Published by the Astronomical League
Vol. 74, No. 1 DECEMBER 2021

Reflector

75TH ANNIVERSARY ISSUE

Contents

M. J. Post (Longmont Astronomical Society) used three hours of H-alpha and O III exposures to capture this view of the Squid Nebula, using an Officina RH350AT with a ZWO ASI6200MM CMOS camera.

Reflector

The Astronomical League Magazine

Vol. 74, No. 1 • ISSN: 0034-2963 • DECEMBER 2021

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

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

Astronomical League National Office:
9201 Ward Parkway, Suite 100, Kansas City, MO 64114

Reflector

QUARTERLY PUBLICATION OF THE ASTRONOMICAL LEAGUE

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

PAPER SUBSCRIPTIONS:

USA & possessions: $3.00 each or $10.00 per year (4 issues)
Canada: $5.00 each or $16.00 per year
Mexico: $6.00 each or $22.00 per year
Other countries: $7.00 each or $25.00 per year

DIGITAL SUBSCRIPTIONS:
All countries, possessions, and territories: $10.00 per year

***REFLECTOR* AND CLUB ROSTER DEADLINES**

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

LETTERS TO THE EDITOR
Send to *editor@astroleague.org* with subject line "letter to editor"

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Editor's Note

If this issue of *Reflector* feels a little different, it's because it is! Thanks to a decision by the AL leadership, this larger issue (four additional pages) is a pilot for a possible permanent expansion of the magazine. Of course, this means that we will have even more room for articles penned by you, our AL members. Please contact editor Kris Larsen *(larsen@ccsu.edu)* with your ideas for articles or to submit completed articles. The entire *Reflector* staff wishes to thank the Astronomical League for honoring us with the G. R. "Bob" Wright Service Award at ALCon '21. We accept it on behalf of you, our readers, whom we are proud to serve.

To the Editor

I am a 74-year-old astrophotographer. I would like to encourage League members to consider doing some solar astrophotography now that the Sun is finally getting more active as we move out of the solar minimum phase. Normally I image deep-sky objects, but with more solar activity I

have enjoyed getting back into daytime imaging also. There is lots to recommend it: the Sun is always changing, it extends the amount of time you can practice our hobby, it doesn't require long hours to capture a single image, and you can get amazing photos without needing big heavy telescopes and costly mounts. You use a simple non-cooled monochrome camera, which is a lot cheaper than the big expensive cooled cameras used for deep-sky imaging. There are many more nice days than great nights, especially if you live where I do, Michigan. You won't have to leave your backyard to get great photos – this was shot from my home in the city. Light pollution is not an issue, and for me the best part is: no mosquitos!

I would like to see more solar images in the *Reflector*. I will start off with one I captured from my house on August 23 this year (group AR2859).

This was taken with an 80 mm, 480 mm focal length refractor with a DayStar Quark H-alpha filter. The camera was a Player One Neptune mono camera. The mount is an older altazimuth iOptron MiniTower Pro; an equatorial mount is not required, nor is polar alignment or any auto-guiding, since the imaging time is very short. I use SharpCap to get the frames as a video, process with AutoStakkert!, and process with Photoshop. The first two apps are free, and while I already use Photoshop for my other work, there are several free apps that will work fine instead. This is a set of 2,000 photo frames taken automatically as a movie in SharpCap, then processed with AutoStakkert! to align all 2,000 as individual photos, stack them, and finally a little bit of tweaking of contrast and sharpness, etc., with Photoshop or a similar program. This is a very fast process compared to normal nighttime imaging. The 2,000 frames take no more than a minute or two to capture; alignment and stacking is also fast and done automatically by the software. From start to end it doesn't take more than half an hour. For those that don't have the funds for an H-alpha filter setup, simple Baader AstroSolar film on your regular telescope will let you capture very detailed sunspots. Other than the camera and H-alpha solar filter, you can use your existing tracking mount and telescope. H-alpha filters are also available from a few other companies, such as Coronado and Lunt. For best results a refractor is recommended. A simple achromat is all you need as you are imaging in such a narrow band of light. The camera must be monochrome for best sensitivity and resolution. The final grayscale image can be colorized if you wish with Photoshop or an alternative.

—Robert Berta

I much enjoyed Dave Tosteson's article about polar ring galaxies (*Reflector*, v.73 no. 4), wherein he describes his experiences hunting down various peculiar galaxies such as were catalogued by Arp. While all of Dave's observations are visual, I could not help but wonder what new information could be revealed in the present era of amateur digital imaging. Members of my own local club often post amazing images which reveal more detail and depth than surely any photographic plate from the sky surveys of old (such as Arp pored over and analyzed).

Even when he got telescope time to examine particular objects, Arp was typically limited to smaller telescopes (1- or 2-meter aperture), and, of course, in his day to only analog/chemical photography. In the profession of astronomy there was and is controversy over Arp's work. This is an opportunity for amateurs: to digitally re-image some of the more contentious of Arp's objects, to re-examine some of his claims, for example, looking for a physical connection between some quasars and "host" galaxies.

Looking forward to clear skies!

—Boris Starosta
Charlottesville Astronomical Society, Shenandoah Valley Stargazers, and Rappahannock Astronomy Club

Star Beams

OUR NEW AND IMPROVED WEBSITE IS ON ITS WAY

Our League Council, the governing group of the Astronomical League, has approved a substantial investment in a new website. A big thanks is also due to the trustees of the trust fund who declared the state of our website as an emergency and provided funds under its bylaws.

