when viewed from Earth, as they seem to occupy nearly the same point in the sky, but in reality, one star may be much farther from



Shown are examples of the kind of images that you can create for any multiple star system on the list.

Earth than another and this is not readily apparent unless they could be viewed from a different angle). Other systems have stars that are actually

gravitationally bound to each other, in which case they are “physical” multiple star systems moving with the same proper motion. In some cases, star systems include orbital pairs, and their movement along an ellipse can be measured over time. The list includes many physical systems that have apparent companions and some that contain orbital pairs. Measuring the separation and position angle of the orbital pairs is encouraged, although optional.

Submissions to the Astronomical League’s Multiple Star Observing Program may be in the form of electronic images and/or sketches.

Our list includes some identifiers that are not included in some planetarium programs. Check *Stelle Doppie* (www.stelledoppie.it/index2.php?section=1) for a list of the most common identifiers.

Link: www.astroleague.org/content/multiple-star-observing-program.

—Steve McGaughey

THE PLANETARY NEBULA OBSERVING PROGRAM

Low- to intermediate-mass stars spend billions of years fusing hydrogen to helium in their cores. When that hydrogen runs low and the cores become clogged with helium ash, this kind of star undergoes a number of evolutionary changes. During its tortured metamorphosis from main sequence star to white dwarf, perhaps the most intriguing period is the brief time it spends as a planetary nebula. The late stages of an evolving star are characterized by the expulsion of its outer atmosphere into a circumstellar shell leaving the star’s hot central core. Intense radiation from the central star ionizes the surrounding gas creating an emission nebula that typically extends a light-year or more across. Several dynamic factors conspire to sculpt these nebulae into a variety of intriguing shapes. Absorbing ultraviolet radiation from the central star and re-emitting visible light makes these nebulae tailor-made for human observers and produces some of the most colorful and beautiful celestial gems.

The Planetary Nebula Observing Program is designed to introduce observers to these fascinating objects. The list of targets for the program encompasses a wide variety of planetary nebulae. The list includes some of the best-known showpieces in the sky as well as some obscure objects to challenge you. You’ll encounter bright but tiny starlike objects hiding among crowded star fields and huge ghostly wisps that will test your observing skills.

The program was designed so that an observer

using an 8-inch telescope under suburban skies can complete the basic program of 60 objects and earn a certificate. For the advanced award, the observer must observe 110 objects. The program is accommodating to those observers whose equipment or sky quality makes detection of some objects impossible. The Planetary Nebula Observing Program allows negative observations with sufficient evidence of diligent effort. Observers who locate all of the objects using traditional star-hopping methods will receive special recognition on their certificate.

A number of alternate objects are available for observers who reside too far north for the entire list to be accessible. Accommodations can also be made for observers whose observatory walls interfere. Substitutions are made on a case-by-case basis and must be approved in advance by the coordinator.

Imagers can complete the program by imaging 90 objects. They can choose from the standard list of 110 planetary nebulae, the four proto-planetary “challenge” objects, or any of the alternate objects.

Southern hemisphere observers can complete the program as well. To create the Southern Planetary Nebula Observing Program, all of the objects on the original list with declinations north of M27, the Dumbbell Nebula (+22°43’16”), were replaced with objects from the southern celestial hemisphere. This will accommodate observers north of about 60°S latitude.

Planetary nebulae have always been my favorite type of celestial object, and it is an honor to be able to offer this program and share these jewels with other observers. I would caution those of you who are considering the program, however: after observing a number of these enigmatic and beautiful objects, you just might become obsessed with them. Don’t say I didn’t warn you!

—Ted Forte

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From Around The League

ASTRONOMICAL SOCIETY OF EASTERN MISSOURI IS RECOGNIZED BY THE MISSOURI PARKS AND RECREATION ASSOCIATION

On April 30, 2021, the Astronomical Society of Eastern Missouri (ASEM) was presented the 2021 Missouri Park and Recreation Association (MPRA) Organization Citation Award at the astronomy viewing area at Broemmelsiek Park in Wentzville.



Past and current club presidents after being presented with the award (left to right: Miki McKee Koelsch, Missouri Parks and Recreation Association president, with Stacey Thater, Jim Twellman, and Jim Roe)

This prestigious award recognizes the ASEM group for their nearly 14 years of dedicated service to the St. Charles County Parks and Recreation Department. Every week, on clear Friday nights, park-goers will find these skillful volun-



teers hosting Friday night stargazing events at the astronomy viewing area at Broemmelsiek Park.

In 2020, ASEM took their volunteerism one step further and graciously dedicated the largest public viewing telescope in Missouri at the astronomy viewing area. Park visitors can now climb the ladder to the top of the massive 32-inch Dobsonian telescope to enjoy awesome views of deep space and Solar System objects.

AWARDS SEASON

By Chuck Allen

The judging is complete for all of the League's youth and general League awards for 2021. Here are the winners!

2021 NATIONAL YOUNG ASTRONOMER AWARD

The National Young Astronomer Award program, now in its 29th year, produced nine extraordinary entries in 2021 despite the difficulties created by COVID-19. Entries were judged by two PhDs and a former Intel International Science and Engineering Fair lead judge.

As always, our deepest thanks go to Scott Roberts and Explore Scientific for their generous sponsorship of the NYAA program over many years and for providing outstanding astronomical instruments to our top winners.

COVID-19 has altered the presentation of this year's NYAA awards. Our first and second place NYAA winners received their awards remotely at ALCon '21 Virtual in August and have been offered expense-paid trips to ALCon '22 in Albuquerque to receive their plaques in person.

NYAA First Place: Ryan Clairmont

Ryan is a rising senior at Canyon Crest Academy in San Diego, California. His passion for astronomy was ignited when, as a young child, he was lucky enough to visit Palomar Observatory on a special viewing night. As members of the Friends of Palomar Observatory, he and his family had the opportunity to look through a 60-inch telescope at the Moon and Jupiter, and it was a stunning experience for him. He then started observing with his grandfather's 6-inch Maksutov-Cassegrain and, later, with his 8-inch Newtonian telescope and a spectrograph that he used to collect data



for his project on astrophysical modeling and structure of the Cat's Eye Nebula.

Ryan created the first three-dimensional (3D) morpho-kinematic model of the nebula using Hubble Space Telescope images and five different motion-velocity diagrams. He also created the first 3D hydrodynamic model of this nebula in order to offer a physically justifiable evolutionary history of its strange bipolar nature. He was able to determine that the rings and inner shell are consistent with formation by two separate precessing wind events and with the existence of a close binary star at the center of the nebula. Ryan collected his own spectra of the nebula using his 8-inch Newtonian, R=600 spectrograph, CMOS camera, cooled CCD camera, and Demetra software. The astrophysical models that he generated explain the nebula's 3D ringed structure and provide a plausible physical explanation of the nebula's evolution, giving further insight into the underlying formation of all planetary nebulae.

