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Reflector

PHOTOGRAPHING THE ENTIRE MILKY WAY

BUILDING A PERSONAL OBSERVATORY

EDWIN HUBBLE'S "EUREKA" MOMENT

AMATEUR SLEUTHING FOR EXOPLANETS

ASTRONOMICAL LEAGUE

ALCON 2021 ALBUQUERQUE NEW MEXICO

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Cover image: *Brian Ottum (University Lowbrow Astronomers) captured IC 2118 (the Witch Head Nebula) from Dark Sky New Mexico using a 10-inch f/5 reflector with a Canon EOS 5D Mark III camera.*

Reflector

The Astronomical League Magazine

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

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

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Reflector

QUARTERLY PUBLICATION OF THE ASTRONOMICAL LEAGUE

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***REFLECTOR* AND CLUB ROSTER DEADLINES**

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

To the Editor

I read with great interest your most informative article published in the June 2020 issue titled "Double Star Observing: Expand Your Toolbox." What caught the eye of some readers is that the inception of this observing program rests with John Wagoner of Dallas, Texas. John is the founding member of the inner-city public outreach "City Lights Astronomical Society for Students" (CLASS). He has been instrumental in too many astronomical initiatives and endeavors to mention in this short write-up.

On that note, he still laments the addition of Porrima (Gamma Virginis) to the roster of required double stars. His assertion is that at the time of inception of this observing program he did not consider the fact that Porrima was approaching periastron and its separation was decreasing. Currently this double star is a challenging observational object.

As with all sciences, we learn from those that go before us, as laid down by Bernard of Chartres in his assertion that we "stand on the shoulders of the giants" that came before us. Those of us who know John have gained invaluable insight and continue to learn from John Wagoner. John has been instrumental in motivating the public to participate in outreach. John is at the forefront of helping the Texas Astronomical Society and CLASS meet that mission goal.

Sincerely,

—Huey Stevens
Texas Astronomical Society of Dallas

Call for Officer Nominations

The two-year term of the office of the secretary and three-year term of the office of treasurer end on August 31, 2021. If you are interested in using your talents to serve in either one of these two important positions, we would like to hear from you. Please volunteer!

For specific information regarding the duties and responsibilities of the secretary and treasurer, please refer to the League's Bylaws, which can be accessed on the League's website, *astroleague.org*.

Candidates should send Nominating Chair Chuck Allen *(vicepresident@astroleague.org)* a background statement explaining why they are interested along with a photo of themselves for publication in the *Reflector*. Please limit all statements to approximately 250 words. All nomination materials must be received by March 15, 2021, so they can be published in the June *Reflector*.

Election Results

At the Astronomical League's National Council meeting on July 16, the results of the 2020 officer elections were announced. The incoming president of the Astronomical League will be **Carroll Iorg** and the incoming vice president will be **Chuck Allen.** The officers assume their duties on September 1, 2020.

We wish to thank the outgoing president, Ron Kramer, for his leadership. He has steered the organization over the past 21 months, keeping it running smoothly while exploring new avenues and new programs.

International Dark-Sky Association

URBAN NIGHT SKY PLACES

Valle de Oro National Wildlife Refuge was named the first IDA Urban Night Sky Place (UNSP). Valle de Oro is 11 km (7 miles) south of the center of Albuquerque, New Mexico, a city with a metropolitan population of over 900,000. This wildlife refuge is managed by the U.S. Fish and Wildlife Service and consists of 560 acres of restored habitat for wildlife and migratory birds. It is promoted as a place for people to enjoy nature along the Rio Grande River and shows how people and wildlife can coexist in a protected area close to a major urban center.

As an aside, it has been my observation that wildlife is amazingly adaptable and can exist alongside humans remarkably well if given modest protection. Think of all the foxes, coyotes, skunks, squirrels, hawks, vultures, owls, and songbirds that live in urban centers. Species like beavers and turkeys, once uncommon, are now so numerous as to be considered pests in some locales. Bears are common in many parts of the country, and even wolves are increasing their numbers and range. Even though the population of the United States has doubled since I was a mere youth, I have witnessed an incredible increase in wildlife over my lifetime. Nevertheless, there is so much more we should be doing for the environment.

Valle de Oro was established in 2012 on the site of a former dairy farm. The former farmland is being returned to a natural floodplain habitat. It is also a place to demonstrate how environmentally responsible lighting can be used in a densely populated area to protect wildlife, save energy, maintain safe levels of lighting, and protect the night sky. The lighting at the refuge is fully shielded with a color temperature of 3000 K or lower to minimize blue light. As a result, "Visitors to Valle de Oro can expect an enriching nighttime experience that shows off good lighting while also providing a natural wildlife experience, and opportunities for stargazing close to home."

IDA developed the concept of Urban Night Sky Places in 2018. Valle de Oro was named the first Urban Night Sky Place in the fall of 2019. I hope other similar locales are in the process for certification as Urban Night Sky Places. Most light pollution is urban skyglow from cities and suburban areas. This is considerable and seems to be increasing in many areas due to population growth and increased use of lighting because of more efficient systems that produce more light for the same amount of energy and money.

From the amateur astronomy point of view, it is important to protect our current dark sites, which are usually removed from urban and suburban areas. We need to do this, of course, and we need to restore darkness to areas disturbed by nearby ill-designed and poorly executed lighting in an otherwise dark area. Conceptually this is easy to do, but it is often difficult in practice.

More difficult is planning how we can gradually restore darker skies to suburban and urban areas. At first glance, it seems impossible. Yet, I have been amazed at how much one can see amid a city if you can just get away from bright lights shining directly on you. If you go to the beach in Santa Monica, California, on a moon-free night, look out over the ocean. You will be amazed at what you can see in the western sky. If you are in Chicago, go to a Lake Michigan beach and look east on a moonless night. Again, you will be amazed at how much of the sky is relatively untrammeled. A pristine darkness? No, but useable. Just think how much more you could see if the lights in Santa Monica near the ocean were toned down. The same goes for Chicago along the lakefront.

Many other urban areas have similar situations. It would not take much to improve things considerably. Having an Urban Night Sky Place contiguous to a large city would help wildlife immensely, and it would provide an example of good lighting for the public to better understand what we are trying to accomplish with the dark-sky movement.

—Tim Hunter
Co-founder, IDA

Night Sky Network

NASA'S SOLAR SYSTEM AMBASSADORS PROGRAM NEEDS YOU!

If you are a fan of NASA's work, there are so many ways to share your passion for astronomy with the public. The Night Sky Network (NSN) is one great program for clubs active in outreach, and it hosts many NASA resources specifically made for outreach-loving amateur astronomers. If you aren't a member of a club or would like to do even more outreach in addition to your club's activities, there is another NASA volunteer program that you should consider: the **NASA Solar System Ambassadors!**

The Solar System Ambassadors recruit highly motivated space science enthusiasts who love sharing the wonders of the universe with the public. Solar System Ambassadors – SSAs – host outreach events to share their wealth of knowledge about NASA science and discovery with their communities. What types of outreach events do Ambassadors host? All kinds! Ambassador events range from participating in special reports for local TV news outlets, presentations about past and future missions in local libraries and schools, rocket launch watch parties, star parties in person and – in this time of COVID-19 – virtual star parties and astronomy-focused livestreams and presentations. This list doesn't do proper justice to the variety of events happening. Ambassadors are encouraged to be creative in their outreach as long as NASA mission science is accurately featured.

So, how do you become a Solar System Ambassador? We asked Kay Ferrari, SSA program coordinator for NASA/JPL, and she gave us the details for this year's application window and a little bit of what they look for in new volunteers:

"We will be seeking new Ambassador candidates in September 2020, when our annual application period opens up again. At that time, an Announcement of Opportunity notice and application form will be available on the Solar System Ambassadors website at *solarsystem.nasa.gov/ssa.*

We look for space enthusiasts who are self-starters, active in their communities, and have a desire to learn about NASA's accomplishments and share that information with their local communities. Once selected, we provide Ambassadors online trainings with downloadable website materials. Hardcopy materials are provided as those become available from the missions."

Solar System Ambassadors will become official NASA representatives, so careful consideration is given to each applicant before they are accepted into the program. The recruitment window opens just once a year, so this is your opportunity to join a great community dedicated to bringing the wonder of NASA to the public.

SSAs host at least four events per year and are sought after for their expertise by their communities, including partnerships with libraries, museums, and schools. Their outreach efforts inspire the next generation of scientists and astronauts to reach for the stars. What are you waiting for? Visit *solarsystem.nasa.gov/ssa* in September and apply!

—David Prosper and Vivian White

Full STEAM Ahead

PUTTING THE PIECES TOGETHER

As we start getting our ALCon Jr. momentum going again, we will rework a few aspects, but overall, we are still a go for 2021. Our original plans have been moved to the new dates of August 5–7 at the same place, the New Mexico Museum of Natural History and Science in Albuquerque.

For a brief refresher, this is where we currently stand. We are offering a telescope making workshop for middle school students to adults on Thursday and Friday, and STEAM activities for elementary school students all day Saturday. Thursday, August 5, from 1 to 4 p.m. will be the first session for telescope making. The second and last session for the ATM workshop is on Friday, August 6, from 9 a.m. to 1 p.m., when scopes will be completed and collimated. While these workshop classes are going on, elementary school students will be participating in activities in neighboring museums in the same complex. On Friday evening, families will be able to learn how to use their scopes as well as get oriented to the night sky. This most exciting night will be "first light" for the telescopes at the star party. Please refer to the ALCon adult schedule.

Here is a sneak peak of Rob Teeter's dry-fit prototype. This 6-inch telescope is an f/8

Dobsonian. Notice the signature Teeter altitude bearing design, Russian Baltic birch wood, and beautiful box joints. The last photo shows the pieces that will be boxed specially for ALCon Jr. Rob is an expectant father and cannot confirm his attendance, so Donna Smith from the Sidewalk Astronomers has happily volunteered to help.

Assembled Dobsonian mount

The telescope parts kit (not shown) is from e-Scopes and features 6-inch Coulter optics, a parabolic primary mirror, matching secondary, 4-vane spider with diagonal holder, 1.25-inch focuser, 25 mm Kellner eyepiece, and 5x24 finder with adjustable mount. The tube will be an 8-inch concrete form with the lining pulled, painted flat black on the inside and black on the outside.

These quality family telescopes are available at a cost of only $402. The Astronomical League will not make any profit on them. I'm on the lookout for volunteers with battery-operated screwdrivers and hammers to help these families assemble their scopes. During the Friday session, volunteers with collimating equipment will help speed up the final stage to finish the scopes for first light at the star party. Please feel free to contact me to join the telescope-making fun.

Saturday is dedicated to hands-on STEAM activities for K–5 students. All activities will be about astronomy, geared to the ages and grades of the students. There will be a dinner break when the room will be set up for the activities planned during the banquet.

Lunch options will have to change, since

Mounting parts kit

the in-house café permanently closed due to COVID-19. We will pursue other lunch and snack options so stay tuned for that update. We would appreciate volunteers with mad stapling and cutting skills and would love for elementary school kids to help us on Saturday.

Registration for the telescope making workshop will end on May 31, 2021, to allow Rob Teeter enough time for fabricating, boxing, and shipping. Registration for elementary activities will closed on June 5. To register, please visit *astroleague.org/al/alcons/alcons.html.*

I am looking forward to working with many dedicated outreachers to accomplish the first ever ALCon Jr. at an ALCon. To volunteer, please contact me at *Astroleague_steam@cox.net.*

All aboard! Full STEAM ahead!

—Peggy Walker

Wanderers in the Neighborhood

THE TWO SIDES OF IAPETUS

In 1671, Italian-born French astronomer Giovanni Domenico Cassini was perplexed by his observations of one of Saturn's moons. He had discovered it in October 1671 to the west of Saturn and he tried to observe it again as it orbited to the east side of Saturn. He was unable to find it on the east side, but the next year he found it on the west side again. Thirty-four years later, using an improved telescope, he was able to find the disappearing moon on the east side, discovering that it was two magnitudes fainter on the east side than on the west side.

Cassini realized that, like our own Moon, Iapetus was tidally locked to Saturn, keeping the same face toward the planet at all times. This made the trailing hemisphere of the moon visible to the Earth on the west side of Saturn as it moved away from us and the leading hemisphere visible on the east side of Saturn as it moved toward us. The apparent magnitude of the forward-facing side is around magnitude 11.9, while the trailing side is around magnitude 10.2. This makes the trailing hemisphere an incredible five times brighter than the leading hemisphere.

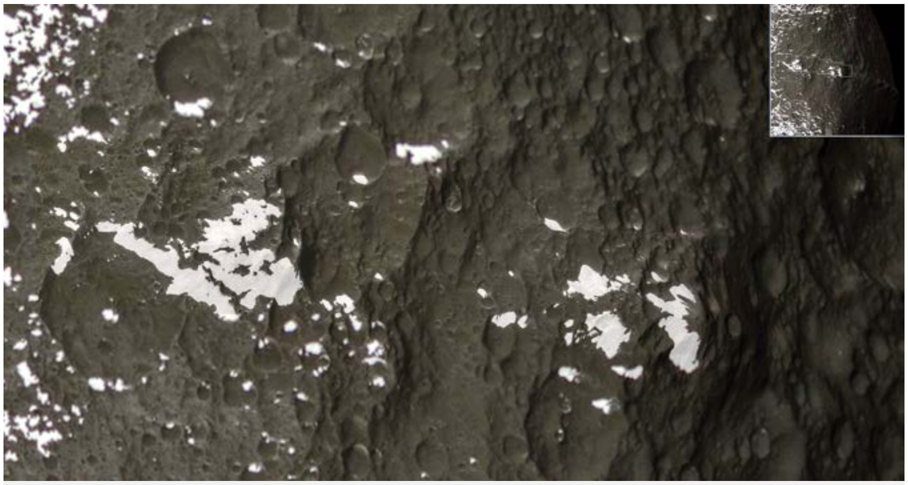
The color of the two hemispheres is also different. The bright hemisphere is white, reflecting just over half of the sunlight that falls on it. The dark side is slightly-reddish brown, reflecting only about four percent of the sunlight. This extreme contrast is unique in our Solar System. While Earth-based astronomers could see the difference in brightness, Iapetus's 914-mile diameter results in a 0.2 arcsecond diameter image, revealing no detail on the surface of this moon.