A MOST SUCCESSFUL ALCON 2021 VIRTUAL

The recent ALCon 2021 Virtual was our first truly international convention, with our outstanding keynote speaker, Dr. Jocelyn Bell Burnell, who discovered pulsars as a graduate student in radio astronomy at Cambridge.

What an incredible event! Big thanks are in order to Scott Roberts and Explore Scientific, who provided the technical online expertise to create this virtual event. Also, past League presidents, Terry Mann and Chuck Allen, currently League secretary and vice president, respectively, did a phenomenal job of co-chairing the event. Many member societies contributed a large number of valuable door prizes. Over 800 people registered for this online event.

With the unprecedented online international reach of this multi-platform effort during ALCon 2021, we truly reached a large audience around the world.

A WORLD-WIDE AUDIENCE REQUIRES A WORLD-CLASS WEBSITE

I see this international exposure of the League to be a large part of our efforts going forward. This is where our new website comes in. We must have a world-class, attractive website to reflect the new stature of the Astronomical League as an international player.

After thorough discussions, we have made the decision to move from the Drupal platform to the more widely used WordPress program. Our existing site contains custom programming and sophisticated applications. Many websites contain mostly static content, but the dynamic features on ours greatly increase the cost of migrating the site and ensuring the new website works correctly and that we are using current data.

RECORD MEMBERSHIP NUMBERS

In the last few months, our membership has increased to over 20,000, an all-time record. Thanks to all our members for their support!

ESTATE PLANNING AND BEQUESTS

In the past few months, we have received a generous payment from the estate of a long-time member who designated the Astronomical League in his estate planning. We also have a substantial bequest in progress from the estate of another past member. These were both designated for the AL trust fund.

We are so appreciative for members who value their association with the Astronomical League so much that they generously remember the organization in their estate planning.

We would like to invite anyone in our membership who is so inclined to do the same. These bequests are most important in allowing the League to expand its educational mission. They may be designated either for the general fund or the trust fund. For more information, please email me at *president@astroleague.org.*

—Carroll Iorg
President

International Dark-Sky Association

CAPTURE THE DARK PHOTOGRAPHY CONTEST

The most powerful way to advocate for dark skies is to take someone to a dark sky site and then take them back to the city, showing them the inevitable light pollution and light trespass found in an urban environment. Seeing a good light fixture with proper nighttime lighting versus one having terrible light pollution is a powerful learning experience. Once you become sensitized to bad lighting and bad fixtures, you can't go back. You will be forever looking askance at bad lighting.

Unfortunately, it is impractical to take most people to a dark site or give them a nighttime city tour of outdoor lighting. The next practical option is to use photographs and drawings to illustrate good and bad outdoor nighttime lighting. In this regard, IDA just published the results of the second annual "Capture the Dark" photography contest which can be seen at *darksky.org/2021-capture-the-dark-winners.*

IDA received 1,122 entries from 66 countries. A panel of esteemed judges reviewed the photos using criteria including technical skill, composition, connection to the category theme for which they were submitted, and the "wow" factor in the photos. I highly recommend you read the biographical sketches for each of the judges, which can be found at *darksky.org/capture-the-dark-2021-meet-the-judges.* These impressive individuals hail from all around the world.

The contest categories were: Connecting to the Dark, International Dark Sky Place, The Impact of Light Pollution, The Bright Side of Lighting, Creatures of the Night, Deep Sky, The Mobile Photographer, and Youth. I, of course, fancy myself a good nighttime lighting photographer and a good astrophotographer. Alas, I am going to have to rearrange my attitude in this regard. My very best efforts are at most mediocre to downright terrible compared even to the honorable mention images for this contest. Fortunately, there is a weblink for "Astrophotography Tips & Tricks" at *darksky.org/astrophotography-tips-tricks.*

For me, the best photographs are those showing the effects of light pollution on the night sky. These bring immediate attention to what we are fighting. Most people really enjoy a gorgeous astrophotograph, but to convince someone of the ill effects of glare or light trespass, it often only takes one or two good images of a barnyard light obliterating the Milky Way from a night landscape scene. Anyway, check out all the winning "Capture the Dark" images on the IDA website, read about the winners, and read about the contestant judges. I guarantee it will be a lot of fun and most instructive.

—Tim Hunter
Co-founder, IDA

Night Sky Network

DIY OUTREACH MATERIALS

Are you crafty in your outreach? At the NASA Night Sky Network (NSN), we design the activities in our outreach toolkits so they can be recreated by anyone familiar with their local craft

and hardware stores. Of course, we encourage everyone who is inspired to design and make their own materials, too!