NYAA Second Place: Tarun Kota

Tarun is a rising senior at Eastview High School in Apple Valley, Minnesota. He is co-founder of the Student Astrophysics Society comprised of high school and undergraduate members from 15 countries. He organizes monthly lectures by astrophysicists and bimonthly astrophysics book



club meetings. He also runs a Discord server where members can chat about the latest space news and events. He developed a research mentorship program where members can conduct research projects with mentor astrophysicists. Recently, he wrote an introduction to an astrophysics book for elementary students, *The ABC's of Astrophysics*, and is currently working on formatting and illustrations for the book.

Tarun's research project arose from his work at Caltech's Infrared Processing Analysis Center (IPAC). He built a data reduction pipeline to search for brown dwarfs, low-mass dwarfs, and white dwarfs in the solar neighborhood using large infrared databases. His work allowed him to make a color-color diagram of motion candidates, and his exceptional research resulted in the discovery of seven dwarfs in the solar neighborhood: a low mass star, a sub-dwarf, four white dwarfs, and a dwarf of "other type," all from the initial testing of his pipeline on the infrared database CatWISE.

NYAA Third Place: Vivek Vijayakumar

Vivek, a past NYAA first-place winner, has become the first person to win top-three NYAA plaques in three separate NYAA competitions.

Vivek's project this year was entitled "Figuring Out Gas and Galaxies in Enzo (FOGGIE): Inflows and Outflows in the Intergalactic Medium." He simulated a galaxy similar to our Milky Way to understand the gas that surrounds the galaxy and to understand whether our general view of gas flows around the galaxy are correct. He also searched for tracers to identify those gas flows and used



computer scripts with appropriate libraries to look at plots that depict different properties of the gas. He found two ions that were promising as tracers of the gas flows.

2021 HORKHEIMER/SMITH AWARD

Each year, the League offers two major youth service awards, the Horkheimer/Smith Award with a \$1,700 prize and an expense-paid trip to the League's national convention, and the Horkheimer/D'Auria Award with a \$1,000 prize. These awards bear the name of their primary benefactor, the late Jack Horkheimer (television's "Star Gazer") and are funded by the Horkheimer Charitable Fund established in Jack's memory. Our thanks go to Dwight Horkheimer for his work with the fund and for his generous support of these youth award programs for more than two decades.

This year, the judges' rankings resulted in a tie between Tyler Westering and Conal Richards for the Horkheimer/Smith Award. Accordingly, the League with the support of the Horkheimer Charitable Fund will award two Horkheimer/Smith Awards and provide both co-winners with full \$1,700 cash prizes and expense-paid trips to the League's national convention in Albuquerque, New Mexico, in 2022.

Horkheimer/Smith Service Award

First Place (tie): Tyler Westering

Tyler Westering is a rising homeschooled senior from Roselle, Illinois. He is vice president of observing for the Northwest Suburban Astronomers and schedules and coordinates weekly observing events for the club's 150 members. He writes the club's monthly observing article for the *Celestial Log* newsletter. He also works with local



libraries, schools, and other venues to coordinate public observing events. Tyler managed the club's COVID-19 restrictions by instituting an RSVP process limiting attendance to 10 people.

Tyler created and staffed deep-sky objects and telescopes exhibits during the club's 2018 and 2019 Astronomy Day events, and, in 2020, hosted a virtual Astronomy Day event online. He also manages the club's Twitter and Instagram social media accounts, an activity that resulted in a gain of 30 new club members during a recent six-month period.

Tyler hosts his own YouTube channel called "Planets Videos." The channel features over 23 astronomy-related videos, has attracted over 300 subscribers, and has logged more than 22,000 views. He has also conducted 10 live-streamed programs on astronomical topics, and his self-published "Planets Newsletter" reaches nearly 100 subscribers.

Horkheimer/Smith Service Award

First Place (tie): Conal Richards

Conal Richards is a recent honor graduate of Abington Heights High School in Clarks Summit,

Pennsylvania. He is president and founder of the Abington Heights High School Astronomy Club, one of only two youth clubs in the Astronomical League and his community's only astronomical society. The club dedicates itself to public outreach and, in particular, outreach to other teens. He instructed new members on basic astronomy, use of equipment, and observing skills so they could, in turn, engage in effective public outreach and conduct public viewing events.



Conal developed a website on which he shared observing guides that he created and linked his favorite books, magazines, and online learning resources. He also created social media accounts to share current events such as the SpaceX Crew Dragon launch, the dimming of Betelgeuse, the Perseverance landing, the supposed discovery of phosphine on Venus, the transit of Mercury, and the Great Conjunction of Jupiter and Saturn.

In 2020, he conducted a virtual event called "Mars Week" to highlight the planet's favorable opposition, and he included self-produced two-minute videos on various astronomical topics such as Mars's climate, geology, and exploration and Lord Rosse's telescope. He curated a list of online resources for ongoing self-learning including live streams from Lowell Observatory and images from the Mars Reconnaissance Orbiter. Conal has also written articles for the *Reflector*, has appeared on League Live Events and on Explore Scientific Global Star Parties, and is currently working with both the League and the Royal Astronomical Society of Canada on new ways to attract younger members.

2021 HORKHEIMER/PARKER IMAGING AWARD

The League hosts a major youth imaging competition, the Horkheimer/Parker Imaging Award, with prizes of \$1,000, \$500, and \$250, respectively, for the top three winners. This award is also supported by the generosity of the Horkheimer Charitable Fund.

Horkheimer/Parker Youth Imaging Award First Place: Jai Shet

Jai Shet is a recent homeschooled graduate from Sugar Land, Texas, and is a member of the Fort Bend Astronomy Club. Last year, he co-authored a feature article in *Reflector* and won both



the League's Horkheimer/D'Auria Service Award and Horkheimer/Parker Imaging Award. This year marks Jai's second consecutive win in the Horkheimer/Parker competition.

Jai's winning image, "Searching for the Milky Way," (shown on page 15) was taken at Moab, Utah, using a Sigma 14 mm f/1.8 lens and a Canon EOS 5D Mark IV camera. He will receive a plaque and the \$1,000 prize associated with this award.

Horkheimer/Parker Youth Imaging Award Second Place: Vivek Vijayakumar

Over the past three years, Vivek Vijayakumar has won first-, second-, and third-place awards in the National Young Astronomer Award competitions, an unmatched accomplishment in that highly competitive research-oriented program. He is a recent graduate of San Marcos High School in San Marcos, California, and is a youth member-at-large of the League.

Vivek's second place image (shown on page 15) is entitled "The Leo Triplet" and was taken in Julien, California, using a C8-N, QHY-268M, and CEM 60.

Vivek will receive a plaque and the \$500 prize associated with his second-place award.

Horkheimer/Parker Youth Imaging Award Third Place: Neil Shet

Neil Shet is a rising homeschooled junior from Sugar Land, Texas, and is a member of the Fort Bend Astronomy Club. Neil and his brother Jai wrote a feature article on astrophotography that appeared in the September 2020 issue of the *Reflector*.