Although astronomers could not see surface details, they could take spectrograms of the two hemispheres. The leading, darker hemisphere appears to be carbonaceous, with darker compounds of carbon, hydrogen, and nitrogen frozen solid at the surface temperature of around –226°F. The bright side shows characteristics of water ice, which reflects more of the Sun's heat back into space resulting in a colder temperature of –280°F.

The Saturnian moons are named after the Titans of Greek mythology, as suggested by John Herschel in 1847. The Titans were siblings of Cronus, another Titan, whom the Romans called Saturn. The names of geological features on Iapetus are taken from the French epic poem "The Song of Roland." These include the northern region of the bright hemisphere, Roncevaux Terra, as well as the craters Charlemagne and Baligant. The dark region, Cassini Regio, is an exception to this rule, being named after the moon's discoverer.

The bright region is split into two sections. Roncevaux Terra is the northern half of the bright region, and Saragossa Terra is the southern half. Saragossa Terra has a very prominent basin 313 miles across named Engelier. This basin was probably the result of a small asteroid impacting the moon. There are two larger craters on Iapetus, but they are both older and more eroded by more recent impacts. Abisme in northern Cassini Regio is 476 miles across, and Turgis, on the equator at the edge of Cassini Regio, is 360 miles across.

To learn more about Iapetus, spacecraft need-



The Voyager 2 spacecraft took low-resolution images of Iapetus showing a line of white spots extending from the bright hemisphere onto the dark hemisphere. The images were not very detailed, and it was presumed the bright spots were the peaks of a mountain range, dubbed the Voyager Mountains. When Cassini made a close approach to Iapetus on September 10, 2007, it imaged these bright spots and found they were bright material, most likely water ice, on the side of the mountains. These mountains are part of the equatorial bulge. Image credit: Gordan Ugarkovic

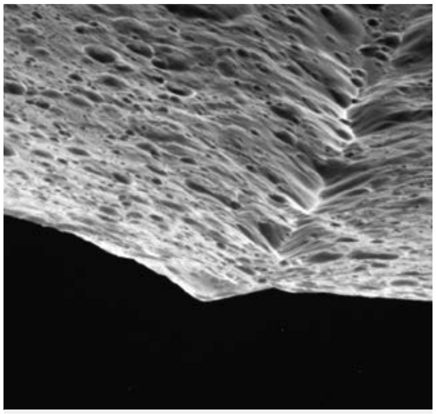
ed to visit the Saturnian system. Pioneer 11 provided the first glimpse of Iapetus in 1979, but the moon was too far away to get images useful in solving its mystery. In 1980, Voyager 1 was targeted to fly by Saturn's moon Titan, so it was too far from Iapetus to get close-up images. Voyager 2 in 1981 got better images that clearly showed craters on the surface. Finally, in July 2004, the Cassini spacecraft entered orbit around Saturn and was able to get close-up images of Saturn's moons, including Iapetus. It made its closest approach to the moon on September 10, 2007.

The Cassini spacecraft revealed a surface that was heavily cratered. This indicates that the surface is very old and unaltered by geological processes. They also indicated that the moon was not spherical. It is an oblate spheroid, a squished sphere with a polar diameter five percent smaller than its equatorial diameter. This would be normal if Iapetus was making a revolution every 16 hours, instead of every 79 days.

This oddity can occur if the crust became frozen in its current shape while the moon continued to slow its rotation until it became tidally locked. The bulging equator has an additional feature, a ridge of individual mountains, mountain ranges, and parallel ridges. Some of the mountains are over 12 miles high, some of the highest mountains in the Solar System. These two factors give Iapetus a walnut-shaped appearance. It is the largest object in the Solar System not in hydrostatic equilibrium.

The equatorial ridge is most prominent in the dark hemisphere where it is well delineated. In the bright area, the ridge almost completely disappears, but there are single mountain peaks over six miles high scattered along the equator in that hemisphere. The ridge is interrupted by craters, indicating that it is as old as the rest of Iapetus's surface. The source of the ridge is poorly understood, but it may be related to the moon's non-spherical shape.

Voyager 2 imaged a line of white spots near the equator as it enters the dark region. These were initially thought to be mountain peaks towering above the dark material. Dubbed the "Voyager Mountains," they were not exactly on the equator, but slightly offset. Cassini images showed that the bright spots are not on the peaks, but on the sides of mountains, forming one of many examples where bright material exists in the dark region and vice versa.

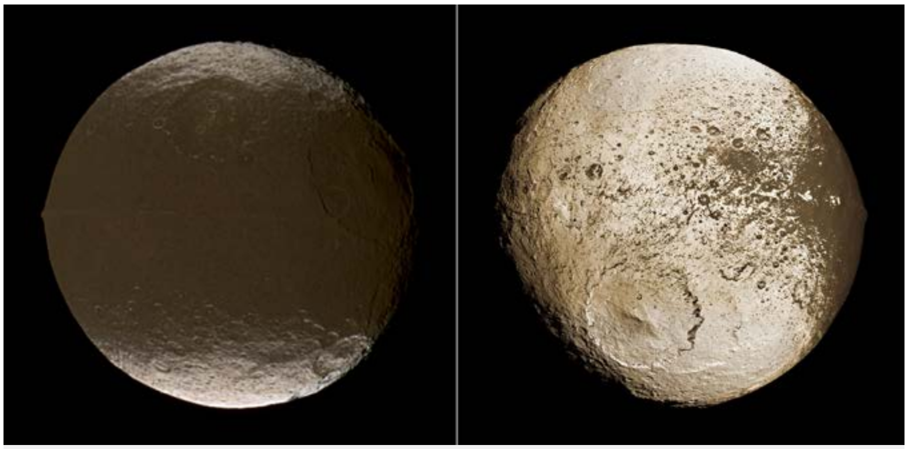


Another image from Cassini's close approach to Iapetus on September 10, 2007, shows the equatorial bulge as it crosses the limb, towering above the surrounding terrain. The equatorial bulge is most likely a result of a much faster rotation rate during Iapetus's formation that was frozen in place as it cooled and the moon's rotation rate slowed. Image credit: NASA/JPL/Space Science Institute

Iapetus has a very low specific gravity, around 1.08, just slightly higher than that of water. This implies that Iapetus is mostly frozen water, with a small amount of rocky material mixed in. The bright areas are most likely ice, accounting for their high reflectivity.

The dark material is only about a foot thick, since small meteorites can punch through it to the underlying brighter ice. It is likely that the dark material had been mixed in with the ice and it was left behind as sunlight sublimated the ice. The dark region absorbs more sunlight and loses more ice, leaving more dark material behind, while the light areas lose much less ice and stay white. Over a billion years, the dark areas lost 70 feet of ice while the light areas only lost 4 inches.

The dark area on the front side on Iapetus probably started getting dark by accumulating material blown off the outer small moons, especially Phoebe, that spiraled down toward Saturn and was swept up by Iapetus's lead-

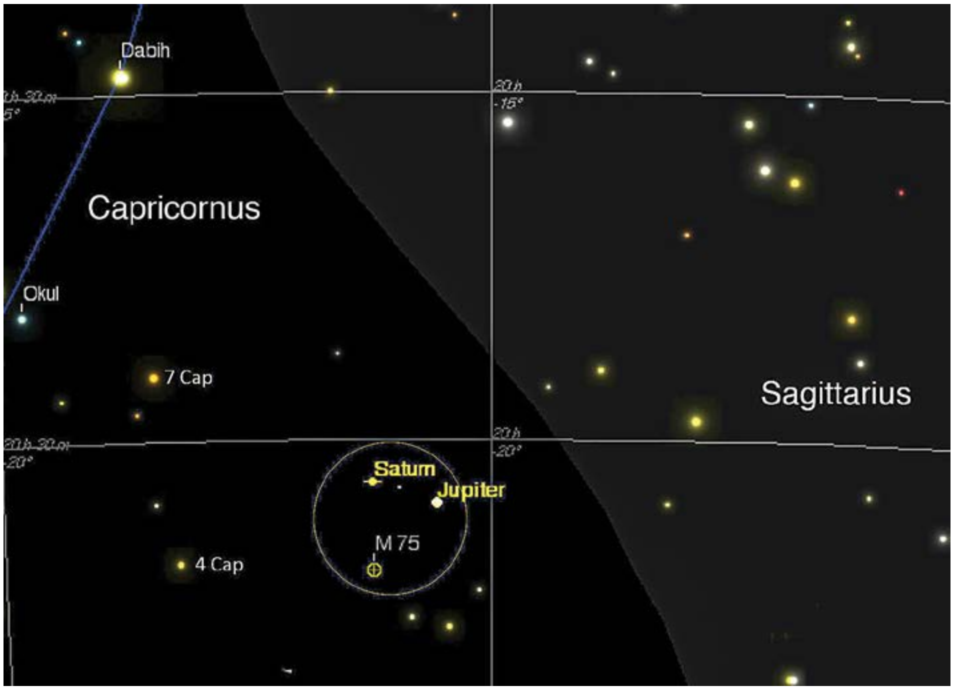


The two hemispheres of Iapetus, the dark and bright. The dark hemisphere is the leading hemisphere, always facing the direction of motion, since the moon is tidally locked to Saturn. The bright hemisphere is the trailing hemisphere. The brightness difference is striking, with one side dark as charcoal, and the other white as snow. The dark area makes up almost 40 percent of the moon's surface. Both hemispheres are dominated by impact craters, both large and small. The prominent crater on the southern bright side is the 313-mile-wide Englelier crater. These images were taken on the September 10, 2007, during a close flyby of Iapetus by the Cassini spacecraft. Image credit: NASA/JPL/Space Science Institute ing hemisphere. Ultraviolet light from the Sun darkened this material. Once enough material had accumulated, the process of sublimating ice would continue without accumulating any additional material.

Iapetus is one of the most bizarre moons in the Solar System. Its striking albedo contrast along with the equatorial ridge and lack of hydrostatic equilibrium makes Iapetus a true moon of mystery.

—Berton Stevens

Editorial note: We have processed the images in this article to make low-contrast features more visible in the printed magazine.



Deep-Sky Objects

GLOBULAR CLUSTER MEETS GAS GIANT PLANETS

One of my favorite classes of deep-space objects to view in telescopes is globular star clusters. Globular clusters contain a hundred thousand to millions of stars in one collection. Unlike galactic or open star clusters that contain many fewer stars, the mass contained in globular clusters is sufficient for the gravitational force to keep all of the stars bound together. The Milky Way Galaxy may contain close to two hundred globular clusters. Unlike most objects in the galaxy that orbit in the galactic disks, globular clusters form a spherical halo in the outer reaches of the galaxy and circle the galaxy in random orbits. Most globular clusters are very old, dating back to the formation of the galaxy.

What is great about globular clusters is they can be seen in any size of telescope. In small telescopes, they may appear as unresolved "globs" (the nickname for these clusters). Small telescopes may begin to resolve individual stars in the nearest globular clusters using higher magnifications. Many of the Milky Way's globular clusters are resolved into hundreds or thousands of stars with an 8-inch telescope. The view is especially exciting in even larger-aperture telescopes.

Near the end of summer and early fall, the constellation Sagittarius rides above the southern horizon as twilight fades to darkness. Most globular clusters are listed in the New General Catalog (NGC). A scan of the NGC list shows there are more globular clusters in Sagittarius (21) than in any other constellation.

The easternmost globular cluster in Sagittarius is M75 (NGC 6864). M75 is neither the largest nor the brightest of the globular clusters in Sagittarius. But its location along the border of Sagittarius and Capricornus means that it is outside of the glow of the Milky Way. Thus, its stars are not lost among the countless stars in the galactic plane. M75 shines at magnitude 9.1 and is roughly 6.8 arcminutes in diameter. Compare this to Sagittarius's best globular cluster, M22, which is magnitude 5.1 and 32 arcminutes in size. M75's smaller and dimmer stars are a result of its distance, 67,000 light-years; M22 is only 10,400 light-years away. Were M75 as close as M22, the two clusters would be comparable in brightness and size.

M75 does not lie near any bright stars. It is located roughly eight degrees south-southwest of the third-magnitude star Dabih (Beta Capricorni). To star hop to it, start at Dabih and move 4.5 degrees south to magnitude 5.2 Sigma Capricorni (7 Capricorni). Another 2.75 degrees south and slightly west of 7 Capricorni lies 4 Capricorni (magnitude 5.8). M75 is 2.75 degrees due west of 4 Capricorni.

My image of M75 was taken with a 10-inch f/6 Newtonian with a Paracorr Type-2 coma corrector and an SBIG ST-2000 XCM CCD camera. The exposure was 40 minutes. The brightest star in the image on the lower left (southeast) edge shines at magnitude 10.6. The faintest stars are magnitude 18.

