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Reflector

LEAGUE AWARDS

KEEPING TRACK OF 1.8 BILLION STARS

LOW-COST RADIO ASTRONOMY

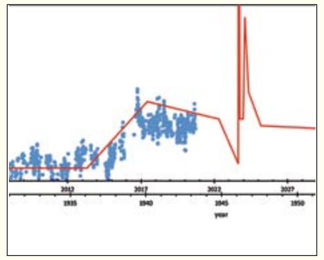
GALAXIES ARE MUCH LARGER THAN YOU THOUGHT

Contents

PAGE 8

PAGE 17

PAGE 23



Joe Ziha (Astronomical Society of Eastern Missouri) captured this image of IC 342 from his observatory in Animas, New Mexico, using a PlaneWave CDK14 with a ZWO ASI6200MM Pro camera.

Reflector

The Astronomical League Magazine

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

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

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Reflector

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***REFLECTOR* AND CLUB ROSTER DEADLINES**

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

To the Editor

I came across a phrase in the June 2022 *Reflector* that seemed quite odd. In the article "Wanderers in the Neighborhood," the author shares some details of the history of the definition of a planet. But a few pages later came the phrase "…virtually all astronomers wanted to keep the number of planets in the Solar System small."

What? Is there some special rule that you can't have more planets than digits on your hands? Who are all these astronomers who want to keep the number small? What is the limit beyond which nothing more can be called a planet? It's such a silly (and unscientific) criterion. We do have the technology to count the number of planets no matter how many there are.

Let's focus on what really is a planet and worry about the count later.

—Mike Sutherland
Beaverton, Oregon

Thank you for "Connecting with Astronomy through Its Amazing Literature" in the June *Reflector*. It is known across many hobbies that enthusiasts build their own personal museums of artifacts and literature. Classic telescopes are a popular topic on the Cloudy Nights discussion board (*cloudynights.com*). In the forum for books and related topics, one member is close to completing a full set of *Sky & Telescope* magazine. Other topic threads reveal passions for vintage charts and planispheres.

Amateur astronomy can be understood as a collecting hobby. In a series of talks to local coin clubs and conventions, Clifford Mishler, former president of the American Numismatic Association, cited the common goals of all collectors, whether of postage stamps, figurines, or automobiles: completeness, condition, rarity, and value.

The Astronomical League programs certainly insist on and reward completeness. For amateur astronomers, the condition of a view begins with the confidence that the target was obtained and extends to the quality of sky as well as the limits of the instrument.

While perhaps a million amateurs have seen the famous Double-Double, Epsilon Lyrae, not that many of us have discovered an asteroid or comet, and fewer still have imaged the recurring nova U Scorpii. With Jupiter's Great Red Spot diminishing, those previously common views could become treasured memories and records.

The value in a report begins with the care invested in our own logs and extends to our ability to share those observations with others. That opportunity can bridge the communities of amateurs with professionals.

— Michael E. Marotta
Editor, Historical Astronomy Division, American Astronomical Society (Amateur Affiliate)

Thank you, John Briggs, for your fine article, "Connecting with Astronomy through Its Amazing Literature," in the June 2022 *Reflector*. It may well "take a trip to a local college or university library," as John writes, for the special thrill of browsing through a century-old journal volume. But at the same time it should also be noted that many of the famous papers of yesteryear can now be retrieved electronically, at no cost, through the SAO/NASA Astrophysics Data System (ADS) at *tinyurl.com/astrodata-systems.* ADS has been scanning the old journal and observatory publications into its database for some time now. To take two of John's examples, Henrietta S. Leavitt's pathbreaking 1912 paper that established the period-luminosity of the Cepheid variables is available here: *tinyurl.com/leavit*. It is a credit to the ADS archivers that this paper can be retrieved in the "author" search field under Leavitt's own name, even though it was formally bylined under only E. C. Pickering's name. For comet aficionados, George P. Bond's epic 372-page tome on Donati's Comet (C/1858 L1) in the 1862 *Harvard Annals,* replete with stunning plates, can be found here: *tinyurl.com/donaticomet*. It may take you more than one cloudy evening to absorb!

I only wish that the Internet and ADS had been available in the 1970s and 1980s, when I was editing *Comet News Service* for McDonnell Planetarium, and researching the brightness of Halley's comet during its 1909–1910 apparition in order to forecast its brightness in 1985–1986. This required photocopying troves of reports in old journals in the astronomy and physics libraries at Harvard, Yale, Creighton, and Washington Universities, and at the U.S. Naval Observatory and Cincinnati Observatory. Interlibrary loans were frequently necessary. From just over one thousand magnitude estimates retrieved, it was clear, on analysis, that something was direly wrong with Halley's light curve. In almost all cases, observers then were estimating the magnitude of the coma's central condensation, rather than the magnitude of the whole coma, "m1," as is the practice today. We issued upgraded forecasts in *CNS* that were four times brighter than most other contemporary forecasts for the comet, and proved close to the truth. The research was completely dependent upon access to those old journals.

My most harrowing research experience during that time occurred in the historic Cincinnati Observatory library. As I pulled an 1870s volume of *Astronomische Nachrichten* off the shelf, the spine disintegrated and the cover fell off, leaving my hands black with soot. It was reminiscent of the scene from the 1960 film *The Time Machine*, based on the H. G. Wells novel, in which the Time Traveler (Rod Taylor) throws a fit in the Eloi's neglected library after the book he touches crumbles to powder in his hands. Cincinnati is the home to Proctor & Gamble and other chemical industries, which long filled the air with acid compounds that are not very good for paper (or people). Thank goodness for ADS.

—Joseph N. Marcus, M.D.
St. Louis, Missouri

Star Beams

As I write these words, just a few weeks before ALCon 2022 begins, I am excited that for the first time in three years we are going to be able to interact in person with astronomy friends from around the country and around the globe.

INDIVIDUAL SPONSORS NEEDED TO COMPLEMENT OUR EXISTING SPONSORS

The League has been generously blessed with several sponsors for our various awards and educational programs over the past many years. Our goal has always been to expand these offerings to recognize as many outstanding achievements as is possible. Despite cyclical swings in the economy, stock market ups and downs, etc., we want to keep consistent from year to year and build on this as more opportunities present themselves.

This is where our individual members come in. In this column, I have mentioned several times the opportunity to make the Astronomical League part of your estate planning. We have had several members accept this offer.

Perhaps there are members who would like to commit to something similar to an ongoing annual scholarship program. Perhaps this would allow more members to participate if the dollar amounts were less than for a full suite of programs, for example, for our youth programs.

Maybe some of our members would like to contribute to our adult programs as well, for example, the Mabel Sterns Newsletter Award program, which recognizes top newsletter editors across the Astronomical League. Please contact me at *president@astroleague.org* if you would like to pursue such a worthwhile and satisfying activity.

THE CHANGING CHARACTER OF OUR NATIONAL CONVENTIONS (ALCONS) AND OTHER SPECIAL EVENTS WITH ENHANCED ONLINE CAPABILITIES

ALCon 2022 will be history when you read this issue of the *Reflector*. For the first time, we will have had a major online presence in conjunction with a national convention.

Thanks to the generous contributions of Scott Roberts and Explore Scientific, social media interviews with participants, speakers, award winners, etc. were scheduled, as a major expansion of our social media reach.

Other astronomical organizations are also seizing the opportunity to increase their footprints in the digital universe. In addition to holding events online, there is an increasing trend to charge an online registration fee.

Over the years, many of our members have faithfully attended ALCons. Others, for a variety of reasons, would like to attend in person but are unable to. With the increased capabilities of stable online connections, perhaps the time has come when we can gradually ease into a hybrid situation with our ALCons and other special meetings. The in-person events will be the preference for many members, but maybe the time has come to offer an online option for the event as well, for a nominal online registration fee.

Please give me feedback on this topic to *president@astroleague.com.*

SPECIAL THANKS TO OUR OBSERVING PROGRAM COORDINATORS AND FIVE NATIONAL OBSERVING PROGRAM DIRECTORS

As we are coming out of the pandemic, with record League membership numbers, the Observing Programs have once again provided the strong personal connection that many members needed to keep engaged with the League during these challenging pandemic related years.

Our Observing Programs continue to be a key reason why members join the League, and a big thanks is in order to the many coordinators who were on the job receiving and processing submissions during the very worst times of the pandemic.

THE STRENGTHENING OF OUR REGIONS

The League is composed of ten regions spanning the United States, plus the new International Region. These are the backbone of the League. Some regions are relatively compact, others are composed of several large states, making the distances to drive to events within those regions challenging. In many of the regions, with those large distances between societies, we have seen a decline in regional activities. The preference is for regions to schedule in-person conventions, star parties, etc., annually, but some regions have become less active because of distance challenges and other issues.

Hopefully, in the next year, the digital capabilities that are becoming increasingly available will allow the League to communicate more directly and regularly with the regions to improve the active relationships.

Clear and dark skies!

—Carroll Iorg, President

International Dark-Sky Association

FIND DARK SKY FRIENDLY LIGHTING

It doesn't take much to learn how to recognize dark sky unfriendly and dark sky friendly lighting. If it is a globe or a wall pack where you can easily see the bulb, it is bad for the sky. If the bulb is up underneath the top of the luminaire and shines down on a reflector to spread out the light, it may or may not be good. If there is glass surrounding the reflector, then it is not good as the glass produces much glare.

If the bulb is totally hidden and shines directly down on the ground with no 'up' lighting, then it is probably dark sky friendly. If you spend a couple of hours traveling around your community looking at the outdoor lighting, you will soon realize what is good and what is bad. Warning: once you are sensitized to the good and the bad, you can never go back. Every time you see a bad light, it will pain you. Even so, you can't run around and try to change every bad light you see. You will soon exhaust yourself. You can focus your energies on lighting that directly affects your home or your observatory or work to preserve a threatened dark location.

One of the great challenges in replacing a neighbor's bad light (after you have convinced your neighbor it needs replacing), is to find a fixture that is dark sky friendly. Things are getting better, as more and more wonderful fixtures are being made. Turning off a bad light and leaving it off is the best solution, but in case that is not possible, check out IDA's Dark Sky Friendly Lighting page *darksky.org/our-work/lighting/*

lighting-for-industry/fsa/fsa-products. IDA's Fixture Seal of Approval Program certifies lighting fixtures as being dark sky friendly. That is, the luminaires must be fully shielded, have minimal light trespass potential, and minimal glare. The luminaire should also minimize the amount of blue light in the nighttime environment.

IDA does not sell lighting and receives no monies for approving a fixture. The Fixture Seal of Approval "provides objective, third-party certification for luminaires that minimize glare, reduce light trespass, and don't pollute the night sky." IDA does charge a fee for the approval process, and you can check out these fees at *darksky.org/our-work/lighting/lighting-for-industry/fsa/apply-fsa.* These underwrite IDA's cost to continue the program. IDA wants responsible nighttime outdoor lighting – lighting that serves a useful purpose and is only on when needed with the proper amount of light to meet the task at hand with minimal glare, minimal light trespass, little blue light emission, and no up lighting.

On the residential dark sky friendly lighting page, you can look over various fixture designs from ceiling mounts, wall mounts, pole mounts, and pathway lighting to deck and stair lighting. You can also search through the fixtures by company, by application, by retailer, and by color temperature.

I spent a bit of time looking through the approved fixtures, and there are a few I don't personally like. I don't like any fixture where light shines down on a reflector and then through a glass shield or glass lamp-like design. I feel glass adds unnecessary glare even though the luminating bulb itself is hidden from direct view. Most of the fixtures illustrated are very worthy not only for their dark sky friendliness, but they also have aesthetic beauty and probably will serve their lighting purposes well. No matter what, it is always best to use nighttime outdoor lighting for a specific task, leaving the light off when not needed.

—Tim Hunter
Co-founder, IDA

Night Sky Network

BECOME AN OFFICIAL NASA PARTNER ECLIPSE AMBASSADOR

A total solar eclipse is truly one of nature's marvels! The rush of darkness and cold that hits your body, the disorientation of animals, the wonder of seeing the stars in the middle of the day – a solar eclipse overwhelms your senses.

A budding young solar astronomer checks out the eclipsing Sun safely with help from local astronomers. Credit: Jason Hissong, Columbus Astronomical Society

Those of us who have been lucky enough to see one know what an amazing experience it is. Not everyone can make it to the center line, but even communities off the path can increase their appreciation of astronomy with a bit of support.

Amateur astronomers are often the local experts when it comes to looking up. Why not take this opportunity to become an official NASA partner as an Eclipse Ambassador, preparing your community to view the eclipses safely no matter where they are! Two solar eclipses grace the continental U.S. in 2023 and 2024. The first, on October 14, 2023, is an annular or "ring of fire" eclipse, while on April 8, 2024, we'll be treated to another total eclipse.

The Eclipse Ambassadors Off the Paths project will partner 500 amateur astronomers across the United States with local college undergraduates to work together as local eclipse experts within their communities. Connect with a new generation of enthusiasts who bring fresh perspectives and resources to astronomy engagement. Share your knowledge of the sky and the joys of amateur astronomy with an enthusiastic college student. The wise, forward-looking members of our amateur astronomy community have been talking about the graying of our clubs for decades. Here's a chance to inspire a new generation of members and learn from each other.

An interactive online training program will prepare Eclipse Ambassador partnerships with fresh ideas, great engagement tips, and all of the resources needed to bring NASA science to their communities before and between eclipses (no need to stay home for the eclipses themselves). Share your passion for astronomy with the next generation and reach underserved communities through libraries, afterschool centers, and more. Already connected? That's great, too!

Apply to become an Eclipse Ambassador today. If you already have an undergraduate partner in mind, you can become certified together. Or get provisionally accepted without a partner, and we will help you connect with an interested undergraduate in your area. Ambassadors receive NASA recognition and the joy of seeing faces light up as we share the science and awe of eclipses with our communities. Sign up at *eclipseambassadors.org.*

Official Eclipse Ambassadors will be supported by the program to:

- Partner with an undergraduate enthusiast
- Share your joy of lifelong learning and love of the sky
- Receive training on best practices in outreach
- Receive an official badge and loads of outreach materials
- Join conversations with NASA scientists
- Connect with nearby Eclipse Ambassadors, libraries, and community centers
- Offer community engagement in underserved communities near you

—Vivian White

Vivian White is the Director of Free Choice Learning at the Astronomical Society of the Pacific, and administers the NASA Night Sky Network (NSN) as part of her work. Vivian designs astronomy activities and demos specifically for informal settings, working with citizen scientists, Girl Scouts, Tibetan monks, and many others to expand the ways we learn astronomy out of school. Beyond the night sky, her passions include pottery, poetry, and social justice.