Neil's third-place image, "The Night Sky Part,"



(shown on page 16) was taken in Page, Arizona, using a Sigma 14 mm f/1.8 lens and a Canon EOS 5D Mark IV camera.

Neil will receive a plaque and the \$250 prize associated with his third-place award.

2021 HORKHEIMER/O'MEARA JOURNALISM AWARD

Each year, the League conducts a major science writing competition for youth ages 8 to 14. The winner of the Horkheimer/O'Meara Journalism Award receives a beautiful plaque and a \$1,000 cash prize funded by the Horkheimer Charitable Fund.

Horkheimer/O'Meara Journalism Award Winner: Mary Kate Bauer

Mary Kate Bauer is a rising homeschooled eighth grader from Oronoco, Minnesota, and is a member of the Rochester Astronomy Club. Her winning Horkheimer/O'Meara Journalism Award entry was a touching tribute to the award's name-



sake and long-time League benefactor, the late Jack Horkheimer, television's famous "Star Gazer." Jack was an enthusiastic popularizer of astronomy whose impact on over six million viewers rivaled that of Carl Sagan's *Cosmos* and whose support continues through his Horkheimer Charitable Fund.

Please take time to enjoy Mary Kate's thoughtful essay about this remarkable popularizer of astronomy:

KEEP LOOKING UP By Mary Kate Bauer

"Twinkle, twinkle little star, how I wonder what you are...." As I recited the four-stanza poem, "The Star" written by Jane Taylor, when I was four years old, during a family recital, I started to wonder what a star really is. Now that I am older, I know that a star is a luminous ball of gas held together by its own gravity, but there is still much to learn about space. Some people in the world today do not know what is above in the amazing outer space or do not even take time to appreciate it. Astronomer Jack Horkheimer encouraged others to continue to look up at the night sky because it brings happiness, and people can learn about the universe.

Jack Horkheimer was born in 1938 to a wealthy family in Randolph, Wisconsin. Ever since he was young, he struggled with a lung condition which made him short of breath his entire life. When he was an adult, Horkheimer moved to Florida because the climate was better for his lungs. In Florida, he served as executive director at the Miami Space Transit Planetarium for thirty-five years. When Horkheimer gazed up at outer space, he felt happier because he could forget about the difficulties of his lung condition and enjoy the beauty of the stars.

Because Horkheimer had a love for astronomy, he wanted to teach others about it. In 1976, he created and hosted his first weekly television program, named *Star Gazer*. During the show, Horkheimer was pictured sitting on Saturn's rings while he told viewers what constellations and planets could be seen in the night sky. An estimated six million viewers watched the five-minute television show every week. *Star Gazer* was popular among children and adults because of Horkheimer's enthusiastic personality. Even my dad watched *Star Gazer* as a child. Although my dad did not have much of an interest in astronomy at the time, Horkheimer's fun presentation made my dad interested about outer space. At the end of every show, Horkheimer signed off with his famous quote, "Keep looking up!" Horkheimer created *Star Gazer* because he wanted to encourage everybody to continue to view and learn about the spectacular night sky.

Horkheimer died in his Florida home on August 20, 2010, due to his lung condition. When I discovered that Horkheimer was buried near my home, my family and I went to visit his

grave. I was surprised to find his self-written epitaph on the back of his gravestone: "Keep Looking Up' was my life's admonition; I can do little else in my present position." Throughout his life and even after, Horkheimer continues to impact others by his motto, the money he donated to many organizations, and his television show. Horkheimer's example of passing down his knowledge about what he loved should be followed by everybody. So, all of us should "Keep looking up!"

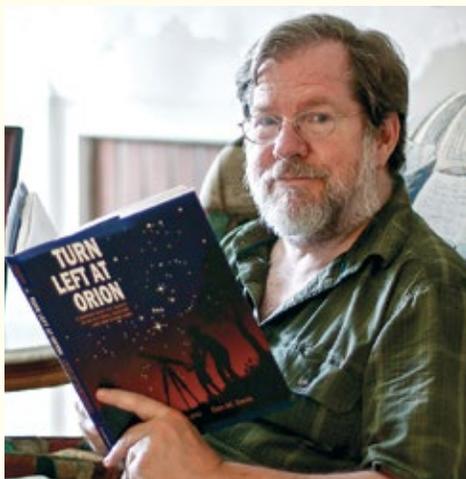
2021 MABEL STERNS NEWSLETTER AWARD

The club newsletter editor's job is to communicate with members. The newsletter is a place where, among other things, members share their images and observation experiences, write scientific articles, advertise equipment sales, report on recent club activities, announce upcoming speakers, recruit members for upcoming public events, and report on finances and committee activities. The editor's job is relentlessly demanding with deadlines to meet every month and content to be collected and formatted within those monthly time constraints.

The award was judged by a panel that included three present or past League club newsletter editors.

Mabel Sterns Newsletter Award First Place: Dale Thieme

Dale Thieme is the newsletter editor of the Warren Astronomical Society Paper (The W.A.S.P.), the newsletter of the Warren Astronomical Society in metropolitan Detroit, Michigan. Digital archives containing many past issues of The W.A.S.P. are available on the club's website, and the June 2021 issue alone featured an astounding 41 pages of articles, club information, sky events, president's notes, observing reports, treasurer's reports, images, and much more.



Imagine putting that together every month! Dale's work is likened more to that of a magazine editor than a newsletter editor and is clearly a full-time challenge.

Dale will receive a beautiful plaque in recognition of his extraordinary work.

Mabel Sterns Newsletter Award Second Place: Andrea Kuhl

Andrea Kuhl is the newsletter editor of the San Diego Astronomy Association. She has put together an excellent club newsletter featuring observing guides, office and committee rosters, workshop information, calendars, articles, and astrophotos. The June 2021 issue featured 12 pages of articles, images, and information about club activities and astronomical events. She will receive a framed certificate recognizing her dedicated work on behalf of the SDAA.

2021 WEBMASTER AWARD

A club webmaster's job is to communicate with the public and potential members. In the modern era of smartphones, tablets, and home computers, an attractive and easily-navigated website is the lifeblood of any astronomy club. It's where people find clubs. The webmaster must create an artistically attractive interface, arrange for easy navigation of the site, keep content updated, maintain contact lists, create galleries, link to outside sources of interest, announce public outreach opportunities, and manage security issues that arise. In many cases, the webmaster must also provide a secure method for conducting financial transactions such as joining the club, paying dues, making contributions to the club, or conducting club sales.

The award was judged by a panel of webmasters and a League officer.

Webmaster Award First Place: Don Knabb Don Knabb is the League's Mid-East Region



(MERAL) chair. He recently attended classes to learn how to develop and host a website and then undertook to create and maintain MERAL's beautiful new webpage. His region now has an attractive home online that will undoubtedly assist both MERAL and the member societies within MERAL.