The NSN's outreach toolkits are one of the highest profile resources we offer to members. If you are unfamiliar with them, we have a list at *bit.ly/nsntoolkits*. Although we package the toolkits in convenient boxes for transport and protection, items can fall out, get lost, or get damaged during outreach. No worries: in most instances they can be fixed or replaced pretty easily! But where to look for supplies? Some items are certainly harder to replace than others, like meteorites and odd rock samples from the "Meteorites or Meteorwrongs" activity. However, with a little creativity and persistence that can be done – rock shows are a great place to pick up odd new rocks and, with a bit of luck, even small, cheap meteorites. Looking for some lenses for a demo about how telescopes work? A local dollar store may have a couple of suitable magnifying glasses, or your club may even have a swap meet, perfect to pick up some spare telescope parts. But you shouldn't have to go to a rock show or depend on a swap meet to recreate the activities in our kits, and we designed them that way. Homemade versions of the NSN activities can often be made with items you have lying around, and craft or hardware stores will have the rest. In fact, that is where we usually get most of our own materials.

Once you start making props and models for your outreach, you may find yourself on the lookout for other potential sources of parts all around you: yard sales, online marketplaces, nature hikes, thrift stores, hobby shops, estate sales, free piles, junkyards – even your own trash and recycling. Is that cardboard tube you're throwing out useful for a potential demo about the brightness of sunspots? Maybe it would make a decent pinhole projector? Just remember to use safe, clean materials in your builds, and file down any sharp parts – no one wants their fun marred by a sharp poke or cut from a dirty prop.

Pressed for time and can't create enough materials for your event? Set up a craft table for your guests and let them do the work. They'll learn a bit more while crafting, plus it's just a ton of fun - and they get to take home a wonderful souvenir! This crafty experience was had at the "Stars at the Library" event held by the San Angelo Astronomical Society and the Stevens Central Library. Thank you to Twyla Oliver for this photo and Andy Oliver for his report.

While our manuals do list our material sources, some NSN toolkits are many years old, so some listed online shops and physical storefronts no longer exist (and our apologies for that, but it's proven to be difficult to keep each manual's PDF up to date with these details). That's why we encourage folks to be flexible with their choices of materials. If no suitable plastic part can be found, cardboard may work just as well for the moment. If you prefer to use papier-mâché instead of Styrofoam, go for it! Substitute printable Solar System cards with asteroids and comets made using a 3D printer instead – and if you don't have access to one, some libraries and maker spaces offer 3D printing classes and services. Your local print shop is also a great resource, as our downloadable copies of the vinyl and cloth banners are made to be easily printed by those shops. Plus, they can often print many copies for a reasonable price if you don't have access to a big printer, along with the previously mentioned libraries and maker spaces.

We have lots more to say on this subject, and we are certain you all do as well. Where do you look for your crafty outreach materials? Let us know at *nightskyinfo@astrosociety.org* – because we're always on the lookout, too! You can find more information about the NASA Night Sky Network program, outreach materials, and member clubs at *nightsky.jpl.nasa.gov*.

—David Prosper

Our toolkit materials and manual are ultimately suggestions, and we encourage members to make their favorite activities their own. Some members are particularly handy and create amazing "toolkit hacks" to improve how they work in the field, as seen here in these two examples sent in from NSN coordinators Jerelyn Ramirez (Kansas Astronomical Observers) with her customized banner frames (directions here: bit.ly/nsnframes*) and Frank Garner (Charlie Elliot Astronomy) with his custom light bench for the "Glass and Mirrors" activities (more details here:* bit.ly/nsnlightbench *)*

Full STEAM Ahead

HERE COMES THE SUN

As the right-brained, creative artistic astronomer that I am, I always look for ways to share astronomy concepts that are inclusive and accessible for students of all ages. My astronomy group is known for this kind of outreach, which is why we have annual events with a select group of organizations.

The activities shared in this article are appropriate not only for elementary-grade students and their families, but also for children and adults with learning challenges. Since I continue to think outside the box and use my imagination, planning and executing these sessions are extremely rewarding.

As the northern hemisphere winter solstice on approaches on December 21, this is the perfect time to talk about the change of seasons. This specific season activity was taught to 2nd to 5th graders in the after-school astronomy club I conducted for two years. This activity covers what many people experience at latitudes of approximately 30 degrees north and above.

This project features the four seasons on a light blue poster divided into fourths, with winter at top left, spring at top right, summer at bottom left, and fall at bottom right. A deciduous tree is the motif that will display the weather as it changes throughout the year while featuring the position of the Sun in the sky. After the students cut and glue the various pieces on the poster in the associated season, they are encouraged to draw what they do outside during that season. Included on the instruction sheet are several points and topics for discussion. I include Earth's obliquity and how this tilt creates the seasons, and how the seasons are opposite in the northern and southern hemispheres. I add the fact that Earth is further from the Sun in northern hemisphere summer and closer in northern hemisphere winter and how this is not logical to the weather that is experienced at that time of year.

The common misconception that our distance from the Sun causes seasons is perpetuated by textbook diagrams that depict the Earth's orbit as an exaggerated oval. A good visual of the Earth's yearly orbit is found at *spaceplace.nasa.gov/seasons/en*. Other videos at this link go into further details and other topics.

Another line of discussion I pursue, which happens to be one of my favorites, is archaeoastronomy. I pose a series of questions: what did ancient civilizations do to prepare for the seasons? How did they use the night sky and Sun to regulate and time their planting and harvesting? Would seasonal changes impact a civilization to move to another location or secure their shelters? How would their food sources change as the animals migrated? Would possible trade with others via sailing and exploring be modified? If there is time, I also mention the importance of cultural lore, festivals, and calendar systems, some of which are still used today.