Full STEAM Ahead

THE WORLD'S OLDEST JUNIOR ASTRONOMER

I made a trip to the Astronomical League's main office in Kansas City to pick up a binder that had old records and correspondence that pertained to the history of the junior astronomy societies and activities. I had received permission to get the binder and look it over and make copies of anything I liked. These documents were from our current vice president, as he was one of the youths heavily involved in the League in his junior high and high school days. Since there was such a rich history, I really could not decide, so I asked permission to take it home and offered to scan the binder and put sheet protectors in and do a proper archiving job in exchange for my research. I was granted that opportunity and it is back at Kansas City all scanned if anybody desires to have some of those files for themselves.

So, with a four-inch binder and many sheet protectors later, what unfolded was a wonderful world of about 75 active junior astronomy clubs, some independent and some under the mentorship of an adult club. A world opened before my eyes of countless students so fully absorbed in this hobby that we love, doing whatever it took to observe the cosmos together.

The success of this program is credited to the adults that sat on the national council, Bob Wright as the advisor, along with the executive secretary Wilma Cherup, president Gene Tandy, and John Cotton, one of the members of the Junior Activities Committee. Imagine my surprise when talking about the JAS at the Mid-States convention, that I was told that John Cotton is in my club. I got the idea to interview him for this article. I was given his contact information and I was surprised to find a man in his 80s, eloquent, sharp as a tack, and so very engaging.

After I introduced myself, John Cotton opened up the conversation by saying "I am the world's oldest junior astronomer." He continued to share that as a young man of 14 years of age, he was a member of the Texas Astronomical Society in the 1950s and had an original Skyscope telescope that was popular at that time. If there was a regional meeting, John was there; an occultation watch, yes, he was there. No opportunity slipped by this young man since there were no astronomy classes offered in the public school system; he had to stay connected to his fellow junior astronomer friends.

John chuckled at the memory of how "back in the 50s, no one had a second thought about junior high students piling into a van of some adult to head out somewhere. It wasn't unheard of for youth to head to Lubbock Texas Tech for observing expeditions and have the kids sleep on the floor." With no classes available in 1956–1957, these youth organized and started clubs, some as satellites of an adult club and some separate with an adult advisor. I told John that as I worked with the junior activities archives, I discovered 72 active clubs, a well-networked organization. I also added that the binder contained lots of correspondence to and from him and that one part included many handwritten notes from students who wanted to get involved because of a story in *Sky & Telescope.*

Observing programs, eclipse watches, comet surveys, star logging, sun spotting were all being conducted by these students, because as John Cotton said, "they read any and everything on astronomy, and *Sky & Telescope* in particular." When they were not reading, writing articles, editing their newsletter, or making movies, they would observe. Most students had the Criterion Dynascope RV-6, a 6-inch Newtonian with a clock drive that cost the families about $160, and that is how the kids all got started in astronomy. "I still have my scope and it is still functional," John said, adding "They were pretty good for a small-aperture telescope."

John talked about his position on the Junior Activities Committee, and his current outlook and philosophy on the youth and astronomy of today. But that will have to wait for the next installment of my conversation with "the world's oldest junior astronomer." I thanked him for his time and offered to send him a thumb drive with the junior binder archives on it. He appreciated this, because, in his words, "I have my book I put together on the Junior Activities." "Is it blue?" I asked. "Yes," came the reply. I enthusiastically said, "I scanned that!"

To be continued...

—Peggy Walker
STEAM and Junior Activities Coordinator

Wanderers in the Neighborhood

ASTEROID CLASSIFICATION

Asteroids (sometimes referred to as minor planets) bring to mind tiny astronomical bodies orbiting the Sun between Jupiter and Mars. But asteroids are scattered throughout the Solar System. Some orbit in the cold depths beyond Pluto, and others are in our own neighborhood.

Those that come close to the Earth's orbit are called near-Earth asteroids (NEAs). These asteroids have the potential to impact the Earth, but very few have actually impacted us recently. Their proximity allows astronomers to bounce radio waves off them to receive reflections, revealing the shapes of our temporary companions. Before interplanetary spacecraft, this was our only way of knowing their shapes directly.

The radio reflections that could be received from more distant asteroids would be too faint to reveal their shapes. Telescopically, these asteroids are too small and too distant to reveal their surfaces: they are starlike even at the highest magnifications. Ceres, the largest main-belt asteroid and now considered a dwarf planet, is well under an arcsecond across as viewed from Earth. For these asteroids, the main way we can learn about them is to study the sunlight that they reflect.

A piece of the stony meteorite that fell on April 9, 1894, in Polk County, Minnesota, near the town of Fisher. Pieces of the meteorite were found over the next few years. A cut and polished section of the meteorite shows the chondrules scattered throughout. Chondrules were molten silicate droplets that solidified before the chondrite meteorite formed. The chondrules are one to five millimeters in size. Image credit: Jon Taylor, Creative Commons Attribution-Share Alike 2.0 Generic License

Because we cannot resolve an asteroid's surface, the light we receive from it is a composite from the entire visible surface. Dark areas and bright areas are averaged together to give the total brightness of the asteroid. Although we cannot discern individual areas on the asteroid, we can split the incoming light into a spectrum of colors and measure the brightness of each individual color, producing a spectrogram of the asteroid.

Knowing how the asteroids reflect different colors of light allows astronomers to classify asteroids into types. In devising a classification system, samples of the objects being classified

A polished slice of a meteorite found in June 1967 in the dry bed of the river Hekandue, near the settlement of Seymchan, Magadan, Russia. It was originally identified as an iron meteorite, specifically an octahedrite, an iron meteorite with a crystal structure that mimics an octahedron. After an iron meteorite has been sliced, polished and etched with nitric acid, the Widmanstätten pattern seen here becomes visible. The pattern is formed by the interleaving veins of kamacite and taenite, alloys of nickel and iron. Later samples of this meteorite showed olivine inclusions, reclassifying this meteorite as a pallasite, even though there are sections that are completely iron-nickel. Source: Basilicofresco, Creative Commons Attribution-Share Alike 2.0 Generic License

are usually required. Surprisingly, we already have samples of asteroids: meteorites. They are chips off the asteroids that have landed here on Earth, giving us up-close samples of these distant bodies.

Meteoriticists had already classified existing meteorites into three groups: stony, stony-iron, and iron meteorites. Stony meteorites are the most common, and stony-iron meteorites are the rarest.

Stony meteorites have some mineral similarities to Earth rocks, being composed of silicates, iron, and nickel. They frequently have a black fusion crust that differentiates them from common rocks. Many stony meteorites contain small, colorful inclusions called chondrules. Chondrules crystallized as melt droplets in the primordial solar nebula and are some of the oldest materials available for study, having formed even before our planet. Stony meteorites with chondrules are called chondrites. The majority of these come to us from asteroids that did not experience melting. These bodies are sometimes referred to as "rubble pile" asteroids that did not differentiate the way our Earth did. In other words, the denser metals never preferentially sank toward the center.

Stony meteorites that do not have chondrules are called achondrites. These form from melted and recrystallized chondrites.

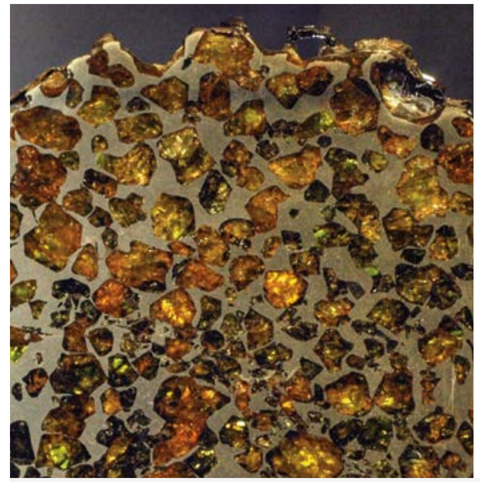
Stony-iron meteorites contain more iron than stony meteorites. They formed near the boundary between the mantle and the core of their parent body. They are the rarest type of meteorite and come in two subclasses, pallasites and mesosiderites. Pallasites contain crystals of olivine, a green mineral of magnesium iron silicate that forms the gemstone peridot. In pallasites, the olivine can be up to gemstone quality embedded in a matrix of nickel-iron. This rare subclass is named after the German naturalist Peter Pallas (1741–1811), who described a specimen in 1772.

Mesosiderites are about half nickel-iron and half stony material. They are breccias, with the two main components mixed as lumps or pebbles. The two components are also found in fine-grained intergrowths in the meteorite. Some mesosiderites are among the largest meteorites known.

The last class is the iron meteorites, formed from the core of the parent body. These heavy, dense meteorites are mostly iron, with the rest being nickel. Cutting one of these meteorites into slabs and etching the surface with a mild solution of nitric acid, a complex interlocking crystalline pattern of iron alloys appears. This pattern is known as the Widmanstätten pattern, after Count Alois von Beckh Widmanstätten, who discovered the structures in the early 1810s.

We can compare the spectra of meteorite samples with the spectra of asteroids to categorize asteroids broadly based on composition. The most common asteroid is the C-type asteroid (chondrite), about 75 percent of the known asteroids. C-type asteroids reflect between three and ten percent of the sunlight striking them. These are the darkest asteroids, composed of carbonaceous material, silicates, and potentially even volatiles such as water. They are the most ancient asteroids and are the source of some stony meteorites, specifically the carbonaceous chondrites.

S-type asteroids (stony-iron) are a little more reflective, returning ten to twenty-two percent of the sunlight that strikes them. Their surface is nickel-iron with iron and magnesium silicates. S-type asteroids represent 17 percent of the known asteroids. These asteroids are the source of the stony-iron class of meteorites and potentially ordinary chondrites.



Found by a farmer digging a hole for a water tank in 1951 near Esquel, a town in southwestern central Argentina, this pallasite meteorite belongs to the stony-iron group of meteorites. This image shows a thin slice that has been polished. Yellowish and green crystals of olivine (peridot) are plainly visible in a matrix of nickel-iron. It is on display in the Vale Inco Limited Gallery of Minerals at the Royal Ontario Museum. Image Credit: Emily Lakdawalla, The Planetary Society. From the Bruce Murray Space Image Library (planetary.org/space-images). GNU Free Documentation License, Version 1.2.

The last group is the M-type asteroids. These make up the remainder of the known asteroids. They are almost pure iron-nickel, like iron meteorites. They reflect ten to eighteen percent of the sunlight they receive.

This system of classifying asteroids was proposed by American astronomer David Tholen in 1984. Using the 61- and 90-inch telescopes at the University of Arizona, a group of astronomers including Dr. Tholen conducted the Eight-Color Asteroid Survey (ECAS). They studied 589 asteroids in eight intermediate-band spectral colors and determined the reflectance of each asteroid in each band from ultraviolet to infrared.

The Tholen taxonomic scheme has fourteen classifications, dividing the three groups above into finer subclasses. Other classification systems have been developed as new instrumentation has allowed finer measurements of asteroids to be made. In addition, spacecraft have visited twenty asteroids, returning images that could never be seen from Earth. We still have much to learn about these tiny members of our Solar System and what they can tell us about its formation.

—Berton Stephens

Deep-Sky Objects

FLYING HORSES AND EXPLODING STARS

The large winged horse Pegasus is one of the most recognizable autumn constellations. Most amateur astronomers and even some non-astronomers can find the Great Square of Pegasus, formed by four stars with magnitudes between 2 and 3. The four stars in order of brightness are Alpheratz (Delta Pegasi), Markab (Alpha Pegasi), Scheat (Beta Pegasi), and Algenib (Gamma Pegasi). Alpheratz is also known as Alpha Andromedae and is a rare case of a star that has a Greek designation in two adjoining constellations.

The Great Square often appears devoid of stars in its interior. But dark skies, away from suburban light pollution, reveal myriad faint stars there. Amateur astronomers flock to Pegasus to spy double stars and some popular deep space objects, such as the globular cluster M15, the Deer Lick Galaxy (NGC 7331), and the famous galaxy cluster known as Stephan's Quintet.

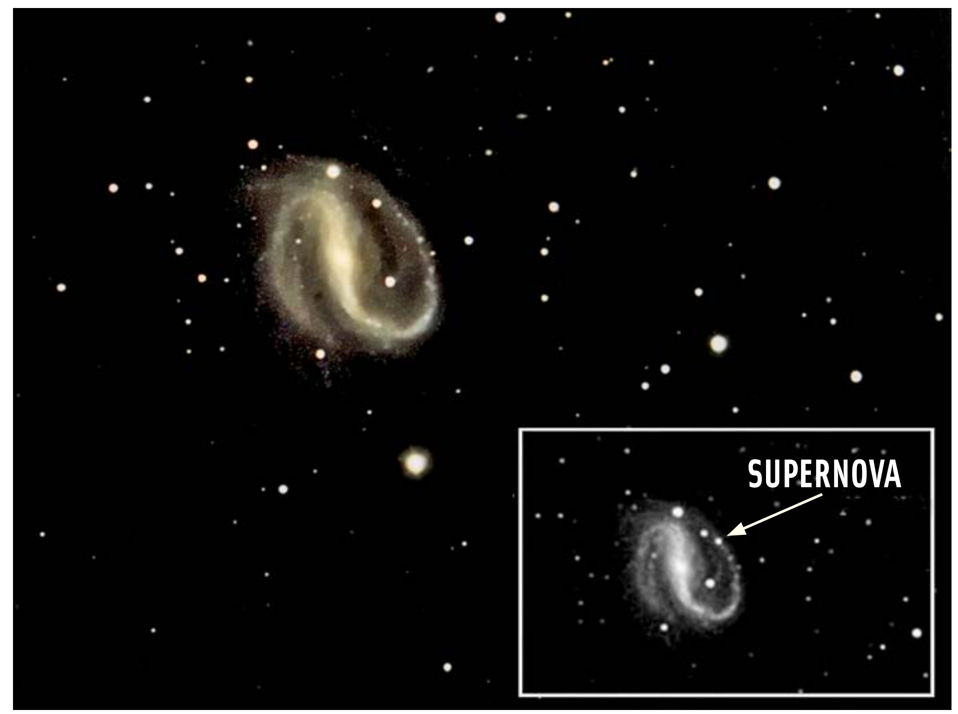
Not as well known but equally impressive is the galaxy NGC 7479. It is a nearly face-on barred spiral galaxy discovered by William Herschel in 1784 using his 18.7-inch Newtonian telescope.

