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Reflector

MORE ON SATELLITE MEGACONSTELLATIONS

AMATEUR CORONA OBSERVATION

AN ARTIST WITH A SCIENTIST'S MIND

JAIPUR'S ANCIENT OBSERVATORY

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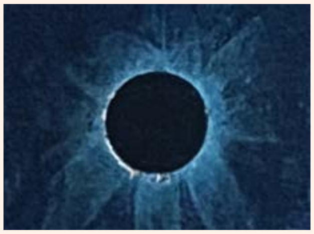

Terry Hancock and Tom Masterson (Western Colorado Astronomy Club) captured this fantastic image (shown cropped here) of Comet C/2021 A1 (Leonard), M3, and a meteor, from the Grand Mesa Observatory using a Takahashi E-180 Astrograph with a QHY367C color CMOS camera.

Reflector

The Astronomical League Magazine

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A NON-PROFIT ORGANIZATION
To promote the science of astronomy

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

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Reflector

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***REFLECTOR* AND CLUB ROSTER DEADLINES**

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Errata

Dave Wickholm pointed out to us that the apparent size of NGC 595 in M33 is 30 arcseconds rather than 30 arcminutes (December issue, page 9). In the same issue we inadvertently misspelled the last name of our resident wordplay expert, Dave Tosteson (page 27). We regret both errors, but greatly appreciate that our readers are sufficiently engaged with the magazine to catch them.

Editor's Note

CELEBRATING THE AL IN YOUR COMMUNITY OUTREACH

As we (hopefully) see the winding down of the pandemic and the return to in-person public outreach, we at the *Reflector* want to help clubs recruit new members. We have a limited number of extra copies of the special 75th anniversary issue of the magazine, which we will make available to clubs to hand out at their in-person outreach events. To apply for these valuable giveaways,

please email editor Kris Larsen *(larsen@ccsu.edu)* describing the outreach event and the approximate number of copies you are requesting. Please make your request a month before the event to ensure proper delivery.

To the Editor

I really appreciated the article "Reaching Out to the Future" by teenager Conal Richards in the June 2021 issue of the *Reflector*.

Our club, the Back Bay Amateur Astronomers (BBAA) in southeast Virginia, is big on astronomy outreach. Our motto is "Bringing astronomy to the people of Hampton Roads."

Having been into amateur astronomy for 21 years myself, I am gratified to have three of my grandchildren also interested. Two of them are members of the BBAA, and the third one lives two hours away.

My granddaughter Samantha had to do a science project when she was in sixth grade, so Pop-Pop (that's me) gave her some astronomy suggestions, and she took off and ran with them. When I saw her interest, I gave her a small Orion XT 4.5-inch Dobsonian reflector, and she quickly became adept at using it. Within two years she had outgrown it, so I took it back and gave her an Orion 8-inch Dob.

She is 18 now, and a college freshman, but before she graduated from high school she got her cousin Chloe interested in astronomy. I gave 13-year-old Chloe that XT scope for Christmas last year, and she loves it! She enjoys attending BBAA public observing events, and revels in showing the stars and planets to visitors. Chloe and Samantha got their 13-year-old cousin Elena, who lives in Goochland, Virginia, interested, and for Christmas I gave each of them an Orion DeepMap 600 and a subscription to *Astronomy* magazine. Elena is fortunate to live in a semi-rural area, and has a dark sky in her front yard. We here in Virginia Beach have to drive an hour or more to find semi-dark skies.

I knew Samantha couldn't fit that 8-inch Dob in her dorm at college, so as a going-away present I gave her an 80 mm refractor on a good, solid Bogen/Manfrotto tripod to take with her to Lynchburg, Virginia, which is darker than here.

As I said, it is gratifying to have some of my grandchildren following in the steps of their "Pop-Pop." Our club also has a few other teenagers in the club, and one in particular, Gabriel Dandrade, is a real whiz at finding deep-sky objects in his 10-inch Orion Dob. He treats visitors at our public skywatches to many glorious sights, and some faint fuzzy ones as well.

I can attest that there is no lack of interest among young people in astronomy, just an access problem, as Conal said in his article. They need transportation to get to events, and they need guidance and equipment. The BBAA receives donated scopes every now and then, which we turn around and give to newbies who show a genuine interest in astronomy. And our members share their knowledge and expertise, patiently mentoring those new to our hobby.

We urge everyone to "keep looking up!"

—George Reynolds
Back Bay Amateur Astronomers (BBAA)

I thoroughly enjoyed the article about Viktor Ambartsumian! This well-written article informs us about the perceptions, and misconceptions, about our understandings of the universe, shining a light into our scientific progress of twentieth-century astronomy. Ambartsumian was a keen observer with even keener analytic ability. He was one of the truly great astronomers of the last century! Armenia has had several excellent astronomers, as you mention Markarian and others. Indeed, the country's president is an enthusiastic promoter of astronomy. What a tragedy that Armenia continues to suffer with local wars.

After learning about Ambartsumian in the early 1970s I always loved saying his name, perhaps when recalling some distant object named for him.

—John M. Roberts

Perhaps the most difficult task I ever set for myself was to complete the Herschel 400 Observing Program, and I am always delighted to read about others who have done the same. I also completed some of the Messier programs, but this one sent me to "sick bay" twice. It has been 27 years and I am amazed at the number of programs now available and in awe of those who attempt them. I learned so much back then and am thrilled that so many still continue to do so. There is so much to learn and we only have one lifetime in which to do it. We are part of a multi-thousand-year tradition, and are enriched by those who came before us and will enrich those who follow.

—Stephen Bryant

Herschel 400 award no. 116 (1995)

Bucks-Mont (Pennsylvania) Astronomical Association

I have received the *Reflector* for decades as a member of the Treasure Coast (Florida) Astronomical Society. The 75th anniversary issue (December 2021) is outstanding. As you wrote in your Editor's Note, it has been expanded, and I believe to great effect. The short articles were excellent, particularly the one by the Night Sky Network on outreach materials and the M33 article by Dr. Dire. I've observed M33 many times. Now I know its position in the Local Group and what to look for in my 12.5-inch Obsession. I was unaware of the contributions of Byurakan Observatory to astronomy until I read the main article by Larry Mitchell. Dr. Daniels' article on "The Megaconstellation Threat" should be read by all amateur astronomers to inspire us to engage in unified efforts to protect our dark night skies, not just for us, but more importantly for the professional astronomers who are constantly advancing our knowledge of the universe. Thanks for your excellent work.

—Lawrence Crary

I am a 74-year-old amateur. These days I engage mainly in visual observation for the sheer joy of it. In the fall and early winter I can spend hours at the eyepiece contemplating the Andromeda Galaxy. Recently I have been astonished by the number of satellites that I see! A satellite in the eyepiece was incredibly rare when I began observing with my homemade 6-inch f/9 reflector back in 1962. Now I see several every night! I had been thinking that this was mainly because my field of view was less than a degree back then, as compared to the 4.7-degree FOV of my 100 mm f/5.4 Tele Vue. Now I realize that a new danger has arisen due to the proliferation of satellites by the thousands! Thanks for this article.

Patrick J. Madden

Shreveport-Bossier Astronomical Society

Star Beams

2021 IN REVIEW

As we start the new year, it is appropriate to look back and see where we have been. We started 2021 with COVID-19 still a force to be reckoned with. Shortly after the year began, we postponed an in-person ALCon in Albuquerque. ALCon 2022 is still scheduled for July 28–30, 2022. The ALCon 2021-Virtual was an outstanding success, with numerous high-quality speakers from around the world and an impressive registration of 900 individuals for this online event. A large number of clubs provided door prizes.

The League, as well as many of our member clubs, continued to schedule multiple online meetings. With the pent-up demand from the public to get out under the stars, many societies modified their usual ways of operating to safely

allow limited ways of sharing the night sky.

Our members continued to observe. Our observing program coordinators continue to process many submissions, although club outreach activities were down dramatically due to COVID-19.

On December 11, I was honored to be the keynote speaker of the Sugar Creek (Arkansas) Astronomical Society's annual Christmas party and its 20th anniversary celebration as a society.

The following week, on December 17, I joined the Baton Rouge Astronomical Society to help celebrate its 40th anniversary as a club. The meeting was at the Highland Park Road Observatory, where some ALCon 2023 activities are being scheduled by the host club, the Baton Rouge Astronomical Society. The observatory is a joint venture between Louisiana State University and the Baton Rouge Astronomical Society.

May 2022 be an outstanding year for our members, as we hopefully make positive steps in returning to "normal," after the two years of disruptions caused by COVID-19!

—Carroll Iorg

President

International Dark-Sky Association

UNDER ONE SKY CONFERENCE

IDA recently held its second annual Under One Sky Conference, an around the clock 24-hour virtual event helping to inspiring kindred souls to fight light pollution in their communities across the globe. The schedule was specifically designed so attendees in any part of the world could literally Zoom in for sessions scheduled for their local times, not necessitating them to get up in the middle of the night to attend a session. Like the event last year, the 2021 Under One Sky Conference was free to anyone who wanted to register and attend whatever sessions piqued their interest. Why am I writing about something after the fact? Because it was so well done and because the entirety of the conference is available on the IDA website *(conference.darksky.org).*

The keynote speaker was Aparna Venkatesan, a cosmologist studying the first stars and quasars in the universe. She is a professor in the Department of Physics and Astronomy at the University of San Francisco, and a former National Science Foundation (NSF) Astronomy and Astrophysics Postdoctoral Fellow. Her topic was most timely, the impact of satellite swarms on the essential human right to dark skies and the inclusion of marginalized and underrepresented communities in developing ethical policies for sustainable space exploration.

My interpretation of her stimulating talk was that dark skies are an inherent human right. How do we couple this with responsible space exploration and with satellite swarms that offer considerable hope for good broadband connections to multiple communities worldwide? She gave many concrete recommendations on how astronomers, dark sky activists, and satellite proponents can work together to protect skies and reap the benefits of satellites. See for yourself, as her talk and all the major sessions are available online at the IDA website noted above.

As I wrote about the 2020 conference, you can watch all the presentations at your leisure just as if you attended the conference. It is too late to virtually hold your hand up to ask a question at the conference, but I am sure the presenters would be receptive to follow-up correspondence from anyone who watched their presentations.

—Tim Hunter

Co-founder, IDA
The International Dark-Sky Association, Inc.
darksky.org

Night Sky Network

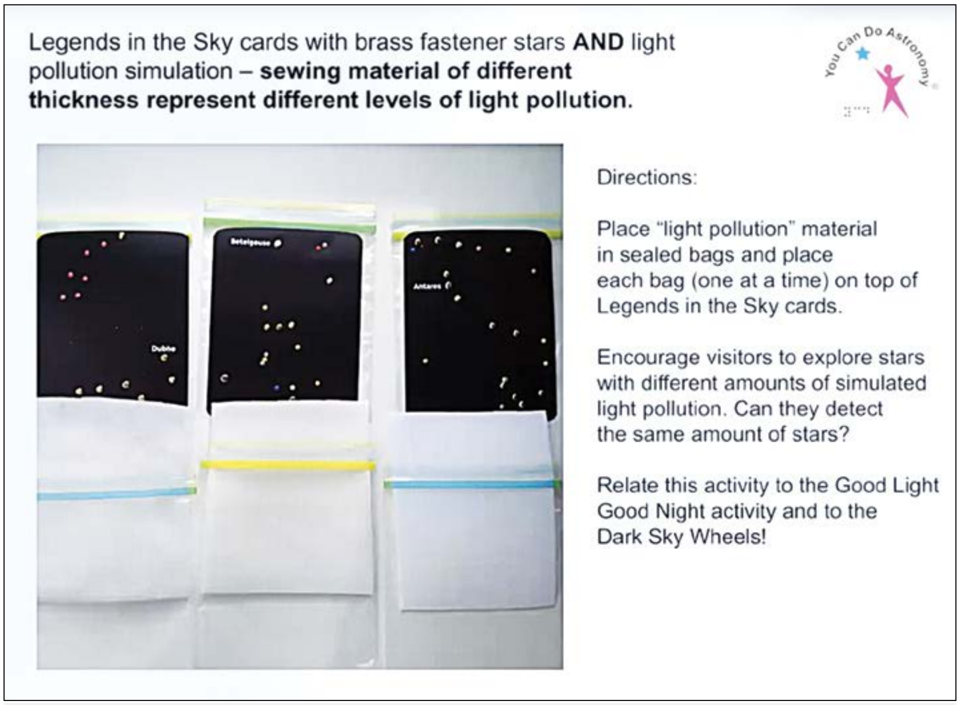
TIPS FOR MORE ACCESSIBLE PUBLIC EVENTS

What do you do to help make your public outreach events accessible to as many people as possible? Making outreach accessible may seem daunting, but there are many small things we can do that can help everyone enjoy astronomy. You've probably made a few adjustments to help make own setup more accessible already, without even realizing it.

For example, if you've worked with kids at the telescope you have almost certainly made some changes to better accommodate them. Do you bring a stool or stepladder to help kids of different heights see through the eyepiece? Maybe you add red lights to help parents and kids see around unfamiliar equipment, too. You just helped your outreach be more accessible! Just as you wouldn't want to deny any kids a chance to look through your telescope just because they couldn't reach the eyepiece, you want to make sure anyone else who stops by your setup has a chance to experience the wonders of space! While no one can accommodate absolutely every person's needs, you can make accommodations as much as your time, budget, and ability allow. A stepladder and some lights or ways to mark your area safely are a great start; the ladder alone helps folks of different heights view through your telescope. If your stepladder has a sturdy grip over the top step, that helps folks that might have trouble balancing at the eyepiece, young and old alike.

Tactile maps of the Moon's surface and craters were a big hit at the Amateur Observers' Society of NY's Apollo 11 fiftieth anniversary event. The tactile lunarscapes give visitors a different way to learn about the nature of the Moon's surface - and as a bonus, allow the artistically inclined to create their own rubbings of the surface for themselves! Credit: Linda Prince

Think about your senses. Are there ways to include folks in your events who might not experience their senses the same way as you? For example, what if some visitors have a hard time hearing your usual telescope banter? Some large signs in big, friendly fonts can help – even just one or two set up next to your telescope or table, listing what you are viewing and some basic facts about tonight's objects can help. Folks might have problems seeing as well; maybe they aren't legally blind, but they have astigmatism or another issue that prevents them from seeing out of an eyepiece easily, or their night vision in general is not great. That is okay – sometimes an additional display nearby, like a laptop or tablet with a red-light filter, can show another view of what you are looking at, or possibly even a live view from your eyepiece or another telescope (which also helps with social distancing requirements when applicable). You may get visitors who are nearly or completely blind, and you can help bring space to them as



A screenshot from a recent Big Astronomy discussion about how to make astronomy lessons more inclusive to all learning styles; this slide features a rework of a light pollution activity to make it more accessible to people with visual impairment. You can find a recording of this lively discussion with Noreen Grice of You Can Do Astronomy, Ken Quinn, Lead Tactile Graphics Evaluator for Haptically Speaking, and Vivian White of Astronomical Society of the Pacific, on the Big Astronomy YouTube Page at: bit.ly/BigAstroAccessible well. Include resources like raised-relief globes and maps of celestial objects, many of which also incorporate Braille text, such as NASA's *Touch the Universe* book (which is sadly out of print) and *A Touch of the Universe* (more at *uv.es/astrokit*). The "Big Astronomy" outreach kit features a guide to help adapt some activities for visually impaired attendees, along with a lively discussion video about making astronomy activities accessible – you can find them at *go.nasa.gov/2Iy7uXM.* If you are lucky enough to have a 3D printer, or access to one, you can also print models of certain objects like asteroids and lunar craters that both sighted and non-sighted guests can enjoy. Some folks may have issues processing information, and many of the above accommodations can help them get the most out of observing as well.