Don didn't stop there, however. When asked to assist ALCon '21 Virtual co-chairs Terry Mann and Chuck Allen with their promotion of the event, Don happily offered to create and host a brand-new website for the virtual convention. Don's work is partly responsible for the attraction and recognition of more than \$7,000 in door prize sponsors and a substantial rise in registrations for the August 19–21 event. The site, which featured beautiful motion backdrops, highlighted convention speakers, and was easily navigated, provided a smooth registration process.

Don will receive a beautiful plaque in recognition of his mastery of website building skills on behalf of MERAL and ALCon '21 Virtual.

Webmaster Award

Second Place: Francisco Gonzalez and Frank Kane

Francisco Gonzalez and Frank Kane are co-webmasters for the Central Florida Astronomical Society in Oviedo, Florida. The publicly viewable title page of their website, which is primarily a members-only venue, exhibits a beautiful color scheme and eye-catching motion features.

They will each receive a framed certificate in recognition of their work for the CFAS.

2021 WILLIAMINA FLEMING IMAGING AWARD

In 2021, the League introduced a new imaging award named in honor of Williamina Fleming (1857–1911), who developed a spectral classification system for stars and cataloged thousands of stars and other astronomical phenomena. She is best known for her discovery of the Horsehead Nebula.

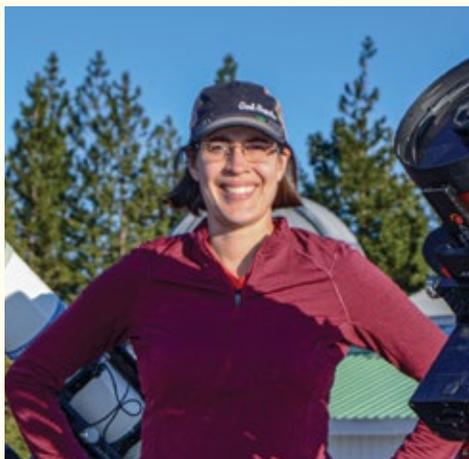
The award was established to recognize superb imaging skills among the many highly skilled female members of the Astronomical League, and was judged by a panel of three widely published award-winning astrophotographers. Three images may be submitted, and the winner is eligible to enter every three years and will be invited to judge the award in the intervening two years.

Despite COVID-19, we had six extraordinary entries that generated reports from all judges that ranking the entries was exceptionally challenging because of their overall quality. One judge, who is internationally published, com-

mented, "Not a single bad image in the bunch! Would be proud to hang any of them on my wall. Again, an extremely difficult task." The three top winners will receive plaques bearing Williamina Fleming's image.

2021 Williamina Fleming Imaging Award First Place: Molly Wakeling

Molly Wakeling is from Dayton, Ohio, and is a member of the Miami Valley Astronomical Society. She maintains an imaging website called Astro-Molly Images and has been a regular presenter on Explore Scientific's Global Star Parties during 2020 and 2021.



Molly is an expert in deep-sky and wide-field CCD and DSLR imaging. Her three entries included (1) "M27" (the Dumbbell Nebula) (shown on page 16) captured in El Cerrito, California, with a Celestron 8-inch f/10 and ZWO ASI1600MM Pro camera, (2) "Rho Ophiuchi" (the Rho Ophiuchi complex) taken in San Pedro de Atacama, Chile, with an astro-modified Sony Alpha 7s DSLR and Rokinon 135 mm f/2 lens at f/2.8, and (3) "Solar Eclipse 2017" taken in Casper, Wyoming, using a Nikon D5300 DSLR. Processing was done with PixInsight.

2021 Williamina Fleming Imaging Award Second Place: Lyn Peterson

Lyn Peterson is from Gilmanton, New Hampshire, and is a member of the New Hampshire Astronomical Society.

Lyn is an expert in deep-sky CCD photography, and her three images included CCD shots entitled (1) "M82, NGC 3034" (the Cigar Galaxy), (2) "M63, NGC 5055" (the Sunflower Galaxy), and (3) "M106, NGC 4258" (shown on page 17). All submissions were taken from her backyard in Gilmanton, New Hampshire, using an Astro-Tech 8-inch f/8 Ritchey-Chrétien with an SBIG STT 8300M, Kodak KAF-8300 camera, and all of them involved multiple exposures over many nights.



2021 Williamina Fleming Imaging Award Third Place: Terry Mann

Terry Mann is from West Manchester, Ohio, and is a Lifetime Member of the Astronomical League. She is secretary of the Astronomical League, chair of the League's Great Lakes Region, and a past League president (2006–2010). She has also chaired, or is chairing, AstroCon '11 and ALCon '21 Virtual.

An expert in DSLR photography of aurorae and the Milky Way, she regularly travels to both Alaska and the Dry Tortugas in pursuit of images. Her three Fleming submissions included photos titled (1) "Mile 48" (Aurora Above Forest) (shown on page 17) captured on the Dalton Highway in



Alaska with a Canon 6D full-frame DSLR, (2) "Superior Night" (Milky Way with island in Lake Superior) taken in Hovlan, Minnesota, with a Canon 6D full-frame DSLR, and (3) "Diamond Ring" (2017 total eclipse) taken in Casper, Wyoming, using a Canon 5D Mark III full-frame DSLR and a Stellarvue 80 mm f/6 Triplet. All processing was done with Photoshop.

2021 SKETCHING AWARD

The purpose of the Sketching Award is to recognize the special art of astronomical sketching at the eyepiece, a skill required by many of the League's Observing Programs.

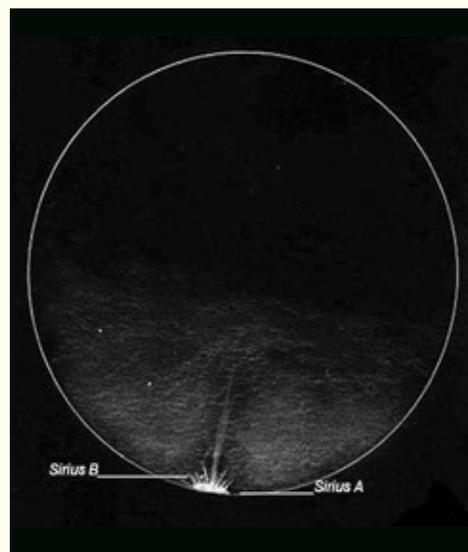
2021 Sketching Award Winner: Michael Rosolina

Michael is from Frankford, West Virginia, and is a member of the Greenbrier Astronomy Association. He observes using a 14-inch Celestron SCT from his roll-off roof observatory. His sketch



of Sirius B, the white dwarf companion of Sirius known as "the Pup," captures his visual view of the elusive dwarf just as he blocks the dazzlingly brilliant primary with the edge of his eyepiece field. He used Bristol board, 2B and HB graphite pencils, and a blending stump to capture the subtle illumination created by Sirius's occulted edge-of-field glare. (Michael drew in the negative; the sketch is shown here reversed to positive.)