NGC 7479 is very easy to find, as it is located three degrees due south of the star Markab. The galaxy has visual magnitude 11.6 and is 3.6 by 2.7 arcminutes in size. Distance estimates place the galaxy 105 million light-years away.

The galaxy has a very bright core and bright long bar structure. The bar appears to extend in the north-south direction. This north-south elongation of the core is apparent in an 8-inch telescope in dark skies. NGC 7479 has two main spiral arms emanating from the ends of the bar, each extending 180 degrees around the galaxy. In most amateur telescopes, the central budge and bar structure are all that is seen, as they are much brighter than the spiral arms. A Hubble Space Telescope image of the galaxy reveals a few fainter spiral arms as well as some spurs off the two main arms.

NGC 7479 is classified as a Seyfert galaxy due to extensive starburst activity in the core and spiral arms. Radio studies indicate the galaxy may have recently (when the light left the galaxy) undergone a galactic merger. Visible dust lanes in the Hubble Space Telescope image do not all correspond to the normal lanes seen in spiral galaxies, adding evidence for a galactic merger.

I imaged NGC 7479 using a 10-inch f/6 Newtonian, with a Tele Vue Paracorr II coma corrector which gave an effective focal ratio of f/6.9, and an SBIG ST-2000XCM CCD camera. The exposure was 210 minutes. The clumps visible in the spiral arms are regions of starburst activity. All of the stars individually resolved in the image are in our Milky Way Galaxy. So those superimposed over the galaxy are actually foreground stars. (The image was cropped and modified by *Reflector* staff for clarity.) The inset frame on the lower right side of the image was taken on

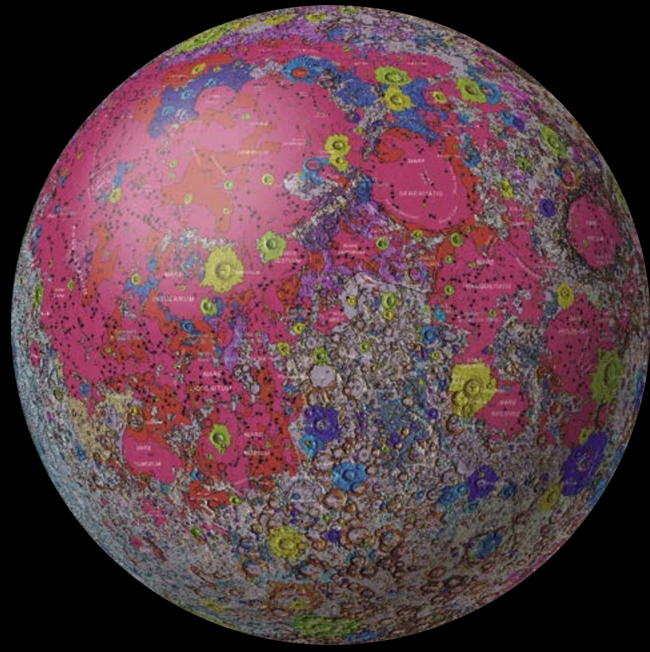


November 6, 2009, using the same camera and a 190 mm f/5.3 Maksutov-Newtonian. The arrow in the inset points to a supernova stellar explosion whose light had just reached Earth a few weeks before this picture was taken. Of course, the star actually exploded 105 million years ago. The supernova was so bright, it rivaled other stars in the field of view which are in our galaxy, and therefore much closer.

This supernova is known as SN2009jf. The automated Lick Observatory Supernova Search discovered SN2009jf on September 27, 2009. Fortunately, it was discovered before the peak brightness, allowing a good light curve to be developed over a few months, and thus determine the type of supernova. At the time of the discovery the exploding star was magnitude 18. By mid-October 2009, the supernova had reached magnitude 15. When I imaged it, it had faded to magnitude 16. SN2009jf was a type Ib supernova. It is thought to have been a massive luminous blue variable (LBV) star that reached the end of its life and exploded.

Even without a supernova, NGC 7479 is a great galaxy to spy in the constellation Pegasus. If you are out hunting galaxies on a crystal-clear autumn night, NGC 7479 should be on the observing list!

—James Dire



Around the League

OBSERVING PROGRAM COORDINATORS NEEDED

The Observing Program Division is once again in search of additional Observing Program coordinators. If you have a desire to get more involved with the Observing Programs, we want you! These Observing Programs currently need a coordinator: Jupiter Observing Program, Mentor Observing Award, and the NASA Special Observing Challenges. We also have two new Observing Programs recommended to the council for adoption in July. If they are adopted, they, too, will need coordinators. There may be more. If you are interested, please send an email to Aaron Clevenson at *aaron@clevenson.org*. Indicate for which Observing Program(s) you would like to be considered, or you can say "all openings." Emails must be received by December 31, 2022, since we will begin the interview process in January. Current coordinators may also apply, but the best practice is to limit the total number for each coordinator to three or fewer Observing Programs. Thank you for helping the Astronomical League and the Observing Program Division.

League Awards

By Chuck Allen

I am happy to recognize the winners of our League Youth Awards and League Awards for 2022.

2022 NATIONAL YOUNG ASTRONOMER AWARD

The National Young Astronomer Award program is now in its 30th year. As always, our deepest thanks go to Scott Roberts of Explore Scientific for his generous sponsorship of the NYAA program over many years.

This year's entries were judged by two PhDs and a former Intel International Science and Engineering Fair lead judge. Our first and second place NYAA winners receive Explore Scientific–sponsored telescope prizes and expense-paid trips to ALCon 2022. Our top three winners receive plaques, and our top six finalists receive framed certificates.

First Place: Harish Krishnakumar

Harish Krishnakumar is currently a senior (award-year junior) at the Nikola Tesla STEM High School in Redmond, Washington. His winning project was titled "Analysis of Ring Galaxies Detected Using Deep Learning with Real and Simulated Data."

His project made first-time use of a convolutional neural network (CNN) to identify ring galaxies from unclassified samples of galaxies. A CNN was trained on a sample of 100,000 simulated galaxies, transfer-learned to a sample of real galaxies, and then applied to a previously unclassified dataset to generate a catalog of ring galaxies that was then manually verified. The properties of these galaxies were then estimated using photometric research. Using this method, a catalog of 580 ring galaxies, currently the largest set of computationally identified rings, was extracted with 6.6 times the accuracy and 7.8 times the detection rate of conventional computational methods.

Runner-Up: Zarar Haider

Zarar Haider is currently a senior (award-year junior) at the Trinity School in New York City. His project was titled "A Novel Method of Transit Detection Using Parallel Processing and Machine Learning."

Zarar introduced a novel GPU fast phase folding technique coupled with a deep convolutional neural network to search for ultra-short-period (USP) planets, Earth-sized planets with the shortest possible orbital periods of all known exoplanets. The network was trained on a set of 2,000,000 synthetic USP planet samples and was able to identify both true and false positive transit signals with 99.5% validation accuracy. His method is 1,000 times faster than the traditional box least squares method in searching for transit signals in a photometric light curve and performs with the same or better precision and recall rate.

Third Place: León García

León García is currently a senior (award-year junior) at Corvallis High School in Corvallis, Oregon. His project was titled "Simulating Off-Axis Short Gamma-Ray Burst Afterglows to Inform Electromagnetic Follow-Up to Future Gravitational Wave Events."

León studied short-duration gamma ray bursts, which are ultra-relativistic explosions formed by neutron star mergers. Since 2005, the afterglows of gamma ray bursts have been observed across the electromagnetic spectrum. To be seen, the merger's jet must be pointed towards Earth. Gravitational wave detectors, however, can detect these mergers without observing the jet.

León derived physical properties from observations of on-axis short GRB afterglows. Using these properties, he simulated light curve models for off-axis GRB afterglow emissions across the EM spectrum and explored their observability in today's telescopes. He found that off-axis bursts at distances of 464.3 megaparsecs are optimally observed at radio wavelengths 1 to 100 days after the bursts and are initially detected using the Very Large Array. He noted that the optimal time to observe the flux shifts to further after the burst occurs as the observing angle is further off-axis.

2022 HORKHEIMER SERVICE AWARDS

The League offers two major youth service awards, the Horkheimer/Smith Award with a cash prize of $1,750 and an expense-paid trip to the League's national convention and the Horkheimer/D'Auria Award with a cash prize of $1,000. The awards bear the name of their primary benefactor, the late Jack Horkheimer (television's "Star Gazer") and are funded by the Horkheimer Charitable Fund established in Jack's memory. Our thanks go to Dwight Horkheimer for his work with the fund and for his generous support of these youth award program for more than two decades.

Horkheimer/Smith Award Winner: William Gottemoller

William Gottemoller, currently a high school senior in Milwaukee, Wisconsin, is a member of the Milwaukee Astronomical Society (MAS) and the founding member of the Menominee Falls High School Astronomy Club. In 2020, he applied for and obtained Optimist Club grants used to purchase over 40 Slooh Remote Telescope subscriptions for members of his high school club, renewing that effort in 2021. William is a Slooh Space Ambassador, and his enthusiasm has inspired other students to use Slooh to image southern sky objects not visible from Wisconsin.

The MFHS Astronomy Club has become one of the largest student clubs at his school. William

regularly arranges school field trips to the MAS Observatory and recently arranged a club field trip to Yerkes Observatory. William even wears a turtleneck in honor of his favorite icon, Carl Sagan, when leading tours through the MAS Observatory on public nights. He has become the youngest MAS member to open the observatory and conduct public events. He leads discussions in committee meetings, presents topics, and assists members in discovering the cosmos and engaging in astrophotography projects. He also assists the club in upgrading its observatory equipment.

Horkheimer/D'Auria Award Winner: Jai Shet

Jai Shet is currently a freshman at the University of Arkansas at Little Rock where he is double majoring in Accounting and Business Information Systems. He plans to acquire a master's degree in Finance.

Jai's volunteer experience includes spreading the awareness of astronomy through the Fort

Bend Astronomy Club's Astronomy on Wheels outreach program at local elementary and middle schools, volunteering at the George Observatory in Brazos Bend State Park, and volunteering at the Annual Houston Gem and Mineral Show. Jai has coauthored three articles in the Astronomical League's *Reflector* magazine. His most recent article, "An Observatory with No Telescopes," was published in the March 2022 issue of the *Reflector*, making it his fourth article to date.

Jai is enthusiastic about traveling, having visited 9 countries, 48 U.S. states, and 43 out of the 63 U.S. National Parks.

2022 HORKHEIMER/PARKER IMAGING AWARD

The Horkheimer/Parker Imaging Award is a youth imaging competition offering prizes of $1,000, $500, and $250 for the top three winners. This award is sponsored by the Horkheimer Charitable Fund.

Winner: William Gottemoller

William Gottemoller (photo at left under Horkheimer/Smith Award) of the Milwaukee Astronomical Society won the Horkheimer/Parker Youth Imaging Award with his capture of Melotte 15, a 1.5-million-year-old star cluster in Cassiopeia's Heart Nebula.

William shares his images publicly, and one was selected as Stellar Shot of the Week in April 2021. In October 2021, William, working with MAS president Tamas Kriska and MAS secretary Agnes Keszler, devoted several months to troubleshooting and installing new imaging trains on $16,000 worth of astronomy equipment at the MAS Observatory. The work included upgrading the club's Celestron Edge HD 14-inch telescope with a ZWO ASI6200MM Pro camera. William acquired the calibration frames and light frames used by Tamas to process a final first light project on IC 1805, the Heart of the Heart Nebula.

To learn more about PixInsight, William took out a free trial and learned from other club photographers while patiently processing his acquired frames of Melotte 15. He completed the entire acquisition, calibration, and processing stages of the image himself.

With his wins in this year's Horkheimer/Smith and Horkheimer/Parker competitions, William becomes only the third person to win two major youth awards and the first to do so in the same year.

Runner-Up: Vivek Vijayakumar

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

Vivek submitted an image of NGC 7822, a star-forming region in Cepheus known as the Question Mark Nebula. The photo was taken in Julian, California, using a TMB Optical 80 mm triplet refractor, Explore Scientific ED80, and QHY 268M camera.

Third Place: Jai Shet

Jai Shet (photo at left under Horkheimer/D'Auria Award) is currently enrolled at the University of Arkansas–Little Rock. His passion for photography won him first place in the youth category of major national and international photography competitions in 2021 including Photographic Society of America Youth Showcase, Travel Photographer of the Year, International Dark Sky Association Capture the Dark, Jostens Photo Contest, and the Natural Landscape Photography Awards. Some of his award-winning pictures have been displayed in exhibits/museums in the United States, United Kingdom, and United Arab Emirates, and have also been published in books and magazines. One of Jai's images was featured on NASA's Astronomy Picture of the Day on February 15, 2022. He has shared his passion for photography by conducting educational workshops and presentations at astronomy and photography clubs in the Houston area as well as virtual presentations at the Astronomical Society of Eastern Missouri and the Astro Imaging Channel.

Jai's image, "Stairs to the Heavens," was taken in Big Bend National Park using a Canon 5D Mark IV and Sigma 17 mm f/1.8 lens.

2022 HORKHEIMER/O'MEARA JOURNALISM AWARD

Each year, the League conducts a science writing competition for youth ages 8 to 14. The top three winners of the Horkheimer/O'Meara Journalism Award receive plaques and cash prizes of $1,000, $500, and $250, all sponsored by the Horkheimer Charitable Fund.

Winner: Thomas Wilson

Thomas Wilson, 12, is the winner of the Horkheimer/O'Meara Journalism Award for 2022. Thomas is currently a seventh grader at the Trinity School at Greenlawn in South Bend, Indiana, and is a member of the La Crosse Area Astronomical Society.

Thomas' winning essay is entitled "A Night to Remember." Please take time to enjoy his essay which will have an emotional impact on anyone who inherited a love of astronomy from someone who has been lost to the ages:

A Night to Remember, by Thomas Wilson

A very memorable night of my life was the night of the 2018 Perseid meteor shower. At this time, my family had just moved from Hyattsville, Maryland, a city which was on the border of bustling Washington, D.C., to rural La Crosse, Wisconsin. One of the major differences I noticed was how many more stars there were in Wisconsin. My family had just arrived in Wisconsin when the Perseid meteor shower peaked. Everyone in my family wanted to see it, so my parents, cousins, grandpas, and I gathered in our backyard at night to watch the meteor shower.