Of course, depending on the age of the students, the discussion is modified to their level. So, if anyone would like to use this session about the seasons, I have made .pdfs for each season including the stencils and images of the finished activity. Please go to this link for all of the information for this activity: *basidewalkastro.wixsite.com/basidewalkastro*. If you have any questions, please feel free to contact me at *astroleague_steam@cox.net*.

I would love to hear how these activities worked for you, your students, and loved ones.

—Peggy Walker
STEAM and Jr. Activities Coordinator

Editorial note: *More information on accessible astronomy can be found at* youcandoastronomy.com *and* astronomerswithoutborders.org/programs/global-astronomy-month/astro-accessibility.

Wanderers in the Neighborhod

MINOR BODIES SPLIT UP AND THEN MAKE UP

The major planets and larger asteroids in our Solar System are all approximately spherical. Before the Space Age, small asteroids and comet nuclei (minor bodies) were too small to observe any detail on their surfaces. Each appeared as a point of light on images, giving no clue to their real structure.

Although the shapes of minor bodies were unknown, the total brightness of each object could be measured. The area of the object visible to us is proportional to the total brightness. An object that is twice the diameter of an identical object has four times the visible area, making it four times brighter. The visible area remains constant with rotation if the object is a sphere, but any other shape will cause the visible area, and thus brightness, to vary as it rotates.

Astronomers, both amateur and professional, take brightness measurements of asteroids. The measurements for a particular asteroid can be plotted to form a light curve, showing how the brightness varies over time. The data can also be analyzed to determine if there are any periodic brightness changes. If the asteroid were perfectly spherical, assuming a homogeneous surface, the light curve would be a flat line, since its brightness would not change. An irregularly shaped asteroid would have a light curve that could be analyzed to determine the period of rotation.

The light curve also provides some information about the asteroid's shape. Many asteroids are elongated in shape rather than spherical. As such an asteroid rotates, the area of the surface we see varies, varying the total brightness. If the asteroid is potato-shaped, we would see a larger area (brighter) when it is side-on than when it is end-on (fainter).

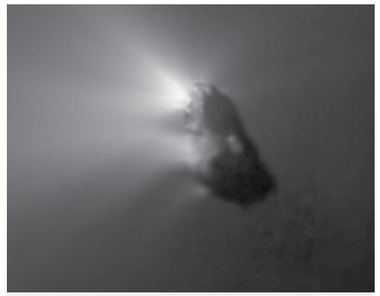
As an asteroid and the Earth orbit the Sun, our view of the asteroid and how the Sun illuminates it will change. This will change the shape of the light curve. By analyzing how the light curve changes as our view of the asteroid changes, the approximate positions of its poles and its general shape can be computed. Comets could be studied the same way, but the coma of gases they emit overwhelms the brightness changes as the nucleus rotates.

Another way to learn about the structure of an asteroid is to observe it blocking light from a star in an event called an occultation, when the star's light is blocked for just a few seconds. By calculating the speed of the asteroid, the length of time it blocks the star for an observer reveals the size of the asteroid. Observers in other locations would see the starlight blocked by a different part of the asteroid. By plotting the individual chords, the shape of the asteroid can be determined. Information on occultations is available from the International Occultation Timing Association (IOTA) at their website, *occultations.org*.

We had no idea what a comet nucleus looked like until the European Space Agency's Giotto spacecraft and Russia's Vega spacecraft imaged Comet 1P/Halley in March 1986 (the United States, trying to save money, did not send a spacecraft). Halley's nucleus was shaped like a peanut, 9.3 miles long and 5.6 miles across. This shape was a surprise, since comets had been thought of as "dirty snowballs," which would be round.

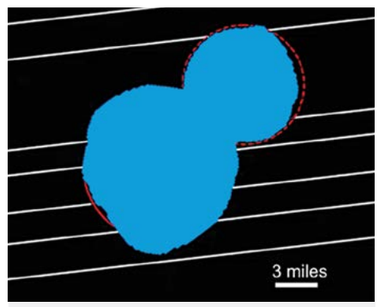
The peanut-shape is called bilobed (having two lobes). The two lobes are connected by a narrow "neck." The spin axis does not run from

lobe to lobe through the neck, but is more likely perpendicular to the lobe-to-lobe line. The rotational period for Halley is 52.8 hours.



The European Space Agency's Giotto spacecraft captured this close-up image of Comet Halley's nucleus as it traversed the inner Solar System. The comet has a very dark surface, with jets of gas and dust spewing out of the comet's sunward side. The nucleus is peanut-shaped, the first example of a bilobed comet to be imaged. This image is a composite taken on March 14, 1986, from a distance of 1,242 miles. Image Credit: European Space Agency

The New Horizons spacecraft flew past the Kuiper Belt asteroid (486958) Arrokoth (2014 MU_{69}) on January 1, 2019. This asteroid is also bilobed, showing that both comets and asteroids can have this shape. Arrokoth is a contact binary; the two lobes are thought to be two similar, but separate, asteroids that have been pulled together by their mutual gravity. The spin axis runs through the larger lobe, just above the neck and perpendicular to the lobe-to-lobe line. It spins once every 15.94 hours.