Michael will receive a plaque and the \$250 League-sponsored prize associated with this award.



Award-Winning Images

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BY THEIR RESPECTIVE
CREATORS

RIGHT: FIRST PLACE
HORKHEIMER/PARKER
YOUTH IMAGING AWARD,
"SEARCHING FOR
THE MILKY WAY,"
BY JAI SHET.



RIGHT: SECOND PLACE
HORKHEIMER/PARKER
YOUTH IMAGING AWARD,
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BELOW: THIRD PLACE HORKHEIMER/PARKER
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"THE NIGHT SKY PART" BY NEIL SHET



RIGHT: FIRST PLACE
WILLIAMINA FLEMING
IMAGING AWARD,
"M27"
(THE DUMBBELL
NEBULA)
BY MOLLY WAKELING





ABOVE: SECOND PLACE
WILLIAMINA FLAMING
IMAGING AWARD,
"M106, NGC 4258"
BY LYN PETERSON

RIGHT: THIRD PLACE
WILLIAMINA FLEMING
IMAGING AWARD,
"MILE 48"
(AURORA ABOVE FOREST)
BY TERRY MANN



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Polar Ring Galaxies

By Dave Tosteson

Why is it we learn most from what is least normal? Why do things that don't fit in hold clues to new discoveries? Edwin Hubble developed a scheme to categorize galaxies which, in modified form, is still used eight decades later. But his protégé Halton Arp sought disorder. He felt the most interesting and instructive galaxies were precisely those that could not easily be placed within a preconceived set of rules. His mind and theories were drawn to alternative explanations, and he will likely be remembered in his pro-

fessional career for two things. An adherence to non-cosmological redshift interpretations led to Arp being labeled a maverick by the astronomical community, so he sought refuge in Germany when telescope time in the United States was denied. His *Atlas of Peculiar Galaxies*, a set of 338 individual and small groups of galaxies displaying a wide variety of structures affected by gravitational interaction, will likely be his legacy. I was fortunate to attend his 1995 Texas Star Party presentation where a kind and gentle manner, interest and dedication to amateurs, and perseverance in the face of marked professional criticism

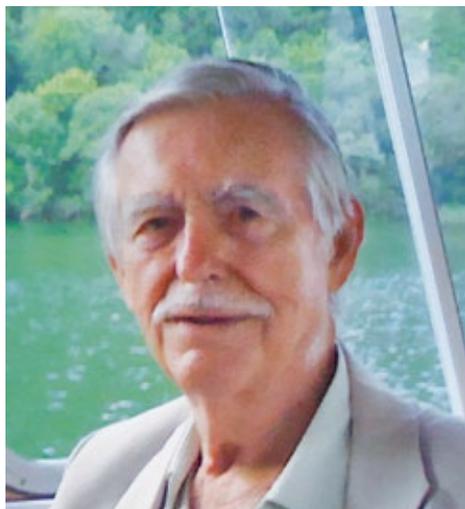
drew the longest and warmest applause of any talk I've witnessed.

Arp's atlas was the most significant early effort to collect single, pairs, and small groups of galaxies that did not fit previous classification schemes. Many subtypes were offered, but less than one percent of his galaxies represent what are now called Polar Ring Galaxies (PRGs). Christopher Q. Trinh, then at Berkeley and later at SOFIA, described Polar Ring galaxies as usually gas-poor, S0 types with a circumferential ring of cool gas perpendicular to the semi-major axis of the central galaxy. The rings show strong hydrogen-al-



NGC 660 as imaged by the Gemini Observatory in 2012. Credit: Gemini Observatory/AURA

pha emission characteristic of star-forming regions. Their prevalence among all galaxies was less than 0.5%, possibly underestimated by factors including viewing angle and extinction. Dynamic considerations predict these rings *should* be short-lived but, in an echo of galaxy rotation discordance, their apparent stability implies additional factors are in play. Studies by the Australian National Telescope Facility on the prototype NGC 4650A suggested this galaxy possesses a flattened distribution of dark matter aligned with its polar ring. The Observatory of Paris reported research



Halton Arp. Family photo, released to public domain

in April 2003, called “Polar Ring Galaxies and Dark Matter,” showing these structures were born from a near-collision of a larger spiral or S0 galaxy with a smaller, gas-rich object. Tidal forces drew material from the smaller galaxy into a bridge, which then relaxed into a circumferential ring of dust, gas, and newly forming stars. The remains of the smaller object were dispersed or thrown from the collision, possibly by a gravitational slingshot effect.

Dynamics of the ring material offer hints about the central galaxy’s dark matter halo. Differences between rotational velocities of the central galaxy and the ring are affected by the shape of the halo. If those velocities are the same, it implies a spherical halo and, if the captured material has a higher velocity, then the halo is flattened in that plane of capture. In general, polar ring material has a higher rotational velocity than its central galaxy, implying more dark matter in the plane of the ring material’s orbit. Some researchers theorize that unusual shapes in

the central bulges of galaxies, as in peanut, box, or X shapes, are failed polar rings where the impacting, smaller galaxy came in at a different angle, velocity, or distance. Comparative masses may also play a significant role, and one of the early researchers, Paul L. Schechter of MIT, called them “an auto wreck that hasn’t been cleared from the road.”

I spent several years after the 1995 Texas Star Party observing all the groups in Arp’s atlas, but even with the power of a 25-inch mirror, much of their detail was not fully appreciated. Arp 336 is also called NGC 2685, and it was the first accepted polar ring galaxy in 1978 when it was identified by Schechter. It is located 3.7° southeast of the nose of Ursa Major, is 4.5 by 2.5 arcminutes in size, and is oriented northeast to southwest. In my 25-inch reflector I could make out “transverse structure,” but could not discern a spindle effect. In 2011, again from the Texas Star Party, I used my 32-inch instrument and saw a “halo around the main galaxy” but could not say with certainty that its faint loops of circumferential matter were observed. There is one about 30 arcseconds in size, just west of the nucleus which is the structure associated with the polar ring. I think in very fine conditions it could be visually appreciated.

The second polar ring galaxy on Arp’s list that is an NGC object is 4650A, identified in 1984, also by Schechter. In this case the polar component has a much larger diameter than the central galaxy, and is unusual in several ways. It has a smooth-appearing portion that is angled to the main galaxy, not quite perpendicular to its main axis. It has little of the blue stellar groups seen in the body, which is wider, less dense, and contains significant warping. I viewed this twice from the Texas Star Party in my 25-inch reflector. In moderately good conditions in 1996 the polar ring could easily be seen, but a few years later in suboptimal skies the main portion of the galaxy positioned east to west was the only part visible. Reviewing all my observations suggests that visibility in the eyepiece for these ephemeral structures strongly depends on sky conditions. NGC 4650A is in the dense Centaurus galaxy cluster, and there are four large dance partners within 5 or 6 of its galaxy’s diameters.