Many folks wonder about accommodations for folks in wheelchairs or limited mobility in general (for example, they can't bend over very far or crouch, or cannot use a step ladder). You can make sure to set up in an area where people can reach you in a wheelchair, either near ramps or places where assistants can help someone in a chair. There are adapters for eyepieces that allow seated folks to take in the view. While those machined adaptors can often be very expensive, 3D printers can be used to create custom adapters as well, in many cases for much cheaper. You can also select objects that are placed in the sky such that the eyepiece is automatically placed well for seated viewers to reach.

Even virtual events, held online, can be made more accessible. Many services have the ability to enable automatically generated captions for live-streamed events, including Zoom and YouTube, and even offer options for live transcriptions, if you have someone available who types fast and accurately! Second audio options for non-English speakers are also another option, and some larger events and conferences even include ASL (American Sign Language) interpreters to assist in presentations to their audiences.

As you can see, accessibility isn't a one-and-done sort of thing; it is an ongoing process that you can continually work with to best serve you audiences. You may find along the way that in thinking about how to better reach those who are not regularly served by your public events, you end up creating an even more welcoming and engaging event for all. How do you make your public engagement more accessible? Do you have any stories or tips to share? Send them to us at *nightskyinfo@astrosociety.org!* We want to help share more accessibility tips and outreach methods from our members as widely as possible, and we look forward to sharing them at *nightsky.jpl.nasa.gov.*

—David Prosper

Full STEAM Ahead

GETTING HANDS ON THE COSMOS

In the last issue of the *Reflector*, I highlighted season-based activities as examples of how we can make astronomy inclusive and accessible. A prime example is "The Sky in Your Hands" planetarium project, led by Amelia Ortiz-Gil and Linas Canas, who work with the International Astronomical Union's Office of Astronomy for Development.

The objective of "The Sky in Your Hands" is to download the planetarium show and the 3D printer file to generate a half dome constellation sphere. The dome ties into the narration, or for a live guide to use, in a planetarium dome or a classroom setting. This project was developed to help blind or visually impaired persons gain an understanding of a segment of the night sky with Orion, Taurus, Ursa Minor, Ursa Major, the Pleiades, Gemini, and Leo and a path that connects them. The project has grown, now being connected with Global Hands-On Universe, the International Astronomical Union (IAU), and Astronomers Without Borders and available in Spanish, Portuguese, and English.

As noted by David Prosper in the preceding article, printable tactile globes are available through *A Touch of the Universe.* The Moon was the first printable globe that was available, and Amelia sent one to me and I took it to the Muskogee School for the Blind in Oklahoma. Students used the globe and gave feedback for improvements. Based on comments, the Moon was improved, reworked, and rereleased. After Amelia put the project together, funding grew and now she provides additional printable celestial objects and activity books that can be used with the 3D models on the site. Currently there are downloads not just for the Moon, but the Earth, Venus, Mars, and Mercury, and activity booklets to use in tandem, including "From Earth to the Universe" (FETTU).

Additional resources found at *chandra.si.edu/edu/fettutactile.html* include images from the Hubble Space Telescope, Chandra X-Ray Observatory, and Spitzer Space Telescope that have been turned into posters for educators to use in the classroom. These were adapted from a book called *Touch the Invisible Sky,* which is available for libraries for the blind. What a potentially great partnership for a library telescope program event, allowing visually impaired individuals to enjoy astronomy together with their friends and family members.

If one is adventurous and has a "maker" mindset and access to 3D printers, included on the site is a link to software called Mapelia *(github.com/jordibc/mapelia)* which will take any map and produce a 3D tactile globe – pretty amazing.

Although these materials were designed for the visually impaired, they also work well for students with other learning needs, such as attention challenges. Individuals who learn best when making direct contact with whatever they are learning about will benefit from these tools. These 3D globes can open the door for classroom or club events when partnered with observational opportunities for a broader educational outcome.

For those unable to pursue 3D printables, one can always purchase the half foam dome at craft store and purchase the supplies that are listed in "The Sky in Your Hands" guide for creating tactile materials to demonstrate, for example, the placement of constellations. In fact, one might be inspired to develop their own countless sections of the night sky. To get started on making your own, go to *tinyurl.com/tactile-sky*.

I made one of the Milky Way band and the constellations that fall along it, which gave the participants an idea of a horizon-to-horizon view of the sky. I worked with the Tulsa Council for the Blind, so they could beta test the design and give feedback to make my own improvements. For more information on Amelia Ortiz-Gil and "The Sky in Your Hands," go to *aorgil.blogs.uv.es/the-sky-in-your-hands*.

Keep making astronomy accessible!

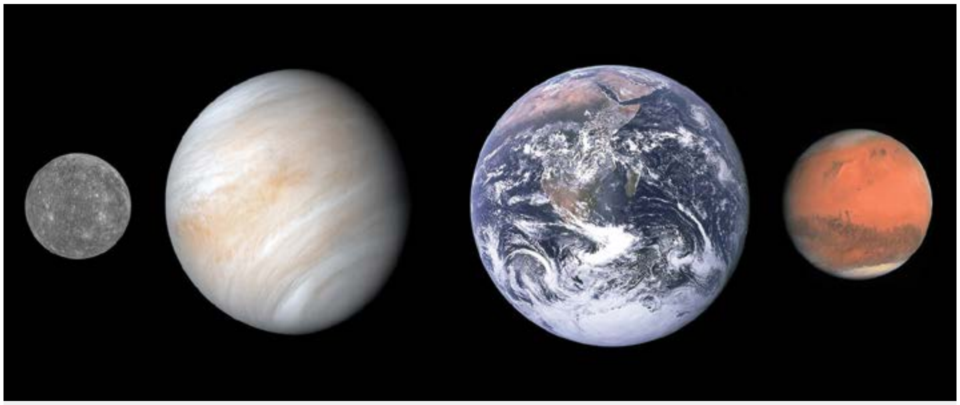
—Peggy Walker

STEAM and Jr. Activities Coordinator

Wanderers in the Neighborhood

NEED IRON? VISIT MERCURY

The smallest planet in our Solar System is never overhead in a dark sky. Mercury stays close to the Sun with an orbit that is only a third of the diameter of Earth's. This keeps Mercury near the western horizon after sunset or the eastern horizon before sunrise. Add to that the maximum size of Mercury's disk when it is closest to the Earth, only around twelve arcseconds, making it



The four terrestrial planets, Mercury, Venus, Earth, and Mars, are shown here at their relative sizes. These rocky planets are vastly different from the gas giants further out in the Solar System. Mercury has the largest core, occupying 55 percent of the planet by volume, and it is a liquid outer core surrounding a solid inner core. Venus has a core that occupies 14 percent and it is probably solid. Earth's core occupies 17 percent of the planet's volume and is a liquid outer core over a solid inner core. Mars has a core that is 16 percent of the volume of the planet and is liquid. Credits: Mercury, Venus, and Earth images from NASA; Mars image ESA/MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA

hard to get good images of the planet's surface. Even the Hubble Space Telescope cannot image Mercury due to the proximity of the Sun.

To get a good look at this diminutive planet, we need to send a spacecraft close to it. A spacecraft heading from Earth down the Sun's gravity well will rapidly gain speed. A large rocket would be needed to put a probe on a trajectory direct to Mercury, but a smaller rocket could do the job if the spacecraft was launched at just the right time to fly past Venus. The Venus flyby would reduce its speed and redirect it toward Mercury.

This course was selected for the first spacecraft to visit Mercury, NASA's Mariner 10. Launched on November 3, 1973, Mariner 10 flew past Venus on February 5, 1974, and made its first flyby of Mercury two months later on March 29. This trajectory made Mariner 10 the first spacecraft to use a gravity-assisted slingshot and the first spacecraft to visit two planets.

Even with the Venus flyby, to enter orbit around Mercury, even more speed must be dissipated. The lack of a significant atmosphere on Mercury ruled out the use of aerobraking, so only rocket motors can slow the spacecraft. Mariner 10 did not carry enough fuel to slow down, so it could only fly by the planet, three times, with the last pass on March 16, 1975. Shortly thereafter, it ran out of maneuvering gas and its transmitters were turned off, leaving it to silently continue orbiting the Sun. Mariner 10 returned over 2,700 images of the planet's surface, and also discovered a weak magnetic field surrounding the planet.

The Earth's magnetic field is generated by a liquid iron layer in the outer core. The spins of two unpaired electrons in an iron atom align with the spins of their neighbors to create a magnetic field. As the planet rotates, the iron layer rotates as well, but it also rises and falls convectively, creating an electric field that in turn generates the observed magnetic field. This dynamo effect generates a dipolar field observed on rocky planets.

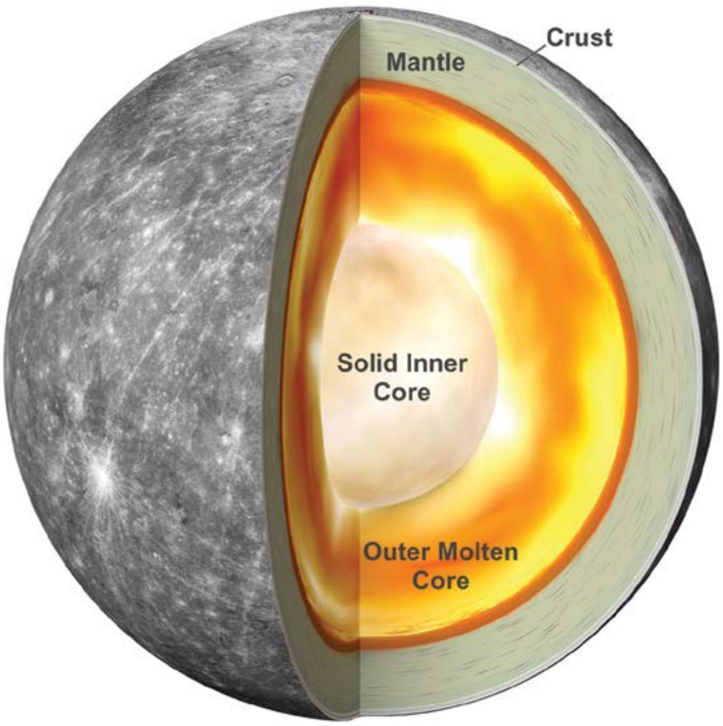
The strength of Mercury's magnetic field is just 1.1 percent of Earth's magnetic field. It is still powerful enough to divert the solar wind around the planet. Mariner 10's detection of this field was a clear indication that Mercury had an iron core and that at least some of it was still liquid.

The quick flybys of Mercury did not provide much detail about the structure of Mercury's interior. Thirty years later, Mercury had a second visitor when NASA's MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) spacecraft flew past the planet on January 14, 2008. MESSENGER had performed slingshots around the Earth and twice around Venus. It would take two more slingshots around Mercury to slow it enough to use its thrusters to enter orbit around the planet on March 18, 2011.

The initial orbit was highly elliptical, ranging from 5,800 miles down to 125 miles. In an elliptical orbit, the spacecraft travels fastest when it is nearest the planet and slowest at its farthest point (apohermion). MESSENGER transmits data back to Earth at a fixed frequency, but the frequency of the signal received at Earth varies due to the Doppler shift.

The Doppler shift raises the received frequency of the signal from MESSENGER when the spacecraft is moving toward the Earth. The higher the speed, the more the frequency changes. Conversely, when the spacecraft is moving away from us, the frequency drops in proportion to its speed. This is similar to a car horn to sounding higher-pitched as it approaches and becoming lower as it moves away, as the Doppler effect impacts both sound and light waves.

MESSENGER's speed at every transmission was computed and recorded. These measurements,



A cutaway view of the planet Mercury's interior. The inner core is solid; the outer core is liquid. They both have an unusually large concentration of iron compared to the cores of the other terrestrial planets. Above that is a solid anticrust (orange-tan layer in this graphic). A silicate-rich mantle supports a thin crust on the top of the planet. Convection in the outer mantle acts a dynamo to generate Mercury's magnetic field. Credit: NASA's Goddard Space Flight Center.

along with data from the Mercury Laser Altimeter, allowed astronomers to determine the shape of Mercury's gravitational field. This, in turn, exposed Mercury's internal structure, since the planet's internal structure shapes the gravitational field. The observations showed that Mercury has a large iron core, occupying the central 55 percent by volume of the planet. This is unusual, since Earth's iron core occupies only 17 percent. Mercury's core is very dense, implying it is mostly iron. It has a higher percentage of iron than the Earth's core. In addition, Mercury's magnetic field indicates that the core is at least in part molten.

It is believed that the central core of Mercury is solid, surrounded by a very thick layer of molten material with a rocky mantle floating on it. The top crust is just 22 miles thick. Many narrow ridges are distinctive features on Mercury's surface, extending up to several hundred miles long. These most likely formed after the surface solidified but the core and mantle continued to cool and contract.

Four hypotheses provide possible explanations for Mercury's high iron content. One model has Mercury forming with two-and-a-quarter times its current mass. It was impacted by a planetesimal one-sixth this size, which stripped away much of the rocky material, leaving the enhanced iron content. A second has Mercury forming at twice its current mass, but the early Sun had not stabilized and its heat vaporized much of the surface rock. The vapor was then carried away by the solar wind.

A third option has the proto-solar nebula creating a drag on the particles that Mercury was accreting during its formation. This drag caused the lighter particles to fall toward the Sun, leaving the heavier iron-rich particles to form the planet. The final possibility, based on models developed at the University of Maryland, has the Sun's early magnetic field pulling iron-rich particles nearer the Sun. The particles forming Mercury would then have been iron-rich, giving the planet its high iron content.

The European Space Agency (ESA) and the Japanese Space Agency (JAXA) launched the BepiColombo probe toward Mercury on October 20, 2018, to help determine how it got its rich iron content. The spacecraft has already made one flyby of Earth and two of Venus, and then it made the first of six Mercury flybys on October 1, 2021. It will attain orbit around Mercury on 2025. We may them learn how this unique planet formed.

—Berton Stevens

Deep-Sky Objects

A TRIO OF GALAXIES IN LEO

You know spring has arrived when the constellation Leo is high above the eastern horizon as twilight fades to darkness. The Lion is one of the oldest recognizable constellations due to bright stars including Regulus, Algeiba, and Denebola forming its feline shape. Visual astronomers migrate to Leo to spy myriad double stars and a plethora of galaxies.

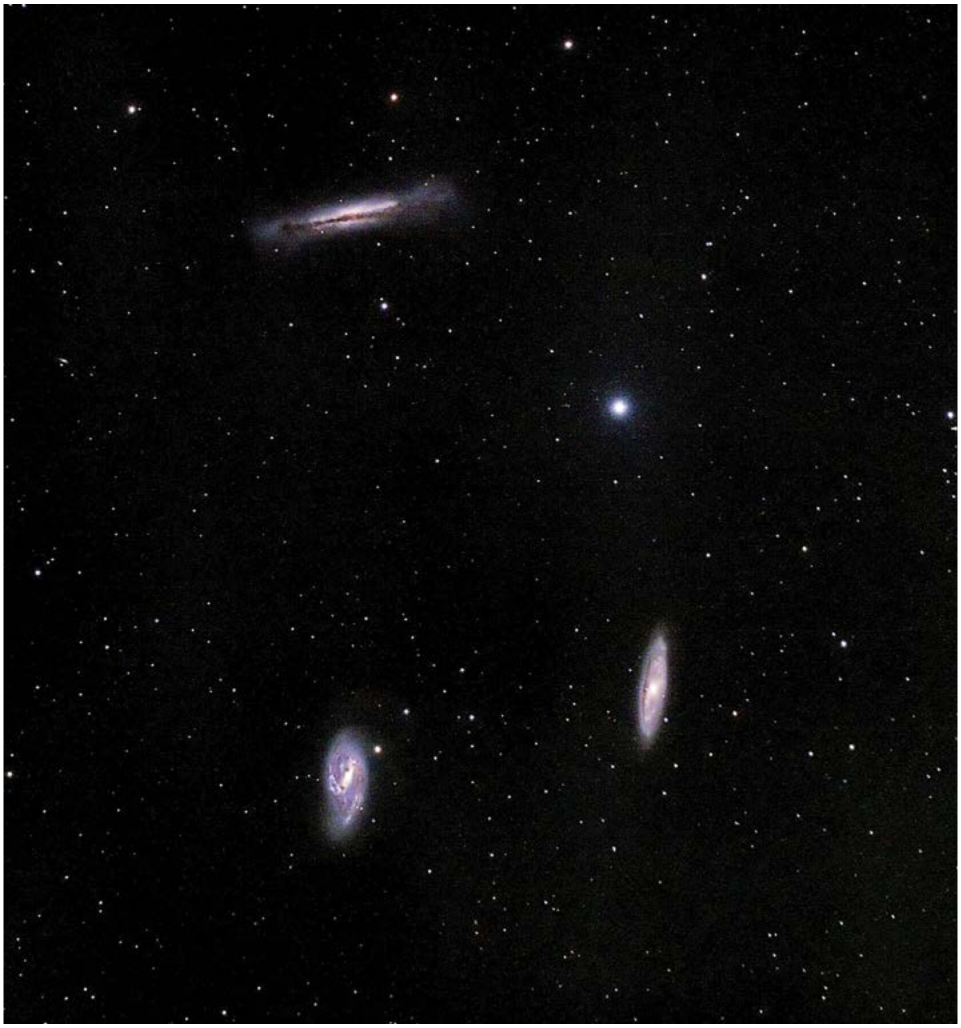
Arguably the best set of galaxies the constellation has to offer is a trio known by the catalog designations M65, M66, and NGC 3628. The first two are found in Charles Messier's catalog and the third is only in the New General Catalog. These spiral galaxies reside midway between the stars Theta Leonis and Iota Leonis.