M75 is a dense cluster with a relatively bright core and circular appearance. The core may appear east of the center, an artifact of brighter stars on the west side from our vantage point. The best views will be at magnifications between 100x and 200x, which will allow more stars to be resolved.

M75 lies close to the ecliptic and has been doing a dance with the giant planets Jupiter and Saturn since the spring. Outer planets trend eastward along the ecliptic, except when approaching opposition when they begin retrograde (westward) motion. Jupiter made it almost as far east as M75 last May before it began moving west. Saturn, on the other hand, passed east of M75 in March, turned around and then passed west of it in July.

After reaching their respective oppositions, Jupiter and Saturn continue their prograde motion along the ecliptic and catch up to M75 in December. For a few days around December 12, both planets will be in the same telescopic field of view with M75 low in the southwest as astronomical twilight ends. The accompanying finder chart for M75 shows the positions of Jupiter and Saturn on December 12, 2020. The circle around M75 and the planets is the field of view through my William Optics 132 mm f/6 APO with a 26 mm Tele Vue Nagler eyepiece. All three objects will be visible simultaneously in the 2.3-degree true field of view.

Whether you are in Sagittarius this autumn hunting star clusters or just viewing the gas giant planets, it's worth making a short hop over to M75. The eyepiece that provides the best detail on Jupiter and Saturn will likely be the best eyepiece to spy this distant globular star cluster.

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

Library Telescopes

YOUR ASTRONOMICAL LEAGUE JUST GAVE AWAY SIX LIBRARY TELESCOPES!

Through the vision of the Horkheimer Charitable Fund, the Astronomical League again offered a free Library Telescope to a lucky Astronomical League club in each region, plus one to a Member-at-Large.

The Library Telescope consists of a 4.5 inch Dobsonian reflector fitted with an 8-24 mm zoom eyepiece, and a name plate commemorating the late Jack Horkheimer. The value of this opportunity is approximately $300; the potential is enormous.

The Library Telescope program was initiated twelve years ago by the New Hampshire Astronomical Society and has grown into a nationwide presence. Clubs donate an easy-to-use portable telescope with quality optics and a sturdy mount to their local library. Patrons can then check it out as they do books.

Thank you to the Horkheimer Charitable Fund, Orion Telescopes, and Celestron for making this wonderful program possible!

CONGRATULATIONS TO THE 2020 WINNERS:

Tucson Amateur Astronomy Association, WRAL
Howard Astronomical League, MERAL
Island County Astronomical Society, NWRAL
Lowcountry Stargazers, SERAL
Door Peninsula Astronomical Society, NCRAL
Amateur Observers' Society of New York, NERAL

New AL Award

THE ASTRONOMICAL LEAGUE HAS RECENTLY APPROVED A LIBRARY TELESCOPE AWARD

This is similar to the highly successful Outreach Award. A Library Telescope is a telescope owned by a library that is made available to adult library patrons for borrowing just like a book. Generally, the telescope is a modified Orion StarBlast 4.5-inch reflector. The new award recognizes the activities that Astronomical League members perform in promoting and assisting successful Library Telescope programs.

The Library Telescope Award has two levels: silver and gold. The silver level requires 20 hours of Library Telescope activities and is recognized with a certificate. The gold level requires an additional 80 hours (100 hours total) of Library Telescope activities and is recognized with a certificate and pin.

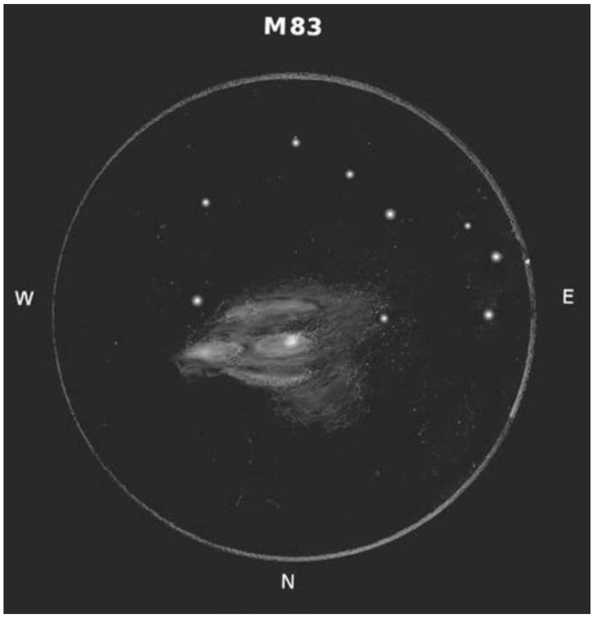
I can't think of a better way to promote astronomy than to make a reasonably high-quality, yet relatively inexpensive, telescope available to the public. Enabling library patrons to use a telescope, maybe for the first time, and maybe with their children, may spark the passion that we all have for this great hobby.

For more information on the Library Telescope program see *LibraryTelescope.org* and the Library Telescope Facebook page *(facebook.com/LibraryTelescope)*. In addition, we expect to have a video event describing the Library Telescope Award sometime in September. Further details on the award are available on the Astronomical League website in the Observing Programs and Awards section.

As the initial Library Telescope Award coordinator, I am looking forward to receiving your submissions.

—Tom Lynch

This sketch of M83 was submitted by member-at-large Roy Troxel of Taos, New Mexico. It was made using an 18-inch f/4.5 reflector, operating at 171x in 3/5 seeing, with a field of view of 0.4º.



GLOBE AT NIGHT 2020

January 16 – 25	July 12 – 21
February 14 – 23	August 10 – 19
March 14 – 24	September 9 – 18
April 14 – 23	October 8 – 17
May 14 – 23	November 7 – 16
June 13 – 22	December 6 – 15

WWW.GLOBEATNIGHT.ORG

Get Out and Observe the Night Sky!

Engage people worldwide in observing the nighttime sky.

Encourage students and families to participate in citizen-science with a hands-on learning activity.

Gather light pollution data from an international perspective to monitor sky brightness and its effects.

Can you see the stars?

NSF's National Optical-Infrared Astronomy Research Laboratory

IDA International Dark-Sky Association

AURA

GLOBE AT NIGHT WWW.GLOBEATNIGHT.ORG

NSF's National Optical-Infrared Astronomy Research Laboratory

Shown above are more than 10,000 observations from over 70 countries during the 2019 campaign. Help us exceed these numbers in 2020!

From Around The League

LEADERSHIP OPPORTUNITIES: PLOT THE FUTURE OF THE AL'S NORTHEAST REGION

Attention AL members from New England, New York, and northern New Jersey: NERAL has openings in all leadership roles. If you are interested in working with the national officers to revitalize your region, please contact *president@astroleague.org.*

CELEBRATING THE WOMEN OF ASTRONOMY

The greatest joy in belonging to an astronomy club is bringing the wonders of astronomy to the people. This necessarily means meeting people where they are, accepting varied levels of interest and varied depths of commitment and participation. Success means being relevant to the people as well as being pertinent to the subject. We chose a yearly theme to bridge this gap.

2019 was a gift. It was the 50th anniversary of the Apollo 11 lunar landing. Fortunately for everyone, the anniversary was on a Saturday, the bow on top. We invited the public to join us at the Charles Temple Observatory at Moorpark College to celebrate the event together. We suggested they bring any Apollo memorabilia they may have saved to share. We were in luck. The observatory is close to Rocketdyne where the Saturn V engines were tested, and JPL, another local brain trust. Five hundred people showed up, some with amazingly well-preserved models, magazines, and newspapers. We even had a speaker who worked directly under Wernher von Braun.

The anniversary falling on a Saturday wasn't the only "gift." The exact moment Neil Armstrong set foot on the Moon was a little after 7 p.m. PDT – the icing on the cake. Our MC, a science reporter from NPR, gathered everyone together and had them start a video recording on their smartphones. He counted down from 10 to the exact moment Neil Armstrong stepped on the moon and in unison everyone shouted out: "That's one small step for man, one giant leap for mankind." It was a beautiful moment.

After that we had an open mic. People shared their memories. Young people shared their hopes and dreams. We honored Vietnam Vets who were in combat at the moment that humans first stepped onto the Moon. Scientists who worked on Apollo from different parts of the country 50 years before met for the very first time that night.

2019 was an excellent year for astronomy and space science. But what to do for 2020? 2020 wasn't a gift we only needed to unwrap like 2019. But there was a hidden treasure. We only needed to do a little digging.

2020 is the 100th anniversary of women's suffrage. What does this have to do with astronomy? That's the wrong question. What do women have to do with astronomy is the right question. Famous women astronomers are recorded as far back as 400 CE. So what's the tie-in?

Women's suffrage doesn't just grant women voting status, it unavoidably recognizes that women have continually contributed to the betterment of humanity in all areas, including medicine, politics, science, art, and astronomy. Our astronomy club decided to recognize the women of astronomy by adopting the following theme: In Recognition of the 100th Anniversary of Women's Suffrage, Ventura County Astronomical Society Celebrates the Women of Astronomy.

The theme has been a smashing success. Our website, *vcas.org,* has a page dedicated to honoring over 100 women who've contributed to our hobby, both in the past and the present. We had plans for a women-run star party in August, nearest the actual anniversary date. We even discussed hosting an African-American woman astronomer as a speaker during Black History Month and a Latina Astronomer for Latin History Month. Then disaster struck: COVID-19.

At present we're trying to salvage the year. We didn't get all the speakers we wanted due to their previous commitments, but that has been made moot by the pandemic. Now we're learning how to present our speakers online, which is a challenge for people who only know how to look through a telescope. I joke at that last point, but the challenges of learning how to effectively operate in the current situation are quite real.

Yet while our group activities have been put on hold, our group enthusiasm hasn't. We're still finding ways to honor the women of astronomy, and we are enjoying the journey. There've been some major surprises, like learning that a woman is primarily responsible for creating the NGC, or that another woman, still alive today, once held the title of having discovered more comets than anyone.

I'm writing this article to implore other astronomy clubs to do the same. While we find new ways to gather together, as we look to our future, let's not forget our past. And in 2020, let's honor all the women of astronomy. See our website for a partial list of ideas.

—Keith Salvas,
President, Ventura County (California) Astronomical Society

2020 HORKHEIMER YOUTH AWARD TOP FINISHERS

Two Horkheimer Service Awards are offered: The Horkheimer/Smith Service Award and the Horkheimer D'Auria Service Award. The winner of the Horkheimer/Smith award will be offered the opportunity to attend ALCon 2021 to receive their plaque in person and give a presentation. All first place Horkheimer winners receive $1,000 for their fabulous achievements. Thanks to Dwight Horkheimer and the Horkheimer Foundation for the continuing outstanding support for these youth award programs.

Horkheimer/Smith Service Award
First place: Vivek Vijayakumar

Our first-place Horkheimer/Smith Service Award winner makes the difficult easy to understand.

Doug Sollosy, founder and board member of the Julian Dark Sky Network in Julian, California, has known Vivek since 2018, when Vivek voluntarily set up his telescope during a public event that had over 1000 attendees. They have collaborated many times at astronomical events since then.

This quote from Mr. Sollosy captures the essence of Vivek's extraordinary abilities, accomplishments, and willingness to share with others:

"This month [March 2020], the Julian Dark Sky Network hosted an event at the Julian Branch of the San Diego County Library, which featured a lively presentation by Vivek on spectroscopy, which has for some time been the area of his science fair projects. The event was advertised in local media and drew over 30 people, which is an excellent turnout in this mountain town of 2500 residents! It was followed by 45 minutes of spirited question and answer, which Vivek handled with both patience and enthusiasm. I heard several people commenting about how impressed they were by Vivek's ability to break down the science and give people answers they could understand."

In Vivek's spare time, he has taken college-level physics and related courses at Palomar College. He will be a senior in high school this fall.

Horkheimer/D'Auria Service Award
First place: Jai Shet

Jai is an eleventh-grade homeschooler from Houston, Texas. His brother, Neil, a ninth-grader, has been with him every step of the way in his journey in astronomy. See a special joint article written by the brothers elsewhere in this issue.

They are both members of the Fort Bend Astronomy Club. In 2018 they both built refractor and reflector telescopes out of items they had around the home (see June 2020 *Reflector*). They were so excited from accomplishing this goal that they decided to volunteer for the Astronomy on Wheels program organized by their club in the Houston area. They have shared their telescope-making and astrophotography skills at schools through Astronomy on Wheels outreach. Their goal is to inspire kids of all ages, and their parents, to enjoy the wonders of astronomy.

They have given presentations at their local club as well as for the Houston Camera Club. They have also volunteered at George Observatory at Brazos Bend State Park and the Houston Gem and Mineral Show. They have travelled extensively around the country and the world with their family, looking for the darker skies for their passion of astrophotography.

Horkheimer/Parker Youth Imaging Award
First place: Jai Shet

Jai Shet used a Canon EOS R camera with a Sigma 135 mm f/1.8 DG lens to produce this out-

standing image. This image is titled "Downtown Milky Way."

Jai is a member of the Fort Bend Astronomy Club. He lives in the Houston area and is a homeschooler starting twelfth grade in the fall.

Much of the story of his passion for astrophotography is captured in the Horkheimer/D'Auria Service Award article, above.

As the first-place winner, Jai will receive a plaque and a $1000 check.

Horkheimer/Parker Youth Imaging Award
Second place: Vivek Vijayakumar

The title of Vivek's image is "The Pacman Nebula in SHO." The image was taken from Julian, California, with a C8-N, ASI-1600mm Pro, CEM60, and Astrodon 5 nm S-II, H-alpha, and O-III filters.

Vivek will receive a plaque and a $500 check for his second-place finish.