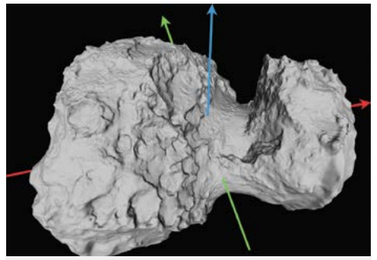


While the New Horizons team was planning for the flyby of (486958) Arrokoth, they discovered that it would occult an unnamed star in Sagittarius for observers in South America on July 17, 2017. Twenty-four telescopes were set up to observe the event and five of them saw the star blink out. This occultation defined the size and shape of Arrokoth in preparation for the flyby. The blue outline of Arrokoth as observed by New Horizons is overlayed on this plot. Image Credit: NASA/JHUAPL/SwRI

Other examples of bilobed minor bodies imaged by spacecraft include (25143) Itokawa, (243) Ida, (951) Gaspra, (5535) Annefrank, and (9969) Braille. Of the seven comets that have been imaged close-up, five are bilobed, suggesting that bilobed comets may be fairly common. Other asteroids have been scanned by radar, but these must come near the Earth to produce a strong enough radar reflection.

Comet 67P/Churyumov-Gerasimenko received a guest on August 6, 2014, when the European Space Agency's Rosetta spacecraft reached the comet. It found that 67P was also bilobed, again with its spin axis perpendicular to the lobe-to-lobe line. It rotates once in 12.4043 hours. 67P has also been identified as a contact binary because the striations on the two lobes are in different orientations.

A team led by Purdue University's Masatoshi Hirabayashi and the University of Colorado at Boulder's Daniel Scheeres have studied 67P intensively and found two cracks in the comet's



Comet 67P/Churyumov-Gerasimenko is another bilobed object that has been studied in detail. The rotational axis, analogous to the north-south polar axis on the Earth, is marked by the blue line. The red (x-axis) and green (y-axis) lines are perpendicular to the rotational axis. This image was generated from data taken by the European Space Agency's Rosetta spacecraft. Rosetta landed on the surface in September 2016 as it ended its mission to this comet. Image Credit: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

neck that are each longer than a football field. They modelled the structure of the comet and used the model to simulate an increase in the rotation rate, reducing the period from the current twelve hours to seven to nine hours. This caused similar cracks to appear on the neck in the model, just where they had been observed on the real comet.

While 67P is unlikely to pull itself apart at its current rotational speed, when the comet flies past the Sun or Jupiter, their gravity could speed up the rotational rate. Gas jets from the comet can also increase or decrease its rotational speed. If the comet spins fast enough, the two lobes will separate. They will not fly apart, but will begin orbiting each other. After a period as short as hours, but probably longer, the two lobes will come together again in a new configuration.

The researchers used their model to create one thousand clones of 67P, each with slightly different initial conditions. They were run through a five-thousand-year period that showed that the comet's rotation sped up and slowed down in a chaotic manner. It is very likely that bilobed comets separate and recombine as a part of their normal lifespans. A separation when the comet is near the Sun would cause more surface area to be exposed to sunlight. This would cause more dust and gas to be released, enhancing the tail. Perhaps this is what creates a great comet.

—Berton Stevens

Deep-Sky Objects

THE TRIANGULUM GALAXY

The Triangulum Galaxy (M33) is the third largest galaxy in the Local Group, the galaxy group that includes our Milky Way. The largest galaxy in the group is the Andromeda Galaxy, M31, followed by the Milky Way. Both the Milky Way and M31 are approximately 20 times more massive than M33. At 2.7 million light-years away, the Triangulum Galaxy is slightly more distant than the Andromeda Galaxy, which is 2.5 million light years away. M33 has an integrated magnitude of 5.7, therefore, in extremely dark skies, some with exceptional night vision can spy this galaxy naked-eye, making it the most distant object visible without optical aid.

M33 lies about four degrees west and one degree north of the magnitude 3.4 star Metallah (Alpha Trianguli). It is also seven degrees southeast of 2nd-magnitude Mirach (Beta Andromedae). These two stars frame the galaxy nicely, making it easy to find.

M33 spans 1.0 by 0.6 degrees in the sky. At its measured distance, the long axis of the galaxy stretches 60,000 light-years, compared to 100,000 light-years for the Milky Way. This nearly face-on galaxy has an Sc Hubble galaxy classification. Sc galaxies are spiral galaxies with small cores compared to their disk diameters. The Milky Way and M31 have much larger cores and galactic bulges for their size.

The first astronomer to catalog the Triangulum Galaxy was an Italian comet hunter named Giovanni Battista Hodierna some time before the year 1654. Charles Messier, also a comet hunter, rediscovered M33 in 1764. Messier, a Frenchman, was probably not familiar with Hodierna and his publications.

The accompanying image of M33 captures most of the galaxy's extent. It was captured with a 132 mm f/7 apochromatic refractor using a

0.8× focal reducer/field flattener to yield f/5.6. The exposure was 180 minutes using an SBIG ST-2000XCM CCD camera. North is up and east is to the left. The bright orange star on the right edge is magnitude 8. Likewise, the bright orange star on the upper left side of the image is also magnitude 8. The image does not resolve individual stars in M33, so most of what appear to be stars in the galaxy are foreground Milky Way stars. However, some of the faintest star-like dots on the image are massive star associations or globular star clusters in M33 that are not resolved.