Arp put his 87th object, NGC 3808 with 3808A, in the same category as M51 and its companion, but the former pair is different

in a significant way. As in NGC 2685, Arp 87 has a component with tendrils of gas and stars wrapped around its minor axis. The material surrounding M51’s companion NGC 5194 has an amorphous retinue of gas and dust and stars accompanying it, but there is no sense of it forming a circumferential, orbiting structure. Arp 87 may be the best example of a pair of galaxies caught in the act of forming the structure of a polar ring. The larger, southern spiral NGC 3808 has many blue star clusters, a sign of recent star formation, likely spurred by tidal interaction from 3808A. There is a bridge of material connecting the two spirals that also contains new stellar members. The bridge wraps around 3808A in a very similar fashion to the archetypal polar ring galaxy NGC 2685, with dust lanes visible in silhouette on Hubble’s detailed image. There is a naming irregularity about this pair. MegaStar uses the RC3 data, calling the southern, larger galaxy NGC 3808 and the northern one NGC 3808A. Other sources, including Kanipe and Webb’s *Arp Atlas of Peculiar Galaxies*, call the southern galaxy NGC 3808A and the northern one NGC 3808B. Here, I use the RC3 nomenclature. In 1998 I used my 25-inch reflector to view this pair, and I could see the bridge starting on the northeast corner of the southern galaxy that extended to and touched the northern one. No polar ring structure was visible at that time, but I did not specifically search for it. The two “ansae,” or extensions that form the polar ring, are easily seen on Arp’s original image, but on the POSS 2 plate are nearly invisible, with only the faintest hint of the eastern loop. With concerted effort, a large reflector may allow its observation. In Arp’s catalog, with all its interacting members, why are there only three examples of confirmed polar ring galaxies? What does this imply about the incidence and prevalence of these structures?

A perusal of Paul Hickson’s *Atlas of Compact Groups of Galaxies* shows several unusual galaxies in his collection of 100 small groups visually culled from the Palomar plates in the early 1980s. Hickson 75d is a small galaxy with an outer shell and a protrusion to the southeast. Galaxy 79e shows a disturbed arm pattern, and 95c is likely two closely interacting galaxies whose cores have almost merged. The most interesting of all the groups is number 92, Stephan’s Quintet. It consists of a linear string of four

galaxies with a foreground spiral, NGC 7320, to the southeast. There is intense interaction between NGC 7318A and B and 7319, where many loops and tidal tails create a dynamic atmosphere that is beautiful to see in Hubble's imaging and in the eyepiece, but there are no signs of polar rings. In 1987, Arp (with Barry Madore) extended his work to the southern hemisphere. Taken together, Arp and Hickson constitute the most complete and accessible collections of nearby interacting galaxies available to the amateur (and possibly professional) community. The much fainter galaxies seen in the Sloan Digital Sky Survey (SDSS) hint at the incidence of polar ring galaxies within a larger and more distant sample.

One of the scientists who studied polar ring galaxies in depth is Bradley C. Whitmore of the Space Telescope Science Institute. In 1990 he and his team published a paper and atlas of these galaxies and related objects. They proposed four categories in regard to certainty: kinematically confirmed (category A); good (B: with orientation suggesting inclusion, without present confirmation from velocity studies); possible (C: with material aligned with the minor axis but not yet "polar"); and related systems (D). This last category includes the box- and peanut-shaped bulge galaxies such as NGC 520, the dust-lane ellipticals such as Centaurus A, "Mayall-type" objects such as Arp 199 where the centers are not aligned, and certain ring galaxies such as ESO 350-40, the Cartwheel Galaxy in Sculptor. Figure 1 in his November 1990 *Astronomical Journal* article nicely displays the importance of orientation in being able to identify them as PRGs. Commenting on their significance, Whitmore noted that these objects "therefore offer the chance to study a system where the two merging components stay relatively distinct rather than quickly mixing together into a single system where most evidence of the progenitors is lost." Getting aligned comes naturally to him, as his STScI bio notes him as a three-time national age group orienteering champion.

Whitmore's research noted a ~0.5% prevalence of S0 galaxies with polar rings now, and estimated their lifetime incidence could be around 5%. Two thirds of the rings are warped, with half having an integral-sign shape, and the other half a banana contour. None of his candidates were regular spirals



NGC 4650A, imaged by the Hubble Heritage Team (AURA/STScI/NASA) in 1999

or had a bar. The widths of the rings seemed evenly divided between narrow and wide subtypes. The orthogonality of the rings appeared nonrandom, with a chance probability of that being only 8%. The systems he deemed younger had less symmetry and more "debris" than older systems, factors likely related to the evolution of the interaction. William Keel of the University of Alabama speculated that, as central galaxies of PRGs, "S0 (galaxies) may be favored for their lack of interstellar material; such material would more likely disrupt the settling into a relatively stable polar orbit of the accreted matter."

One of Whitmore's "good" candidates was IC 1689, a magnitude 14.7 S0 galaxy in Pisces. Follow up studies done in 1996 by Hagen-Thorn and Reshetnikov at the St. Petersburg State University with the 6-meter SAO Russian telescope showed what they termed an "inner polar ring," within the body of the galaxy. Most parts of the ring could be studied, as they called the body of the galaxy

"practically transparent." Viewed from my home in 2005 a few weeks after I obtained my 32-inch reflector using a 9 mm eyepiece to give 361 \times , the galaxy's core was nonstellar and oriented nearly north-south along the major axis of the galaxy. In Hagen-Thorn's 1997 *Astronomy & Astrophysics* paper (319, 430) the polar disk extends around this core circumferentially, but this feature was not visible in the eyepiece. In northern Draco lies a galaxy that was claimed in a 2002 paper to also carry an inner polar ring. UGC 5600 is a 14th-magnitude S0 galaxy with a surrounding, face-on, blue outer ring, and a linear, transverse structure just extending from the minor axis of the central galaxy. A later, second paper gives conflicting interpretations of these structures, and it appears further study is needed to confirm their claim. I have not yet observed this object, which appears paired with a "Cartwheel"-type companion ring galaxy, UGC 5609, 1.3 arcminutes to the southeast.