The Leo Trio, as astronomers affectionately call them, can all be seen in a 3-inch telescope in dark skies. But 8-inch and larger telescopes are required to bring out their spiral galaxy nature. All three galaxies lie within a half-degree field of view. So any telescope-eyepiece combination providing a field of view wider than half a degree will show all three simultaneously.

Charles Messier discovered the two brighter galaxies, M65 and M66, on March 1, 1780. Messier's comet of 1773 passed right through the Leo Trio on November 2, 1773, but Messier did not note the galaxies then. Perhaps it was a cloudy week and Messier did not have the opportunity to spy his comet on November 2 that year, thus delaying discovering M65 and M66 by more than six years. William Herschel discovered the fainter NGC 3628 on April 8, 1784.

At magnitude 9, M66 is the brightest galaxy in the trio. M66 is on the southeast side of the trio, and is approximately 9.1 by 4.2 arcminutes in size. We see M66 more face-on than the other two galaxies. The galaxy has a bright core with two main spiral arms. The galaxy has an asymmetrical shape, and in amateur telescopes may appear teardrop- or comma-shaped. This asymmetry may be the result of a close interaction with one of its neighbor galaxies. The core of M66 appears elongated, which may be a result of the angle at which we see it, compounded with dark dust lanes obscuring parts of the core.

It is also possible that the galaxy may be



intermediate between a normal and barred spiral galaxy.

M65 is slightly fainter and smaller than M66. It is listed at magnitude 9.2 and measures 7.6 by 1.9 arcminutes in size. We see M65 part way between edge-on and face-on, and in small telescopes it appears elongated in the north-south direction. Both M65 and M66 are classified as Sb spiral galaxies. However, M65 appears to be more symmetrical in shape than M66, including its core and spiral arms. Photographs of M65 show a dark dust lane circling the east side of the galaxy, that is, the side closest to us. Typical of spiral galaxies, this dust lane probably surrounds the entire galaxy. Both galaxies are approximately 35 million light-years away.

At magnitude 10.2, NGC 3628 is the northernmost and faintest of the triplet of galaxies. It is also the largest, measuring 13 by 3.4 arcminutes in size. Because it is fainter and its light is spread out over a more extended region, NGC 3628 is more difficult to see than M65 or M66. The galaxy is seen edge-on with its brighter galactic disk split in half by a dark dust lane. Since the galaxy resembles a hamburger patty with a bun, astronomers call NGC 3628 the Hamburger Galaxy.

Like its neighbors, NGC 3628 is an Sb spiral galaxy 35 million light-years away. This means the galaxies are actually cosmic neighbors! M65 and M66 may be as little as 200,000 light-years apart with NGC 3628 a mere 300,000 light-years away from the Messier pair. Those distances are comparable to the Milky Way and its satellites, the Large and Small Magellanic Clouds. The big difference is the Magellanic Clouds are much smaller galaxies than the Milky Way while all the galaxies in the Leo Trio are big galaxies like the Milky Way! At those small distances, the views of the other two galaxies from any one are undoubtedly more impressive than the Magellanic Clouds are from Earth.

The image (previous page) of M65, M66, and NGC 3628 was taken with a William Optics 132 mm f/7 refractor with a 0.8× focal reducer/field flattener to yield f/5.6. The 120-minute exposure was taken with a SBIG ST-4000 color CCD camera. In the image, north is up and east is to the left. The brightest star in the image is magnitude 7.1, whereas the faintest stars are magnitude 16.5. The detail in this image should allow visual observers to test their optics and observing location to see how much detail can be captured with the eye at the telescope!

—Dr. James Dire

Women in Astronomy

A GUIDE FOR EDUCATORS AND OUTREACH SPECIALISTS

Just in time for Women's History Month, this newly expanded and updated guide to resources for teaching about the challenges that face women in astronomy, and the achievements that women have made despite those challenges, is now available at *bit.ly/womenastronomers.*

The materials have been selected so they can also be assigned to students at the Astro 101 level. The guide was compiled by Andrew Fraknoi, emeritus chair of astronomy at Foothill College and the former executive director of the Astronomical Society of the Pacific.

After sections listing resources on general history and issues related to women's roles in astronomy, the guide features more specific books, articles, videos, and webpages on 19 women of the past and 21 women of today. At the end of the 28-page document, there is a list of one or two resources about 27 other women whose work may interest students and the public.

(NOTE: Given the growing number of women who are making important contributions to astronomy, this guide could only be representative, and not comprehensive. One important criterion for inclusion was that non-technical materials about each woman had to be available for non-science majors.)

—from press release

Become an Author!

The *Reflector* Team encourages you to write and submit an original 500 to 2,000-word article on any astronomical topic of interest. Longer articles are considered on a case-by-case basis. Your article should be submitted as a simple text file (MS Word or any rich text format application) to editor Kris Larsen *(larsen@ccsu.edu)*. Figures, tables, and photos should NOT be embedded within the text, but instead attached to your submission email as individual files.

Make sure that you have permission to use any images under copyright, and provide a text document with captions and credits for photos and graphics. All images must be at least 300 pixels *per inch of reproduced size* – e.g., a 2-column image (5 inches wide) should be 1,500 or more pixels across..

Around the League

Librarian Cina Shirley (left) and library clerk Karen Demel (right) with the new library telescope

LIBRARY TELESCOPE

The Kansas Astronomical Observers are proud to donate the telescope won through the Astronomical League to the Douglass Public Library in Douglass, Kansas. The modified telescope was delivered on November 10, 2021. Their telescope is now registered on the *librarytelescope.org* website. They are eager to catalog their new telescope so their patrons can check it out. Their new telescope was posted on the library's Facebook page and was well received with positive responses that librarian Cina Shirley "is the best librarian ever."

—Jerelyn Ramirez
KAO president

"THE WAGONER WAY"

John Wagoner
September 23, 1945–December 11, 2021

John was a dedicated Texas Astronomical Society member and a fixture at meetings from the 1970s to 2021, but he is also known at the national level for his contributions to the Astronomical League. He served on the AL Council as the Southwest Region representative and as an editor of the *Reflector* magazine. He helped establish the early *astroleague.org* website. Perhaps most notably, John is known for creating six of the Astronomical League observing programs: Binocular Messier, Deep-Sky Binocular, Double Star, Southern Skies Binocular, Urban, and Arp Peculiar Galaxy. He earned the rare AL Master Observer award, meaning he completed at least ten AL observing programs, several by way of creating them.

John was also a founding member of the Texas Star Party, for which he created three binocular observing programs and the annual telescope observing program. He created award pins he then presented to those who completed these observing programs.

Locally, John was a perennial TAS board member and regularly volunteered in various positions for the club. He was on the team that scouted and purchased our dark site, and for many years he served as our observing coordinator. John started the City Lights Astronomical Society for Students, aimed at outreach to inner-city and minority students. He connected with local schools and libraries around the Metroplex and would regularly speak and teach astronomy to the public at these venues.

John had a rare passion and dedication for sharing his love of astronomy which we've come to know as "The Wagoner Way." In December 2021, in special recognition of John Wagoner's lifetime of outstanding service and contribution to amateur astronomy in terms of education, outreach, and observation, the Texas Astronomical Society of Dallas named the main entry road into the Atoka dark site "Wagoner Way" and will maintain signs stating such. We hope that as members see these signs, they will be reminded of John's passion for astronomy, and be motivated to educate themselves and others, participate in outreach, and complete the observing programs he established. The road runs from the entrance to the learning center area.

—Gary Carter
Texas Astronomical Society of Dallas

BOB GENT OBSERVATORY DEDICATION

On October 9, 2021, it was my honor to dedicate the new Bob Gent Observatory at the 2021 Hidden Hollow Astronomy Conference. This dedication was made possible through the kindness and generosity of the Richland Astronomical Society, which conducts the conference each October and maintains the Warren Rupp Observatory and its 31-inch Newtonian reflector in the hills east of Mansfield, Ohio.

Although there was a small chance of rain, the skies cleared to billowy cumulus clouds, bright sunshine, and 75-degree temperatures for the

ceremony. Chad Ruhl of the RAS opened the proceedings. We were regaled with beautiful guitar music and singing provided by two talented RAS members, Julia Jones and Dan Wade. Girl Scout Troop #5142 then presented the colors followed by a recitation of the Pledge of Allegiance.

Author and famed geodetist Brent Archinal could not be present, but he sent a wonderful letter that I read to the audience. After mentioning his own remembrances of Bob and noting all of Bob's contributions to the preservation of dark skies, educational outreach, and mentoring, he channeled a quote from national park plaques honoring Stephen Mather, first national parks director: "There will never come an end to the good that he has done."

I then spoke of my efforts to find one word that best described Bob Gent, a good friend who served as League vice president when I was president and who helped me in the early days of the National Young Astronomer Award (NYAA) program. The word I found was "protector." As a

retired United States Air Force lieutenant colonel and space systems officer, Bob devoted his career to the protection of his nation. He fought to protect the beauty of the night skies though his work with the International Dark-Sky Association as both vice president and president, his creation of International Dark Sky sites, his work with lighting fixture companies and labs, his contacts with Congress through the offices of Representative Gabby Giffords, and his mantra for dealing with light polluters: "make friends, not enemies." He protected our future though his mentoring of countless young people, and his extensive public

outreach. He protected amateur astronomy in its key role in educating the public through his work as the League's *Reflector* editor, vice president, and 30th president, through his service as chair of League national conventions in 1995, 2001, and 2010, and through his work with NYAA. For all of this, he was fittingly recognized with both the League's G. R. Wright Award for service and a President's Award. Last, but hardly least, he pro-

tected his family. He was the constant companion of his beloved wife of 48 years, Terrie, who is also a retired USAF colonel, and later in life, he and Terrie gave up their home in Arizona to be near elderly family members.

The new Bob Gent Observatory houses a 14-inch f/8 Meade LX850 with Advanced Coma Free (ACF) optics on a beefy equatorial mounting. It is set up for use as an astrograph, entirely appropriate given Bob's own astrophotographic skills. A Bob Gent Observatory plate appears on the door of the observatory dome.

RAS member Deloris Mlay presented a beautiful plaque with Bob's photo that will be on permanent display in the observatory's education center. She also presented a replica plaque to Terrie Gent, who traveled from her home in Maryland to attend the dedication.

All photos are courtesy of Mike Romine of the Richland Astronomical Society.

—Chuck Allen

STELLAFANE HISTORY ONLINE

In the run-up to the centenary of the Springfield Telescope Makers' 1923 official chartering, club website assistant Patrick Dodson is publishing an ongoing series of feature articles about the founding members of the club *(stellafane.org/history/early/founders).* History buffs and

attendees of past Stellafane Conventions will find this series of particular interest.

CALL FOR AWARD SUBMISSIONS

The application or nomination deadline for all 2022 Astronomical League awards is March 31, 2022. Applications and criteria can be found at *astroleague.org/al/awards/awards.html*. League membership is required for all awards except the NYAA.

Important: Due to the increasing problem of misdelivery of emails, award submissions are not deemed complete unless you receive a confirmation email acknowledging receipt. If no confirmation is received within 48 hours of submission, contact the League vice president.

YOUTH AWARDS

National Young Astronomer Award

Qualified U.S. citizens (or U.S. school enrollees) under the age of 19 who are engaged in astronomy-related research, academic scholarship, or equipment design are encouraged to apply for the National Young Astronomer Award. The top three winners receive plaques. The top two winners receive expense-paid trips to the League's national convention (U.S. travel only). The winner receives an Explore Scientific telescope prize. Applications must be emailed to *NYAA@astroleague.org.*

Youth Service Awards

Qualified League members under the age of 19 who are engaged in service to the amateur astronomy community are encouraged to apply for the Horkheimer/Smith and Horkheimer/D'Auria Youth Service Awards. Club or regional officers may also nominate candidates. The Horkheimer/Smith winner receives a plaque, a $1,750 cash prize, and an expense-paid trip to the League's national convention (U.S. travel only). The Horkheimer/D'Auria winner receives a plaque and a $1,000 cash prize. Applications or nominations must be emailed to *HorkheimerService@astroleague.org.*

Youth Imaging Award

Qualified League members under the age of 19 who are engaged in astronomical imaging are encouraged to apply for the Horkheimer/Parker Youth Imaging Award. Club or regional officers may also nominate candidates. Winners receive plaques and cash prizes of $1,000 for first, $500 for second, and $250 for third. Applications or nominations must be emailed to *HorkheimerParker@astroleague.org.*

Youth Journalism Award

Qualified League members age 8 to 14 who are engaged in astronomy-related writing are encouraged to compete for the Horkheimer/O'Meara Youth Journalism Award. Club or regional officers must sponsor applicants. The winner receives a plaque and $1,000. Second and third places receive $500 and $250, respectively. Applications or nominations must be emailed to *HorkheimerJournalism@astroleague.org*.

GENERAL AWARDS

Mabel Sterns Award

Club officers may nominate a newsletter editor by emailing a copy of the club's print newsletter as a PDF file, or by emailing a link to an online newsletter, to *sternsnewsletter@astroleague.org* along with a nomination cover letter (PDF) that includes the name and address of the nominee and an attached JPEG photo.

Williamina Fleming Imaging Award

This award, now sponsored by Explore Scientific, is open to female League members who are 19 years of age or older. Submissions are made by emailing the entry form and up to three JPEG attachments not exceeding a total of 25 megabytes to *flemingaward@astroleague.org.* Rules have changed; please check the AL website for current info. Winning images may be published in the *Reflector* and on League social media sites.

Webmaster Award

Club officers may nominate a League club webmaster by emailing a newsletter link to *WebmasterAward@astroleague.org* along with a nomination cover letter (PDF) that includes the name and address of the nominee and an attached JPEG photo.

Sketching Award

This award is open to League members of all ages. The winner receives a plaque and $250. Second and third place winners receive $125 and $75, respectively. Sketches should be submitted as high-resolution JPEG files (10 megabytes maximum) along with a JPEG photo of the applicant to *Sketch@astroleague.org*. Winning sketches may be published in the *Reflector* and on League social media sites.

— Chuck Allen

CALL FOR OFFICER NOMINATIONS

Nominations for league president, vice president, and executive secretary must be received by nominating committee co-chair John Goss at *goss.john@gmail.com* no later than **March 31, 2022.**

The president is chief executive officer of the League and has general supervision of the business affairs of the League. The president executes and terminates legal instruments in the name of the League as authorized by council, presides over League council, business, and executive committee meetings, and appoints persons to all League committees.