The Triangulum Galaxy is a great object to view in binoculars and small telescopes. These devices allow the entire disk of the galaxy to be seen in the same field of view. Larger telescopes are able to zoom in on regions of the galaxy, revealing more detail in the eyepiece.

One of the best regions to view in M33 is the bright red emission nebula NGC 604. Located on the northeast side of the galaxy, NGC 604 is one of the largest H II (ionized atomic hydrogen) regions known and extends 1,500 light-years. In comparison, the Orion Nebula is only 24 light-years in extent. NGC 604 contains more than 200 stars 15 to 60 times the mass of the Sun. There are three other emission nebulae in M33 found in the New General Catalog: NGC 588, NGC 592, and NGC 595. Entries 131 to 143 in the Index Catalog (IC) also belong to nebulae or star clusters in M33. All are 13th to 14th magnitude or fainter. All of these NGC and IC object are visible in dark skies using 16-inch or larger telescopes.

As can be seen in the accompanying image, M33 has two main spiral arms with several dimmer arms branching from the main arms. Dark nebulae are found throughout the galaxy. NGC 604 is the bright pinkish-red patch on the upper left side of the galaxy in the image. This light comes from the neutral hydrogen-alpha transition at 656.3 nanometers. NGC 604 is approximately 1.9 arcminutes in size. It's cataloged at magnitude 12 and is visible in an 8- to 10-inch telescope in really dark skies.

The other pinkish-red nebula located to the upper right of the galactic core on the accompanying image is NGC 595. NGC 595 is 30 arcminutes in size and is magnitude 13.5. It should be visible in 12- to 14-inch telescopes. Down and to the right of NGC 595 is NGC 592, an association of up to 12 massive O and B stars embedded in a star-forming nebula. The combined magnitude of this association is 13.0 and it is about 42 arcseconds in size.

The Triangulum Galaxy is located a mere 750,000 light-years from the Andromeda Galaxy and may be gravitationally bound to it. Regardless, an unobstructed view of M33 from a planet in M31, and vice versa, must be quite impressive. The separation of the two galaxies is decreasing, and both galaxies are approaching the Milky Way. The views will only get better!

In the late autumn and early winter evening hours, M33 is well positioned for northern hemisphere astronomers. On clear nights, the cold, steady winter skies should be ideal for exploring the Triangulum Galaxy!

—Dr. James Dire

From around the League

ALCON '21 — A VIRTUAL SUCCESS

When the seventh deadliest pandemic in world history forced two consecutive in-person ALCon postponements, the Executive Committee decided that it could not let the League's 75th anniversary year pass without a convention. League Secretary Terry Mann and League Vice President Chuck Allen volunteered to co-chair the event and began initial planning in March. Don Knabb offered to create the convention website while Terry and Chuck recruited speakers, award winners, and door prize donors to fill out an ambitious 21-hour schedule of live-streamed programming split into afternoon and evening sessions on three successive days, August 19–21, 2021. The event was hosted with the generous assistance of Scott Roberts on his Explore Scientific Zoom platform. In the end, the event drew 874 registrations and reached over 79,000 people via live-stream and recorded sessions on Facebook, YouTube, and the Explore Scientific platform.

The co-chairs suggested that League societies be asked to consider sponsoring a single door prize in the $150 to $250 range. Amazingly, 39 societies, companies, and individuals, recognized in this issue, answered the call by offering an astounding $9,500 in door prizes, an ALCon record that will probably never be eclipsed. Donor societies were given the opportunity to share three-minute slide presentations about their clubs, leaving many viewers amazed by the extent of observatory development and public outreach that exists among just this sample of our more than 310 member societies. Scott Roberts generously provided the exceptional grand prize, a $750 FirstLight 125 mm Maksutov-Cassegrain telescope on a Twilight 1 mount; it was won by Gary Carter.

SPEAKERS

Six of our nineteen speakers joined us from the United Kingdom and Canada, giving the convention a strong international flair. Most notably, our convention keynote speaker was one of the most famous astronomers in the world today, **Dr. Jocelyn Bell Burnell** of Oxford University. Her mesmerizing talk provided an intimate personal look at the work leading to her 1967 discovery of a 1.33-second repeating signal emanating from the constellation Vulpecula and the post-discovery work needed to confirm its huge significance to science. She had discovered the first known pulsar, a previously predicted rapidly rotating neutron star left over from a supernova. Perhaps more interesting, and moving, was her account of the difficulties she faced because of the gender bias that has affected so many female scientists in decades past.

Also speaking from the U.K., **Paul Cox** gave a compelling presentation about the PlaneWave telescopes that his company, Slooh, maintains in the Canary Islands for remote use by subscribing amateur astronomers. He offered an apprentice membership to one of our student award applicants.

Four speakers came to us from among our friends in the north, the Royal Astronomical Society of Canada. **Karim Jaffer**, professor of physics and astronomy at John Abbott College, presented a talk entitled "Two-Eyed Astronomy" that examined the observations of ancient cultures. Noted astrophotographer **Alan Dyer** gave us a spectacular look at the science of aurorae and the methods he uses in taking spectacular auroral photos and videos. **Dr. Chris Gainor,** past RASC president, author, and an expert in the history of technology, provided a beautiful visual look at three decades of contributions by the Hubble Space Telescope. Our friend **Dr. David Levy,** author, poet, and comet discoverer, regaled us with poetry at the start of each session and offered a talk that might well have been on an astronomical topic but for the untimely loss of his dear friend and fellow comet discoverer, Carolyn Shoemaker. David used his time, instead, to present a touching tribute to his friend entitled "Did Carolyn Shoemaker Have a Sense of Humor?" We look forward to a joint convention with the RASC in 2024.