In a concise summary in an April 2017 *Monthly Notices of the Royal Astronomical Society* article, Burcin Mutlu Pakdil of the University of Minnesota describes four main types of galaxy rings. Polar ring galaxies are usually lenticulars with an orthogonal ring or structure of blue material surrounding them in an irregular distribution. Their widely accepted formation theory is that a smaller galaxy was gravitationally caught by a larger lenticular or elliptical galaxy, and waves of star formation ensued, with colorful fireworks induced in the enwebbed intruder, as in Centaurus A, a galaxy I was thrilled to see naked eye from Chile. The second type is collisional, best exemplified by the Cartwheel Galaxy, ESO 350-40, in Sculptor. In this form of ring galaxy, the interloper makes a central hit on the larger galaxy and waves of gravitational disruption provide new star formation within the larger galaxy, as opposed to the polar ring's production within the smaller galaxy. I have viewed the 14th-magnitude Cartwheel with my 32-inch reflector from the Okie-Tex Star Party, though no *aintno* "spokes" were seen. On the POSS and in the eyepiece, the Cartwheel is in one way opposite of Hoag's Object: the outer ring is its brightest part. In the case of Hoag, such a collision formation seems less likely, as the relative speeds of the core and ring are near zero, and we see no nearby "interloping" galaxy.

The Beautiful Skies OF THE MAINE WOODS

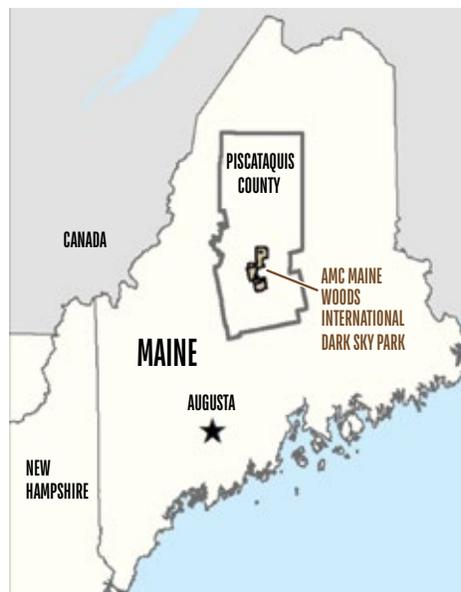
by Doug Arion

Pakdil describes the third category as accretion, citing IC 2006 in Eridanus as an example. The ring around this galaxy was studied in 1992 by Bertsek from the Glavnaya Observatory in Kiev. On the POSS 2 plates, it is ephemeral at best on the red image, and on the blue it is large, circular, and ghostly faint at 4 arcminutes in diameter. I have not yet observed this galaxy. Her last subtype of ring galaxy is formed from “secular evolution,” as forces within the galaxy change its shape. These include star formation induced by spiral density waves, and bulge growth through the funneling of gas into the core in barred spirals that contributes to starburst activity.

The most visually striking image of a polar ring galaxy is Gemini North’s rendition of NGC 660 in Pisces (shown at the beginning of this article). This SB central galaxy has an S-shaped, warped, and dusty disk within a flattened oval, surrounded by a stringy, twisted tangle. The captured galaxy’s remains are aglow in the light of a hundred new star clusters. I have viewed it twice with large reflectors in moderate skies, and noted detail in the disk of the main galaxy and the dark lanes, but the low surface brightness polar extensions that should be visible with careful scrutiny in excellent conditions have eluded me. Two UGC galaxies have designations as PRGs. These are UGC 9796 (II Zwicky 73) and UGC 7576. The former is a 16th-magnitude structure in northern Boötes. The latter is the same magnitude, located 27 arcminutes north-northeast of Gamma Comae Berenices. These two galaxies were observed in the late 1990s with my 25-inch reflector from the Texas Star Party. The faint extensions of UGC 9796 were not visible, but on a good night, the “spike” piercing the heart of UGC 7576 could be noted in moments of excellent seeing.

The creative mind is always searching for new expression. Artists and musicians are judged in the court of public opinion, but scientists adhere to a stricter standard. A well-trained person can see when something is outside the realm of accepted theory, and that is the seed of discovery. Not all seeds will grow, but some produce the strongest oaks. Just as Halton Arp was attracted to the breakthroughs and persona of Edwin Hubble and for a time orbited this giant of astronomy, we are now drawn like polar matter to his peculiar objects capable of teaching us tendrils about how the Universe works. ★

You wake up in a beautiful cabin, step out onto the front screened porch overlooking a pristine Maine lake. You hear loons... perhaps see a moose grazing. Off in the distance is Mount Katahdin. You’re sipping your morning coffee, awaiting a beautifully prepared breakfast in the lodge. You’re a little groggy – after all, you were up late observing under a truly dark, **Bortle Class 1 sky**. What, you say? A Class 1 sky accessible to us here in New England? Yes – it’s true. And you can experience it, and all of the above, in the newly-designated **AMC Maine Woods International Dark Sky Park**.



In 2012 I launched the “Mountains of Stars” program in partnership with several academic institutions and the Appalachian Mountain Club (AMC), the country’s oldest outdoor conservation, education, and recreation organization (www.outdoors.org). It has been a fruitful partnership, through which we create *environmental awareness from a cosmic perspective*, using astronomy to connect the public with the environment. One of the major components of our work has

been promoting dark skies preservation as an important environmental and conservation issue, which organizations such as the AMC need to take on as part of their missions. Light pollution doesn’t just rob us of the stars; indeed, that is the *symptom* of the larger issue of excessive and poorly shielded lighting. The serious detrimental effects on human health and safety and the impact on flora and fauna, combined with the environmental impacts and costs of producing excess electricity to generate light that we don’t actually use, make this a much bigger and more important issue than it is even for us stargazers. I am proud to say that our program convinced the AMC to include dark skies preservation in its conservation mission, improving outdoor lighting at its facilities, and leading the way in founding the new dark sky park encompassing their lands, lodges, and cabins in northern Maine.

The AMC Maine Woods International Dark Sky Park (AMC MWIDSP) encompasses over 75,000 acres of land in the Moosehead Lake region that the AMC has preserved for its natural environment and recreational opportunities. A campaign is ongoing to acquire and protect an additional 25,000 acres. The AMC MWIDSP complements other dark sky preservation efforts in the region, including the Mont Mégantic International Dark Sky Reserve and the Katahdin Woods and Waters Dark Sky Sanctuary, contributes to the economic development of Piscataquis County, Maine, and is a destination for people to connect with the natural environment and the night sky. A significant part of the park area is a Bortle Class 1 environment, providing a true dark sky experience to visitors. The Maine Woods is within a few hours’ drive to nearly a quarter of the U.S. population, making the AMC Maine Woods International Dark Sky Park a valuable resource that can engage and impact a significant number of people.

continued →



AMC's Medawisla Lodge and Cabins, in the Maine Woods, offers pristine star gazing opportunities for guests. Photo by Cait Bourgault

As part of Mountains of Stars, the AMC facilities in the park – Gorman Chair-back Lodge and Cabins, Medawisla Lodge and Cabins, and Little Lyford Cabins – have all been equipped with telescopes and observing gear, including several 9.25- and 10-inch reflectors along with hydrogen-alpha scopes for daytime solar observing. Programs are offered to guests and at local schools and parks. The incredibly dark sky makes it possible to see things we can only dream of from even good rural sites. The instruments are available for guided observing activities and for your own use, and you are, of course, welcome to bring your own gear as well. It is an astro-imaging paradise. There are also plans for a new, smaller lodge to be built on Shaw Mountain near Medawisla by 2023, which will include an observing deck and additional telescope gear. All of the locations are vehicle-accessible on a three-season basis, and Medawisla Lodge can be reached by car year-round. Minimizing environmental impact, the AMC lodges and cabins are all off-grid, using solar and wind power to supply electric-

ity, reinforcing the conservation mission and message. You can see why dark sky preservation is a natural fit for this place.