The vice president assists the president and assumes the presidency if the president cannot serve. The vice president is responsible for managing all League youth and general award programs not otherwise assigned, is responsible for national convention planning, and chairs (or co-chairs if a candidate) the nominating committee.

The executive secretary oversees the League national office, conducts business as prescribed by the council, and, in cooperation with the national office manager, the League treasurer, and the ALCor from each member society, verifies that an up-to-date list of League members is maintained.

Nominations should include (1) a background statement of 250 words indicating qualifications and/or reasons for seeking the position and (2) a photo of the nominee, both for publication.

—Chuck Allen

GALAXY CHALLENGE

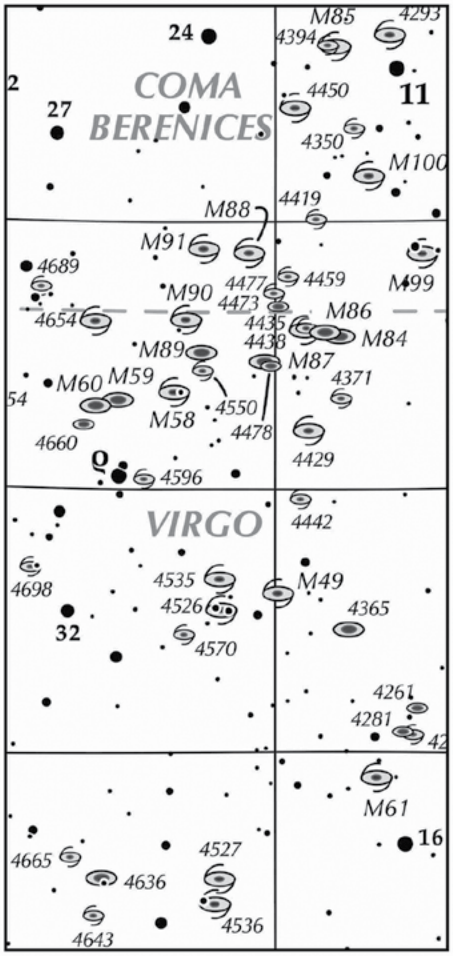
Galaxy season is upon us! This is the time of year when the densely populated Virgo-Coma region of galaxies rises in the east, coming into early evening view. With the glittery winter star clusters sinking lower in the west, perhaps this is a good time to try your skills at galaxy hunting!

Looking at a star chart packed with Messier and NGC galaxies, you are bound to ask yourself, "Where do I begin? Which of these many targets can I hope to see through my telescope? I want to see more than just 'faint fuzzies.'"

The Astronomical League offers a list of galaxies suitable for observers who want to attempt a galaxy foray. The objects give more than an impression of just being faint and fuzzy, they show features such as odd shapes, contrast variations, or companion galaxies for amateurs with telescopes 8 to 12 inches in aperture.

Astronomical League members who complete the challenge will receive a certificate through email from the program coordinator. It will recognize their multi-million-light-year achievements.

Complete details for the challenge can be found at *astroleague.org/content/al-observing-challenge-special-observing-award*.



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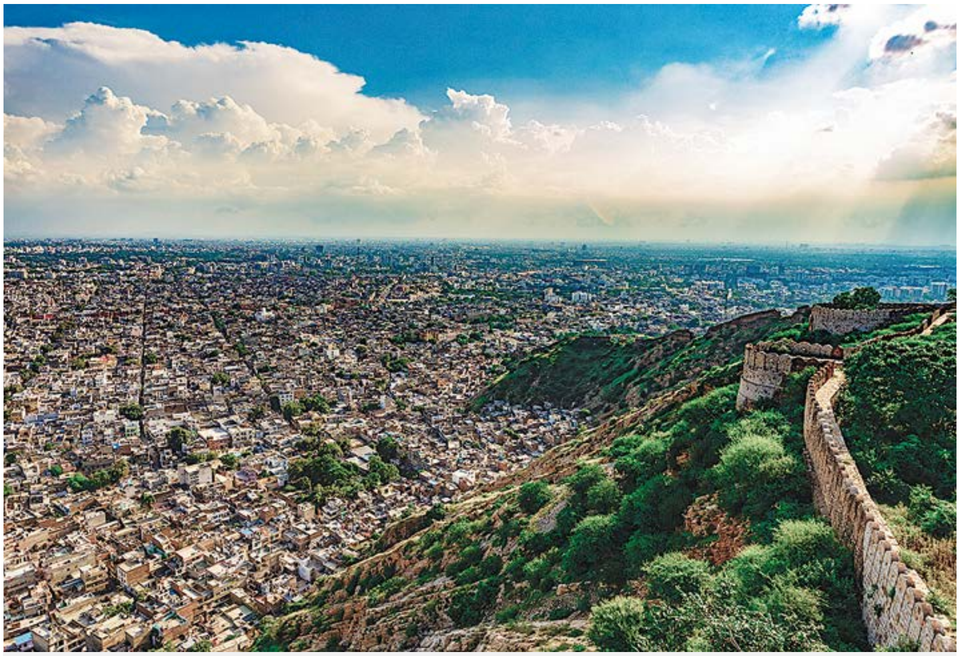
An Ancient Observatory With No Telescopes



The city of Jaipur. All photos are by the author.

By Jai Shet

The city of Jaipur, located in the arid region of North India, is home to ancient palaces, forts, and monuments. The city was named after its founder, Maharaja Jai Singh II. He was a king with a particular interest in astronomy and mathematics, and is considered one of the most scientifically educated rulers of the Mughal period. His greatest scientific achievement was Jantar Mantar, a collection of observatories built between 1724 and 1735. Derived from the Indian language Hindi, Jantar Mantar translates to "a calculating instrument." Although five such observatories were built in North India, only four remain to this day.

The world's largest stone sundial

The observatory in Jaipur is the largest of the remaining four and consists of nineteen fixed astronomical instruments with different functions. It is a common notion that observatories have telescopes; however, in the nearly 300-year-old Jantar Mantar, not a single telescope was ever built. The Europeans had telescope observatories since the 1600s, but such observatories were not used in India for centuries. The ruler of Jaipur at the time presumably knew about European advancements in telescope observatories yet chose to implement older methods of observation. He believed in the importance of preserving the culture of traditional Indian astronomy.

Before Jantar Mantar was built, the older brass instruments they had at the time were worn out. Astronomical charts created using those instruments turned out to be inaccurate when compared with their current observations of the night sky. As a result, Jantar Mantar was constructed with long-lasting materials. They are all static, unmoving constructions of local stone and marble. Their uses included measuring time, tracking the movement of stars and planets, and even predicting eclipses. They all had one thing in common: enabling astronomers to make precise measurements with just naked-eye observations, an impressive feat.

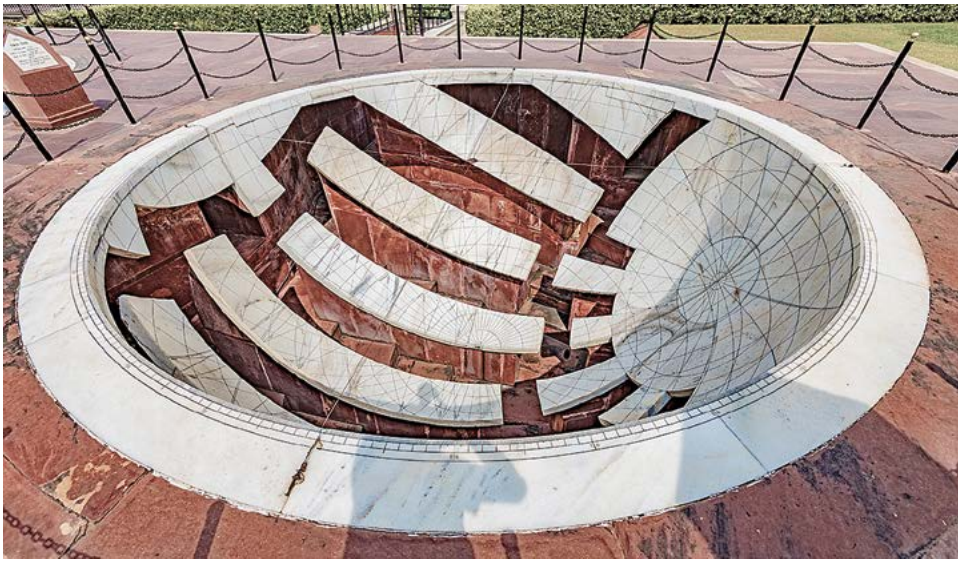
To visitors, the main feature that stands out is the world's largest sundial. With its remarkable height of 27 m (89 feet), the sundial can measure the time of day with a precision of 2 seconds. The shadow cast by the sundial's gnomon (the triangular part) moves noticeably at 1 mm per second, which gives the viewer a sense of the Earth's rotation. The sundial was built on the concept that the larger the structure, the more accurate it would be. This idea of "bigger is better" is apparent in many instruments within the observatory.

Some instruments are said to have been devised by the founder of Jaipur himself. These are two peculiar structures that were some of the most elaborate devices used in 18th-century India: the Rama Yantra and Jaya Yantra (Yantra translates to “device”). Both these instruments were innovative, as they were each split into complementary pairs. Splitting them into two allowed observers to walk inside the structures to more closely inspect the readings on the scale. The Rama Yantra was used to find the altitude of the Sun, and a centered pole cast a shadow on the column’s scale from which a measurement was made. The Jaya Yantra is a pair of hemispherical sundials 5.3 m (17.5 feet) wide that are below ground level. Astronomers could walk down a flight of stairs to observe from underneath. A metal disk at rim level (just visible in the photo, near the top, suspended from crossed wires) casts a shadow during the day on a bowl-like surface that is engraved with equatorial and altitude-azimuth coordinate systems. The disk also serves as a sighting device for nighttime use. In fact, combining the two hemispherical sundials would produce an inverted map of the heavens.

There are many instruments in the observatory that represent architectural and scientific innovations of Jai Singh and Indian scholars of the 18th century. When I visited Jantar Mantar in 2019, I felt as though I had traveled back in time. The ancient structures towered over me in the afternoon sun as I strolled around in wonder. I quenched my curiosity during my visit to learn more about astronomy from the perspective of an ancient culture.

In the present day, Jantar Mantar is recognized as a scientifically and culturally significant collection of astronomical instruments. Many of the Jantar Mantar instruments had precision never before achieved. In 2010, Jantar Mantar in Jaipur was designated a UNESCO World Heritage Site. The observatory is still used for teaching, research, and observation, and serves as a meeting ground for scientific, cultural, and religious communities. More importantly, Jantar Mantar is preserved for future generations to behold as a piece of history and a scientific work of art. ✶

Jai Shet is a member of the Fort Bend Astronomy Club in Houston, Texas



Part of the Jaya Yantra (top), the Rama Yantra (middle), and an equinoctial sundial (bottom).

The Artist And the Eclipse

By Bob Kerr

By the mid 1930s, D. Owen Stephens had become the preeminent painter of astronomical art. This is an account of his travels with a Hayden Planetarium Expedition into the Peruvian Andes to paint the total solar eclipse of June 8, 1937. It was a journey from which Stephens did not return.

The astronomy community had long been aware of the historic nature of the June 8, 1937, eclipse. Maximum totality would last 7 minutes and 4 seconds, and total eclipses with durations of 7 minutes or greater don't come around often. The last totality exceeding 7 minutes had been 7 minutes and 5 seconds, 839 years earlier in 1098.[1]

But circumstances were inopportune. Commencing in the tropics shortly after sunrise over isolated reefs northeast of Australia, the umbra's path would traverse the emptiness of the Pacific Ocean. No land suitable to plant a tripod stood remotely close to the prized 7-minute-plus maximum totality.

Crossing the International Date Line, the shadow would journey almost 9,000 miles, averaging 150 miles in width. Late on June 8, the umbra would make landfall north of Lima, Peru, and travel 250 miles into the heart of the Andean highlands. Totality would be greatly reduced, and the Sun would set still partially eclipsed.

Notwithstanding the challenges, a few organizations mobilized eclipse campaigns. One was the Hayden Planetarium–Grace Expedition of New York's American Museum of Natural History (AMNH). The planetarium had recently opened in 1935, and this highly publicized expedition to Peru would stimulate public awareness and provide compelling attractions for Hayden's public programs.

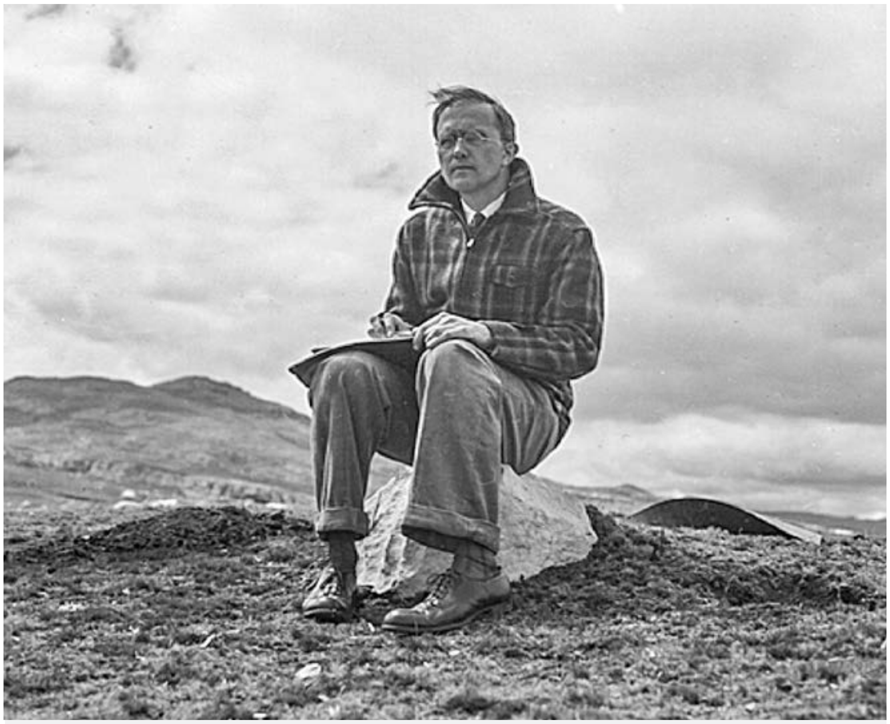
Hayden's curator of astronomy, Dr. George Clyde Fisher, acknowledged suitable locations were few. After evaluating sites based on weather, duration, and accessibility, he deemed several Peruvian locations acceptable.

Invited to accompany Fisher's assembly of scientists was respected astronomical painter D. (Daniel) Owen Stephens. His inclusion was considered essential. He would observe and paint the eclipse to accurately record the subtlety of colors and contrasts that could be discerned by the human eye, but that color film emulsions of that time were incapable of reproducing. It was said that 43-year-old Stephens combined an artist's eye with a scientist's mind.

AMNH president F. Trubee Davison penned a press release embracing Stephens' participation:

Mr. Stephens will make a valuable contribution toward the success of the expedition by virtue of the fact that an artist can make a truer, more accurate record of the actual eclipse appearance than the camera. He can see the extents of the outer corona that are too faint to be captured by the plate, at the same time he views the inner corona and the prominences. Nothing except the eye of an artist and his hand can reproduce this most beautiful of sights and the most significant of astronomical phenomena.[2]

When Stephens, known as Owen, was 10 years old, his parents moved to Rose Valley, an arts and crafts community in southeastern Pennsylvania. Here, his artistic inclinations initially turned to landscape painting. When he developed a passion for astronomy, his parents built him a small observatory where his artist's eye relished the splendid bounty he witnessed in the heavens. He studied at the Pennsylvania Academy of Fine Arts and majored in astronomy at



D. Owen Stephens, image 287289, Charles H. Coles, American Museum of Natural History Library

"Total Eclipse," The Sky *Magazine, Amateur Astronomers Association of New York.*

nearby Swarthmore College. These interests intermingled, and he became intrigued by the possibility of translating scientific knowledge into art forms.