Dr. Richard Gott, author and professor emeritus of astrophysics at Princeton University, outlined the research by which he became the first to predict the spongelike structure of the universe, the "cosmic web" as it is known today. **Tyler Cohen** and **Montana Williams** led us on a fascinating virtual tour of the Very Large Array in New Mexico. **Dr. Brian Haidet,** an expert in materials science and creator of the extremely entertaining physics-based YouTube channel, *AlphaPhoenix,* spoke on the search for near-Earth objects and the measurement of asteroids using planetary radar. In a similar vein, **Dr. David Dunham,** a trajectory design engineer at KinetX Aerospace, joined us to speak about near-Earth object occultations. **Dr. Caitlin Ahrens,** an expert on planetary ices and a post-doctoral fellow at NASA's Goddard Space Flight Center, offered a forward-looking view of proposed lunar exploration.

David Eicher, editor-in-chief of *Astronomy* magazine and author, gave a presentation on "Galaxies," the title of his most recent book, and **Kelly Beatty,** senior editor for *Sky & Telescope* magazine and former IDA board member, addressed ways to deal with the ever-worsening problem of light pollution and loss of the night sky. **Dr. Larry Crumpler,** research curator of volcanology at the New Mexico Museum of Natural History and member of the Mars 2020 Perseverance rover and Ingenuity helicopter science team, gave us a thorough update on the work of his team's ongoing exploration of Mars.

Two students appeared as speakers. **Conal Richards,** a freshman at Penn State majoring in aerospace engineering and co-winner of the Horkheimer/Smith Award, gave a talk on "Rising Stars" and how to attract young people to the hobby. **Ryan Clairmont,** a senior at Canyon Crest Academy in San Diego and 2021 Regeneron International Science and Engineering Fair and National Young Astronomer Award winner, outlined his amazing research into the structure of the Cat's Eye Nebula using, in part, spectroscopic studies that he performed using his own equipment.

AWARDS

The convention provided our first opportunity to present the League's many general and youth awards for 2020 and 2021, starting with our highest honor, the Astronomical League Award, which had not been previously announced for either year.

Astronomical League Award 2021

A week before the convention, Terry Mann visited her long-time friend Carolyn Shoemaker

in Flagstaff, Arizona, and revealed to her that she had won the Astronomical League Award for 2021. Carolyn, of course, discovered 32 comets and more than 500 minor planets during her career. Terry showed her the beautiful plaque, a sight that brought Carolyn to tears, and Terry was to visit Carolyn a week later to present the plaque formally during the virtual convention. Tragically, Carolyn passed away mere days after Terry's initial visit. We're thankful that Carolyn got to enjoy the news of her award and for her friendship and her many contributions to astronomy. She will be deeply missed by the entire astronomy community.

Astronomical League Award 2020

Carroll Iorg surprised our convention platform host, Scott Roberts, with the 2020 Astronomical League Award. Scott has been a major benefactor and supporter of the League for nearly 30 years. While at Meade, Scott stepped forward to provide telescope prizes to our National Young Astronomer Award winners in 1994. Years later, Scott offered Explore Scientific as the new NYAA sponsor. He has invited the League to present door prizes which he contributes to the League at scores of Global Star Parties. He makes his platform available for monthly League Live Events and made it available, again, for our virtual convention. He has even offered to assist in recording and live-streaming ALCon '22 in Albuquerque. In September, he undertook sponsorship of the Williamina Fleming Award.

G. R. Wright Award 2021

The G. R. "Bob" Wright Service Award went to a most deserving group indeed – the entire *Reflector* staff. The award plaques went to Editor Kristine Larsen, Assistant Editor Kevin Jones, Photo Editor Dan Crowson, Design/Production Manager Michael Patterson, and Advertising Representative Carla Johns. Two other key staffers, Managing Editor Ron Kramer and Coming Events Editor John Wagoner, having received the Wright Award previously, received Special Presidential Awards.

In addition, 15 youth and 13 general award winners from 2020 and 2021, all previously recognized in the *Reflector* for their work, were presented their awards in front of the large live-stream audience. Tom Lynch and League past president John Goss offered a Library Telescope presentation and drawing for the 11 Library Telescopes offered each year by the League. Aaron Clevenson summarized the activities of our Observing Program Division, introducing Marie Lott as a new national director and noting that over 16,000 certificates have been awarded to more than 5,600 different League members since the inception of the League's Observing Programs in 1967.

We want to thank to all of you who appeared or served as speakers, awardees, door prize donors, club presenters, convention hosts and staffers, and League officers and committee chairs for your enthusiastic, generous, and punctual participation in the convention. And we especially want to thank each of you, the nearly 900 registrants and tens of thousands of viewers, who made this event a successful gathering and a wonderful celebration of the League's 75th anniversary in a most trying time.