We laid in a row of blankets, gazing at the sky for hours as we watched the meteors soar above us. My cousins and I talked, laughed at each other's jokes, and told stories as we stared at the stars. We exclaimed with delight every time we saw a shooting, bright streak in the sky. Meanwhile, I overheard my grandpas, who were both amateur astronomers, talk about astronomy.

I learned that night from my grandpas that the Perseid meteor shower is caused by the Earth passing through the trail of particles left by the Comet Swift-Tuttle, which orbits the sun every 133 years. Every year, the Earth passes through the comet's trail, and the particles ram into Earth's atmosphere and disintegrate, making colorful streaks in the sky. When we look at the sky, the meteors radiate from the Perseus constellation, and that is why they are called Perseids. This meteor shower is considered one of the best of the year. At its peak, you can see up to 100 meteors per hour just before dawn. The Perseid meteor shower is also known for its fireballs, which are larger, more vivid bursts of light, and last longer than your average meteor. Fireballs occur when larger chunks from the comet hit the atmosphere and disintegrate. I learned from my grandpas that this meteor shower happens every year in late summer. I was happy to know that this was something we could do every summer together as a family.

Astronomy really united my family that night, and that was the first major astronomy night I had ever had. That was also one of my last astronomy nights with my Grandpa Wilson, for a few months later he was unexpectedly diagnosed with stage four lung cancer, and about a month after his diagnosis he passed away. I will always cherish the memory I have of him talking about his love of astronomy and watching the night sky together. Now every year, when the Perseid meteor shower comes, I will remember my Grandpa Wilson as I gaze at the sky.

Runner-Up: Benjamin Covington

Benjamin Covington, 15 (age 14 on the award deadline), submitted the runner-up essay in this year's contest. Ben is currently a sophomore at Olympus High School in Halladay, Utah, and is a member of the Salt Lake Astronomical Society.

Ben's work was entitled "The Crab Nebula: From New Star to Supernova Remnant" and provided an overview of the discovery of the supernova and its development to the remnant we see today.

Third Place (tie): Patrick Wilson and Michaela Hutkin

Two young journalists tied for third place in this year's competition. Each received a plaque and the full third-place cash prize of $250.

Patrick Wilson, 10, and younger brother of our winner, Thomas, submitted an essay on the James Webb Space Telescope. Patrick is currently in fifth grade at St. Thomas More Academy in South Bend, Indiana. He is a member of the La Crosse Area Astronomical Society.

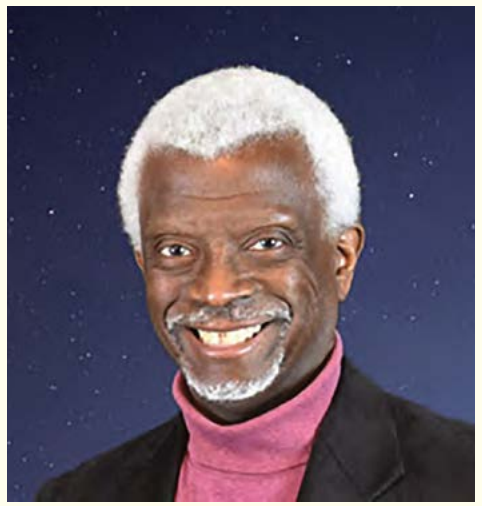
Michaela Hutkin, 13, submitted an essay entitled "Dust Storm Protection on Mars" which examines possible ways of protecting astronauts from dust storms on the Red Planet. Michaela is currently in eighth grade at the Lindfield Learning Village in Lindfield Village, New South Wales, Australia, and is a Youth member-at-large.

2022 MABEL STERNS NEWSLETTER AWARD

The club newsletter is a place where members share their images and observations, write scientific articles, sell equipment, report on club activities, announce upcoming speakers, recruit members for upcoming public events, and report on finances and committee activities. The editor's job is relentlessly demanding with deadlines to meet every month. The award was judged by three present or past League club newsletter editors.

Winner: Sandullah Epsicokhan

Sandullah Epsicokhan of the Twin City Amateur Astronomers is our 2022 Mabel Sterns Newsletter Award winner. Sandullah has served as



editor of TCAA's newsletter, *The Observer,* since March 2021, and has elevated its content and appearance to levels that are drawing compliments from beyond TCAA's membership. Sandullah is a long-time member of the TCAA, a current board member, and an editor of newsletters for several organizations. *The Observer* is produced in full color, is typically 15 to 20 pages in length, and is delivered electronically to the TCAA membership. The newsletter creates an immediate impression with its colorful appearance and its extensive scientific content and member-contributed articles and photos.

Mike Jensen of the Southwest Florida Astronomical Society won runner-up honors in this year's Mabel Sterns competition for his expert editing of his club newsletter, *The Eyepiece.*

George Keighton and **Tom Nolasco** of the Delaware Valley Amateur Astronomers won third-place honors for their co-editing of their club newsletter, *The Delaware Valley Amateur Astronomer.*

2022 WEBMASTER AWARD

An attractive and easily navigated website is the lifeblood of any astronomy club. The webmaster must create an artistically attractive interface, arrange for easy navigation of the site, keep content updated, maintain contact lists, create galleries, link to outside sources of interest, announce public outreach opportunities, and manage security issues. In many cases, the webmaster must also provide a secure method for conducting financial transactions such as joining the club, paying dues, making contributions to the club, or conducting club sales.

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

Winner: Richard Bell

Richard Bell is the longest-serving president in the history of the Kalamazoo Astronomical Society. Richard has served as webmaster for the KAS for 25 years, taking it through seven re-designs, and has edited the KAS's online newsletter, *Prime Focus,* for 21 years, producing over 240 issues.

The KAS website and *Prime Focus* create a visually stunning and colorful online presence for the KAS. Both online publications are extraordinarily easy to navigate, are kept meticulously current, feature a wide range of menu selections, and boast one of the largest galleries that the award committee has seen on any club website nationwide. His website also earned him the Great Lakes Region's Webmaster Award in 2020.

Richard has been involved in substantial fundraising for the club over the years, hosts online viewing sessions featuring a remote telescope in Arizona, and conducts a five-part introduction to amateur astronomy lecture series.

Please visit *kasonline.org* to see the extraordinary work that a dedicated webmaster and educator like Richard Bell can produce.

2022 WILLIAMINA FLEMING IMAGING AWARDS

Now in its second year, the Williamina Fleming Imaging Award competition accepted entries in four categories of astrophotography: deep sky (>500 mm, no Solar System); Solar System (>500 mm), rich field (201–500 mm), and wide field (200 mm or less). The three top three winners in each division will receive plaques sponsored by Explore Scientific. Last year's overall winner, Molly Wakeling, served as one of our judges this year.

Deep Sky Winner: Lyn Peterson

Lyn Peterson won the deep sky award for her spectacular image of Jones-Emberson 1, a planetary nebula in Lynx more commonly known as the "Headphone Nebula." Lyn is a member of the New Hampshire Astronomical Society and took her winning photo from her backyard in Gilmanton, New Hampshire, using an AstroTech 8-inch Ritchey-Chrétien reflector and an SBIG ATT 8300M camera.

Andrea Girones, of Ottawa, Canada, was runner-up in the deep sky category with an image of IC 1396, the Elephant Trunk Nebula, taken with a C-11 Edge HD with Hyperstar Reducer to 540 mm and ASI 462MM camera.

Solar System Winner: Barbara Harris

Barbara Harris won the Solar System award with an incredible black and white image of Comet Leonard passing in front of globular cluster Mess-

ier 3 in Canes Venatici. Winner of this year's Leslie Peltier Award, Barbara is a member of the Central Florida Astronomical Society and took her winning photo at the Bar J. Observatory in New Smyrna Beach, Florida. She used an Orion 80 mm f/6.25 refractor and a ZWO ASI 2600MM camera.

Andrea Girones of Ottawa, Canada, won runner-up honors in the Solar System category with a photo of Saturn taken with her C-11 Edge HD and ASI 462 MV planetary camera.

Rich Field Winner: Ann Chavtur

Ann won the rich field award with a striking image of the Rosette Nebula in Monoceros. Ann is a member of the Colorado Springs Astronomical Society and a League member-at-large. She took

the winning photo from her backyard in Monument, Colorado, using a 73 mm f/5.9 Williams Optics ZenithStar 73 III refractor and a Nikon D5300 DSLR.

Barbara Harris won runner-up honors in the rich field category with her image of the Rosette Nebula using an Orion 800 mm f/6.25 refractor and a ZWO ASI 2600MM camera.

Wide Field Winner: Andrea Girones

Andrea won the wide field award with an image called "The Boat," a photoshop-blended sequential photo of the June 10, 2021, annular eclipse of the Sun as it rose behind the mast of an anchored sailboat. Andrea is a League member-at-large and took the images from Pinhey's Point Historical Site on the banks of the Ottawa River in Ottawa, Ontario, Canada. She used a Nikon D5500 and a Nikon 18–140 mm lens operating at 50 mm.

Terry Mann and **Ann Chavtur** tied for runner-up in the wide field competition. Terry's runner-up entry is titled "Day Ends-Night Begins," a panoramic auroral photo taken at Cleary Summit, Alaska, using a Canon EOS Ra camera and Rokinon 20 mm f/1.8 lens. Ann's runner-up entry is titled "Milky Way Panorama" and was taken at Eleven Mile State Park in Colorado using a Nikon Z6 and Nikkor Z 14–24 mm lens at 14 mm and f/2.8.

2022 SKETCHING AWARD

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

Winner: Cindy Krach

Cindy is from Kula, Maui, Hawaii, and is a member of the Haleakala Amateur Astronomers. She observes using a 12.5-inch Portaball telescope and a 4-inch SV102ED refractor. Her

winning sketch was created at the eyepiece using black paper with white and black charcoal. Her winning sketch is an amazing lunarscape of three craters, Ptolemaeus, Alphonsus, and Arzachel. Her work rivals the sketches of the great Alika Herring from the 1950s and 60s.

Brian Chopp's composite sketches of three globular clusters in Ophiuchus won runner-up honors in this year's sketching competition. **Richard Francini's** sketch of Pickering's Triangular Wisp in the Veil Nebula complex won third-place honors.

SOME AWARD WINNING IMAGES

CLOCKWISE FROM TOP LEFT: ROSETTE NEBULA BY ANN CHAVTUR; MELOTTE 15 BY WILLIAM GOTTEMOLLER; COMET LEONARD PASSING M3 BY BARBARA HARRIS; JONES-EMBERSON 1 (THE HEADPHONE NEBULA) BY LYN PETERSON; SKETCH OF LUNAR CRATERS PTOLEMAEUS, ALPHONSUS, AND ARZACHEL BY CINDY KRACH; "THE BOAT" BY ANDREA GIRONES. SOME IMAGES ARE SHOWN CROPPED. ALL IMAGES © 2019-2021 BY THEIR RESPECTIVE AUTHORS.

HOW TO ACCESS DATA ON ALL 1.8 BILLION STARS IN THE GAIA CATALOG

Mark Sproul and Keith Sproul

INTRODUCTION

The European Space Agency developed the Gaia space observatory[1] to create the largest, most precise three-dimensional map of the Milky Way by surveying about 1 percent of the galaxy's 100 billion stars. It was launched in December 2013 and became operational in July 2014. Gaia collected data on almost 2 billion stars: position, brightness, proper motion, and more. The first release of data, information on about 1 billion stars, was in September 2016. The second release of data, 1.6 billion stars, was in April 2018. The current release (EDR3) came in December 2020, and contains information on 1.8 billion stars.

Many of us use planetarium programs to learn the night sky or control a telescope for imaging or observing. Many such programs are available, some commercial, some free and open-source, on all platforms – Windows, Mac, Linux, and cell phones.

All planetarium programs support common star catalogs, such as Yale Bright Star (9,000 stars), Hipparcos (118,000), and Henry Draper (272,000). Today's computers can easily store this much data in random-access memory. It is desirable to keep all of the data in memory for speed. However, the Gaia star catalog is over 6,000 times the size of the Draper catalog. Fitting all that into memory would be tough. Therefore, although we would like to have the entire Gaia catalog at our fingertips, storing it in memory won't work.

Our software should provide quick access to all of the stars. However, we do not need or want all of the stars in memory at the same time, so only storing in memory the area we are currently looking at is acceptable, and desirable for speed. We also require the ability to search for a particular star by name, and to provide this with as little user interaction as possible. In other words, it should all happen "auto-magically." The solution is to put the data into a database that can be accessed from the planetarium software. However, it is still a daunting project if you don't know where to begin. Note that all of the software described below is open source and available on GitHub.

According to John Hoot in his article in the *2020 Symposium* of the Society for Astronomical Sciences, "Gaia Data Enables New Methods of Analysis and Discovery,"[2]

> It is possible with enough disk space and bandwidth to own your own copy of (Gaia) DR2. The separate tables can be downloaded directly from the ESA at *gea.esac.esa.int/archive*, or from other mirror sites. But once you get the data, you need to be somewhat of a database expert to load all the tables into a relational database, generate the right queries and cross link all these tables on the appropriate fields in order to tease insights out of this mountain of data.

Thankfully, we don't want or need all of that huge amount of data. We just want to be able to display these stars in a planetarium program. Most modern databases on the internet run using some variant of Structured Query Language (SQL). There are many SQL database programs, some commercial, and many free and open source, on all popular platforms. In order to limit the amount of data in each query, we want to be able to ask the database for all of the stars in any 1 by 1 degree block.

IMPLEMENTATION

The computer we are using is an older 2014 Dell desktop we had sitting around. We installed more memory, and the most important thing we did was install a 2-terabyte solid-state drive (SSD) instead of the older-style spinning-platter hard drive. SSDs are as much as 100 to 500 times faster than spinning-platter drives. If you really want to bump up the speed, get a commercial-grade NVMe SSD.