The Hayden contingent commenced their voyage from New York to Peru on May 14. As their ship slipped south, the ever-observant Stephens delighted in witnessing the overhead celestial theatre reveal wonders he had never seen. He wrote:

We are going south nearly 300 miles every day, and that makes all the stars at night look different. The Pole Star is getting lower and lower, and stars that we can never see in Rose Valley come up over the horizon. Monday night we were sailing straight toward Alpha and Beta Centaur [sic]... Sirius and another almost as bright...guessed Canopus and confirmed in atlas – what a sun! A shade less white than Sirius toward yellow, or if Sirius is bluish, Canopus is white.[3]

Once they reached Peru, Clyde Fisher took command of a station at coastal Huanchaco, about 40 miles off the centerline where totality would last 2 minutes and 33 seconds. A second location was Moro. At 1,400 feet and approximately a mile off the centerline, it would experience 3 minutes and 29 seconds.

Stephens and his group were dispatched to Cerro de Pasco, an unaccommodating mining site. It occupied a high desolate plateau 250 miles inland at 14,200 feet, within the towering coastal range of the Andes. Fisher's strategy was to position an outpost likely to remain above the fog and clouds known to cloak lower elevations. Ten degrees south of the equator, Cerro de Pasco's range of temperatures of 28–55°F remained fairly uniform, yet rain, fog, sleet and snow were possible anytime in its Alpine tundra climate. About 30 miles from the centerline, totality would be 2 minutes and 38 seconds, happening low at 5°40', with fourth contact not occurring prior to sunset.

Soroche, or altitude sickness, afflicted virtually everyone. They progressed to higher altitudes incrementally. In a letter dated May 29, Stephens noted, "Staying a few days at 12,000 feet manufacturing more red blood corpuscles.... With only half an atmosphere there [Cerro], we need more oxygen carriers. Did not sleep much last night – headache, heart pounding, general strangeness."[4]

William H. Barton, associate Hayden curator, was placed in charge at Cerro de Pasco, and Dorothy Bennett, assistant curator, was site manager. Numerous elements of the following narrative are according to Bennett's detailed post-expedition report.[5]

According to Fisher, an acceptable color photograph of an eclipse had never yet been taken, and he was determined to succeed. Arrangements had been made with Eastman Kodak to provide their recently introduced Kodachrome color film cut to fit the telescopic cameras. High on his priority list were filming and photographing the corona's size and shape and to verify any correlation between those and the elevated sunspot activity of 1937.

They had been allocated two long focal length cameras, a 6½-inch Ross lens with an 84-inch focus and a 4-inch lens with 136-inch focus, both with driving clocks. Motion pictures would be filmed in 16 mm and 35 mm formats in black and white and Kodachrome.

A makeshift encampment had been erected within an enclosed acre two miles from town. There were rough, heated living quarters, workshops, portable darkrooms, and an operations area where delicate instruments could be fenced off from curious townsfolk and wandering llamas.[6]

"Diamond Ring," Image 1246192496, American Museum of Natural History Library.

Since their arrival, the skies had been mostly overcast, punctuated by episodes of sleet and snow, but there were rare nights when the skies turned magnificently pristine. At high altitude under skies darker than Stephens had ever seen, the sumptuous southern sky mesmerized him. To his wife, Lucie, he wrote, "The astronomy is queer. The sun in the north and moving apparently backward across the sky, all the familiar constellations are on their backs and new ones we never see...." Stephens memorialized the galaxy's bounty with "The Milky Way from Sagittarius to Crux," an expansive canvas of stunning detail.

On the morning of the eclipse, the weary group arose to find heavy frost with dense fog obscuring the mountains. They were incredulous when local residents matter-of-factly informed them this was a good sign. The weather was changing.[7]

As morning progressed, unexpected patches of deep blue slowly melted the clouds in the northwest. By mid-afternoon large swatches of sky were cloud-free, and scientists hurried to complete preparations. First contact was estimated a little past 4:18 local time.

Stephens installed his easels and kits adjacent to the Hayden instruments, organizing materials according to his planned workflow. Dorothy Bennett stood ready to assist with flashlights and field glasses.

At 4:18:13 first contact was called, the minutely notched solar disk drawing cheers of approval. As the Moon crept across the Sun, hundreds of visitors congregated outside the enclosure. Stephens, to whom little was insignificant, jotted down the fearful comments of some. "Moon will bump into sun and kill it!" "No sun, nothing will grow, and we die!"

By 5:18:58 a fine display of Baily's beads decorated the Moon's limb and soon the last solar remnant collapsed into a blazing diamond ring. The bright globe-like solar corona exploded as though at the throw of a switch. Its brilliance appeared, Stephens observed, "Curiously misplaced against the blackness of the sky."

Over the course of the 2 minutes and 38 seconds of totality, numerous exposures were made with each long-focus camera according to a predetermined schedule: 1 second, 4 seconds, 16 seconds, 24 seconds, 16 seconds, 8 seconds, 1 second.

Stephens ordained a schedule of his own. He quickly worked with sketching pencils and paints, according to the system he had perfected painting the eclipses of 1925 over New York and 1932 over New Hampshire.

Stephens sketched the shape and extent of the corona, which the astronomers called a "sunspot maximum type," and then added the locations and sizes of the dozen or so prominences. He was careful to match the colors of Moon, corona, prominences, and sky. In a letter he explained, "I devoted 77 seconds to drawing the corona, 45 seconds to painting the corona, and 25 seconds for prominences – 147 in all!" He would later render finished paintings.

Third contact occurred at 5:22, and, in time, the partially eclipsed Sun, crescent tips pointing upward, sank through clouds hanging over the mountains. Stephens must have painted this magnificent scene he called "Sunset Eclipse" with the relish of the landscape artist he was at heart.

He summed up his satisfaction, "I painted before totality and after also and lastly the crescent sunset with grand clouds. A gorgeous eclipse with the weirdness of the light impressing me more than before [earlier eclipses] – and what a setting!"

The coronal display was estimated to have extended a solar diameter and a half, with distinctive streamers running out from the sun's northeast limb. Later, Dorothy Bennett reported that Stephens' painting "Total Eclipse" "represents the corona with remarkable transparency and shows the wealth of streamers, arches and brushes that were observed, as well as the prominences."

Afterward, the Hayden parties returned to Lima, but Stephens spent another week at Cerro de Pasco finishing the "big canvases," as he called them. Reading his commentaries, I wondered what might have run through his mind as he looked upon what were certainly his finest paintings. He couldn't be faulted for imagining exciting future opportunities.

Upon Stephens' return to Lima on June 15, the staff observed he appeared to be in good spirits. Expedition leader Fisher was gratified all Hayden stations had experienced clear skies and reported excellent results.

The group embarked upon their passage home in a celebratory mood, presumably anxious to regale their contemporaries with stories of adversity and accomplishment. But

"Sunset Eclipse," Image 1246194624, American Museum of Natural History Library.

this was a voyage over which great gloom was about to descend.

Several days out, after becoming ill and falling into a coma, D. Owen Stephens was brought ashore and transferred to a hospital in Balboa, Panama Canal Zone, where he passed away on June 23, officially of a thrombotic stroke. I found nothing to indicate there was ever a connection suggested between the activities of the expedition and his death.

Back in New York, astronomers who had observed the eclipse firsthand were extremely impressed with Stephens' accurate portrayals. One in particular commented he was surprised that he had accomplished so much. Later that year, a memorial exhibition of Stephens' astronomical art was held at the Hayden with scientists and members of the public praising his work.

AMNH President Davison remarked, "We are deeply grieved to have lost a man so valuable to both astronomy and painting." The chairman of the Planetarium Advisory Committee charged that the principal eclipse painting "will hang permanently in the Hayden Planetarium...." Having been displayed for decades, most of Stephens' paintings have been retired to storage. However, "Total Eclipse" hangs there to this day.

In the intervening years, the Hayden has been reimagined as the Rose Center for Earth and Space. Their stylish website states:

Softly illuminated by deep blue light, the 87-foot Hayden sphere contains the 430-seat Hayden Planetarium Space Theater.... Just west of the giant glass structure lies a terrace where colored lights and jets of water represent the principal stars of the constellation Orion, and inlaid granite suggests the shadow geometry of an eclipse.

I'd say the center's inspired architecture is a realization of Stephens' own grand vision, the appreciation of science expressed through art form. He would approve.

How glorious it would be to see his paintings displayed once again in an exhibit saluting great astronomical works of art, to coincide with the Great American Eclipse of 2024. The sweep of the shadow will grace New York State, as it did almost 100 years earlier when D. Owen Stephens first painted it there. ✶

"The Milky Way from Sagittarius to Crux," The Sky *Magazine, Amateur Astronomers Association of New York.*

NOTES

1. *Eclipse Predictions by Fred Espenak and Jean Meeus (NASA's GSFC).*

2. *Clyde Fisher. Summary of Expedition, including quote from a T. Davison letter dated 1937; D. Owen Stephens collection; American Museum of Natural History, Special Collections.*

3. *D. Owen Stephens, letters provided by granddaughter, Loring Starr.*

4. *Ibid.*

5. *Daniel Owen Stephens, 1893–1937; D. Owen Stephens collection, May 14–June 8, 1937; American Museum of Natural History, Special Collections Mss .S747 1937.*

6. *Joel Stebbins and A. E. Whitford, 1938; "The Total Light and Color of the Solar Corona of June 8, 1937,"* The Astrophysical Journal, *vol. 87, no. 3, p. 227–228.*

7. *Ibid.*

ACKNOWLEDGEMENTS

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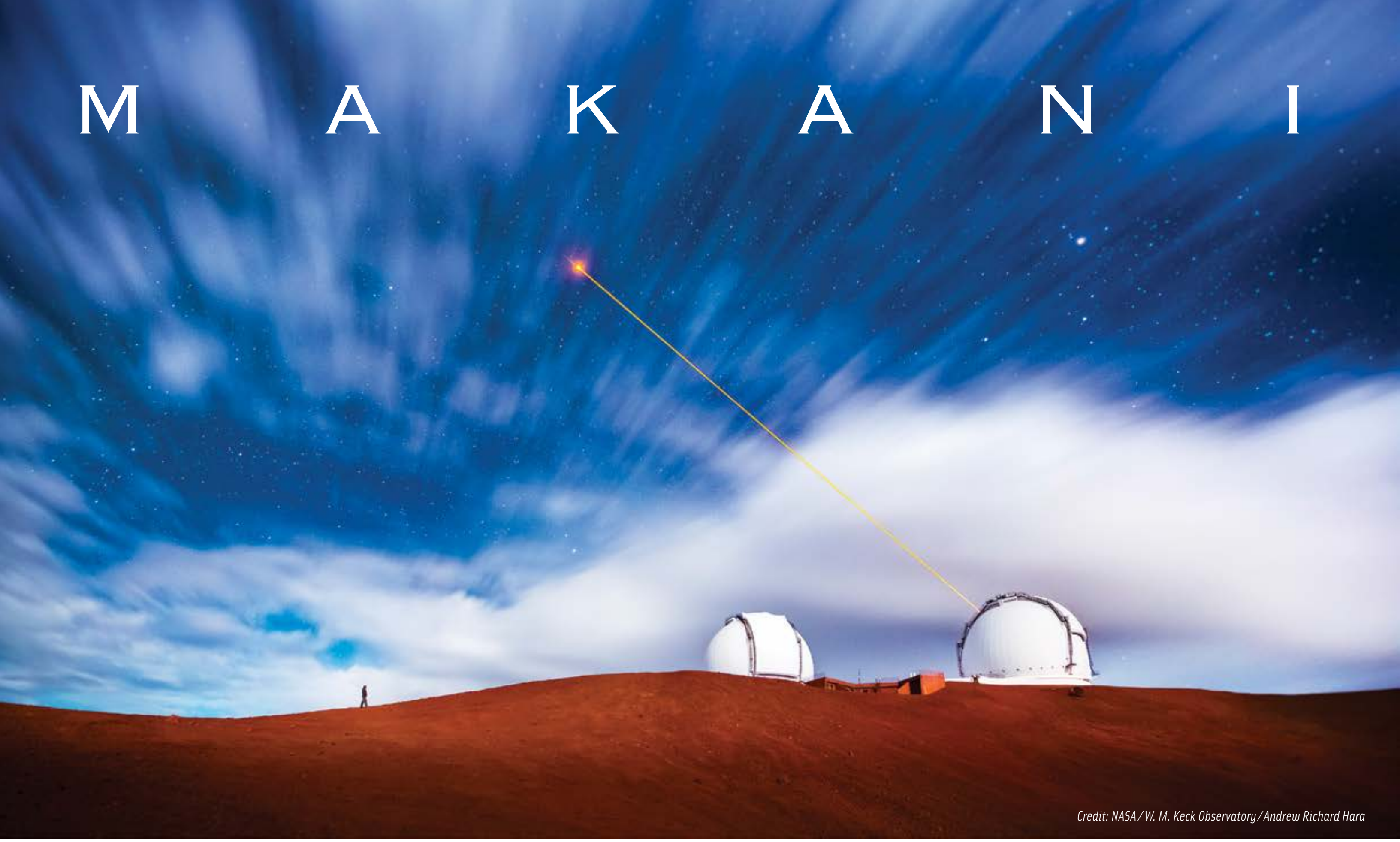
Bart Fried, executive vice president, Amateur Astronomers Association of New York, New York.

Loring Starr, granddaughter of D. Owen Stephens, Vermont.

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

M A K A N I



Credit: NASA/W. M. Keck Observatory/Andrew Richard Hara

A TINY, DISTANT GALAXY CAUGHT IN THE ACT OF BREATHING

By Dave Tosteson

The serene beauty of a spiral galaxy is just a façade. If we could view a time-lapse movie of its history to observe it interacting with the large space around it, we would have a new appreciation for how places like our Milky Way form and constantly change. With the benefit of simulations and a new imager on one of the world's largest telescopes, that picture is becoming clearer. A compact, massive merger whose light has been traveling toward us since before our Sun was born is revealing galactic inspiration.

When Galileo modified the new instrument we now call a telescope and pointed it at the sky, a revolution began. Of course, he could see only the visual wavelengths reflected or produced by what he was viewing. William Herschel used a prism in 1800 to discover a new kind of light: infrared. The next one hundred years saw light sawed into its various wavelengths: ultraviolet, X-rays and, in 1900, gamma rays, its highest energy form. The invention of spectroscopy in the mid-nineteenth century was the key development to help understand what made celestial bodies tick. Its use allowed atomic and molecular emissions and absorptions within them to be identified.

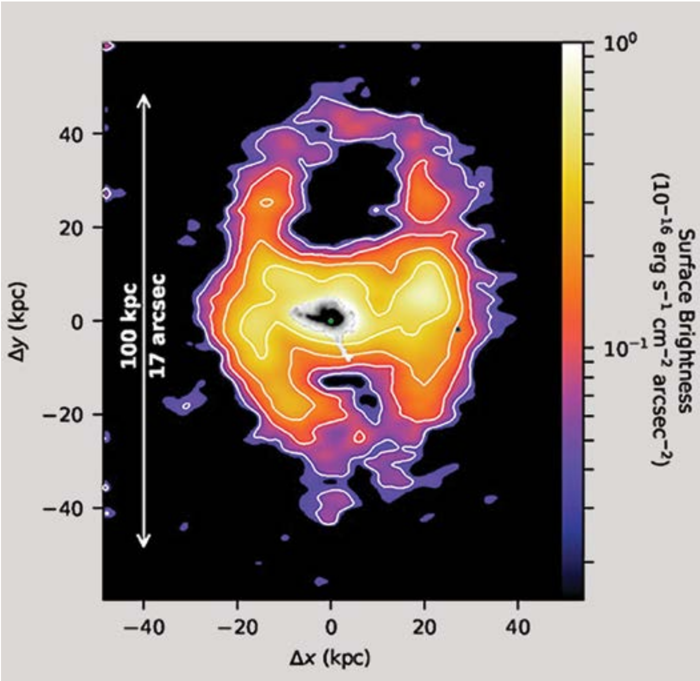
The highest mountain in the world sits not in the snow-capped Himalayas, but forms an island in the middle of our largest ocean. Mauna Kea has a peak over 14,000 feet above sea level, but its base on the Pacific floor lies 35,000 feet below the dormant top that is one of Earth's best observing sites. This sacred site of the native Hawaiian people, which they graciously allow astronomers to use, holds the twin 10-meter Keck telescopes. An instrument called the Cosmic Web Imager (CWI) has recently been used to see, for the first time, details in the outflows of galaxies that are redefining our understanding of how they live and breathe.