Horkheimer/O'Meara Journalism Award
First place: Lucia Castillo

Lucia Castillo will be in ninth grade this fall at Willows Academy in her hometown of Des Plaines, Illinois. She and her family are members of the Northwest Suburban Astronomers.

As the first-place winner of the Horkheimer/O'Meara Journalism Award, she will receive a check for $1000 and a first-place plaque recognizing her splendid achievement, compliments of the Horkheimer Foundation. Her well-written essay is entitled "How Kids can be Interested in Astronomy.

Horkheimer/O'Meara Journalism Award
Second place: Stephen Castillo

Stephen finished sixth grade this year at Northridge Preparatory School. Like his sister, he lives in Des Plaines, Illinois, with his family, and is also a member of the Northwest Suburban Astronomers.

Stephen will receive a check for $500, compliments of the Horkheimer Foundation. The title of his essay was "SpaceX Falcon 9 Rocket."

Horkheimer/O'Meara Journalism Award
Third place: Seth Fenderson

Seth completed fourth grade this year at Legacy Christian Academy in Broken Arrow, Oklahoma. He is a member of the Astronomy Club of Tulsa.

Seth will receive $250 for his third-place finish, compliments of the Horkheimer Foundation. The title of his essay was "Mars 2020 Rover."

2020 MABEL STERNS NEWSLETTER AWARD RESULTS

This purpose of this award is to recognize the newsletter editors across the Astronomical League family of societies who, on a regular basis, share essential information with their societies' members. These heroes are the main link for that information, often having to solicit articles near publication deadlines and selecting alternative articles when the needed number of articles is not available.

Suggested questions for judges to consider when evaluating the submissions included: Does it include meeting schedules and locations? Is the layout pleasing? Is the content pertinent to the club's membership? Is the newsletter of appropriate length? And, is the League logo on the front page?

The first-place winner receives a beautiful plaque recognizing this fine achievement.

The first-place finisher in the 2020 competition is **Bruce Bowman,** editor of the Indiana Astronomical Society's *News and Views*.

The *News and Views* issues perused for evaluation answered "yes" to most of the questions above. The newsletter was informative, attractively presenting much material from members. To read the current newsletter, visit the IAS website, *iasindy.org*.

Other top finishers:

Second place: **Mark Reed,** editor of the *Newsletter,* the member publication of the Shenandoah Astronomical Society, Middletown, Virginia.

Third place: **Jackie Richards,** editor of *Monthly Notices* of the Everglades Astronomical Society, Naples, Florida.

2020 NATIONAL YOUNG ASTRONOMER AWARD TOP FINISHERS

This award season has been much different, due to the COVID-19 situation. We postponed ALCon 2020 to the first week of August 2021 as ALCon 2021. As a result, top 2020 finishers for the National Young Astronomer Award (NYAA) will be offered the opportunity to attend ALCon 2021 to receive their plaques in person and give their presentations.

Thanks to Explore Scientific for its generous sponsorship of this program for many years. Each year the top two finishers are given a trip to the national ALCon and one of Explore Scientific's outstanding astronomical instruments. We had many excellent submissions this year. Thanks to all who participated.

NYAA Awards First place: Karen Lei

Karen is a rising senior at Saratoga High School in Saratoga, California. She became hooked on astronomy while a high school freshman, after looking through her father's telescope. The next year she started an astronomy club at her school, and she currently serves as president of the group.

The goal of her astronomy research project was to identify the unknown source of a detected 21 cm neutral hydrogen emission. As she explains, "Characteristics of the source, including right ascension and declination, brightness temperature, and vLSR (velocity relative to the local standard of rest) were calculated and appropriate queries made in the astronomical database SIMBAD. These characteristics were compared against the 20 resulting objects that matched the initial criteria of hydrogen emission line, right ascension, and declination. The brightness temperature was then compared with the two objects that passed the previous criteria, and although the brightness temperature obtained from this research's data was higher than both that of FVW 173.0+0.0 and FVW 173.0+3.0, this can be explained by the large beamwidth of the homemade radio telescope since it could take a combined brightness value possibly from several different sources. Thus, it was reasonably concluded that the source of the weak hydrogen signal detected at 5h 40m 0s, 40° was from a combination of both FVW 173.0+0.0 and FVW 173.0+3.0."

Karen recently had the privilege of visiting Mount Wilson's 100-inch Hooker Telescope. She has studied the field of radio astronomy extensively. Outside of astronomy, she loves math and is a three-time AIME (American Invitational Mathematics Examination) qualifier. She also likes to watch a variety of movies.

NYAA Awards Second place: Vivek Vijayakumar

Vivek is a rising senior at San Marcos High School in San Marcos, California. He is a youth Member-at-large of the Astronomical League.

His project is titled "Characterizing the pulsations of Delta Scuti stars using the Mg Ib triplet."

Vivek's research objective "is to study the relation between pulsations and changes in the light curves of Delta Scuti variables and the profiles of the Mg Ib triplet spectral feature, including optical depth, Doppler shifts, and broadening. Question: How do the pulsations of Delta Scuti stars correlate to the profiles of the Mg Ib triplet?"

He found that "the Mg Ib spectral feature, despite demonstrating no detectable change of appearance in profile, demonstrated peculiarities and activity that shifted the spectral lines and broadened their profile. The strong positive correlations between apparent rotational velocity and broadening demonstrate the effect of fast rotation on the Mg Ib triplet. Additionally, after accounting for rotational broadening, the strong negative correlations between the residual broadening demonstrate that as the period of the star increases, the detected broadening as caused by chromospheric activity on the star decreases. This is related to regular radial pulsations and activity. There is also possible evidence of the interference of non-radial pulsations in the profiles and their particularly strong shifts as they are not always consistent between spectral lines, and demonstrate no significant correlation with the period." Vivek further notes that "Delta Scuti stars, as stars along the instability strip and in various evolutionary stages close to the main sequence, are important to understanding and characterizing various different modes of chromospheric activity and the field of asteroseismology. The results also serve to establish the capabilities of amateur astronomers and citizen scientists to contribute to the active observation of stars not only through photometry, but spectroscopically, and in time series."

Vivek gave special thanks to Curiosity Peak Observatory. The observatory gave him access to its observing sites to collect data. Also, his parents were invaluable in driving him to the facility, often on bitterly cold nights.

2020 SKETCHING AWARDS

The purpose of this award is to recognize the special art of amateur astronomical sketching.

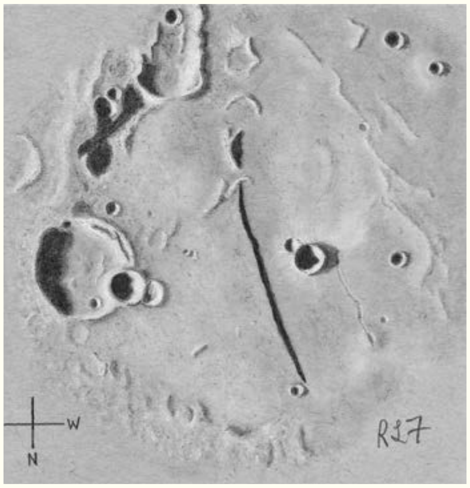
Thanks to Astronomics for its outstanding generosity in sponsoring this program.

The top finishers in the 2020 competition are:

First place: Richard Francini

Richard lives in De Pere, Wisconsin, and is a member of the Neville Public Museum Astronomical Society.

The lunar area he sketched was the fault Rupes Recta (the Straight Wall) and its surroundings. His sketching media were graphite art



pencils and black and white charcoal pencils on gray paper. There was no digital manipulation.

He scheduled three telescopic sessions on October 8, November 5, and December 5, 2019, all between the hours of 6 and 10 p.m. CST. Seeing and transparency were both average.

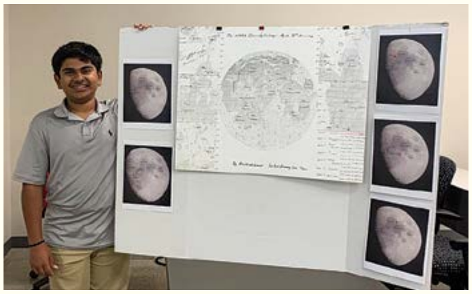
His instrument was a 13-inch Dobsonian telescope. Magnification was 240x, 310x, and

350x, with fields of view of 1/3°, 1/3°, and 1/4°, respectively.

He will receive $250 for his first-place finish, compliments of Astronomics.

Second place: Abhi Milind Giudipati

Abhi lives in Sugarland, Texas. He is a member of the Fort Bend Astronomy Club.



Abhi's project was the NASA observing challenge for the Apollo 50th anniversary. The task was to plot all of the six Apollo missions on the Moon in their respective positions and drawing and sketching the details.

No digital manipulation was used. The sketching media were paper, pencils, and a red pen. The task required several observing nights in May to July 2019, during different phases. Seeing conditions ranged from excellent to very good, with transparency rated as 4 and 5.

A 10-inch Dobsonian telescope and 10x50 Vortex Binoculars were used. Telescopic magnification ranged from 48x to 120x.

This program was a collaborative effort between NASA and the Astronomical League, and Abhi received a beautiful certificate recognizing this accomplishment signed by a representative of Goddard Space Flight Center and the president of the Astronomical League.

Abhi will receive a $150 check to recognize his outstanding second-place finish. Thanks to Astronomics for its support of this program! We appreciate this very much.

DOING OUTREACH IN A PANDEMIC

Almost every astronomy club loves to do outreach and does a great job with it. Then came the pandemic. Clubs had to discontinue in-person outreach for the safety of club members and their guests.

But there is still a way to conduct outreach events even in the midst of COVID-19. Some clubs began having online star parties. Zoom and similar platforms make these possible, and such events can count toward the Outreach Award program.

The focus of the Astronomical League's Outreach Award has always been face-to-face contact so that participants could interact with experienced astronomers. Pre-recorded videos are not acceptable, but we have clarified our Outreach Award webpage to let everyone know that online star parties and other similar online events *are* acceptable and encouraged. For example, our *Reflector* editor reports successfully working remotely with girl scouts in Vermont from her home in Connecticut. The key to whether such online events are accepted in Outreach Award submissions is that the events must make it possible for guests or participants to interact with an astronomer.

—Dr. W. Maynard Pittendreigh

A detail from Abhi Miland Giudapati's Lunar drawing

A Journey through Space and T

Here in the *Reflector* we obviously cannot adequately reproduce Jai and Neil's full Milky Way composite image, which is over 64 inches long at 300 ppi. You can download a .jpg copy at *https://tinyurl.com/shet-milkyway.*

By Jai Shet and Neil Shet

We wrote an article about our telescope-building experiences and our interest in astrophotography that appeared in the June 2020 edition of the *Reflector*. We would like to further share our interest in astrophotography. We are passionate about travel, photography, and astronomy. Combining these passions would naturally make us interested in astrophotography in remote dark-sky places across the country. We have traveled to all the lower 48 United States and to several other countries. Being homeschooled high school students made it easier for us to travel and explore our world to enhance our learning experience.

During the day we enjoy different types of photography including nature and landscapes, and we eagerly await nightfall to image the night sky. We have captured stunning landscapes from the mountains of Washington to the wetlands of Florida, and from the deserts of California to the rugged coastlines of Maine. We have seen many interesting things, such as nebulae, meteors, and the zodiacal light, but what blew our minds was our first glimpse of the Milky Way in all its splendor. We were so enamored by this experience that our focus shifted to capturing stunning images of the Milky Way in different dark-sky locations across the United States. However satisfying they appeared, though, we felt there was always something missing in our pictures. Our images lacked fine detail and resolution due to their wide-angle format. We needed to photograph smaller sections of the Milky Way to get the finer details and stitch them together in the form of a panorama. Thus, the idea was born to embark on an ambitious project to create a panorama of the Milky Way at the highest possible resolution we could achieve.

We set out on this mission equipped with a Sigma 135mm f/1.8 DG HSM lens on a Canon EOS R camera mounted on an Orion Sirius Pro AZ/EQ-G computerized go-to telescope mount. This appeared to be the best combination due to its significant light gathering capacity and magnification. Tracking was a necessity rather than a luxury at that magnification. The next step was to pick a dark-sky place. Living in the Houston area, none came to mind other than Big Bend National Park. We traveled to Big Bend since the skies there were as dark and clear as obsidian with no interference from planes flying overhead. The only moving objects visible were satellites, yet even those were outshined by apparitions of speedy meteors.

Upon reaching the park, we immediately got on the "Road to the Milky Way" and drove around until we found the perfect spot to set up our equipment. The Milky Way boldly arched over us while we felt cold in the dark desert with only the distant howls of coyotes to keep us awake. We encountered a rattlesnake on the road, which reminded us to not only admire the skies above but also to keep an eye on the ground below. Lest we felt lonely, a curious tarantula kept us company for the entire night.

We set up the tracking mount and started taking pictures. This was how it went: Align. Compose. Focus. Capture. Repeat. Capturing the Milky Way piecemeal at 30 seconds per exposure was backbreaking work, and the freezing cold weather only made it worse. Most of the Milky Way looked like a vast ocean of stars and dust at high magnification, making it difficult to differentiate between images. We relied on our knowledge of the night sky, without which we would have been lost like a ship at sea. The only "landmarks," so to speak, were the intriguing nebulae that confirmed we were heading in the right direction. After several hours of imaging each night, we returned to our hotel exhausted, only to return to the same spot the next night to repeat the process. We did not give up until we had the entire northern portion of the galaxy wrapped up.