We are running Ubuntu Linux version 20 with either MariaDB or MySQL for the database engine. These are almost identical, and both have run this successfully. The code supplied in this project has successfully run on both MariaDB and MySQL. We recommend MariaDB. The entire Linux operating system can be installed from scratch in less than an hour.[3] Installing the SQL database server might take another hour.[4]

Then there is the database itself. We are currently using Gaia database EDR3 (Early Data Release 3).[5] This database consists of 3,386 compressed files totaling 660 gigabytes. Downloading these files alone can take hours even on a high-speed network connection. Each compressed file is over 180 megabytes. When uncompressed, they are over 400 megabytes each. Once these are all uncompressed, it is a whopping 1.5 terabytes of data.

Each of these 3,386 files has over 500,000 records and each record has 99 fields of data. We are only interested in a few of these fields.

Designation	Text string with source and index number
source_id	Star Index Number (integer)
ra	Right Ascension
dec	Declination
phot_g_mean_mag	Magnitude
bp_rp	Blue/red color information

All but the first two of these fields are floating-point numbers. Searching and indexing floating-point numbers is very slow; it is much faster to search on integers. Therefore, we added a couple fields to make indexing much faster. We take the integer portion of right ascension and declination and use those integer fields for indexing and searching. We use the FLOOR() function rather than the INT() function, because using INT(), both −0.5 and +0.5, for example, end up as zero. It is important to note that the integer declination goes from −90 to +89. The final database structure looks like this:

Field	Type
designation	char(32)
source_id	bigint
ra	double
decl	double
phot_g_mean_mag	double
bp_rp	double
ra_int	int
dec_int	int

The newly generated SQL files are now only 80 gigabytes compressed, smaller than the original Gaia files, which were 660 gigabytes compressed. These compressed SQL files are available on our GitHub site.[6]

DATABASE FEATURES

SQL is a fairly simple language for what we are doing. But like any programming language, it can be hard to understand until you learn it. This entire system is set up so that a non-programmer can do it. We have simplified the searches for a couple of reasons. The first is simplicity, which also buys us speed. But the other reason is that doing it this way allows tighter security.

The SQL queries that we have written could be used by anyone wanting to incorporate the Gaia data into their software, not just the software we are writing (described below).

The routines are:

- GetRaDec(raInt, decInt); Returns all star data in the specified 1 by 1 degree grid.
- GetDeclination(decInt); Returns all star data in that declination. Only for use near the poles, that is, poleward of 84 degrees declination.
- GetStarFromID(source_id); Returns the star data with the given source ID (integer).
- GetVersion; Returns the current Gaia version number (currently "Gaia EDR3").

These routines can be called from any language with an SQL library. We use C/C++, but it would be easy to do from Python or another programming language with remote SQL capabilities. Additional routines can be written easily as needs change.

SECURITY

As with any computer endeavor, security is a concern, and we have done a fair amount in that regard. SQL servers allow you to limit what accounts can and cannot do. We set up the account for this to be read-only, and only able to execute predefined scripts in the SQL system. It can't issue SQL commands directly. It can't even look at the raw data. It can only do what it is supposed to be doing. This prevents SQL insertion hacks.

If you are only using it in-house, behind a firewall, you don't have to worry about much, but if you open your SQL server to the outside, you need to pay a lot more attention to security. We have the server on the standard SQL port, and it does get attacked, especially from IP addresses from overseas. These can be restricted using IPTABLES security settings on the Linux server. On Windows or Mac, use the built-in firewall settings. You also need to lock down the admin accounts on the SQL server. However, these security measures are the default when you install the MariaDB or MySQL software.

More detailed information on the security implementation is on the GitHub site below.

PLANETARIUM SIDE

Mark has been writing a planetarium program called SkyTravel in conjunction with my AlpacaPi observatory control project.[7] This planetarium program was modified to be able to request the data from the SQL server. The logic is as follows:

If Gaia is enabled, and if the screen field of view is 5 degrees or less, send a request for the current 1 x 1 degree square.

This is where the integer values for right ascension and declination speed up the database search dramatically. This occurs in the background so that you can continue to use the planetarium. When the server returns the data, it is then displayed *(Figure 1)*. Figures 1 and 2 have the "all stars" option set. Normal operation would display fewer stars.

Options exist in the software to read adjacent blocks as well, either 3 x 1 or 3 x 3 one-degree blocks.

Exceptions: If the declination is above 84 degrees or below −84 degrees, then the entire right ascension ring is requested for that value. This is because the 1 x 1 degree blocks get very small, some containing only 40 stars. In memory, each of these is treated as one block of data (see Figure 2).

When you are zoomed in enough, the star designations, magnitude, and spectral class

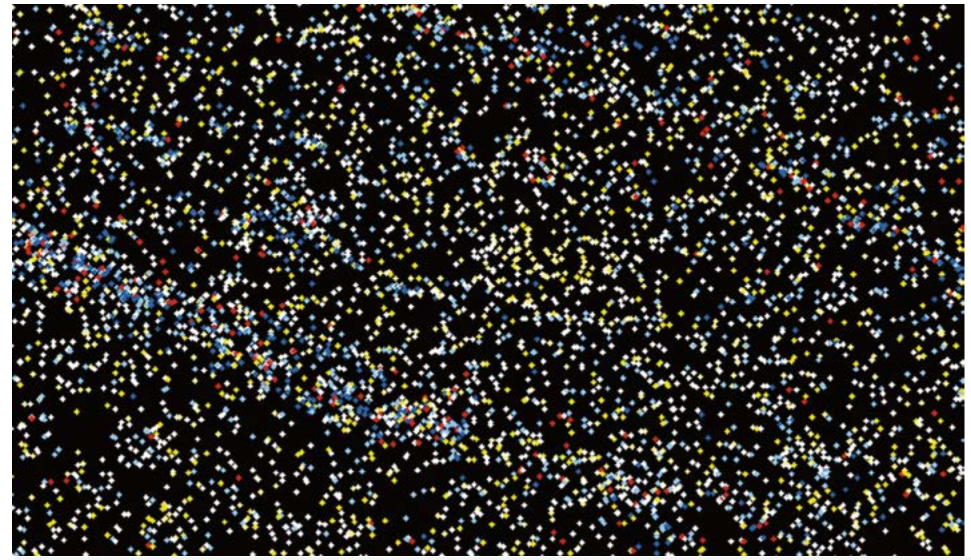


Figure 1: All Gaia-surveyed stars displayed in a portion of M31, the Andromeda Galaxy

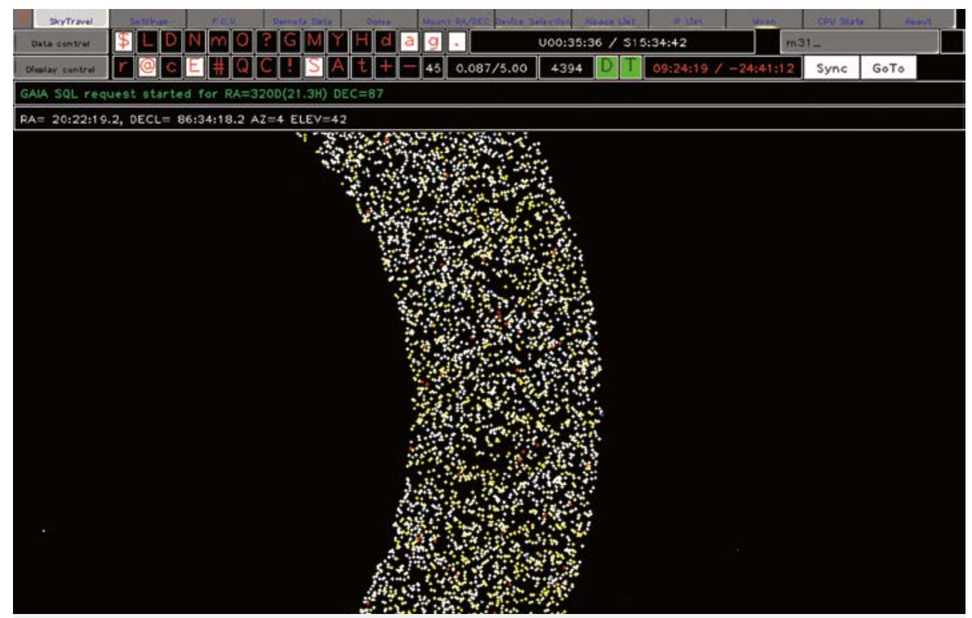


Figure 2: Northern sky showing declination of 87 degrees

Figure 3: Andromeda zoomed in to show Gaia star labels

are displayed. These can be turned on or off in the settings.

Up to 30 blocks are stored in memory. When the array is full and another block needs to be loaded, the block that is farthest from the current center of the screen is discarded. The value of 30 has no particular significance; it could easily be changed.

CURRENT STATUS

We have the Gaia EDR3 database with 1.8 billon stars and we have the Two Micron All Sky Survey (2MASS) database with 470 million stars.[8] The SkyTravel program can select which one it uses and it retrieves stars from that database. It is also easy to add more star databases by updating the configuration files. We have been testing this with both of us using it at the same time and exploring areas of the sky with high star counts. We also have one user connecting from Oregon all the way to New Jersey.

In the Gaia database, the average number of stars per one degree grid is 28,000; the minimum is less than 50 at the poles and the maximum is 1.1 million. The average time to retrieve all the stars in a single grid is about 3 seconds.

Our current configuration is with the server in central New Jersey with a gigabit connection to the Internet, and Mark is in northeastern Pennsylvania, 100 miles away, with a 50 megabits per second connection. We both run the planetarium program at the same time and have even tried loading the same large data sets at the same time. It worked perfectly! The difference in response time from Mark using it remotely versus Keith using in the same house is minimal.

Full documentation on how to implement this SQL server is also on our GitHub site; see footnotes. Mark's SkyTravel program is also on the GitHub site. If anyone would like to either connect to the SQL server or set up their own SQL Gaia star database server, please contact Keith Sproul at *ksproul@skychariot.com*. For help with the SkyTravel program or the AlpacaPi project, contact Mark Sproul at *msproul@skychariot.com*. ✶

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2. *Proceedings for the 39th Annual Symposium of the Society for Astronomical Sciences*, "Gaia Data Enables New Methods of Analysis and Discovery," John Hoot, *socastrosci.org/wp-content/uploads/2021/12/2020_Proceedings_final.pdf.*

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4. Installing MariaDB Server: *mariadb.org*. *Installing MySQL Server: mysql.com.*

5. Gaia EDR3: *cosmos.esa.int/web/gaia/earlydr3, gea.esac.esa.int/archive*

6. Gaia SQL project on GitHub: *github.com/msproul/GaiaSQL*

7. AlpacaPi project on GitHub: *github.com/msproul/AlpacaPi*

8. 2MASS (Two Micron All Sky Survey): *irsa.ipac.caltech.edu/Missions/2mass.html*

100 YEARS AGO IN ASTRONOMY

While Arthur Stanley Eddington's observations of the May 29, 1919, total solar eclipse are credited by most sources with providing the first incontrovertible evidence for Einstein's general theory of relativity, the scientific history is more complicated. Questions concerning the accuracy of Eddington's results led astronomers to continue to test the predicted deflection of starlight at later eclipses. William Wallace Campbell, director of Lick Observatory, brought 35 tons of equipment, including a 40-foot camera, on his massive expedition to Western Australia to photograph apparent star positions during the September 21, 1922, eclipse. Careful measurements of the shifted positions of over 100 stars provided more rigorous evidence that the bending of starlight matched that predicted by Einstein. Campbell's work demonstrates how, in science, it's not always about being first. For more information about his eclipse expedition, see:

atlasobscura.com/articles/the-1922-eclipse-expedition-to-remote-western-australia

—Kristine Larsen

A PORTABLE, LOW-COST HYDROGEN 21 cm (1.42 GHz) RADIO TELESCOPE PROJECT FOR BOTH DAY AND NIGHT ASTRONOMY

B. Alex Pettit Jr.

INTRODUCTION

For me, it began as a simple quest to see if ultra-high frequency (UHF) ham radio antennas could receive solar noise. After a few months of Internet searches, I found information on small radio telescopes. The construction, data collection, and analysis described here is within the ability of a motivated middle or high school student, with help, and the equipment described here can certainly be the basis for investigations from casual to advanced.

This project has exceeded my expectations. The system can actually receive and record the hydrogen 21 cm emission spectra of the Milky Way. One can measure the relative RF (radio-frequency) intensities of the clouds and the Doppler effect frequency shifts from different regions. The data can be used to calculate and plot hydrogen cloud velocities relative to Earth.

The cost is under $300, and the entire electronics package can be purchased from one source. The software is free, and the mounting can be as simple as a vertical pole in the ground. Data is acquired by positioning the antenna at a chosen sky location and then capturing hours of data as the sky drifts by.

IMPORTANCE OF HYDROGEN 21 cm ASTRONOMY

Hydrogen is the most abundant element in our universe, and there are huge clouds of neutral hydrogen left over from star formation. Mapping this neutral hydrogen using the RF radiation it emits can provide an accurate view of the shape of our Galaxy. The radiation comes from hydrogen's transition between two levels of its ground state, called the spin-flip transition. The state with parallel proton and electron spins is slightly higher in energy, so when the electron's spin flips, it releases that energy as photon at a very specific frequency: 1420.405751 MHz. It is a low energy, but there's lots of hydrogen.

The main frequency bands used in radio astronomy, including the 21 cm line of neutral hydrogen, have been protected by international agreement. "Protected" means that these frequencies are provided special treatment by governing organizations to keep them clear of harmful interference from human activity; no transmission is allowed in this particular band.

The Scope in a Box complete system is available for $295 from radio-astronomy.org/node/366

WHAT CAN BE DONE WITH A SMALL RADIO TELESCOPE

In this article I describe how to create a map and animations of the relative densities and velocities of neutral hydrogen clouds in the Milky Way, an interesting, ongoing project.

The parabolic reflector mounted on a telescope mount.

The parabolic antenna and electronics can detect the 21 cm RF emission of hydrogen within the Milky Way and measure and quantify its relative amplitude and velocity. I began constructing this system in August 2021. I used an existing Celestron CG-4 mount to make positioning easy. It is portable and I've had it set up several times for small outings.

The Scope in a Box project is offered by SARA, the Society of Amateur Radio Astronomers, and contains everything required to get started. It is a great way to begin; you know it will work out of the box, and then you can get creative.

SYSTEM DESCRIPTION

❶ A parabolic reflector acts like an optical mirror, capturing and focusing electromagnetic energy. Instead of visible light energy being focused to an eyepiece or digital camera, the radio frequency energy is focused on a small antenna.