The visible portions of spiral galaxies belie their true nature. What we see in images is only a small part of the greater structure that surrounds and interacts with them. Dark matter halos hold about ten times the mass of the visible portion and extend far beyond those borders. There is another part called the circumgalactic medium (CGM) that is an integral piece of how they form, grow, evolve, and survive. Until recently the only way to study this glory was through its absorption of light from distant quasars. Most galaxies have such a small apparent size on the sky that only one quasar might be seen within its halo. On August 27, 2020, the Hubble site released a landmark study using forty-three background quasars to outline the Andromeda galaxy's outer halo. Its upgraded apparent size is the diameter of three Big Dippers, extending up to two million light-years away from M31's core. On more distant galaxies this pointillist and painstaking procedure produced wonderful but limited data about their CGMs, and astronomers wanted a more complete picture.

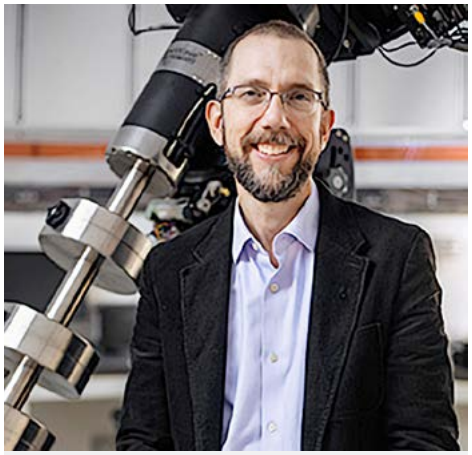
David Rupke of Rhodes College in Memphis, Tennessee, is interested in the outer structures of galaxies, particularly the gas that surrounds them. He wanted to know how it got outside their visible boundaries, and what happened to it when it did. Fortune introduced him to Alison Coil of UC San Diego, and they formed a partnership to use Keck's novel imaging system to study these galactic winds. The Cosmic Web Imager is a wide-field integral field spectrograph optimized to image low surface brightness phenomena. Rupke's team used it on a number of galaxy candidates, most of them nearby ones with supermassive black holes at their centers. When fed by infalling matter, these can become active nuclei (AGNs), energetic producers of radiation. Many experts in the study of galactic winds thought AGNs were their source. Instead, a small and very distant object with a broad, known oxygen emission line stood out in the data set. The initial interpretation was that the lines were produced within the tidal tails of a galactic merger. It was only two months later, on a second look at his data, that Rupke realized the oxygen emission found by Keck's CWI was on a much larger scale than the galaxy's visible light: over a hundred times larger than its core!

This result prompted him to contact a group that was studying molecular outflows from galaxies using ALMA, the millimeter instrument located in Chile's Atacama Desert. Jim Geach saw that Rupke's ionized wind correlated well with their data, and that their stellar formation modeling matched two outflows seen on Keck's images. In honor of the discovery's Hawaiian location, Geach offered the name Makani, which means "wind" in the native language. Like my breath on a cold January Minnesota day, Makani was seen exhaling. This galaxy is also known from its Sloan survey coordinates as SDSS J211824.06+001729.4. It is a massive, compact galaxy with one hundred billion solar masses and two tidal tails extending 50,000 light-years. A dense stellar core of only 1,500 light-years diameter contains ten percent of its light, with half its light found within 9,000 light-years of its center. Three ages of star formation were seen: at over a billion years, 400 million years, and less than seven million years. The latter two were likely produced in separate merger events, and correlate with two outflows identified on the Keck imaging. Geach and his team artistically depicted them on a rotatable, color-coded video. The outflow from 400 million years ago was expanding at about 700 kilometers per second, and the recent one had winds three times that fast. The researchers found X-ray luminosity in the core suggesting obscured nuclear activity.

Our Milky Way has a leisurely star formation rate of just one solar mass per year. Makani is furiously making new stars two hundred times faster. Such starburst galaxies are capable of producing fast galactic winds independent of their nuclear activity, as seen in Messier 82, the nearest large starburst galaxy to us at twelve million light-years. The usual winds from compact galaxies are found out to thirty thousand light-years or so, but the CGM in some extends ten times farther. Before Rupke's discovery, the connection between galactic winds and the CGM was suspected but unproven. His composite diagram of Makani's structure shows the hourglass, bipolar shape that he explains is characteristic of galactic winds. It has limb-brightened, evacuated bubbles with temperatures of 10,000 Kelvin (K) and metal-enriched, ionized gas in an area 330,000 by 270,000 light-years, the largest O II nebula detected in a single galaxy. One estimate is that this very large structure has reached only a tenth its eventual size.



David Rupke's diagram of outflow from Makani



David Rupke. Photo credit: Rhodes College

Astronomers think ninety percent of the Universe's baryons exist outside the visual bounds of galaxies, within CGMs or the intergalactic medium (IGM). Makani's nebula contains twelve to thirteen billion solar masses of molecular gas, with six hundred million solar masses of ionized gas, including a large amount of oxygen (O II). Atoms heavier than hydrogen and helium are called "metals" in astronomy, and most of these metals are found outside galaxies, in their CGM. Unlike their lighter cousins, metals act as a coolant, so gas nearer a galaxy is usually about 10,000 K, as opposed to the much hotter hydrogen farther out that can be 300,000 to a million K. Jason Tumlinson of the Space Telescope Science Institute has called CGMs "a multiphase medium characterized by rich dynamics and complex ionization states." He says they are "a source for a galaxy's star-forming fuel, the venue for galactic feedback and recycling, and perhaps the key regulator of the galactic gas supply." There is thus a correlation between a galaxy's CGM and what occurs within its interstellar medium, where stellar winds, planetary nebulae, kilonovae, and supernovae enrich and mix the gas between the stars.

The complex interplay between galaxies, their CGMs, and the IGM has been simulated on the FIRE (Feedback in Realistic Environments) computer program. This multi-team project was led by a core group of four contributors: Phil Hopkins, Claude-André Faucher-Giguère, Dušan Kereš, and Eliot Quataert. It uses data representing the universe of 13.6 billion years ago, just after the Big Bang, to follow how these three areas interact during and after the formation of galaxies. What was surprising as I watched the animation was how disruptive supernova explosions were to nascent, forming galaxies in their early stages. Makani's outflow rate was calculated at about 250 solar masses per year, but the simulated galaxies continued to "inhale" new material from their CGMs even during strong outflows, and that relentless inflow is what appears to allow spiral structure to form. Before instruments such as Keck's CWI and Hubble's Cosmic Origins Spectrograph it was difficult to study galactic inflows, so outflows, such as those in Messier 82, were the main area of research. The graduate student–led Astrobites website has a nice explanation of the complex interaction between the CGM, dark matter halos, and IGM, and their roles in galactic evolution.

Makani is classified as a compact massive galaxy, one that contains as much mass as a spiral like our own, but held within a structure only five to ten percent its diameter. Some astronomers consider them the cores from which later, larger galaxies such as giant ellipticals grew. Pieter van Dokkum of Yale stated that "the vast majority of compact, massive galaxies observed at z = 2 ended up in the center of a much larger galaxy today." Their growth, he said, was "probably dominated by minor mergers" (those where a much smaller galaxy is accreted into a larger one). These mergers stimulated star formation whose energy, winds, and end products enriched their CGMs to make them up to a thousand times denser than the intergalactic space around them. There is still mystery as to why certain galaxies appear "healthy," making new stars at a rapid pace, and why in others this process rather suddenly stop. Do they run out of gas, or does the delivery mechanism change? Blue-white jewels of freshly made clusters quickly fade, and their stars age to redden the whole galaxy. When star formation stops, a galaxy is "quenched," like a fire doused with water.

Because the active, star-forming phase in galaxies was more common in the crowded early Universe, and from the post-merger starburst phase being a short-lived portion of a galaxy's life, dynamic structures like Makani's outer nebula may be rare and hard to find in our local Universe. The nearby analog NGC 6240 is a merger of three galaxies at a distance of 400 million light-years, twelve times closer to us than Makani. X-ray studies pierce its dusty veil to show two active nuclei whose energy lights up the shrouded structure to make it an ultraluminous infrared galaxy. But even this powerful galaxy's CGM is ten times smaller than Makani's.

What can we see of Makani in the eyepiece? At almost five billion light-years away, and with such a small optical footprint, could anything be visible to amateurs? Fortunately, the answer is yes. But it is faint, very faint. The Sloan data give a (g) magnitude of 19.78, and it carries a redshift of 0.459 for a light travel time of 4.8 billion years. Its SDSS designation contains J2000.0 coordinates, and Dr. Rupke's Rhodes College video informs us that most of its light is concentrated in the core, which is what appears on the Sloan and POSS images. It is a mere nonstellar dot, minimally elongated east-west and a few arcseconds across. It lies 3.9 degrees west-northwest of the globular M2 in northwestern Aquarius, and can be found by going in a line south of Alpha Equulei the same distance (5 degrees) and direction as that between Gamma and Alpha Equ. There is a 10.6-magnitude star 1.7 arcminutes south-southwest of Makani, and an equilateral triangle 20 arcseconds on a side of 15th–16th magnitude objects centered half an arcminute to its west. Makani is on a line east of the two northern parts of that triangle, the same distance between them, about 20 arcseconds, from the northeast piece of the triangle, which is the faintest of the three members. That object appears as a galaxy slightly elongated in the north-south direction on the POSS and SDSS images.

Megastar has that galaxy at magnitude 16.5, and it and the other two stellar members of the triangle were easily seen in my 32-inch f/4 scope from my home on the morning of May 21, 2020, at 3:45 a.m. CDT with a 9 mm Type 6 Nagler eyepiece. Conditions were excellent, with no moon, dew, or wind, and seeing of 7/10 and transparency of 8/10. It took the greater magnification and clarity of my Zeiss 6 mm Ortho eyepiece to spot the stellar-appearing, almost 20th-magnitude Makani several times. No sign of its nebula was seen. With research showing how galaxies form and interact with their surroundings, and from our growing understanding of the cosmic web, dark matter, and active nuclei, it is tempting to imagine the Universe as somehow alive with breathing, evolving galaxies. ✶

From the four winds come, O breath
That they may live

Makani: 21h 18m 24.06s, +00d 17m 29.4s

The Keck Cosmic Web Imager. Photo: Christopher Martin, Caltech

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MEGACONSTELLATION SATELLITES

Practical Ways Amateurs Can Help

By Brad Young

The December 2021 issue of the *Reflector* included an abridged version of an article by Dr. Paul Daniels, "The Mega Constellation Threat." The original article[1] contains additional relevant data.

Dr. Daniels and many others have been alerting us to the threat to scientific research since the Starlink and OneWeb constellations began launching. The astronomy community has also produced several papers on this issue, and the concern over several other low Earth orbit (LEO) projects in the works. The National Science Foundation's NOIRLab and the American Astronomical Society have convened two Satellite Constellations Conferences, producing reports on everything from best practices of brightness estimation to global policy development.[2] To their credit, SpaceX attended these and other conferences, and has been active in mitigation efforts including redesigning spacecraft, raising operational orbits, and working with concerned stakeholders. Anthony Mallama has written an article in *Sky & Telescope* regarding the effect on brightness resulting from these efforts.[3]

PREVIOUS STUDIES

There are many works available that describe the brightness of the Starlink and OneSat payloads, the effect of redesigned spacecraft (VisorSat, DarkSat) and orbit manipulation. Many of these are based on a reasonable sample size and present the data with appropriate caveats. The approximate 1,000 km magnitudes (defined in detail later in this article) derived by arguably the best methods are magnitude 6 for the original Starlink and magnitude 7 for OneWeb and the VisorSat Starlink.

Despite the progress made in quantifying the impact, there are lingering concerns to keep in mind:

1. Much data has been compiled with many measurements at one location, or few measurements at several locations.

2. In most cases, the data was gathered using imaging equipment at sites or by researchers who would be affected by any effect on sky darkness.

3. Satellite brightness is notoriously difficult to measure accurately and consistently, even with imaging equipment.

4. Most importantly, there are several new satellite and constellation designs and operators coming soon.

Items 1 and 2 are important only in that they provide weaknesses in reliability. However, this is easily managed by adding other sources of data and increasing the sample size. Item 3 is an inherent characteristic; there will always be errors. However, it is reasonable that the accuracy of predicted brightness will increase with more and better data.

Item 4 is the real conundrum. Putting aside current concerns, all the prediction models being built now will have to be modified once new assets are launched. Although some equipment parameters will be known, not all will, and this will stymie the operators in their design as well. As more models are flown (and there's no doubt the existing operators will modify their assets), it will become even more important to understand what is happening before the situation is more alarming. This will provide useful information for improved design, policy, and licensing.

HAVE WE LOST SCIENCE?

It is much harder to determine whether scientific data may be lost if we are not careful. The current approach by those upset with the spike in spacecraft numbers is a well-meaning, poorly funded mandate that is competing with a trillion-dollar industry. That industry is crucial infrastructure and is innovating internet access for all. Neither side of this issue is wrong; informed, rational decisions are needed.

Engineering decisions about mitigation and threat management rely on real data about several items, including the actual brightness of the satellites after achieving their stable, final orbits. There is opportunity for the amateur astronomy community to make valid, crowdsourced measurements to provide these crucial data to both effect change and influence policy and opinion. The issue is educating our observing community, so they can both contribute data and act as motivated and informed voices as citizen scientists.

MOVING FROM PROBLEM TO PRACTICALITY

The number of active amateur satellite observers who report data is small, and much of that is concentrated on deriving orbit details, called elements, via symbiotic work of observer reports and orbital analysts. There are some observers who report varying brightness such as flaring or flashing (tumbling) but this is an even more niche area.

As with astronomy in general, satellite spotting is not easy and requires time and effort to learn and do. On the bright side, expenses can be kept low; in fact, most of you already have all the necessary equipment. An overview of the process for estimating satellite brightness is given in the chart below, with blue items indicating preparatory or subsequent indoor activities, and orange representing real-time observing or imaging

STEPS IN MAKING OBSERVATIONS OF BRIGHTNESS

SELECT TARGET SATELLITES → GET PREDICTIONS FOR YOUR SITE → CHOOSE WELL-VISIBLE FOV OF PASS → CHOOSE COMPARISON STARS IN FOV →

OBSERVE COMP STARS WITH TARGET → RECORD POSITION (OPTIONAL) AND MAGNITUDE VS. COMP STARS → RECORD ANY SIGNIFICANT BRIGHTNESS VARIATION → REDUCE AND REPORT DATA activities. This simplistic view can be expanded as follows.

SELECT TARGET SATELLITES

There are thousands of Starlinks (global coverage is the key) so, given clear skies, this is not an issue but for one point. The Starlinks do not attain their final orbits and controlled orientations until up to a month after launch. They are wonderful to see in the early days after launch, but data taken at that stage quickly become obsolete. Consequently, until each object attains its final orbit, observational metric data are usually not useful.

GET PREDICTIONS FOR YOUR SITE

This also is usually not a problem, with several websites and apps available. At a minimum, you will need to know your location, expected time of observation, and your equipment's limiting magnitude. Remember, moving objects may appear dimmer visually, and imaging may not provide the usual gain on brightness you see with stationary objects.

CHOOSE WELL THE VISIBLE FIELD OF VIEW (FOV) OF PASS

Now things become more challenging. Many apps will give you an expected brightness, culmination point (where it is highest in sky), or a sky chart for the pass. However, satellites do not always match the predictions, especially in brightness (hence the whole point of this effort). You will also need to consider the following:

1. How will I find this FOV?
2. Are there comparison stars nearby I can use to estimate magnitude?
3. Is the sky dark enough?
4. Is this the right part of the pass? See phase angle discussion below.