The next tedious process was to stitch those individual images to make the panorama. When it all came together, it looked absolutely stunning, like nothing we had ever seen before. However, deep down, we felt the panorama was incomplete without the southern portion of the Milky Way. But we had no easy way to get to the southern hemisphere. We continued with our other travel and astrophotography pursuits over the next few months until one day our parents planned a trip to the South Island of New Zealand. Our eyes immediately lit up at a possible opportu-

Time: the Road to the Milky Way

nity to capture the southern part of the Milky Way. We desperately convinced our parents to agree to carry the heavy telescope mount with us on this trip. We then got down to the business of studying the night sky of the southern hemisphere.

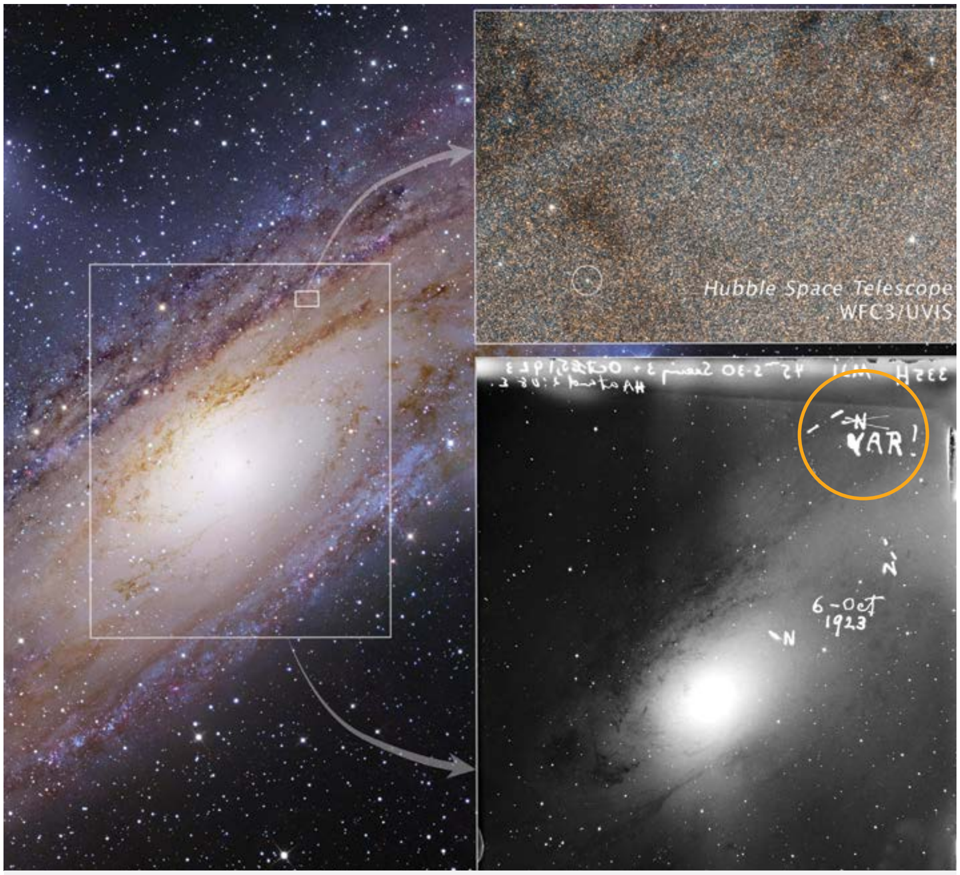
Our online research of travel in New Zealand indicated that the best way to explore the country was by renting a campervan. Once we got there, we drove around the countryside, marveling at the turquoise blue lakes at the feet of towering snowcapped mountains. We took plenty of pictures during the day and as evening approached, eagerly looked for campsites that gave us the best opportunity to photograph the night sky. As if driving on the left side of the road was not challenging enough, finding suitable campsites for astrophotography was a beast on its own. Though each campsite was unique, they all had the same weather: heavy cloud cover, fog, and rain. Despite enjoying the daytime experiences, our hopes of making the panorama dried up as the trip progressed. We only got short glimpses of the Large and Small Magellanic Clouds and the Milky Way, for the clouds just kept crashing the party. Our excitement abruptly fizzled out as clouds engulfed the galaxy like a blanket.

We set up our equipment on several occasions and desperately captured however many images we could during periods of respite offered by the thick cloud cover, but the random images were of little use in creating a panorama. We finally gave up and reluctantly went to bed after unproductively waiting for hours. This happened at every campsite we visited during the trip. We visited Mount Cook National Park, designated an International Dark Sky Reserve by the International Dark-Sky Association. We considered ourselves fortunate to find a camping spot in an otherwise crowded national park campground. However, the good fortune did not follow us into the night as heavy cloud cover forced us to go to bed early with only rain showers forecast for the rest of the night. At one of the campsites, we came across a spectacular view of sheep grazing in the setting sun. Although we saw many such sights that gladdened our hearts, our biggest desire was to complete the panorama. It was a hopeless situation because capturing bits and pieces of the galaxy would not help us merge them with the northern part.

We had almost completely given up hope by the time we were down to the last several days of the trip. We researched remaining interesting places to visit while also keeping an eye on the weather forecast. We decided upon a route back that would offer us the best weather while still providing enough sights to enjoy. The skies at our last campsite seemed to magically hear our calls for help because the clouds simply departed, revealing the galaxy's mighty face. Recognizing that this was our last chance, we spent the entire night imaging the remaining portions of the galaxy. There was an occasional cloud passing by, but on this night, even those clouds dared not impede our progress. Our goal was to image the southern part of the galaxy all the way to the galactic center, allowing us to connect it to the northern hemisphere. Since the galactic center would not be visible until 3 a.m., we had to wait an incredibly long time just to get a glimpse of it. Our parents and the rest of the folks at the campground were fast asleep – we were the only ones wide awake that night. The Milky Way slowly rose and we took images every ten minutes. We finally captured the last bit of the galactic center that completed the panorama, making it appear as a single image instead of two disjointed pieces. It was 5:30 a.m. by the time we finished, and we hurried to the airport to catch our 9 a.m. flight back home. The rest of the journey was a blur because our tiredness got the best of us. The only memories of the return journey were pleasant dreams of a galaxy far away and yet so close to our hearts.

By the end of the project, we had spent 35 hours taking over 200 images during a six-month period. But as if that was not enough, it took an additional 200-plus hours, along with several computer crashes, to process and stitch the images. We even had to borrow our dad's computer because it was much faster. The final file amassed a whopping 3 gigabytes which we cropped and compressed several times to create a more manageable output. The magnificent panorama of the Milky Way showed all the details we had hoped for. We were happy that we accomplished this seemingly impossible task. The breathtaking final image proved that all our efforts were worth it, and we thoroughly enjoyed the experience. While proudly admiring our work, we wondered if we were the first kids in the world to create such a high-resolution image of the Milky Way. ✷

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



Credit: E. Hubble, NASA, ESA, R. Gendler, Z. Levay and the Hubble Heritage Team

Edwin Hubble's Moment of Discovery

BY DAVE TOSTESON

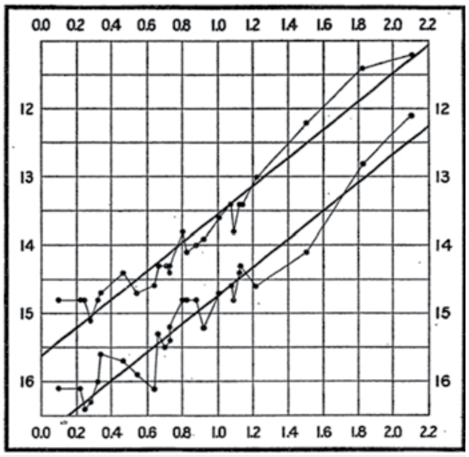
Ninety-seven years ago, nearly to the day, Edwin Hubble imaged a star in the Andromeda Galaxy. He initially thought it was a nova, but after following it for a period of time, realized it was a variable star and crossed out the "N" next to it on his plate and wrote "Var!" This seminal observation would eventually prove not only that the "spiral nebulae" whose nature had been debated for decades were truly outside the Milky Way, but opened the door for Hubble to show the Universe was not static as had been thought for millennia, but expanding. Dave Soderblom of the Space Telescope Science Institute (STScI) called this Cepheid variable "the most important star in the history of cosmology." I try to imagine how the great astronomer felt when he realized he was the first to understand these deep truths about creation. Hubble's eponymous telescope and members of the American Association of Variable Star Observers (AAVSO) imaged it with CCD technology in 2010–11. Can this star be seen *visually* in an amateur instrument?

Variable stars are ones that change in brightness. They were documented in Chinese and Korean texts, but the first European discovery was of Omicron Ceti, or Mira, by the German pastor David Fabricius in 1596. The star's eleven-month cycle was determined in 1638 by the Frisian astronomer Johannes Holwarda. Three decades later, in 1669, Algol (Beta Persei) was found to vary with a period just under three days. It took over a century until eighteen-year-old John Goodricke of England offered an eclipse between stars orbiting in our plane of view as an explanation of Algol's nine-hour forty-minute drop in magnitude. He did not let deafness in early childhood, possibly from scarlet fever, keep him from pursuing his passions. His neighbor, Edward Pigott, had a well-equipped observatory where he and Goodricke studied variable stars, including Algol in November 1782. His explanation of its nature led Goodricke to receive the Royal Society's highest honor, the Copley Medal, a few months later. He was also credited with the discovery of Delta Cephei's variability, now considered the prototypical Cepheid variable. Unfortunately, this young man's promising life was cut short in 1786, only a few days after being elected to the Royal Society.

Cepheid variables are massive stars that pulsate in size with periods between 1 and 100 days, and have very high luminosities between 500 and 300,000 times that of the Sun. They contain relatively large amounts of helium and, since their cores are much hotter than less-massive stars, increased energy can ionize the element. Doubly ionized helium, produced near the hot core, is relatively opaque to the transfer of energy, so this layer in the inner portion of the star makes it dimmer. This shell then absorbs energy to expand itself and the star's outer portions. As it grows larger it cools, allowing recapture of

Portrait of John Goodricke, said to have been painted in 1785 by James Scouler.

an electron to form singly ionized helium, a substance more transparent to the passage of light and energy. The star becomes brighter, but loses energy and starts to shrink and heat up, restarting the cycle of pulsation. This process is known as the *kappa mechanism.*



Plot from Leavitt's 1912 paper. The horizontal axis is the logarithm of the period of the corresponding Cepheid, and the vertical axis is its apparent magnitude. The lines drawn correspond to the stars' minimum and maximum brightness, respectively.

Leavitt, Henrietta S., and Pickering, Edward C., "Periods of 25 Variable Stars in the Small Magellanic Cloud," Harvard College Observatory Circular, vol. 173.

Edward Pickering directed the Harvard College Observatory from 1877 until his death in 1919. He recruited more than eighty women to assist in studying and classifying stars. They were called the "Harvard computers," and their contributions to astronomy and the understanding of the Universe can hardly be overstated. Annie Jump Cannon organized the classification of stellar spectra into what, with minor modifications, is still used today. Her stellar types of O, B, A, F, G, K, and M are taught in all introductory astronomy classes. Henrietta Swan Leavitt, a colleague of Cannon, established the period-luminosity relationship of Cepheid variable stars (now called Leavitt's Law), a fundamental cornerstone of modern cosmology. Of the 1777 variable stars she identified in the Large and Small Magellanic Clouds on plates taken at Harvard's Boyden station in Peru, she identified 25 as Cepheids in the lesser Cloud. She correctly assumed they were at the same approximate distance, so when she found a linear relationship between the log of their periods and their apparent magnitudes it opened up a means for astronomers to calculate the intrinsic luminosity of Cepheids in other "nebulae" and thereby determine their distances. The initial reports were published in 1908, and four years later Harvard published refined and calibrated information including distances derived from parallax measurements by Ejnar Hertzsprung. Interestingly, both Leavitt and Cannon, like Goodricke, were deaf. Edwin Hubble said more than once that Leavitt should have received the Nobel Prize for her work.

Annie Jump Cannon and Henrietta Swan Leavitt. Unknown photographer, Harvard University Library.

Starting in 1906, even before his 60-inch telescope that would be the world's largest was complete, George Ellery Hale set plans in place for a much bigger instrument. With the financial help of his friend, businessman John D. Hooker, Hale began work on the glass and building to house a 100-inch reflector. A dreamer with boundless energy and enthusiasm, Hale convinced Andrew Carnegie and other key players that such a telescope, one that would revolutionize astronomy, could be constructed. The concept pushed the limits of mirror making and technical requirements needed to support and operate such a behemoth. Eleven years passed until, on the night of November 1, 1917, a small group gathered to see first light. The dome had been left open during the day, heating the 8.3-foot, nine-thousand-pound mirror. Jupiter was a mess in the eyepiece. The band of celestial pioneers had to wait a few hours to see if the telescope that the invited English poet Alfred Noyes said would "attack [the] darkness [...] and win new worlds" could perform as promised. It did. At 3 a.m., a star shone brightly as a finely focused pinpoint, justifying the collaborators' toil and treasure.

The mirror of the Hooker Telescope on its way up the Mount Wilson Toll Road on a Mack truck in 1917. Public domain.

Into this fertile field came Edwin Hubble, a young American astronomer who had had a varied career before arriving at Mount Wilson in 1919.

Born in Missouri in 1889, he was an accomplished athlete, earning awards in track and leading his University of Chicago basketball team to their first conference title in 1907. He turned down an offer to train for the heavyweight boxing title, preferring to study abroad at Oxford as one of its first Rhodes scholars. He had promised his father he would study law, which he did at these two schools, but after his father's death in 1913 his academic interests turned to astronomy. He entered the Yerkes Observatory program, receiving his PhD in 1917. Two years later, after a stint in the American Expeditionary Forces where he did not see combat, he accepted an offer from Hale to join the staff at Mount Wilson.