❷ The RF energy is transferred to a Nooelec SAWbird H1 module which consists of a pre-amplifier, a filter to remove unwanted frequencies, and a final gain amplifier.

❸ The RF output is passed to a software-defined radio (SDR) Module. An SDR is a radio receiver whose functions are primarily implemented and controlled by a software program. The analog RF data are processed and converted to a digital format via an analog-to-digital converter (ADC) within the SDR module. Its output to the PC is a stream of digital amplitude and phase information that represents the original RF signal.

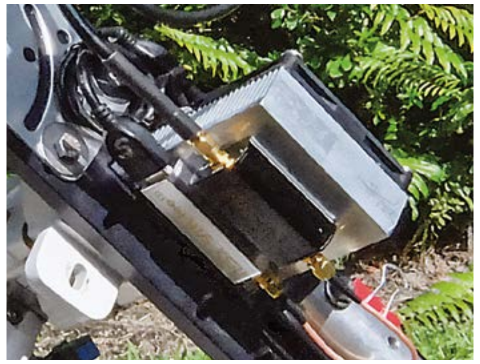
❹ Via a USB cable, the SDR is controlled by SDR# (SDR Sharp) software running on the PC.

❺ An Airspy SDR# control program sets parameters within the SDR such as sample rate, center frequency, resolution, and bandwidth. These functions allow a specific frequency to be "tuned in" like a radio station. In the PC, the digital data is converted to a frequency spectrum and displayed. And, like a normal radio, the sound of the hydrogen RF signal is also output as an audio signal. It sounds like a hiss.

❻ Since the hydrogen signal amplitude is so small, thousands of averages must be combined to create a smooth plot. An IF Average plug-in program performs this function.

❼ The software creates and stores ASCII text files for further analysis. Typical files are from 30 seconds to 5 minutes of data averaging.

An equatorial telescope mount is convenient for pointing the antenna to a specific area. The mount is not tracking. A quick compass alignment allows use of the right ascension and declination setting circles. Since the antenna's beam-width is about 10 degrees, alignment is not overly critical. Another option is to use a vertical pole and adjust the antenna using the supplied clamp.



The optional ($11) but recommended heat sink shown above provides cooling for the SAWbird and SDR and a place to securely mount the components. Keep the connection between the antenna and SAWbird short because cable losses are high at these frequencies.

EXAMPLES OF RESULTS

Chart 1 shows data from a single sample of emissions from the Milky Way. The processing software saves a two-column table of frequency and amplitude. These data can be plotted as shown using a spreadsheet program.

Chart 2 shows data from twenty-five 5-minute intervals. There is a distinct change in the spectral frequency content as the sky drifts by. That equates to a right ascension shift of only 1.25 degrees per plot – good resolution for such a small parabolic reflector.

Chart 3 Shows Doppler redshift velocity calculations. In chart 2, you can see a left bias in the data: a significant portion of the data is at frequencies less than 1420.405751 MHz. This lower-frequency content is due to the Doppler shift caused by this area of our galaxy moving away from Earth: a redshift. The frequency shift can be converted to an actual velocity with the following redshift equation

$$V = \frac{(HI - F_{measured})}{F_{measured}} * c$$

where **HI** = 1420.405751 MHz (non-moving spin-flip frequency); **c** = speed of light, 299,792 km/sec; $F_{measured}$ = Measured frequency, from spreadsheet.

Neutral hydrogen (H I) RF emission is redshifted – shifted to a lower frequency – when that area of the galaxy is moving away from Earth: the speed of light is constant, but the frequency decreases as the RF signal gets "stretched" by the velocity as the hydrogen moves away from us. Conversely, when hydrogen clouds move towards the Earth, the frequency increases as the light is blueshifted: the RF signal gets "compressed" and thus the frequency increases.

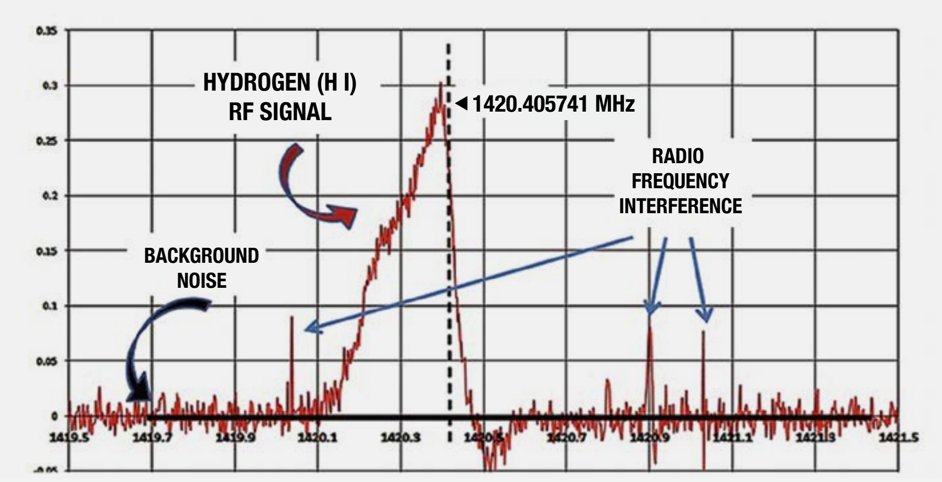


Chart 1: Plot of single-sample data saved by processing software

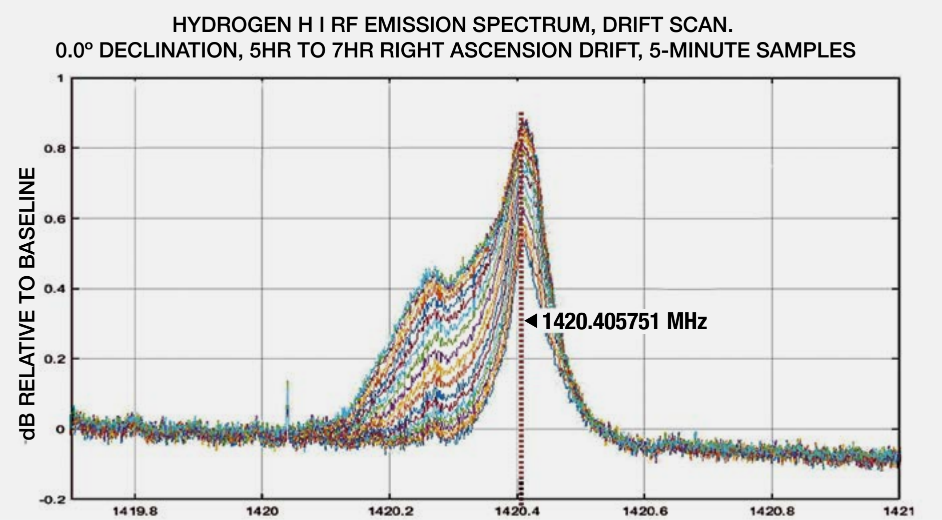


Chart 2: Plot of multiple samples at 5-minute intervals

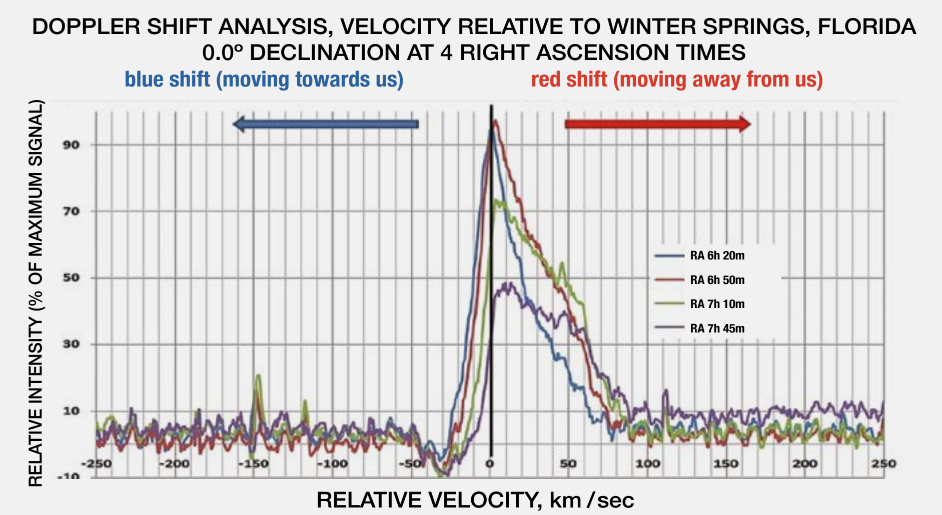


Chart 3: Plot of relative velocity calculated with Microsoft Excel from Doppler shift, using the equation at left. The horizontal axis now shows relative velocity.

FINAL NOTES

Radio-Frequency Interference (RFI): The receiving system is sensitive. If you have noise in the spectrum (generally sharp frequency spikes), try changing the position of the cables and the PC. Many items in a home can generate RFI: chargers, televisions, light dimmers. Try turning items on or off to help identify the source. Perhaps relocating the antenna will be the solution. Perfection is not required; the peaks can be photoshopped out of your plots.

Remote Operation: A normal USB cable is limited to about 15 feet. A convenient way to set up the antenna and electronics outside with the PC inside is to use a USB over Cat5 cable extender such as this one: *tinyurl.com/hubextender.* It uses a power supply at the PC end and will power both its USB hub unit and all USB radio telescope modules through a Cat5 cable. Cable and extender can be purchased for about $100. I have verified that the system works with a 75-foot cable. Do remember that none of the connectors or electronic modules are waterproof.

Noise Temperature: All objects with temperatures above absolute zero (–273°C, –460°F) radiate electromagnetic (EM) energy. This system will detect the RF portion of that energy coming from the ground, trees, buildings, and clouds, in addition to the intended 21 cm radiation of hydrogen. Try to keep the antenna away from buildings and trees, and preferably pointed upwards to minimize the EM energy from the ground. When clouds drift into the field of view, they will shift the background and signal levels upwards but have the overall effect of slightly reducing the signal-to-noise ratio.

IT'S EASY... TRY IT!

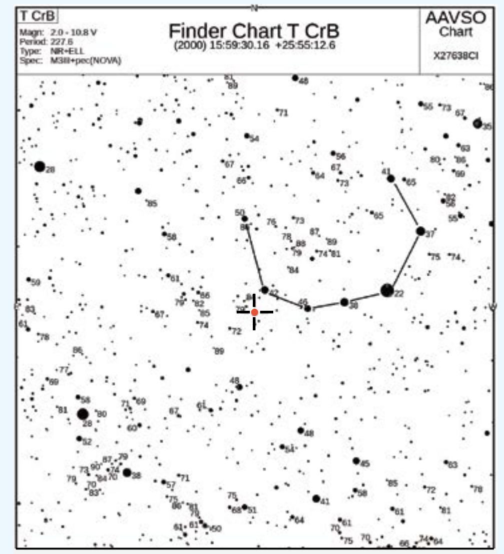
Don't get overwhelmed with the seeming complexity of this project. It's easy to set up the system to capture and display signals from vast, moving, swirling hydrogen clouds within the Milky Way. If it impresses you as much as it did me, then it will create a motivation to learn more, and then you can delve into the technical details. The Scope in a Box and optional accessories can be purchased from *radio-astronomy.org/node/366* and detailed setup advice can be found at *tinyurl.com/radio-astro-setup.* ✶

Further Reading can be found at these sites:
radio-astronomy.org • *ccera.ca* • *setileague.org/index.html* • *wvurail.org/dspira-lessons/tour.*

KEEP AN EYE ON THIS ONE

by Jamey Jenkins

For several years now I've practiced techniques of differential photometry, the goal being an avocation to embrace in my retirement years. Photometry is the scientific measurement of visible light (brightness variations). Having reached the retirement plateau, the first task has been to develop a list of stars I wish to follow on a regular basis. My current list consists of a collection of long-period variable (LPV) stars, three young stellar objects (YSOs), three recent novae, and the star T Coronae Borealis (T CrB). I upload my observations to the database of the American Association of Variable Star Observers (AAVSO).

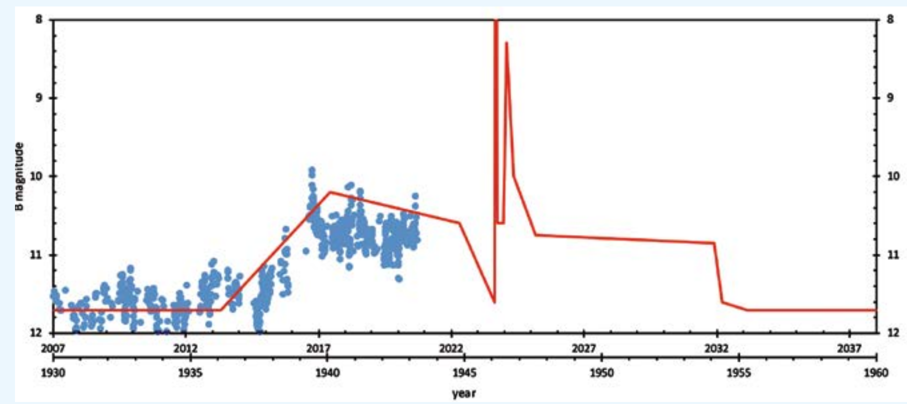


T Coronae Borealis is the star found in the center of this 20° wide AAVSO field chart, marked with a red dot. Credit: AAVSO, modified by Reflector staff.

T Coronae Borealis, also known as the Blaze Star, is the nearest symbiotic recurrent nova. Symbiotic novae are slow irregular eruptive variable stars with nova-like outbursts. They are a binary star system in which a white dwarf accumulates matter from its red giant companion through the system's accretion disk. The accreted material is ignited thermonuclearly on the surface of the white dwarf and produces a nova eruption. Outbursts of T CrB were recorded in 1866 and 1946, hinting at a recurrent event time of approximately 80 years. Ordinarily this star shines near 10th magnitude, however, the 1866 outburst quickly reached magnitude 2.0 and in February 1946 it attained magnitude 3.0 overnight. Professional astronomers predict the next eruption to occur between 2023 and approximately 2026.