The natural resources of the region, including the deep forests and mountains as well as the streams, fish, birds, and other wildlife, are a major draw for ecotourism. The 100-Mile Wilderness section of the Appala-



chian Trail passes through the area, and the nearby town of Monson is the gateway to the last stretch to Mt. Katahdin and the northern terminus of the Appalachian Trail. Northern Maine was, like many areas, once a booming logging and paper-producing region. The loss

of those industries has caused these areas to depend primarily on ecotourism. The dark sky above these lands is just as important a natural resource, and provides the opportunity to support the region through astrotourism. We hope that you will take advantage of this unique and beautiful place for an astro-vacation. Great observing in a beautiful setting, comfortable lodging, and terrific meals make for an outstanding experience for you and your family.

You can contact AMC reservations at 603-466-2727 or amclodging@outdoors.org, and learn more about the AMC Maine Woods International Dark Sky Park at tinyurl.com/maine-stars. Learn more about the Mountains of Stars program at www.mountainsofstars.org, and feel free to reach out to me to learn more about our programs and opportunities. ★

Douglas Arion is Executive Director, Mountains of Stars, and a member of the Springfield Telescope Makers



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GALLERY

This page, top: Kevin Witman (Astronomy Enthusiasts of Lancaster County) created this composite view of the June 10 solar eclipse from Little Britain, Pennsylvania, using a Canon X5 and 55 mm lens. The image consists of eleven exposures of the eclipse layered on the original foreground scene.



This page, below: Tom Nolasco (Delaware Valley Amateur Astronomers) captured these images of the June 10th solar eclipse from Belmar, New Jersey, using a Canon T3i with a 75-300 mm zoom lens at 300 mm on a static tripod.

Right, top: Michael Rosolina (Greenbrier Valley Astronomy Association) captured this image of the SpaceX Falcon 9 launch on April 21, 2021, using a Canon T5i with lens at 33 mm f/4.5. This view six minutes into the launch shows the first stage falling away just below and to the right.

Right, bottom: Mark Harter (Colorado Springs Astronomical Society) captured this view of the Milky Way at Balanced Rock in Arches National Park using a Nikon D5600 camera using a single 13-second exposure with a 20 mm Sigma f/1.8 lens on a static tripod.





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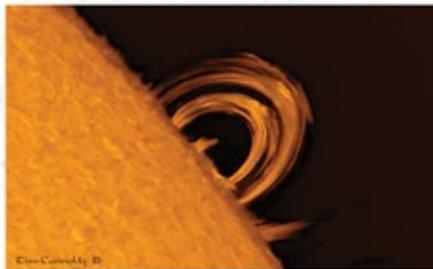
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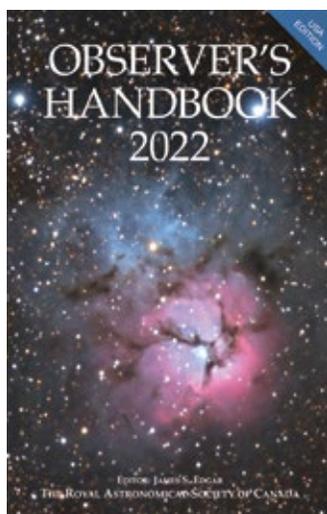
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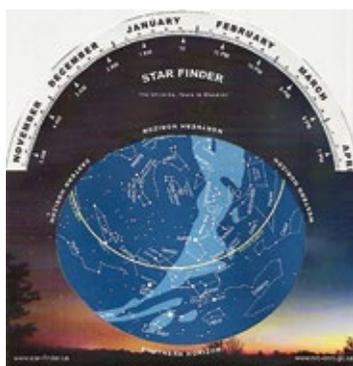
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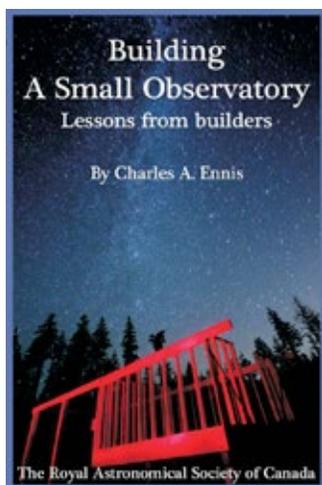


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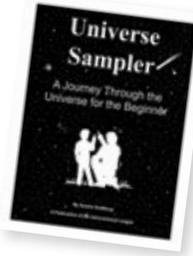


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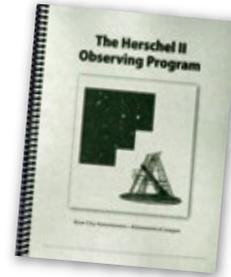
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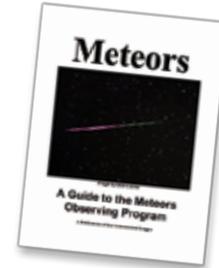
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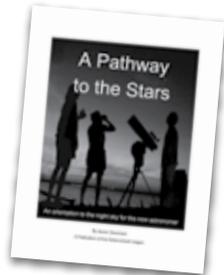
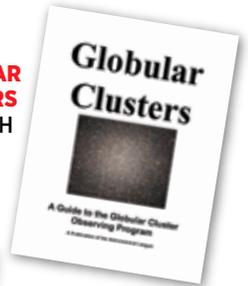


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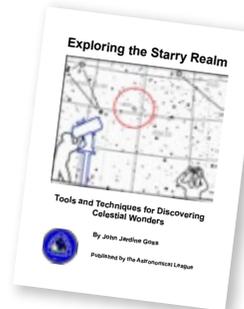


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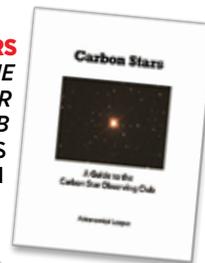


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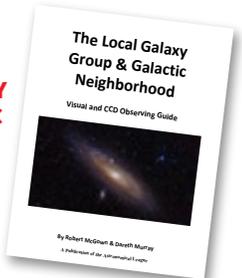
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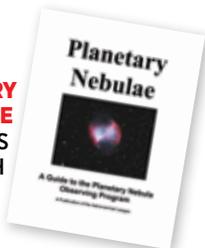


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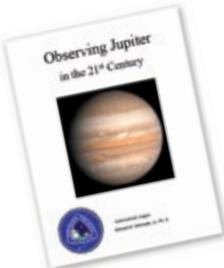


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