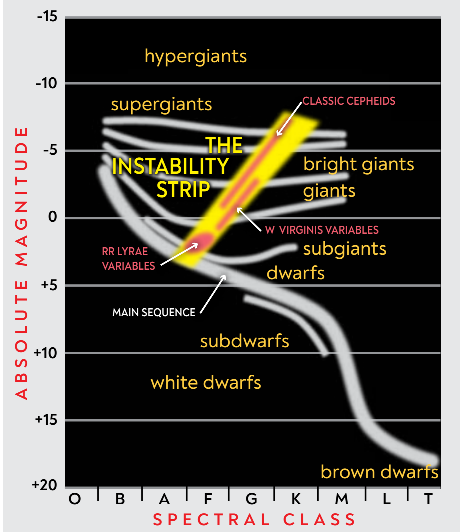
Hubble knew of the Cepheid period-luminosity relationship and initiated a search for these variables in the Andromeda Galaxy with the 100-inch Hooker Telescope. The nature of spiral nebulae was at the center of astronomical debate at the time, with many believing the Milky Way to be the whole of what existed. On the night of October 5–6, 1923, Hubble noted that a star southwest of M31's core that he had marked with an "N" for nova was, in fact, dimming and rebrightening. This defied the known behavior of novae, and Hubble

Edwin Hubble. Studio photo by Johan Hagemeyer, 1930.

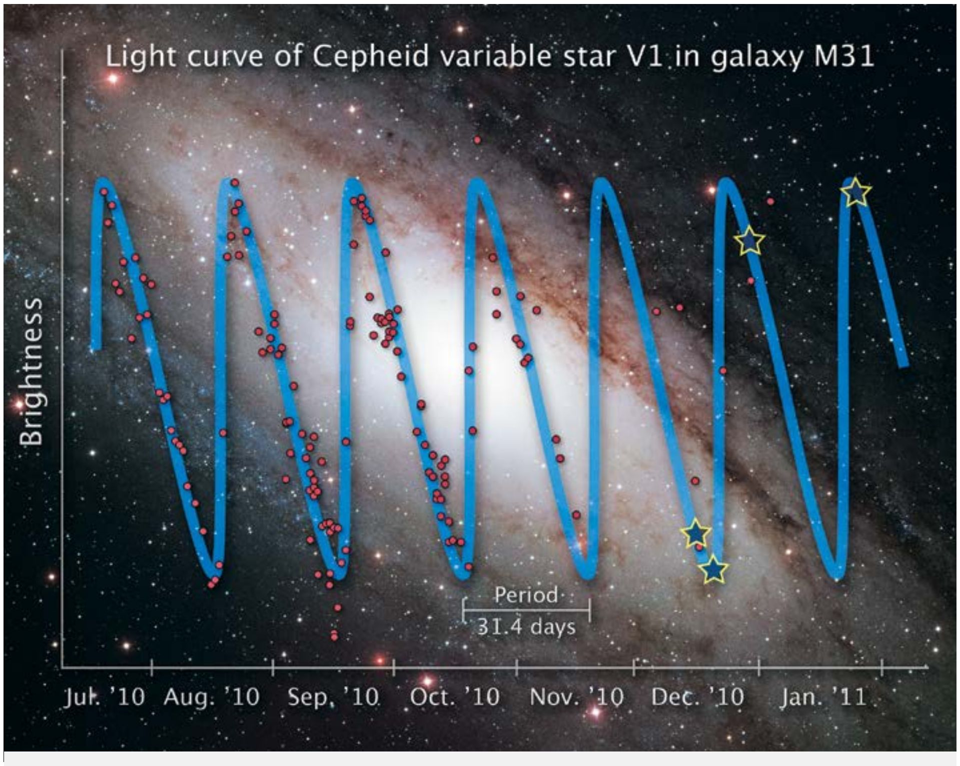
realized this star was varying. He crossed out the "N" and marked "Var!" This was the first of several dozen Cepheids he would find in this galaxy, followed by ones in M33 and others. His distance calculations quickly led him to surmise that all these "nebulae" were extragalactic, outside the bounds of the Milky Way. Many colleagues, particularly Harlow Shapley, strongly disagreed with his conclusions. The results were first reported about a year after the find, in the *New York Times* on November 23, 1924, and then presented at the January 1, 1925, meeting of the American Astronomical Society. It took more than four years for the findings to be published in the *Astrophysical Journal*. 1929 was the same year Hubble realized the relationship between the distance of these galaxies and their speed of recession. According to their redshifts, the further a galaxy was from us, the faster it was receding. The Universe was expanding! These two revelations must have offered a profound sense of discovery and accomplishment for the young astronomer.

In a tribute to the legendary man and his observations of this star, NASA planned to point the Hubble Space Telescope at M31's famous Cepheid in late 2010. They wanted AAVSO members to image it earlier that year to obtain a light curve, since it had only been studied once since Hubble's work in the 1920s. Between July and December of 2010, eleven observers made 214 observations during four cycles of variation, and determined a period of 31.394 days and a magnitude range of 18.0–19.7 (r). HST took four images of the star in December 2010 and January 2011. The Cepheid displayed a relatively slow decline for most of its cycle through 25 days, then a more rapid recovery in 6–7 days. They used the following formula for the Julian date of maximum brightness and the cycle length: JD_{max} = 2455430.5 + 31.4.

Since hearing about this work, I had the idea to observe this Cepheid visually. Its magnitude range is accessible in my 32-inch reflector from my home in Minnesota, but recent fall weather patterns have been unfavorable. Autumn is usually the best season for observing, with clear, crisp, low-humidity nights, but clouds, rain, and higher dew points have ruled for several years. I tried for this star a number of times in the last two years, but could quickly tell that conditions would not allow its observation. The AAVSO has a finder chart for the area, and I plotted stellar magnitudes for its neighbors using data from Megastar. Most nights I could not get within two magnitudes of seeing it. The late evening of September 23, 2019, was different. There was no dew or wind, and I had until just past midnight before a waning crescent Moon entered the sky. I rapidly found the field using Megastar charts and a red image from the POSS 2.



Credit: Reflector *staff, after Wikimedia image by Rursus*



This illustration shows the rhythmic rise and fall of starlight from the Cepheid variable star V1 over a seven-month period. Cepheid variables are pulsating stars that brighten and fade in a predictable pattern. The illustrated graph shows that V1 completes a pulsation cycle every 31.4 days. The red dots on the graph represent observations by the American Association of Variable Star Observers (AAVSO), who partnered with the Space Telescope Science Institute's Hubble Heritage Project to study the star. The four stars on the graph denote observations made by the Hubble Space Telescope's Wide Field Camera 3. Credit: NASA and STScI

The Cepheid sits within an arrowhead-shaped asterism of seven stars 1.5 arcminutes across, with the tip pointing west. The three westernmost stars of that group form an equilateral triangle 20 arcseconds on a side, with M31 V1 its southeastern member. The "tip" star to the Cepheid's west-northwest is magnitude 18.9, in the middle of our target star's variable range. I hadn't calculated the cycle for that night, so I did not know what its magnitude should be, but could tell right away that it was quite a bit fainter than the tip star. As chance had it, the Cepheid was at day 23 of its 31.4-day cycle, just before minimum magnitude of 19.7. I observed the area for about 75 minutes, employing a number of eyepieces that gave from 363x to 650x, in seeing that was 7/10 and transparency 7–8/10. Finally, with a 6 mm Zeiss Abbe Ortho at 521x, I confirmed it just before midnight. Being sure to see it several times, I rejoiced in a journey retracing the history, and appreciating the importance, of this singular star. Someday, I may try to follow it visually through a whole cycle. ✷

Coordinates for Hubble M31 V1: 00h 41m 27.30s, +41d 10m 10.4

ASTRONOMY IN THE SANDS

BUILDING A PERSONAL OBSERVATORY IN NEW MEXICO

By Steve Solon

A common dream among enthusiasts of the night sky is to have a permanent building, an "astro-house," if you will. A haven from which to observe, image, commiserate with friends of the same ilk – and while we're at it, to have all your stuff in one place, albeit in several totes. It's a wonderful feeling to stroll down a gravel path off the back patio and unlock the door to an observatory of your own, something never to be taken for granted.

I've been in awe of the stars since I was ten years old, and I credit the original *Outer Limits* television series for starting me down a path I've enjoyed traveling for over fifty years. Some creative thinker on the show decided to run the ending credits against a backdrop of images from the 200-inch Hale telescope on Mount Palomar in California, and the beauty and shapes of the portrayed galaxies transfixed me, especially M104. I was hooked. From there, it was an astronomy-passionate fifth-grade science teacher, a steady stream of *Lost in Space, The Golden Book of Astronomy,* and a 2.5-inch Sans & Streiffe refractor. My very first view of Saturn was through this monster, and a ten-year-old kid was lost to the stars.

Over the ensuing years, with various telescopes in various locations, I've been fortunate to witness, with eye and camera, the marvels of space: our Moon and Sun, planets, beautiful galaxies of all types, comets (and their collisions with Jupiter and the Sun), and planetary nebulae that paint a picture of our star's eventual destiny. As time advanced, it became desirable to wander less, to forgo the darkest of distant sites, and stay close to home. While I am an enthusiastic observer, imaging is my primary focus (pun intended), and so a permanent facility became a goal.

Years ago, while living just south of Denver, I had a seven-foot Astro-Haven clamshell dome in our yard, an observatory that gave me many inspiring years. While it was a bit of a gymnastic endeavor to maneuver around the Paramount ME and two telescopes inside, I controlled everything from the house. Remotely controlling was a wonderful advantage, but I did miss the experience of actually being with the instruments under the stars. Sadly, as with a growing number of suburban locations, encroaching light pollution gradually brightened the skies to an unacceptable level; once-visible deep-sky targets were rendered invisible, and image processing software, at the time, could only do so much. My wife and I decided that a move to New Mexico, something we'd planned for retirement years down the road, had become an immediate possibility. I parted ways with the Astro-Haven, donating it to the Boulder astronomy club, and in 2018, we relocated to Rio Rancho, New Mexico, about fifteen miles northwest of Albuquerque.

While we were getting settled in our new home, I explored the many options for an observatory, and decided that a roll-off structure would meet several criteria, including plenty of open sky, increased interior space, good protection from the elements, and ease of use. Now, I'm a fairly decent DIY kind of person, but there are projects I leave to those who engage in them every day; the experience, reliability, and craftsmanship of professionals are traits I am comfortable

The completed roll-off roof observatory. Photos by the author.

After toe-nailing was removed, the roof was temporarily supported on 2x6 stacks.

counting on. With this in mind, I contacted our Tuff Shed company here in Albuquerque and pitched them the idea of building an 8- by 10-foot premium shed, but toe-nailing the roof on instead of permanently attaching it. This was definitely a curve ball for them, but the purpose of the building as an observatory was intriguing, so their design manager, Coltrane Winslow, got together with other engineers in the office and prepared a set of drawings. In order to meet local codes, several modifications to the upper wall supports were necessary to stabilize the building, something a permanently-attached roof would normally do. In addition, this roof had to be modified to be a platform, instead of an integrated part of the structure, so the toe-nailing could be removed and the roof lifted to facilitate installing the track sections and roller wheels.

As all this planning was going on, my good friend Terry Chatterton and I began the task of digging the pedestal foundation. The ground here in Rio Rancho, New Mexico, is essentially sand, loose on the surface and tightly packed further down; digging proved to be a not-too-strenuous endeavor. We decided on 3- by 3- by 3-foot pit, with a grill of half-inch rebar at the bottom to support and stabilize a sixteen-inch-diameter shaft of Sonotube. Then came the "fun" part: since foliage did not allow us to bring even a portable cement mixer into the backyard, we manually mixed and poured forty-five bags of Quikrete cement for the foundation and Sonotube pedestal, for a total of 2700 pounds. Anyone who lives down here can tell you that doing all this in July warrants a medal of some kind for endurance.

The next step was placing sixteen 8- by 4- by 2-inch concrete blocks in the proper pattern to support the building when they came to assemble it; the blocks were arranged so that the long wall faced west. Our plan was to build the roll-off structure on the south side, so the roof would block some of the light pollution from Albuquerque, fifteen miles to the southeast. The builders came, and assembly went without a hitch. The guys added several additional floor joist blocks around the Sonotube so the building wouldn't contact the pedestal. All in all, things went smoothly. It was now time for Terry and me to get to work – again.

After running a PVC-enclosed 12/3 Romex electrical line underground from the breaker box to the observatory, the first task was building the roll-off structure for the roof to travel on. We decided to sandwich two 10-foot 2x6 planks, glued and screwed together, on both sides; these would support the tracks and would be hung from the main building on joist hangers, with small 2x4 blocks underneath for added support. On the far end, ten feet to the south of the building, we installed two 4x4 posts in 8-inch Sonotube and concrete. To these, we affixed additional joist hangers to support the track planks, again adding 2x4 blocks underneath. For cross-bracing on the east, west, and south sides, we used 2x4 planks anchored at stress points to prevent sway. We also added a 2x6 cross brace between the track support planks midway between the building and the outer support posts. Since ten-foot planks for the track supports were the longest we could get while guaranteeing straightness, we added a two-foot extension on both sides to expose an additional ten degrees of declination. This helped immensely with Jupiter, Saturn, and Mars in 2018, and facilitated observing and imaging other objects lower in the sky.