The "blue light" magnitude graph (below) by Bradley Schaefer, Louisiana State University, shows the 1946 eruption (red line) versus the recent 2020 AAVSO data as blue dots. Noteworthy is the similarity of the pre-outburst activity which began again around 2014–2015. Something is happening with T CrB, something that warrants keeping a watchful eye on this star. I suggest interested stargazers check out the field of T CrB each night they venture out, looking for a noticeable surge in brightness. The amateur astronomer Leslie Peltier recounted his misstep with this star in his classic book, *Starlight Nights,* after having faithfully watched it for many years. Peltier it seems opted to "call it a evening" on February 9, 1946, instead of checking out T CrB the night that it unexpectedly rose from its sleep, a once in a lifetime error that he regretted. Maybe we'll have to wait until 2026 for the next eruption but maybe not, as astronomy is always full of surprises. Here is one star worthy of your watchful eye, one guaranteed to put on a spectacular show! ✶

T Coronae Borealis, mag: about 9.8, R.A. 15h 59m 30s, Dec. +25° 55′ 12″



THE NEW ANDROMEDA

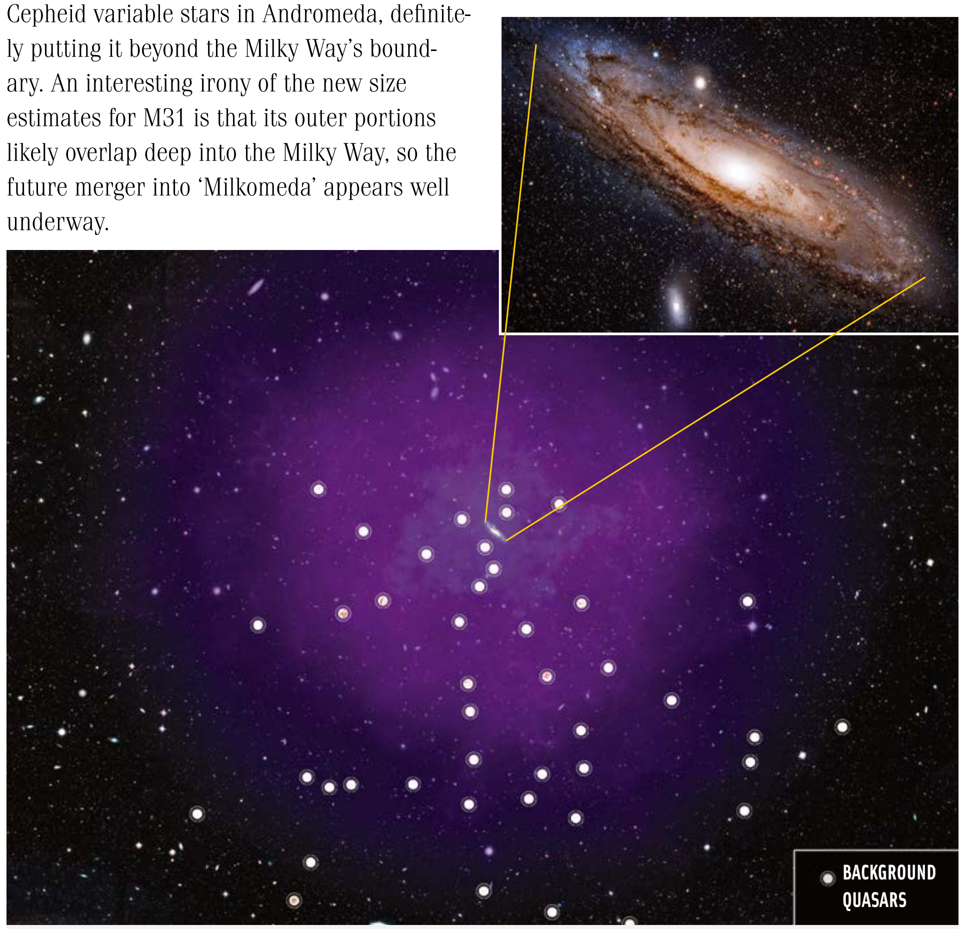
GALAXIES ARE MUCH BIGGER THAN YOU THOUGHT

By Dave Tosteson

Welcome to the universe of extremely large galaxies. These are not your great grandfather's spiral nebulae, and their true size dwarfs even the recently found 'super spirals.' They are even bigger than the dark matter halos surrounding galaxies that were identified at the turn of the millennium, which were ten times the size of their visible outlines. The first evidence for these structures dates to a 2003 study by Michiel Reuland and his colleagues, where the absorption of UV light from distant quasars showed that some galaxies possess an enormous massive halo of material. This came be known as the 'circumgalactic medium,' or CGM, and a recent study of its outer region revealed the true size of our Local Group luminary, Messier 31.

From a dark site with eyes adapted to seeing faint light, the farthest thing most people can see is the great spiral galaxy in Andromeda. It lies 2.5 million light-years from us, elongated 3:1 in a northeast to southwest direction. Its very bright, one-degree core is what most people see with a casual view. In very good conditions, experienced observers can follow it to two or three degrees in length, and with optical aid its faint outer disk can be traced to five degrees. The Persian astronomer Abd al-Rhaman al-Sufi (903–986 CE) was the first to publish an observation of M31, in his *Book of Fixed Stars* in 964, calling it a "nebulous smear." This landmark work attempted a synthesis of Ptolemy's star catalog *Almagest* with the Arabic constellations.

One of the first telescopic observations of M31 was by the German astronomer Simon Marius, in 1612. William Herschel thought its core had a reddish hue in 1785, and the 3rd Earl of Rosse, William Parsons, made the first drawing of its spiral structure in 1850. Isaac Roberts took an early photograph of the Andromeda Galaxy in 1888. The possibility of its being extragalactic can be dated to the French mathematician Pierre Louis Moreau de Maupertuis (in 1745), and to Immanuel Kant (in 1755) who speculated that certain 'nebulae' were actually "island universes" similar to our Milky Way. Spectroscopy in the late nineteenth and early twentieth centuries suggested M31 had a strong stellar component, though it was unresolved. The 'nova' of 1885 implied that it was a nearby object, within the confines of the Milky Way, as supernovae were not yet understood. The debate about its nature and distance were settled in 1925 when Edwin Hubble discovered the first Cepheid variable stars in Andromeda, definitely putting it beyond the Milky Way's boundary. An interesting irony of the new size estimates for M31 is that its outer portions likely overlap deep into the Milky Way, so the future merger into 'Milkomeda' appears well underway.



The lower image is a Hubble Space Telescope map of the halo around the Andromeda Galaxy. Credits: NASA, ESA, and E. Wheatley (STScI); modified for clarity in print by Reflector staff. Andromeda Galaxy image at top is by David Dayag, via Wikimedia, Creative Commons Attribution Share Alike license.

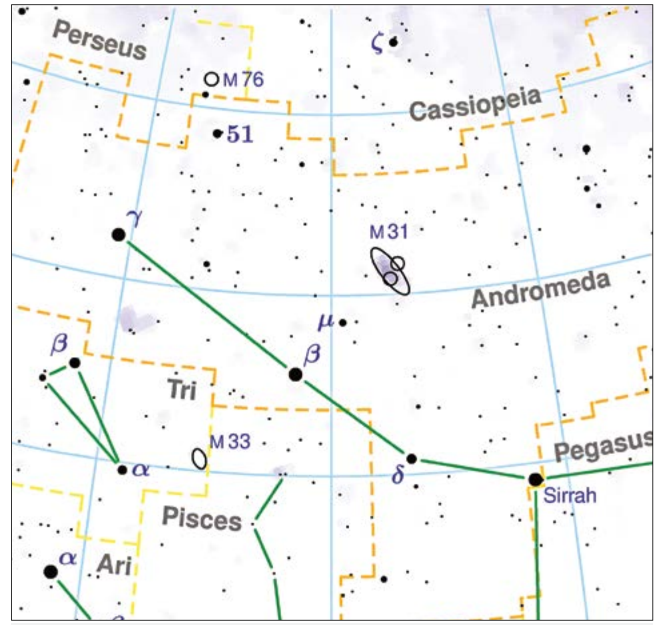
The visual boundaries of galaxies are defined by their stars, nebulae, H II regions, associations, and open clusters taken en masse. They don't usually include the outer halo of globular clusters but, as we will see, they likely should. The bright portion of Andromeda's stellar disk is 120,000 light-years across, a bit larger than the Milky Way. Data from the Keck telescopes show an extended, faint stellar component 220,000 light-years wide. Were we to follow this out with our eyepieces or imaging, it would extend to a diameter of five degrees on the sky.

I have observed globular clusters in M31 for about three decades. My first observation with my newly acquired 32-inch reflector in September 2005 was of them. Without a finder, I was restricted to things I could see by sighting along the edge of the scope. I had a chart of M31's globulars and was delighted to see 30 of them in little over an hour. New studies of these clusters have expanded Andromeda's retinue every few years. It has over 420 confirmed globulars, with hundreds more under consideration. These star cities have been spotted out to a radius of half a million light-years, vastly increasing our appreciation of the galaxy's true size. In a 2012 study of the dark matter halo of M31 by Tamm, the diameter was 1.3 million light-years, or just larger than its known globular distribution. Studies at the edge of galaxies' dark matter halos will likely find globulars lurking there, shepherded into their orbits by the gravity of their tenebrae.

The first hints that galaxies were embedded in extremely large halos came in 2003. Research in the first decade and a half of the new millennium showed a number of galaxies with absorption of background quasar light by ionized metals such as oxygen in their CGMs. Almost all of these had just one quasar that could be studied in this way, as their apparent size on the sky was small. What was needed was a larger target. The Milky Way contains numerous complications in this regard, as we reside within it, so our sister galaxy Andromeda seemed the best choice.

In 2015, Nicolas Lehner of Notre Dame used the Cosmic Origins Spectrograph (COS) aboard the Hubble Space Telescope to study eighteen quasars around M31. His team's paper, "Evidence for a Massive, Extended Halo around the Andromeda Galaxy," suggested that its CGM had a diameter of two million light-years, fifty percent larger than the dark matter halo with its attendant globulars. They called their work Project AMIGA, for Absorption Map of Ionized Gas in Andromeda. This work was expanded in their August 27, 2020, *Astrophysical Journal* paper, which used 43 quasars to trace the CGM. The farthest quasar from the center of our sister galaxy in their work was Markarian 1014, a full 44 degrees away in Cetus. That is the same angular distance between M31 and the Pleiades. Its light was passing through Andromeda's outer halo almost two million light-years from its center! This meant that M31's true size was a sphere two-thirds of a million light-years across, with extensions up to three times farther. The Hubble site released an artistic image on August 27, 2021, of what M31's extended halo may look like were it visible.

There is a massive compact galaxy in northwestern Aquarius I observed that lies five billion light-years away. It was studied in 2019 by David Rupke of Rhodes College and Alison Coil of UC San Diego using the Keck Telescope's Cosmic Web Imager, a spectrograph similar to Hubble's COS. This type of dense, small galaxy carries the mass of the Milky Way in a size only 5 to 10 percent as large, and is thought to be the precursor to cores of giant elliptical galaxies. Their galaxy, called Makani, from the Hawaiian word for wind, was stellar on images such as the Palomar plates. This represented its core of about 3,000 to 5,000 light-years, but its CGM was almost a hundred times larger, about 12 arcseconds across. Were M31 placed at that same tremendous distance, its CGM would appear a little over one and a third arcminutes across, an angle discernible to the human eye.



Locator map by Torsten Bronger, via Wikimedia Commons, Creative Commons Share Alike license.

The CGMs of galaxies are divided into two main parts, the inner and outer regions. As might be expected, the inner portions are more complex and dynamic in terms of density and atomic variations, and in cycling and movement of substructures with chemically inhomogeneous parts. Powerful winds from supernovae, massive stars, and nuclear activity provide energy that stirs this pot, and the ionized carbon, oxygen, and silicon of M31 that is half as massive as its stars. For Andromeda this proximate area ranges from 80,000 to 500,000 light-years from its core. The outer regions are more diffuse and less active, and merge at their edges with intergalactic space. The significant metallicity differences between the regions suggest incomplete mixing, and this pattern is seen in all types of galaxies: actively star-forming, quiescent, and massive. Computer models suggest the halo formed at the same time as the rest of their galaxy. Simulations are also attempting to account for factors within the CGMs, including time-variable winds and accretion flows, as astronomers try to understand how material is cycled in and out of the galaxy to keep star formation active. M31 seems to be slowing down in its production of new stars. Certain galaxies, mainly ellipticals, have stopped forming stars completely, and are 'quenched.'

As known for several decades, M31 and the Milky Way are on a collision course, with their cores expected to interact and merge in about four billion years. With the new information on its size, and assuming our galaxy has a similar halo, then this merger, in terms of its outer structures, has already started. The near edge of M31 may be only half a million light-years away, far inside our halo's boundary, and mingling with our most distant sentinels, the globular clusters. Hubble and Keck imaging will likely be around throughout the 2020s, and in the future the next-generation ultraviolet space telescope LUVOIR is expected to advance this area of research.

In the fall, when Andromeda sits high near the zenith, consider its true size. Instead of just covering your outstretched thumbnail, realize that its halo caps the sky at thirty degrees across, with portions of its outer edge stretching halfway to the horizon! Though we cannot spot this halo directly, amateurs can observe the quasars in Lehner's group that are defining this new era of study. The object nearest in apparent angular distance to M31's core is RX J0048.3+3941, a 16.0-magnitude Seyfert galaxy 1.8 degrees southeast. At the greatest angular distance, all the way out in Cetus, is Markarian 1014, a 15.7 magnitude quasar 44 degrees radially from Andromeda. Both should be visible in 12- to 15-inch telescopes. ✶

Data:
Messier 31: 00h 42m 44.4s, +41d 16m 08s.
RX J0048.3+3941: 00h 48m 19.0s, 39d 41m 11.7s.
Markarian 1014: 01h 59m 49.7s, +00d 23m 41s.

References:

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Reuland, et al.: *ApJ* 592, 755, August 2003.
Tamm, et al.: *A&A* 546, A4, 2012.

GALLERY

All images © 2022 by their respective authors.