CHOOSE COMPARISON STARS IN THE FOV

This is very similar to the process used for variable stars, except the target is moving. You must also use the same spectral basis for magnitude. Do not use defocus or large dithering with imaging techniques, as the satellite may be rendered unseen or the trail poorly integrated.

OBSERVE COMPARISON STARS WITH TARGET

This is the first outdoor activity, and the most important of all. Imaging or visually observing the object, as it passes the field stars selected, is crucial.

ESTIMATE AND RECORD MAGNITUDE AND NOTE ANY SIGNIFICANT BRIGHTNESS VARIATION

Very rarely, a Starlink or other target may show flaring (brightening and dimming over several seconds) or flashing behavior. Although these should not be used for determining standard magnitude, they are still important to report, as such behavior also needs to be tracked.

REDUCE AND REPORT DATA

After the observing or imaging is complete, there are several paths to a final, useful report.

- Visual observers that have the comparison star magnitudes are ready to reduce their findings.
- Imagers will need to do the same, using software to process the image to determine the same data.
- Using either the prediction or the actual time and position, the range and phase angle must be determined. This is the distance from object to observer and the Sun-object-observer angle. Both are available using predictions only, but the best data will come when the actual position and time are measured.

AN EXAMPLE

The following is far from a procedure, but will act as a guide. On December 20, 2021, I observed several Starlinks from my home, using 8×40 binoculars and the stopwatch on my Android phone, set using WWV by phone. Following steps outlined above:

Selecting targets

(NORAD catalog number, satellite name):

48571	**STARLINK-2221**
48583	**STARLINK-2237**
48595	**STARLINK-2252**
48556	**STARLINK-2151**
48604	**STARLINK-2757**

Getting predictions

(STARLINK-2757 will be used as a single example): *Heavens-above.com* gives the prediction shown at the bottom of the page, with the object passing between Taurus and Aries:

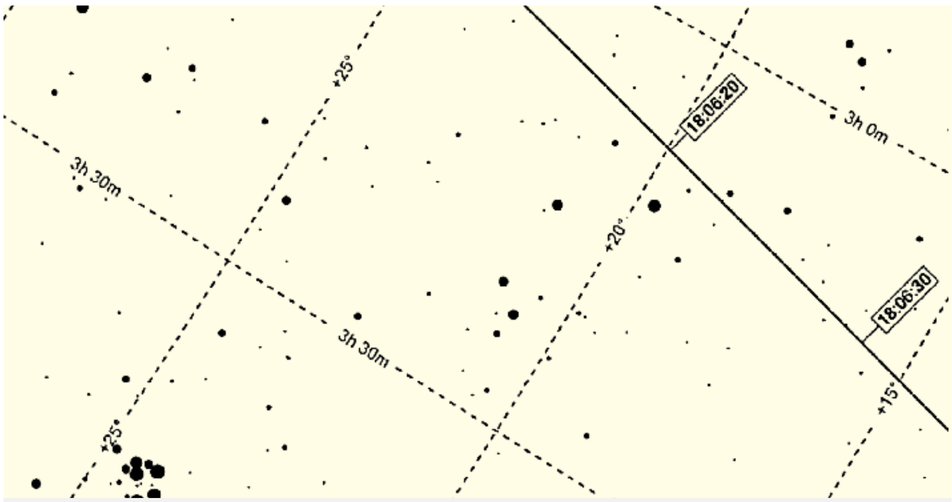
I chose to observe and record when the spacecraft was predicted to pass between the comparison stars Epsilon Arietis (magnitude 4.63) and Delta Arietis (4.35). I found an apparent magnitude of 4.4, equivalent to Delta Arietis. It was steady in brightness and passed at a time of 00:06:20 UT, which means it was on time.

Using another prediction app, I found the following:

Range (miles) = 436
Phase Angle = 62.9°

Note that phase angle for satellites is defined as 0 degrees at exactly opposite the sun – this may be unusual if you are used to observing minor planets, etc.

Standard magnitude for a satellite is comparable to that of a star, except that both distance and phase angle are used. Many analysts use the 1,000 km magnitude as standard, determined at a range of 1,000 km and a phase angle of 0° (fully lit). The example calculation is based on a simplifying but important assumption, that the satellite has a perfectly spherical Lambertian surface. One way to describe this is a diffuse reflective sur-



Heavens-above.com's *prediction of the path of Starlink-2757 for the time of the author's observation*

DERIVED STANDARD MAGNITUDES OF EXAMPLE STARLINKS

NORAD ID	Name	Range R (km)	Phase Angle φ (degrees)	Apparent Magnitude M_a	Standard (1000km) Magnitude M_{1000}
48571	STARLINK-2221	782	39	4.4	5.9
48583	STARLINK-2237	1011	45	5.1	6.0
48595	STARLINK-2252	881	49	5.5	6.7
48556	STARLINK-2151	806	55	5.1	6.4
48604	STARLINK-2757	702	63	4.5	5.9

Based on: $M_{1000} = M_a + 15 - 5 \times \log(R) + 2.5 \times \log[\sin(\varphi) - (\pi - \varphi) \times \cos(\varphi)]$ (see ref. 4)

face. Of course, neither of these things apply for the megaconstellation satellites, and the art is to determine, from reported apparent magnitudes, the correction factor that models the actual reflectivity of the surface over a range of phase angles.

A FIRST STEP — THE EOSOC

The Astronomical League has an Earth Orbiting Satellite Observing Club, with instructions and activities that may help you take the first step. Doing a few of the observations could inspire you to complete that program, and/or report Starlink magnitudes. After this initial step, you may find satellites to be a nice addition to your hobby.

TOWARDS A REAL SOLUTION

Megaconstellations are a real concern to the public, amateurs, and astronomical researchers. Currently, there are groups working on this problem, and hopefully they will be able to provide a more effective way of gathering data. Perhaps you would like to contribute as a citizen scientist, monitoring and reporting data on the megaconstellations. If so, please contact me and I will try to point you to resources or just have a conversation with you about how you can become involved.

As amateur astronomers, we should be highly motivated to effect change in this critical area that may impact not only our hobby, but the serious study of the universe. ✶

Brad Young is a member of the Astronomy Club of Tulsa and an AL Platinum Observer. You can contact him at allenb_young@yahoo.com

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AMATEUR OBSERVATION OF THE SOLAR CORONA OUTSIDE OF A SOLAR ECLIPSE

By George Hripcsak and Klaus Hartkorn

Amateur observations of the solar corona outside of a solar eclipse have been an elusive goal. Amateurs view and image solar prominences all the time with modern equipment. However, prominences are about 100 times brighter than the corona and benefit from the fact that they emit their light in narrow bands of wavelengths like hydrogen alpha (656.3 nanometers), combined with the fact that the Sun's overwhelmingly bright photosphere (the visible surface of the Sun) is blocked in those same wavelengths.

During a total solar eclipse, the corona is revealed to be a beautiful collection of white streamers several times the Sun's diameter. Author George Hripcsak first saw the corona during the 1998 total solar eclipse. He had seen photographs of the corona, which used to show little more than a diffuse glow. On his way to the viewing site, he saw a hand-painted beach towel for sale, and it showed the solar corona as a fanciful collection of pearly white streamers emanated from the eclipsed Sun. After seeing the eclipse, he realized that that beach towel was the only image he had ever seen that captured the beauty of the solar corona, and he wished he could see it again.

SAFETY FIRST

AMATEURS ATTEMPTING SOLAR VIEWING OR IMAGING WITH HOMEMADE EQUIPMENT MUST EXERCISE EXTREME CAUTION TO MAKE SURE NO STRAY UNFILTERED SUNLIGHT REACHES THEIR EYES.

Seeing the corona outside of an eclipse is another story. The corona has several components. The E-corona is nearest to the photosphere and is due to emission of light in several lines such as Fe XIV (530.3 nm), although unlike the prominences, the photosphere's light at that wavelength is unblocked. The K-corona is due to photospheric light reflected off electrons above the photosphere and is polarized. The F-corona is due to photospheric light reflected off dust that reaches even further from the photosphere. Despite making up only one percent of the total light of the corona, the E-corona is the most feasible for amateurs because it emits light in narrow bands, which allows for the use of narrowband filters to reduce the effect of stray atmospheric light.

The main challenge to seeing the corona, which is almost as bright as a full moon, is the million-times-brighter photospheric light right next to it, due to light that is scattered both within the atmosphere and within the telescope. The general approach to viewing the corona, developed by Bernard Lyot in the 1930s, is to build an instrument that produces an artificial eclipse, handle all the stray light that is induced, and view from a high mountain to reduce atmospheric scattering.

The advent of narrowband filters also makes the E-corona more feasible. Some amateurs have built their own coronagraphs, but until recently, there have been no clearly reported coronal sightings with images.

Co-author Klaus Hartkorn started working on seeing the corona about two decades ago. After his first eclipse in 2017, he renewed his efforts, and using a home-built coronagraph and a pair of surplus 532.0 nm filters tilted enough to bring them on-band, he saw and imaged the E-corona in his scope for the first time in November 2020, viewing from Mount Mitchell at 6,684 feet above sea level. To our knowledge, that is the first documented amateur sighting and image.

Coincidentally, Hripcsak set out to detect the corona through advanced image processing based on images through a used Baader prominence viewer. Summer viewing revealed a defective field lens with no chance of coronal detection. Hartkorn's posting of his accomplishment led to a correspondence and collaboration with over a thousand messages between them and a retooling of the prominence viewer. Hripcsak had his first documented coronal sighting and image in October 2021 from Utsayantha Mountain (Stamford, New York) at 3,209 feet and later observations even at sea level. We report here on Hripcsak's experience, as the instrument is the most feasible for other amateurs.

Baader prominence viewers were produced decades ago before the popularity of modern amateur H-alpha solar filters, and their purpose was to view and photograph solar prominences in the chromosphere. They came as a set of metal segments with a set of cones, lenses, an iris, and an H-alpha filter that is wide by today's standards (10 angstroms), and they were intended to be attached at a refractor's focuser. The cones block the photosphere, reflecting its light to the sides and allowing the solar prominences in the chromosphere to peek around the cone. They are sized for the focal length of the objective lens and for the season because the Sun changes in size during the year. You want to just cover the photosphere so that the prominences are not blocked. The cone is held in place by a screw attached to a field lens, which focuses the light such that a subsequent iris can block light scattered by diffraction at the objective lens. Then a pair of relay lenses refocuses the image of the prominences, an H-alpha filter reduces the effect of scattered light by filtering most of it out while allowing the prominences to pass, and the amateur's own eyepiece or camera is placed for viewing or imaging. An optional x-y lateral adjuster allowed the eyepiece or camera to move to the side to focus on the prominences at high power, because the center of the field of view is always the black shadow of the cone. The devices showed prominences brightly but were not designed for the much dimmer corona.

Hripcsak's Baader prominence viewer came with a Celestron 80 mm f/11.4 First-Scope, but the viewer came with cones sized for 910 mm and 1,000 mm. He replaced the Celestron objective with a 50 mm f/20 uncoated laser singlet with very low scratch and dig, which minimizes the light scattered by the objective. The lens sits on the First-Scope's dew shield to accommodate the extra focal length. He removed the baffles from the optical tube to reduce light that is reflected back up from the cone to the baffle and back to the eyepiece.

Hripcsak modified his Baader prominence viewer as follows. His field lens had been damaged and partly repaired by an earlier owner, so that needed replacing. He kept the Baader cones, attaching them with an M3 screw cemented with J-B Weld to a new achromatic doublet field lens. Between the cone and the field lens, he placed a new knife-edge aperture stop made from a thin aluminum sheet with an 18 mm hole, limiting the field to two solar diameters to reduce light scattered from the cone to the instrument wall and then back down toward the eyepiece. He replaced the iris with another knife-edge aperture stop and placed a tiny spot of paint (known as a Lyot spot) on a slip of glass to block light reflected within the objective lens. He kept the Baader relay lenses, although he changed their positioning to make the final rays more telecentric, and he kept the x-y adapter and removed the now-defective H-alpha filter. He blackened all the inside surfaces with Culture Hustle Black 3.0 paint. The instrument was tested with the Sun and also using a very bright LED and collimating lens set in front of a light trap in an unlit room at night. The modifications and testing took about a year.

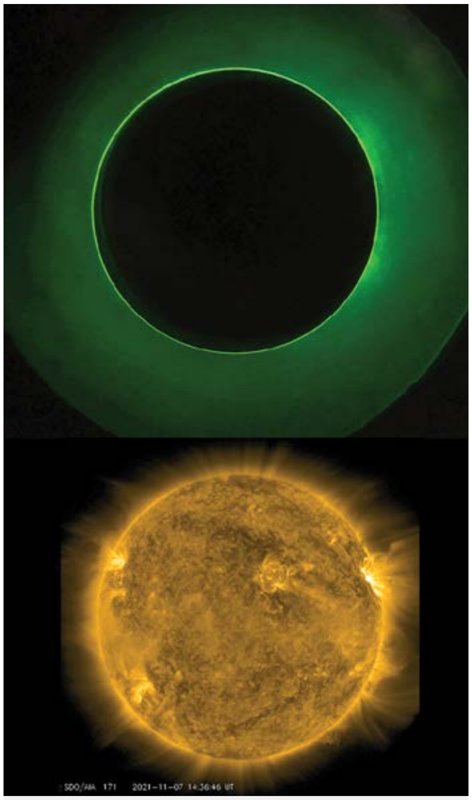

Figure 1: Hripcsak's image at top, compared to a Solar Dynamics Observatory image from about the same time.

The main filter is a pair of 25 mm single-cavity filters purchased from Andover Corporation centered at 530.3 nm (Fe XIV) when at 32°C. Each is 2 angstroms wide with 42–45 percent transmission. They are sandwiched between a generic ultraviolet-infrared cut filter and an old Meade green CCD filter. They are held in a homemade optical oven (two thermistors and two strip heaters with two solid-state controllers) to maintain the temperature at 32°C. full telescope, the modified Baader prominence viewer with the cone exposed, and the homemade oven for the 530.3 nm filter.

The first definite sighting and imaging with Hripcsak's telescope was in October 2021, but the image in the top of figure 1 was taken at 9:34 a.m. EST, November 7, 2021, from Utsayantha Mountain. The corona was seen immediately in the eyepiece. The image was taken with an iPhone 7 with its 12-megapixel color sensor and its f/1.8 lens held by hand afocally into a Tele Vue 32 mm Plössl.

The image is in its original true green color with only some contrast adjustment and no sharpening. The black disk in the middle is the shadow of the cone, which causes the artificial eclipse; it is not image processing. The bright green rim around the disk is due to diffraction. The diffuse green glow around the disk is scattered light in the atmosphere.

At 2 o'clock and 4 o'clock, the image shows two large areas of brightening that

Figure. 2: Hripcsak's telescope, the modified Baader prominence viewer with the cone exposed, and the homemade oven for the 530.3 nm filter.

represent the corona at the Fe XIV line. One can see some lobes in the image. Most other odd brightenings are artifacts (including the green arc in that area). That this is actually the corona is proven in several ways.

1. Hripcsak turned the heater on and off several times to confirm that the two areas disappeared completely and returned when the filter came near 32°C. At 16°C, the filter shifts by about 2.5 angstroms, which pulls it off the Fe XIV line.

2. The images are always compared to a satellite image taken at the same time by the Solar Dynamics Observatory (SDO) at 171 angstroms, which matches the corona well. A download from about the same time is shown in the bottom of figure 1. As can be seen, the two regions at 2 and 4 o'clock match those on the SDO image very well. In the green image, there is something at 11 o'clock but that is an artifact. If one looks closely, there is a slight brightening at 10 o'clock. That also matches the SDO image. Most importantly, the images were not aligned to make the coronal glows match. Instead, the image is oriented based on an image of solar prominences taken at the same time.