Our next step was to literally "raise the roof." After removing the nails that had temporarily secured the roof to the building, we nailed a 2x4 across two roof joists, and used a Handyman jack and a six-foot plank to lift one side of the roof at a time, placing stacks of three 2x6 blocks underneath at several points for support. With the roof "flying" on these wooden bricks, we then laid sections of inverted v-groove track on the lightly-greased upper wall headers, eyeballed the straightness down the length of the wall,

Terry Chatterton attaches track sections to the upper wall header.

then loosely secured the track. The shape of the screw holes in the track would permit about 1/4-inch of floating travel; after the roller wheels were attached and the roof lowered, this would allow for self-alignment with the track before tightening the track screws. Once all the track and wheels were attached to the building, we secured the roof with four large eyelets and turnbuckles; between these and the considerable weight of the roof, Terry and I were confident it wouldn't go sailing in New Mexico's brisk spring and autumn winds.

The working machinery inside the new "second home."

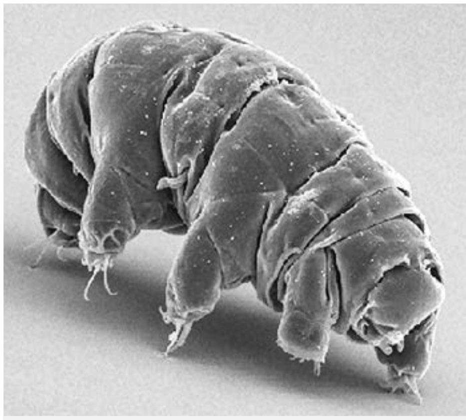
Finally, we attached additional sections of track to the roll-off structure on the south side of the building, loosely securing them, then held our breath as we rolled the roof off the building on to our new frame – smooth as glass (for a 600-pound roof, anyway). Some final touches included adding rubber panels along the roof edges to cover the gap created by the wheels-on-tracks, air vents near the base to facilitate cross-flow, and several heavy-duty pull straps to help with rolling the roof. At some point as I get older, I may install a motor to do the rolling, but for now, it's good exercise, especially at 4 a.m. We installed several outlet boxes, and gave the interior the astronomy-necessary coat of flat black paint. I was glad to finally unpack the instruments, and even happier to see that they'd all fared well on their 450-mile journey south. Lastly, deciding on a name for the observatory was straightforward, given the wide expanse of sky under which it sits – "Mare Stellarae" – loosely translated to "Sea of Stars."

This larger building, as you might expect, greatly increases the ability to observe and image comfortably when time allows. I'm able to open up and work at a moment's notice – important as I'm not yet retired – and after years of portable set-ups, long-distance travel to dark sites, and a *very* cozy seven-foot dome, this is a welcome and much-appreciated astronomical office space. Additionally, while significant advancements in image-processing software, namely PixInsight, make removing light pollution much easier, there is always a standing invitation to visit fellow astronomer friends to the southwest, in Quemado, New Mexico, under some of the darkest heavens in the United States, so the ultimate magic of jet-black skies will always be there. For now, and hopefully for years to come, a "second home" lies just outside the back door, a few welcome steps away. ✷

"Dilbert" the observatory mascot waits casually for the night to come.

EXOPLANET SLEUTHS in the Era of TESS

THE INDISPENSABLE ROLE OF AMATEUR ASTRONOMERS



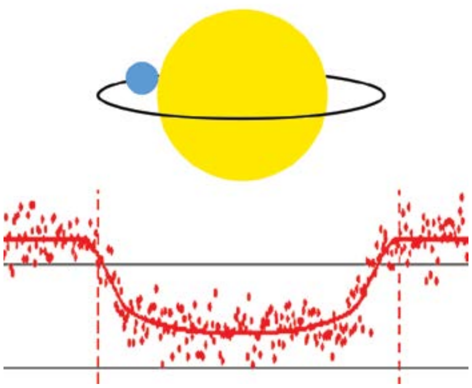
A tardigrade extremophile. Image credit Schokraie E, Warnken U, Hotz-Wagenblatt A, Grohme MA, Hengherr S, et al. (2012), via Wikimedia.

By Dennis M. Conti

Is there life on other planets? Since we first became aware of the existence of exoplanets, this question has energized our quest to find planets that have the right characteristics to support life. Finding "life," however, does not necessarily mean finding life as we know it – merely finding evidence of current (or past) microbial life on another planet, ideally a rocky one that could sustain liquid water, will be a major milestone in human history. In fact, the discovery of extremophiles that live in extreme environments here on Earth has challenged our common notion of "life as we know it." A tardigrade is an example of an extremophile that can withstand radiation and extreme pressure and temperature.

Confirming the existence of exoplanets and weeding out suspicious "imposters" is akin to a detective story in which amateur astronomers are playing an essential role alongside their professional counterparts as exoplanet "sleuths." (I will provide a commentary at the end of this article on the growing use of the term "citizen scientist" in place of "amateur astronomer".) And just as with any detective story, we have a target of our investigation, evidence, suspects, and clues. More on all of this later.

Astronomers now suspect that most stars have one or more planets orbiting them. For a planet that is orbiting at an inclination that causes it to pass in front of its host star from our point of view, each transit will result in a light curve with a dip in the brightness of the star, often detectable with small backyard



A light curve showing the effects of an exoplanet transiting the face of its host star.

telescopes and imaging equipment identical to that used by amateurs doing deep-sky imaging.

By observing the depth of the transit and knowing the radius of the host star, we can estimate the radius of the transiting exoplanet. To know how "rocky" the planet is (that is, its density), we need one other measurement – its mass.

Our journey to find "habitable" exoplanets began in earnest with the now-decommissioned Kepler space telescope. It continues today with NASA's latest planet hunter, TESS – the Transiting Exoplanet Survey Satellite.

TESS began its mission in April 2018 with some 200,000 relatively bright, nearby stars as its targets. The stated "level 1" science objective of TESS was to find at least 50 exoplanets that have a radius of "super Earth" size (4 Earth radii or less) and a known mass. This generates a good set of candidates for later atmospheric characterization by the James Webb Space Telescope (JWST).

In fact, TESS has been likened to a "finder scope" for JWST. JWST will view TESS's confirmed exoplanets in the near-infrared in an attempt to characterize their atmospheres and hopefully detect biosignatures that are evidence of possible life. Having completed its initial two-year mission and now in a two-year extended mission, at the time of this writing, TESS is well on its way to achieving and most likely exceeding its original science objective. As we shall see, what is particularly exciting is how indispensable amateur astronomers have been in helping TESS achieve this goal.

As its name implies, TESS is looking for transits of planets in front of their host stars. Since the design goal of TESS's mission was to survey approximately 85 percent of the sky within 24 months, some tradeoffs in resolution were necessary. For example, TESS's cameras have a large image scale of 21 arcseconds per pixel. Compare this with a typical amateur astronomer image scale of 1 arcsecond per pixel. Furthermore, because TESS also uses a relatively large photometric aperture (nominally 1 arcminute) to detect any dips in light, it is possible that the light from several stars could be blended together in TESS's aperture. Thus, even if TESS detects a dip in light in its photometric aperture, this alone is not sufficient evidence to conclusively confirm that a candidate exoplanet transit is occurring across the target star. It may be the case, for example, that two nearby stars are eclipsing each other, resulting in a "false positive." Thus, likely candidates, called TESS objects of interest (TOIs), need further investigation by ground-based observers.

Like a detective following up on a lead, ground-based observers, particularly amateur astronomers, have been essential in following up on TOIs to determine "who (really) done it." And as we shall see, like a detective story, there are sometimes fingerprints that lead to suspects in the target's vicinity who are the real culprits.

The process of moving a TOI from "candidate" to "confirmed" status consists of a number of subgroups that are part of the TESS Follow-Up Observing Program (TFOP). The first TFOP subgroup in this pipeline consists of ground-based observers who use differential photometry to determine if the predicted transit is indeed occurring on the host star, or if the TESS event is really one of several possible false-positive cases described below. Differential photometry compares the flux of the target star to the flux of an ensemble of presumably non-varying comparison stars to determine the relative change in flux of the target star. A large number of amateur astronomers are part of this TFOP subgroup and are actively conducting such ground-based observations. The American Association of Variable Star Observers (AAVSO) has been a major provider of amateur astronomer talent to TESS through training provided by its exoplanet observing courses, through a qualification program for membership in TESS that it established, and by way of its continuing mentoring and support of amateur astronomer exoplanet practitioners. In addition to conducting exoplanet observations with their own equipment, amateur astronomers have also been helping to analyze TESS observations made at professional observatories, such as Las Cumbres Observatory, in both the northern and southern Hemispheres.

Once a candidate exoplanet passes through the initial photometry gate, other subgroups in the TESS pipeline continue with the confirmation process using techniques such as spectroscopy of the host star, high-resolution imaging, high-precision radial velocity measurements, and even other space-based photometry.

So, when a dip in light is seen in a TESS aperture, our detective story begins with an investigation to find out the real source of the event. That is, was this dip really caused by a true exoplanet transit, or was it caused by an "imposter?" First, let's consider the more common suspects that could result in such false-positive cases. They are:

- **CASE 1:** The target is actually an eclipsing binary consisting of a primary star and a secondary star, where the secondary's transit is mimicking an exoplanet transit.

- **CASE 2:** A variant of case 1 is where the light of the eclipsing binary is blended with a neighbor.

- **CASE 3:** The target is an eclipsing binary where the secondary star "grazes" the primary star.

- **CASE 4:** The target star and a nearby eclipsing binary are blended together in the TESS photometry. In this case, ground-based observations with greater resolution are able to distinguish the target star's change in brightness from its neighbor to see if this condition occurs.

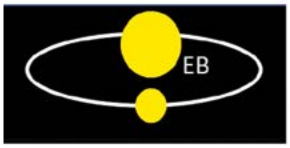
- **CASE 5:** Same as case 4, except the nearby eclipsing binary and target star are too close together for even ground-based observations to separate them. This is where some of the other techniques in the TESS pipeline are helpful, such as high-resolution imaging.

- **CASE 6:** The target star and the nearby eclipsing binary are orbiting each other.

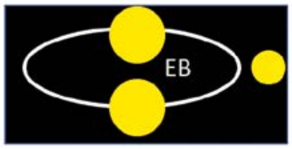
The light curve itself may contain one of the following clues to help our exoplanet detectives determine which, if any, of the above suspects might be the actual culprit behind the TESS detection:

- **CLUE 1:** Is the light curve bucket-shaped or V-shaped? If bucket-shaped, the target star is more likely to host a transiting planet rather than a companion star

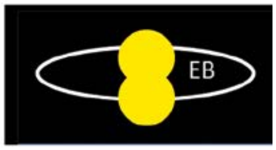
- **CLUE 2:** Is the light curve V-shaped and does it exhibit different depths for alternating dips? If so, the target star is an eclipsing binary.



CASE 1: Target is an EB



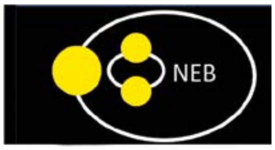
CASE 2: Target is an EB, but blended with a neighbor



CASE 3: Target is an EB with secondary grazing primary

CASE 4: Target with an NEB resolvable by ground-based telescopes

CASE 5: Target with an NEB not resolvable by ground-based telescopes



CASE 6: target and an NEB are orbiting each other.

- **CLUE 3:** Is the depth of the light curve different when different filters are used? If so, this chromaticity difference means that the transiting object is not a planet, but rather a companion star with a different color than the original target.

- **CLUE 4:** Does the light-curve depth indicate a non-planetary body? For example, if the estimated radius of the transiting object, based on the light-curve depth and radius of the host star, is greater than 2.5 times the radius of Jupiter, then the transiting object is considered too big to be a planet.

Amateurs participating on the TFOP team are given access to a very useful tool called the TESS Transit Finder (TTF). The TTF allows an observer to determine which TOIs are observable on a given night at the observer's location. In addition to predicted transit times and depths, the TTF provides guidance on the goal of the observation, typically to see if any of the above clues exist. Examples of such guidance are:

- **If no transit has yet been detected,** check for nearby eclipsing binaries in a 2.5-arcminute field around the target. To help both amateur and professional observers perform such a check on sometimes upward of several hundred stars, the author has created an automated tool.

- **If a transit has been detected by a ground-based observer** using a particular filter, check for any chromaticity difference by observing the TOI with a different filter.

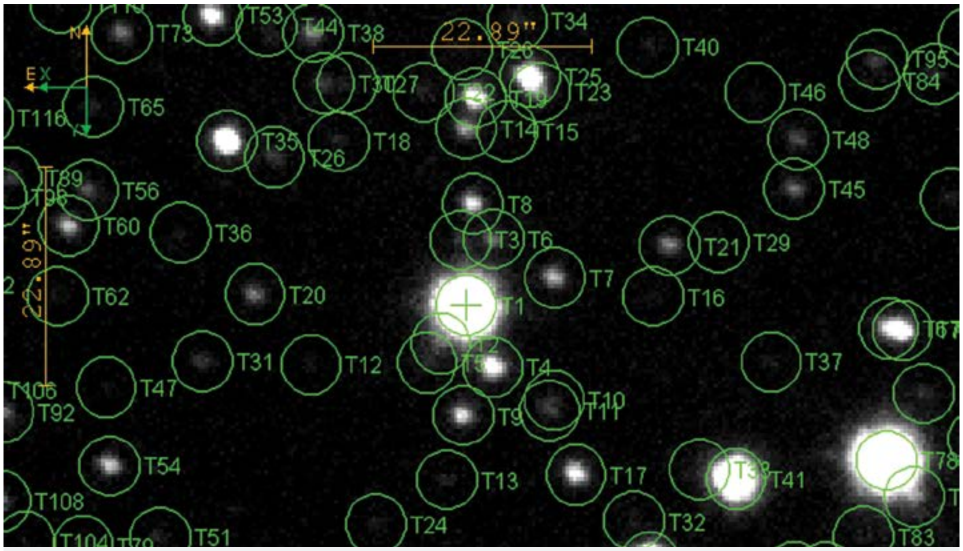
- **If a transit has been detected,** check if there is a difference in depth between every other predicted transit event.