*TOP: **Bernard Miller** (East Valley Astronomy Club) captured this image of M100 with a PlaneWave 17-inch CDK with an FLI 16803 CCD camera from his observatory in Animas, New Mexico.*

*BELOW: **Steven Bellavia** (Amateur Observers' Society of New York) captured this image of the Lynds Bright Nebula (LBN) 558 from Cherry Springs State Park, Pennsylvania, using a William Optics Star 71-II f/4.9 refractor and a ZWO ASI294MM Pro camera.*

*LEFT: **Dan Crowson** (Astronomical Society of Eastern Missouri) created this image of NGC 3201 using Telescope.Live's remote PlaneWave CDK24 at f/6.5 3974 mm and FLI PL9000 camera in Chile. Globular clusters are featured in the current Astronomical League Observing Challenge.*

*BELOW: **Mark A. Brown** (River Bend Astronomy Club and Grand Strand Astronomers) captured these images of the Flower Moon Eclipse from Pleasant Creek Recreation Area near Palo, Iowa, using a Celestron CPC 1100 at f/6.3 and a Canon 6D DSLR.*

Observing Awards

Active Galactic Nuclei Observing Program
No. 27-I, **David Whalen,** Atlanta Astronomy Club

Advanced Binocular Double Star Observing Program
No. 46, **Viola Sanchez,** Albuquerque Astronomical Society

Alternate Constellations Observing Program
No. 12-G, **Vincent Michael Bournique,** Gold, Lifetime Member

Arp Peculiar Galaxies Northern Observing Program
No. 111-I, **Terry N. Trees,** Amateur Astronomers Association of Pittsburgh; No. 112-I, **Mark Mitchell,** Delaware Astronomical Society; No. 113-V, **David Wickholm,** San Antonio Astronomical Association

Asterism Observing Program
No. 72, **Pete Hermes,** Tucson Amateur Astronomy Association

Asteroid Observing Program
No. 70, **Lauren Rogers,** Gold, Escambia Amateur Astronomers Association; No. 71, **James M. Roe,** Gold, Astronomical Society of Eastern Missouri

Beyond Polaris Observing Program
No. 56, **Sam Pitts,** Temecula Valley Astronomers; No. 57, **Chris Kaiser,** Denver Astronomical Society; No. 58, **Michael Blase,** Olympic Astronomical Society

Binocular Double Star Observing Program
No. 195, **István Mátis,** Member-at-Large; No. 196, **Conal Richards,** Lifetime Member; No. 197, **Mike Conley,** Night Sky 45 Astronomy Club

Binocular Variable Star Observing Program
No. 60, **Vincent Michael Bournique,** Lifetime Member; No. 61, **Dave Tosteson,** Minnesota Astronomical Society

Caldwell Observing Program
No. 282, **Debra Wagner,** Silver, Member-at-Large; No. 283, **Dan Posey,** Silver, Hill Country Astronomers; No. 284, **Viola Sanchez,** Silver, Albuquerque Astronomical Society; No. 285, **Claire Weaverling,** Silver, Minnesota Astronomical Society; No. 286, **Andrew Jaffe,** Silver, New Hampshire Astronomical Society

Carbon Star Program
No. 137, **John C. Barentine,** Lifetime Member; No. 138, **Viola Sanchez,** Albuquerque Astronomical Society; No. 139, **Tim Hunter,** Lifetime Member; No. 140 **Pete Hermes,** Tucson Amateur Astronomy Association

Citizen Science Special Program
Dan Crowson, Astronomical Society of Eastern Missouri, Active Asteroids, Active, Gold Class 15 & 16; **Dan Crowson,** Astronomical Society of Eastern Missouri, Variable Stars, Observational, Gold Class 40; **Dan Crowson,** Astronomical Society of Eastern Missouri, IASC, Active, Gold Class 4; **Christopher Kaiser,** Denver Astronomical Society, SCOPE, Stellar Classification, Active, Bronze; **Christopher Kaiser,** Denver Astronomical Society, Exoplanet Explorers, Active, Bronze; **Christopher Kaiser,** Denver Astronomical Society, Disk Detective, Active, Gold Class 1; **Christopher Kaiser,** Denver Astronomical Society, GWitch Hunters, Active, Bronze; **Christopher Kaiser,** Denver Astronomical Society, Planet Hunters NGTS, Active, Bronze; **Christopher Kaiser,** Denver Astronomical Society, Planet Hunters, Active, Bronze; **Christopher Kaiser,** Denver Astronomical Society, Active Asteroids, Active, Gold Class 5 & 8; **Christopher Kaiser,** Denver Astronomical Society, Star Notes, Active, Silver & Gold Class 1; **Rich Krahling,** Richland Astronomical Society, SuperWASP Variable Stars, Active, Gold Class 10 & 11; **Al Lamperti,** Delaware Valley Amateur Astronomers, SCOPE Stellar Classification, Active, Silver; **Al Lamperti,** Delaware Valley Amateur Astronomers, Galaxy Zoo, Star Notes, Active, Gold Class 73; **Al Lamperti,** Delaware Valley Amateur Astronomers, Active Asteroids, Active, Gold Class 37; **W. Maynard Pittendreigh,** Lifetime Member, Rosetta Zoo, Active Bronze; **Brad Young,** Astronomy Club of Tulsa, Variable Stars, Observational, Gold Class 4; **Brad Young,** Astronomy Club of Tulsa, Galaxy Zoo Mobile, Active, Gold Class 5

Constellation Hunter Northern Skies Observing Program
No. 285, **Glynn Germany,** Rio Rancho Astronomical Society

Deep Sky Binocular Observing Program
No. 440, **David Wickholm,** San Antonio Astronomical Association

Double Star Observing Program
No. 694, **George Zanetakos,** S.T.A.R. Astronomy Society; No. 695, **Viola Sanchez,** Albuquerque Astronomical Society

Foundations of Imaging Observing Program
No. 5, **Mark Simonson,** Everett Astronomical Society

Galaxy Groups and Clusters Observing Program
No. 50-DA/I, **Keith Kleinstick,** Lifetime Member; No. 51-DA/V, **Mark Simonson,** Everett Astronomical Society

Globular Cluster Observing Program
No. 379-V, **Steve Riegel,** Colorado Springs Astronomical Society; No. 380-V, **Debra Wagner,** Member-at-Large

Herschel 400 Observing Program
No. 646, **Steve Riegel,** Colorado Springs Astronomical Society; No. 647, **Debra Wagner,** Member-at-Large; No. 648, **David Alan Babb,** Member-at-Large

Herschel Hustle Observing Certificate
No. 4, **Aaron Clevenson,** North Houston Astronomical Society; No. 5, **Kevin Mayock,** Tucson Amateur Astronomy Association

Herschel II Observing Program
No. 116, **Rob Ratkowski,** Device-aided, Haleakala Amateur Astronomers

Library Telescope Awards
No. 23, **Richard Schwentker,** Silver & Gold, Eastern Missouri Dark Sky Observers; No. 24, **Ray Mueller,** Silver & Gold, Eastern Missouri Dark Sky Observers; No. 25, **Dennis Borgman,** Silver & Gold, Eastern Missouri Dark Sky Observers

Lunar Evolution Program
No. 22, **John T. Varn,** Cedar Amateur Astronomers; No. 23, **Terry N. Trees,** Amateur Astronomers Association of Pittsburgh.

Lunar Observing Program
No. 1173, **Steve Riegel,** Colorado Springs Astronomical Society; Nos. 1174 and 1174-B, **Jason Christian,** Cincinnati Astronomical Society; No. 1175-B, **Chris Kaiser,** Denver Astronomical Society; Nos. 1176 and 1176-B, **Dana Bostic,** Raleigh Astronomy Club; Nos. 1177 and 1177-B, **Heidi Lang,** Northern Virginia Astronomy Club; Nos. 1178 and 1178-B, **Eric Lang,** Northern Virginia Astronomy Club; Nos. 1179 and 1179-B, **Carolyn Mirich,** Member-at-Large; No. 1180, **Chris Kaiser,** Denver Astronomical Society; Nos. 1181 and 1181-B, **Brett Belingheri,** Utah Valley Astronomy Club; No. 1182-B, **Juan Velasquez,** Denver Astronomical Society.

Lunar II Observing Program
No. 128, **Jason Wolfe,** Member-at-Large; No. 129, **Lauren Rogers,** Escambia Amateur Astronomers Association

Mentor Program
Brett Boller, Prairie Astronomy Club; **Dan Delzell,** Prairie Astronomy Club; **Bob Kacvinsky,** Prairie Astronomy Club; **Jim Kvasnicka,** Prairie Astronomy Club; **Jason O'Flaherty,** Prairie Astronomy Club; **ames White,** Prairie Astronomy Club

Messier Observing Program
No. 2885, **Thomas V. Schumann,** Honorary, Lifetime Member; No. 2886, **Laura Ryan,** Honorary, Member-at-Large; No. 2887, **Jim Michnowicz,** Honorary, Raleigh Astronomy Club; No. 2888, **Mike Kearns,** Honorary, Prairie Astronomy Club; No. 2889, **Jeremy Gaulke,** Honorary, Patron Member; No. 2890, **David DeWayne Carver,** Honorary, Tallahassee Astronomical Society; No. 2891, **Tim Moyer,** Honorary, South Jersey Astronomy Club; No. 2892, **Ian Slepian,** Honorary, Howard Astronomical League of Central Maryland

Meteor Observing Program
No. 202, **Lauren Rogers,** 18 hours, Escambia Amateur Astronomers Association

Nova Observing Program
No. 21, **Steve Boerner,** Gold, Member-at-Large; No. 22, **Dick Francini,** Gold, Neville Public Museum Astronomical Society

Open Clusters Observing Program
No. 106, **Bernard Venasse,** Advanced, Lifetime Member

Outreach Program
No. 952-M, **Alfred Schovanez,** Eastern Missouri Dark Sky Observers; Nos. 1001-S and 1001-M, **Rakhal Kincaid,** Haleakala Amateur Astronomers; No. 1167-M, **Laurie V. Ansorge,** Lifetime Member; No. 1254-O, **David R. Catlin,** Boise Astronomical Society; No. 1255-O, **Eric Edwards,** Albuquerque Astronomical Society; No. 1256-O, **Jim Hontas,** Cincinnati Astronomical Society; No. 1257-O, **Mark Jordan II,** Cincinnati Astronomical Society; Nos. 1258-O, 1258-S, and 1258-M, **Dennis Borgman,** Eastern Missouri Dark Sky Observers; Nos. 1259-O, 1259-S, and 1259-M, **Amy Elbert,** Eastern Missouri Dark Sky Observers; Nos. 1260-O, 1260-S, and 1260-M, **Richard Schwentker,** Eastern Missouri Dark Sky Observers

Planetary Nebula Observing Program
No. 97, **Edward Fraini,** Advanced, Houston Astronomical Society; No. 98, **Karla Zielke,** Advanced, Houston Astronomical Society

Sketching Observing Program
No. 55, **Dave Tosteson,** Minnesota Astronomical Society; No. 56, **Jason Wolfe,** Member-at-Large

Sky Puppy Observing Program
Allison Horn, Youth Member-at-Large; **Jesse Lamb,** Independent

Solar System Observing Program
Nos. 201 and 201-B, **Jeffrey Corder,** Ancient City Astronomy Club; Nos. 202 and 202-B, **Sam Pitts,** Temecula Valley Astronomers; Nos. 203 and 203-B, **Stephen J. Nugent,** Member-at-Large; Nos. 204 and 204-B, **Craig Lamison,** Houston Astronomical Society

Southern Sky Binocular Observing Program
No. 105, **Gordon Pegue,** Albuquerque Astronomical Society

Southern Sky Telescopic Observing Program
No. 62, **Gordon Pegue,** Albuquerque Astronomical Society

Stellar Evolution Observing Program
No. 93, **Pete Hermes,** Tucson Amateur Astronomy Association

Sunspotter Observing Program
No. 209, **Rakhal Kincaid,** Haleakala Amateur Astronomers; No. 210, **Lauren Rogers,** Escambia Amateur Astronomers Association; No. 211, **Eric Edwards,** Albuquerque Astronomical Society; No. 212, **Carolyn Mirich,** Member-at-Large; No. 213, **Andrew Corkill,** Lifetime Member; No. 214, **Douglas L Smith,** Tucson Amateur Astronomy Association; No. 215, **Scott Cadwallader,** Baton Rouge Astronomical Society

Two in the View Observing Program
No. 52, **Linda Hoffmeister,** Olympic Astronomical Society

Universe Sampler Observing Program
No. 159-T, **Conal Richards,** Lifetime Member; No. 160-N, **Celsa Canedo,** Houston Astronomical Society; Nos. 161-T and 161-N, **Pete Hermes,** Tucson Amateur Astronomy Association; No. 162-T, **Stephen Pavela,** LaCrosse Area Astronomical Society

Urban Observing Program
No. 232, **Jeffrey Corder,** Ancient City Astronomy Club; No. 233, **Karl Schultz,** Central Arkansas Astronomical Society; No. 234, **Andrew Corkill,** Lifetime Member

Variable Star Program
No. 54, **Bernard Venasse,** Lifetime Member; No. 55, **Glenn Chaple,** Member-at-L arge

Master Observer Progression

OBSERVER AWARD

Jeffrey Corder, Ancient City Astronomy Club; **Stephen Pavela,** LaCrosse Area Astronomical Society; **Sam Pitts,** Temecula Valley Astronomers; **Conal Richards,** Lifetime Member

MASTER OBSERVER AWARD

No. 251, **Viola Sanchez,** Albuquerque Astronomical Society; No. 252, **Gordon Pegue,** Albuquerque Astronomical Society; No. 253, **Debra Wagner,** Member-at-Large

ADVANCED OBSERVER AWARD

Jeffrey Corder, Ancient City Astronomy Club; **Rakhal Kincaid,** Haleakala Amateur Astronomers; **Lauren Rogers,** Escambia Amateur Astronomers Association; **Bernard Venasse,** Lifetime Member

MASTER OBSERVER AWARD – SILVER

Jeffrey Corder, Ancient City Astronomy Club; **Eric Edwards,** Albuquerque Astronomical Society; **Rakhal Kincaid,** Haleakala Amateur Astronomers; **Dave Tosteson,** Minnesota Astronomical Society

MASTER OBSERVER AWARD – GOLD

Vincent Michael Bournique, Lifetime Member; **Rob Ratkowski,** Haleakala Amateur Astronomers; **Dave Tosteson,** Minnesota Astronomical Society

MASTER OBSERVER AWARD – PLATINUM

David Whalen, Atlanta Astronomy Club

BINOCULAR MASTER OBSERVER AWARD

Eric Edwards, Albuquerque Astronomical Society; **Dave Tosteson,** Minnesota Astronomical Society; **Bernard Venasse,** Lifetime Member.

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