3. For previous views, the optical tube was rotated to ensure that the corona does not rotate but stays with the Sun.

4. It so happens that Hartkorn was observing the same day and on the phone that night the authors both described identical formations, the two big ones 30 degrees apart and a fleeting one across the disk.

Hripcsak subsequently observed the corona from a few yards away from the Peconic Bay, Long Island, so quite close to sea level on an extremely clear fall day. The corona was very subtle, however. Hripcsak also uses the coronagraph to observe prominences in various wavelengths, including H-alpha, H-gamma, and helium D3. He has also seen prominences in their natural color without filtering (other than ultraviolet and infrared blocking and some neutral density for safety).

The primary concern is eye safety. It is quite easy for the Sun to peek around the cone during a breeze or an accidental bump. The builder needs to consider all the solar wavelengths from 200 nm to 2,500 nm, the size of the objective lens, the degree to which the image is magnified by the series of transfer lenses, the properties of each filter in the chain, and how to ensure that there is backup so that if one aspect fails or is accidentally forgotten, the eye is saved through another. While Hripcsak started on the coronagraph only a year ago, both authors have been engineering solar equipment for over two decades.

The solar corona is now an achievable amateur target. Without NASA-level engineering, using typical home tools like pliers, screwdrivers, a small file, tin snips, a handheld drill, soldering iron, and so on, one can convert used astronomy equipment into a device capable of capturing the corona. If the device will be used for imaging only and not for viewing, then the path is straightforward. If actual viewing is desired, then it would be wiser to start with simpler devices combined with **an exhaustive study of eye safety.** The new book *Solar Astronomy* by Christian Viladrich provides instructions on the design of a coronagraph. ✶

George Hripcsak lives in New York City, and is a member of the Amateur Astronomers Association of New York. Klaus Hartkorn lives in Painted Post, New York.

GALLERY

RIGHT: ***Jeff Padell*** *(Skyscrapers, Inc.) captured this image of M83 using Slooh's 17-inch PlaneWave CDK17 with a FLI ProLine FL16803 monochrome camera. This image combines exposures taken over eight months. Slooh can be a great resource for capturing images of objects you can't reach from home.*

BELOW: ***Gregg Ruppel*** *(Tucson Amateur Astronomy Association) captured these images of Comet C/2021 A1 (Leonard) from his remote observatory at DSNM in Animas, New Mexico, with an ASA 10N f/3.8 Astrograph with a SBIG STL-11000M CCD camera and from his Tucson-area home with a 200 mm lens. Gregg's November 24 image was the Astronomy Picture of the Day (APOD) for December 3, 2021.*

*ABOVE: **Dan Crowson** (Astronomical Society of Eastern Missouri) took this close up view of NGC 6749 from Dark Sky New Mexico using an Astro-Tech AT12RCT with a SBIG STF-8300M camera on a Paramount MX+ mount.*

*LEFT: **Bernard Miller** (East Valley Astronomy Club) captured this deep image of NGC 896 with a PlaneWave 17-inch CDK and an FLI PL16803 CCD camera from his observatory in Animas, New Mexico.*

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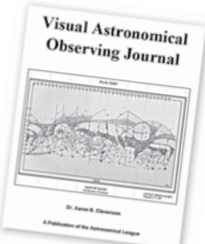

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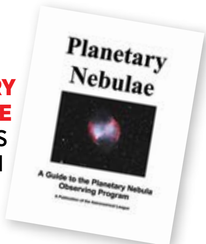

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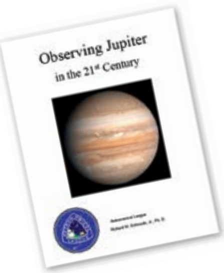

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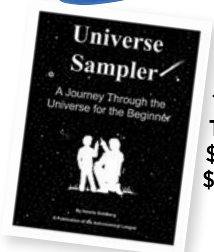

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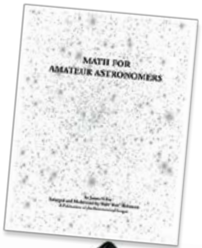

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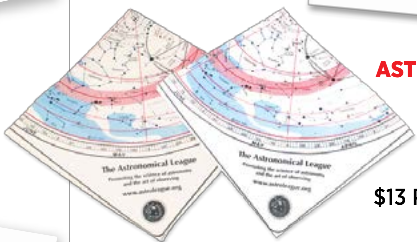

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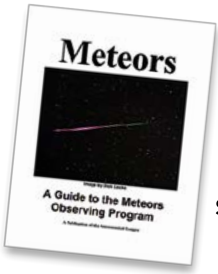

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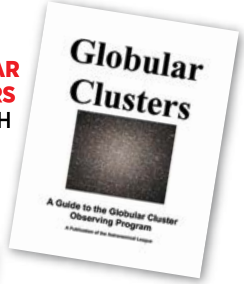

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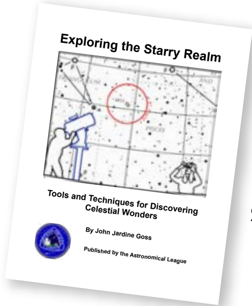

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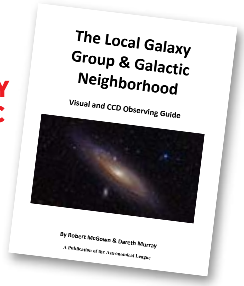

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No. 56, **Karl A. Schultz**, Central Arkansas Astronomical Society

Library Telescope Awards

No. 14, **Karey Todd**, Silver, Astronomical Society of Eastern Missouri; No. 15, **Bill Fisher**, Silver, Astronomical Society of Eastern Missouri; No. 16, **Marv Stewart**, Silver, Astronomical Society of Eastern Missouri; No. 17, **Richard Kamp**, Silver, Astronomical Society of Eastern Missouri; No. 18, **James Bruce McMath**, Silver, Central Arkansas Astronomical Society; No. 19, **Edward Swaim**, Silver, Central Arkansas Astronomical Society; No. 20, **Don Ladwig**, Silver, Astronomical Society of Eastern Missouri; No. 21, **Mark Job**, Silver and Gold, Minnesota Astronomical Society

Lunar Evolution Observing Program

No. 18, **Debra Wagner**, Member-at-Large; No. 19, **Lauren Rogers**, Escambia Amateur Astronomers Association

Lunar Observing Program

Nos. 1156 and 1156-B, **Rick Ginanni**, Greater Hazleton Area Astronomical Society; Nos. 1157 and 1157-B, **Ray Owens**, Member-at-Large; Nos. 1158 and 1158-B, **Paul Runkle**, Chapel Hill Astronomical and Observational Society; No. 1159, **Kathy Hollatz**, Steele County Astronomical Society; No. 1160, **Dennis Hollatz**, Steele County Astronomical Society; Nos. 1161 and 1161-B, **Robert Lee**, Houston Astronomical Society; No. 1162-B, **Gene Riggs**, Salt Lake Astronomical Society; Nos. 1163 and 1163-B, **Peter Hermes**, Tucson Amateur Astronomy Association; No. 1164, **Pamela Lowe**, Boise Astronomical Society; Nos. 1165 and 1165-B, **Amanda L. Grzyb**, Member-at-Large

Lunar II Observing Program

No. 122, **George A. Reynolds**, Back Bay Amateur Astronomers; No. 123, **Jonathan Schuchardt**, Rio Rancho Astronomical Society; No. 124, **Doug Lively**, Raleigh Astronomy Club

Mars Observing Program

No. 13, **István Mátis**, Member-at-Large

Messier Observing Program

No. 2832, **Glynn Germany**, Honorary, Rio Rancho Astronomical Society; No. 2861, **Andy Jaffe**, Honorary, New Hampshire Astronomical Society; No. 2877, **Joe Kraus**, Regular, Denver Astronomical Society; No. 2878, **Karl A. Schultz**, Honorary, Central Arkansas Astronomical Society; No. 2879, **Ronald Birkhoff**, Honorary, Houston Astronomical Society; No. 2880, **Brent Knight**, Honorary, Escambia Amateur Astronomers Association

Meteor Observing Program

No. 191, **Gregory T. Shanos**, 30 hours, MARS Astronomy Club; No. 202, **Lauren Rogers**, 12 hours, Escambia Amateur Astronomers Association; No. 206, **Eric Edwards**, 6 hours, Albuquerque Astronomical Society

Multiple Star Observing Program

No. 11, **Paul Harrington**, Member-at-Large; No. 12, **Gerard Jones**, Minnesota Astronomical Society; No. 13, **David P. Rudeen**, Etna Astros Astronomy Club

NASA Observing Challenge – International Observe the Moon Night

Catherine S. Anderson, Tucson Amateur Astronomy Association; **Paul Anderson**, Tucson Amateur Astronomy Association; **Phillip Auby**, Independent; **Jim Barbasso**, North Houston astronomy Club; **David Berish**, Greater Hazleton Area Astronomical Society; **Steve Boerner**, Member-at-Large; **Vincent Michael Bournique**, Lifetime Member; **Scott D. Cadwallader**, Baton Rouge Astronomical Society; **Aaron Clevenson**, North Houston Astronomy Club; **Dan Crowson**, Astronomical Society of Eastern Missouri; **Mervin T. D'Souza**, Independent; **Thomas L. Epps**, Back Bay Amateur Astronomers & Tucson Amateur Astronomy Association; **Samantha Erb**, Back Bay Amateur Astronomers; **Rick Ginanni**, Greater Hazleton Area Astronomical Society; **Dan Graham**, Independent; **Pamela Graybear**, Independent; **Brian LaFitte**, Back Bay Amateur Astronomers; **Leigh Anne Lagoe**, Back Bay Amateur Astronomers; **Shawn Loescher**, Back Bay Amateur Astronomers; **Marie Lott**, Atlanta Astronomy Club; **Mike McCabe**, Astronomical Society of Southern New England; **Alison Menzmer**, Independent; **W. Maynard Pittendreigh**, Lifetime Member; **Jerelyn Ramirez**, Kansas Astronomical Observers; **Robert P. Rubendunst**, Champaign-Urbana Astronomical Society; **Mark Simonson**, Everett Astronomical Society; **Brent Snyder**, Independent; **Melvin Spriull Jr.**, Back Bay Amateur Astronomers; **Jeffrey Thornton**, Back Bay Amateur Astronomers; **Andy Walker**, Independent; **David Wood**, Astronomical Society of Eastern Missouri; **Brad Young**, Astronomy Club of Tulsa

Nova Observing Program

No. 17, **Terry N. Trees**, Gold, Amateur Astronomers Association of Pittsburgh; No. 18, **William Clarke**, Gold, Tucson Amateur Astronomy Association; No. 19, **Steve Boerner**, Silver, Member-at-Large

Occultation Observing Program

No. 1, **Aaron Clevenson**, North Houston Astronomy Club

Open Clusters Observing Program

No. 101, **Robert Harrison**, Advanced, Patron Member; No. 102, **Gerard Jones**, Advanced, Minnesota Astronomical Society; No. 103, **Alfred Schovanez**, Advanced, Astronomical Society of Eastern Missouri; No. 104, **Mark Bailey**, Member-at-Large

Outreach Observing Award

No. 423-M, **Chuck Simms**, Astronomical Society of Eastern Missouri; No. 770-M, **Brian Chopp**, Neville Public Museum Astronomical Society; No. 1164-S, **Brad Payne**, Northern Virginia Astronomy Club; No. 1235-O, **Rich Dollish**, Amateur Astronomers Association of Pittsburgh; No. 1236-O, **Jim Pryal**, Seattle Astronomical Society; Nos. 1237-O and 1237-S, **Dan Crowson**, Astronomical Society of Eastern Missouri; No. 1238-O, **Mike Modrcin**, Omaha Astronomical Society; Nos. 1239-O and 1239-S, **Dave Tosteson**, Minnesota Astronomical Society; No. 1240-O, **Andy Walker**, Astronomical Society of Eastern Missouri; No. 1241-O, **Kent Marts**, Sugar Creek Astronomical Society; No. 1242-O, **Brian LaFitte**, Back Bay Amateur Astronomers; Nos. 1243-O, 1243-S, and 1243-M, **Shawn Loescher**, Back Bay Amateur Astronomers; No. 1244-O, **Kevin Habhegger**, La Crosse Area Astronomical League; No. 1245-O, **Aryan Gupta**, Temecula Valley Astronomers

Planetary Nebula Observing Program

No. 19, **Alan Sheidler**, Advanced Imaging, Popular Astronomy Club; No. 20, **Jeffrey Padell**, Advanced Imaging, Skyscrapers, Inc.; No. 43, **Mike Reitmajer**, Basic, Rose City Astronomers; No. 44, **Ken Cameron**, Basic, Huachuca Astronomy Club; No. 45, **Craig Gundy**, Basic, Huachuca Astronomy Club; No. 94, **Terry N. Trees**, Advanced, Amateur Astronomers Association of Pittsburgh; No. 95, **Dave Lacko**, Advanced Manual, Member-at-Large

Radio Astronomy Observing Program

No. 15-G, **Eric Edwards**, Gold, Albuquerque Astronomical Society; No. 27-S, **Kevin L. Wilson**, Silver, Astronomical Society of Greenbelt; No. 34-B, **Nikolay Kurtov**, Bronze, Member-at-Large; No. 35-B, **Paul Runkle**, Bronze, Chapel Hill Astronomical and Observational Society

Sketching Observing Program

No. 50, **Gerard J. Jones**, Minnesota Astronomical Society; No. 51, **Douglas Smith**, Tucson Amateur Astronomy Association; No. 52, **Bernard Venasse**, Lifetime Member

Solar System Observing Program

No. 181-B, **Viola Sanchez**, Albuquerque Astronomical Society; No. 182-B, **Juan Velasquez**, Denver Astronomical Society; No. 183-B, **Bernard Venasse**, Lifetime Member; No. 184, **Paul Runkle**, Chapel Hill Astronomical and Observational Society; No. 185, **Karl Schultz**, Central Arkansas Astronomical Society; No. 186, **David Berish**, Greater Hazleton Area Astronomical Society; Nos. 187 and 187-B, **Patrick McNeil**, Lifetime Member; No. 188-B; **Eric Edwards**, Albuquerque Astronomical Society; Nos. 189 and 189-B, **Conal Richards**, Youth Member-at-Large; No. 190, **István Mátis**, Member-at-Large; No. 191-B, **Andrew Corkill**, Member-at-Large; Nos. 192 and 192-B, **Michael Phelps**, Atlanta Astronomy Club.

Stellar Evolution Observing Program

No. 85, **Yu-Hang Kuo**, Seattle Astronomical Society; No. 86, **Eric Edwards**, Albuquerque Astronomical Society; No. 87, **István Mátis**, Member-at-Large; No. 88, **Albert E. Smith**, Member-at-Large; No. 89, **Karl A. Schultz**, Central Arkansas Astronomical Society; No. 90, **Brad Payne**, Northern Virginia Astronomy Club

Sunspotter Observing Program

No. 204, **Juan Velasquez**, Denver Astronomical Society; No. 205-I, **David Wickholm**, San Antonio Astronomical Association

Two in the View Observing Program

No. 50, **Bill Hennessy**, Neville Public Museum Astronomical Society; No. 51, **Jeffrey A. Corder**, Ancient City Astronomy Club

Universe Sampler Observing Program

No. 157-T, **Michael Phelps**, Telescope, Atlanta Astronomy Club

Urban Observing Program

No. 229, **Bill Castro**, Central Florida Astronomical Society

Variable Star Observing Program

No. 52, **Brian Chopp**, Neville Public Museum Astronomical Society; No. 53, **Brad Payne**, Northern Virginia Astronomy Club

Master Observer Progression

OBSERVER AWARD

Kevin McKeown, Member-at-Large; **Mike Titus**, Cincinnati Astronomical Society; **Michael Grabner**, Rose City Astronomers

ADVANCED OBSERVER AWARD

Matt Orsie, Tri-State Astronomers

MASTER OBSERVER – SILVER AWARD

Brad Payne, Northern Virginia Astronomy Club

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