Apart from helping move a TOI from "candidate" to "confirmed" status, amateur astronomers are also helping to refine the ephemerides of confirmed exoplanets. For example, because TESS has been able to dwell on most of its targets for only 27 days, further observations are needed to refine the ephemerides of confirmed exoplanets. This is especially important for the exoplanets that will later be observed by JWST in order to restrict JWST's precious observing times to precisely known transit times.

As we have seen, the detection of a dip in light of a star by TESS is not proof-positive that it was caused by an exoplanet transiting the face of the star. A rigorous process requiring ground-based observers has been essential in eliminating false positives. With the geographic and temporal coverage they provide, amateur astronomers have proven essential in helping TESS achieve its main science objective. In fact, in the past 30 days from the time of this writing, *more than half* of all TESS ground-based observations submitted were done by amateur astronomers! With their indispensable contributions to TESS, amateur astronomers are materially contributing to humankind's search for "life beyond."

Commentary: In spite of the increasing use of the term "citizen scientist" in place of "amateur astronomer," I have chosen the latter term throughout this article for the following reason. Non-professional astronomers have had a long, proud history – from innovative telescope making to contributing to the science of astronomy. Throughout this history, we have been happy and proud to self-identify as "amateur astronomers." Recently, however, there has been a growing trend to label us as "citizen scientists," primarily by the professional astronomy community. I have been told by more than one of my professional colleagues that this is because they are recognizing more and more our contribution to science and believe that we would view the term "amateur" in a pejorative way. As well intentioned as this may be, I for one would not want to lose my identity as an "amateur astronomer." As I have pointed out to my professional astronomy colleagues, the word "amateur" is derived from the French *amateur* – "lover of." So, since we are all "lovers of astronomy," I would maintain that we and our professional colleagues alike should all be proud to be called "amateur astronomers!" I would be happy to hear what others think on this topic. Email your comments to me at *dennis@astrodennis.com*. ✷

Editor's note: Dr. Conti is the chair of the AAVSO Exoplanet Section. (aavso.org/exoplanet-section)



Part of a field of some 722 stars in the 2.5-arcminute neighborhood of the target (T1) that needed to be checked as potential NEBs which, when blended with the target, could mimic what TESS saw as a potential exoplanet transit. A tool was developed by the author to help automate this NEB check process.

GALLERY

MEMBER ASTROPHOTOGRAPHS

Top this page: Joe Ziha (Astronomical Society of Eastern Missouri) captured this image of M46 and NGC 2438 from Dark Sky New Mexico using a SkyWatcher Esprit 120 refractor with a ZWO ASI1600MM Pro camera.

Just above: Venus captured by Kevin Witman (Astronomy Enthusiasts of Lancaster County) using a Meade LX50 10-inch SCT with a ZWO ASI290MM camera.

Near right: Straight Wall captured by Steve Thornton (Temecula Valley Astronomers) using a Celestron 9.25-inch SCT with a 2x Barlow and a ZWO ASI120MM camera.

Far right this page: Plato and the Alpine Valley captured by Ralph Ford (South Bay Astronomical Society) using a Takahashi Mewlon 210 with a QHY 5-III 290C camera.

Above: Bruce Blair, Jim Cuca, and Jim Shwatal (Chicago Astronomical Society) captured this image of NGC 2264 from Rodeo, New Mexico, using a 12-inch PlaneWave CDK with a modified Canon 6D camera.

Below: Kevin Witman (Astronomy Enthusiasts of Lancaster County) captured this image (shown slightly cropped) of NGC 2403 with a Lyrid meteor using a Celestron Edge HD 9.25-inch SCT (1645 mm with 0.7x focal reducer) with a modified Canon 1000D camera.

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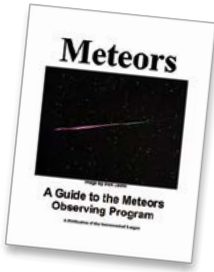

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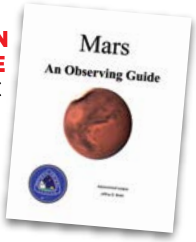

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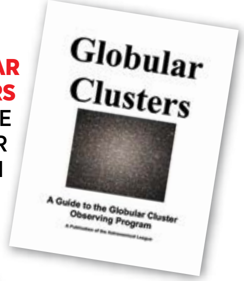

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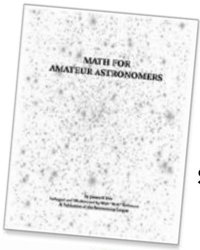

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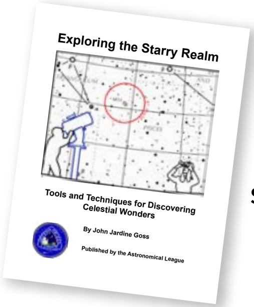

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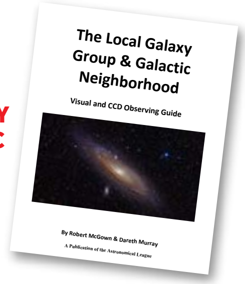

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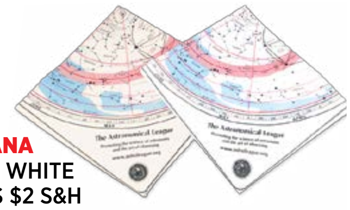

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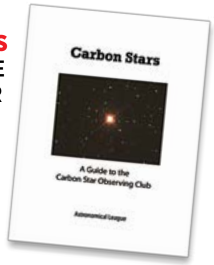

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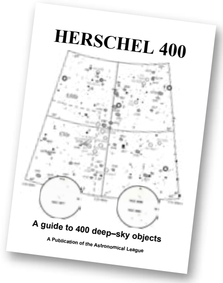

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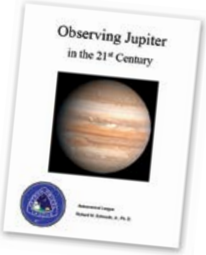

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No. 98-V, **Steve Goldberg,** Houston Astronomical Society

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No. 58, **Joe Timmerman,** Minnesota Astronomical Society;
No. 59, **Gerard J. Jones,** Minnesota Astronomical Society;
No. 60, **Frank Angelini,** Chester County Astronomical Society

Asteroid Observing Program

No. 57, **Tom Richter,** Regular, Austin Astronomical Society;
No. 58, **István Mátis,** Regular, Member-at-Large;
No. 66, **Jonathan L. Schuchardt,** Gold, Rio Rancho Astronomical Society

Beyond Polaris Observing Program

No. 38, **Marc Machin,** Member-at-Large;
No. 39, **Chris Morisette,** Houston Astronomical Society

Binocular Double Star Observing Program

No. 155, **Stephen Hildenbrandt,** Miami Valley Astronomical Society; No. 156, **Michael McShan,** Oklahoma City Astronomy Club; No. 157, **Rich Krahling,** Richland Astronomical Society

Binocular Messier Observing Program

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No. 1191, **Jenny Stein,** Houston Astronomical Society;
No. 1192, **John Strebeck,** St. Louis Astronomical Society;
No. 1193, **Allen Klüs,** Tucson Amateur Astronomy Association;
No. 1194, **Wyatt L. Davis,** New Hampshire Astronomical Society; No. 1195, **James F. Petruzzi,** Haleakala Amateur Astronomers; No. 1196, **Mike Titus,** Cincinnati Astronomical Society; No. 1197, **Steve Goldberg,** Houston Astronomical Society

Binocular Variable Star Program

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No. 17, **Jim Kaminski,** Advanced, Lifetime Member;
No. 18, **Mark Bailey,** Advanced, Member-at-Large;
No. 19, **Martin Griffiths,** Basic, Member-at-Large

Caldwell Observing Program

SILVER AWARDS

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No. 267, **Dave Wickholm,** San Antonio Astronomical Association; No. 268, **Jim Chenard,** Member-at-Large; No. 269, **Steven L. Bardus,** Member-at-Large; No. 270, **Edgar G. Fischer,** Albuquerque Astronomical Society

Carbon Star Observing Program

No. 109, **Rakhal Kincaid,** Haleakala Amateur Astronomers;
No. 110, **Bill Sanders,** Central Arkansas Astronomical Society;
No. 111, **John Marchetti,** Minnesota Astronomical Society;
No. 112, **István Mátis,** Member-at-Large;
No. 113, **Mark Bailey,** Member-at-Large

Citizen Science Observing Program

No. 1, **Steve Boerner,** Member-at-Large, Radio Meteor Zoo, Observational Gold Class 1; No. 1, **Brad Young,** Astronomy Club of Tulsa, Variable Star, Observational Gold Class 2; No. 1, **Dan Crowson,** Astronomical Society of Eastern Missouri, Variable Star, Observational Class 25; No. 1, **Aaron Clevenson,** North Houston Astronomy Club, Planet Hunters TESS, Active Gold Class 1; No. 1, **Al Lamperti,** Delaware Valley Amateur Astronomers, Galaxy Zoo Star Notes, Active Gold Class 7

Comet Observing Program

No. 112, **Rakhal Kincaid,** Silver, Haleakala Amateur Astronomers

Constellation Hunter Northern Skies Observing Program

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Deep Sky Binocular Observing Program

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Globular Cluster Observing Program

No. 343-V, **David Wickholm,** San Antonio Astronomical Association; No. 344-V, **Jim Chenard,** Member-at-Large;
No. 345-I, **Martin Griffiths,** Member-at-Large; No. 346-V, **Alan Scott,** Albuquerque Astronomical Society; No. 347-I, **David E. Collier,** Indiana Astronomy Society

Herschel 400 Observing Program

No. 619, **Francisco L. Aponte,** Olympic Astronomical Society;
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Herschel Society

No. 4, **Brad Young,** Gold, Astronomy Club of Tulsa

Herschel II Observing Program

No. 111, **Andrew Edelen,** Manual, Eugene Astronomical Society; No. 112, **Michael Overacker,** Manual, Star City Astronomy Network

Lunar Observing Program

No. 1097, **Ed Foley,** Tucson Amateur Astronomy Association;
No. 1098-B, **Stephen Hildenbrandt,** Miami Valley Astronomical Society; No. 1099, **Keith Kleinstick,** Member-at-Large;
No. 1100, **Sam Finn,** Central Pennsylvania Observers; No. 1101, **Mike Titus,** Cincinnati Astronomical Society; No. 1102, **Marc Machin,** Member-at-Large; No. 1103, David Berish, Greater Hazleton Area Astronomical Society; No. 1104, **Don Windseth,** Minnesota Astronomical Society; No. 1105, **Jenny Stein,** Houston Astronomical Society; No. 1106, **Robert Stein,** Houston Astronomical Society

Lunar II Observing Program

No. 105, **Jerelyn Ramirez,** Kansas Astronomical Observers; No. 106, **Stephen L. Snider,** Albuquerque Astronomical Society; No. 107, **Alan Snook,** Member-at-Large; No. 108, **Steve Boerner,** Member-at-Large; No. 109. **Gerard H. Jones,** Minnesota Astronomical Society

Messier Observing Program

No. 2682, **Benjamin Toman,** Honorary, Baton Rouge Astronomical Society; No. 2793, **Raymond David Whatley,** Honorary, Northeast Florida Astronomical Society; No. 2808, **Robert J. Olsen,** Honorary, Member-at-Large; No. 2820, **David Wickholm,** Honorary, San Antonio Astronomical Association; No. 2831, **Shawn Grant,** Honorary, Knoxville Observers; No. 2832, **Glynn Germany,** Regular, Rio Rancho Astronomical Society; No. 2833, **Hans M. de Moor,** Honorary, Member-at-Large; No. 2834, **Gary Fugman,** Honorary, Northeast Nebraska Astronomy Club

Meteor Observing Program

No. 183, **Mark Colwell,** 24 hours, Member-at-Large; No. 189, **David Whalen,** Honorary 70, Atlanta Astronomy Club; No. 193, **Kiefer Iacaruso,** 18 hours, Harford County Astronomical Society; No. 200, **Stephen Snider,** 6 hours, Albuquerque Astronomical Society

Multiple Star Observing Program

No. 1, **Terry Trees,** Amateur Astronomers Association of Pittsburgh; No. 2, **Brad Young,** Astronomy Club of Tulsa; No. 3, **Aaron Clevenson,** North Houston Astronomy Club; No. 4, **Charles Allen,** Evansville Astronomical Society; No. 5-I, **David Douglass,** East Valley Astronomy Club; No. 6, **Al Lamperti,** Delaware Valley Amateur Astronomers; No. 7, **Michael Hotka,** Longmont Astronomical Society

Outreach Observing Program

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Astronomy Association; No. 1211-S, **Rick Paul,** Tucson Amateur Astronomy Association; No. 1211-M, **Rick Paul,** Tucson Amateur Astronomy Association; No. 1212-O, **Susan Vale,** Tucson Amateur Astronomy Association

Planetary Nebula Observing Program

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Master Observer Progression

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