ALCON '21 VIRTUAL DOOR PRIZE DONORS

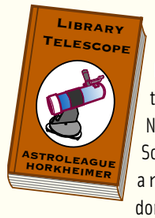
The Astronomical League wishes to recognize the following member societies, companies, and individuals for their contribution of more than $9,500 in door prizes for drawing and presentation during ALCon '21 Virtual:

Explore Scientific (grand prize)
The Albuquerque Astronomical Society
Chuck Allen
Amateur Observers' Society of New York
Astronomical League
Astronomical Society of Eastern Missouri
Astronomical Society of Kansas City
Astronomy Club of Asheville
Back Bay Amateur Astronomers
Buffalo Astronomical Association
Central Arkansas Astronomy Association
Charlottesville Astronomical Society
Chester County Astronomical Society
Paul Cox (Slooh)
Eugene Astronomical Society
Evansville Astronomical Society
Everett Astronomical Society
Fort Worth Astronomical Society
Robert Garfinkle
Hill County Astronomers
Houston Astronomical Society
Paul Hummel Astronomy Club of Boulder
Island County Astronomical Society
Terry Mann
Milwaukee Astronomical Society
Neville Public Museum Astronomical Society
New Hampshire Astronomical Society
Northwest Suburban Astronomers
Olympic Astronomical Society
Omaha Astronomical Society
Robert Scott
Shoreline Amateur Astronomy Association
Mark Simonson
ScopeStuff
Southern Maine Astronomers
Southwest Florida Astronomical Society
Texas Astronomical Society of Dallas
Tucson Amateur Astronomy Association
Twin Cities Astronomical Society

YOUR ASTRONOMICAL LEAGUE JUST GAVE AWAY SIX LIBRARY TELESCOPES

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

The Library Telescope consists of a 4.5-inch Dobsonian reflector fitted with an 8–24 mm zoom eyepiece, and a name plate commemorating the late Jack Horkheimer. The value of this opportunity is approximately $325; the potential is enormous.



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

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

Congratulations to the 2021 winners:

- **Skyscrapers, Inc**. (Amateur Astronomical Society of Rhode Island), Northeast Region
- **Caddo Magnet High Astronomy Club,** Southeast Region
- **Kansas Astronomical Observers,** Mid-States Region
- **Tucson Amateur Astronomy Association,** Western Region
- **Island County Astronomical Society of Washington,** Northwest Region
- **David Knighton,** Member-at-Large

Your Astronomical League is continuing this incredible opportunity in 2022 by giving away up to eleven library telescopes, one to each region and to a member-at-large. We prefer that you submit your completed entry form electronically so the Astronomical League national office receives it by the deadline of July 8, 2022. Please email it to *HorkheimerLiTel@astroleague.org.* If mailed, the entry must be postmarked no later than July 8. The winning entries will be selected at ALCon 2022. Full details of this program can be found at *astroleague.org.*

The Library Telescope Program is a great club project that brings members together while benefiting their community. Indeed, it is the perfect outreach program!

More information about Library Telescopes also can be found at *librarytelescope.org.*

CALL FOR AWARD SUBMISSIONS

The application or nomination deadline for 2022 Astronomical League awards is **March 31, 2022**. No applications will be accepted prior to January 1, 2022. Award information, including applications and eligibility criteria, can be found on the League's "Awards" web page, *astroleague.org/al/awards/awards.html.*

Important: Due to the increasing problem of mis-delivery of emails, please do not consider your award submission complete until you receive an email confirming receipt. If no confirmation is received within 48 hours of your submission, contact the League vice president.

YOUTH AWARDS

The League offers five major youth awards including the National Young Astronomer Award, the Horkheimer/Smith and Horkheimer/D'Auria Service Awards, the Horkheimer/Parker Imaging Award, and the Horkheimer/O'Meara Journalism Award.

National Young Astronomer Award

Qualified U.S. citizens or U.S. school enrollees under the age of 19 who are engaged in astronomy-related research, academic scholarship, or equipment design are encouraged to apply for the National Young Astronomer Award, now in its 29th year. League membership is not required. The top three winners receive plaques. The top two winners win expenses-paid trips to the League's national convention (U.S. travel only). The winner receives an Explore Scientific telescope prize. Applications must be emailed to *NYAA@astroleague.org.* Deadline: March 31.

Youth Service Awards

Qualified League members under the age of 19 who are engaged in service to the amateur astronomy community are encouraged to apply for the Horkheimer/Smith and Horkheimer/D'Auria Youth Service Awards. Club or regional officers may nominate candidates. The Horkheimer/Smith winner receives a plaque, a $1,750 cash prize, and an expenses-paid trip to the League's national convention (U.S. travel only). The Horkheimer/D'Auria winner receives a plaque and a $1,000 cash prize. Applications or nominations must be emailed to *HorkheimerService@astroleague.org.* Deadline: March 31.

Youth Imaging Award

Qualified League members under the age of 19 who are engaged in astronomical imaging are encouraged to apply for the Horkheimer/Parker Youth Imaging Award. Club or regional officers may nominate candidates. The winner receives a plaque and a $1,000 cash prize. Applications or nominations must be emailed to *HorkheimerParker@astroleague.org*. Deadline: March 31.

Youth Journalism Award

Qualified League members age 8 to 14 who are engaged in astronomy-related writing are encouraged to compete for the Horkheimer/O'Meara Youth Journalism Award. Club or regional officers may nominate candidates. The winner receives a plaque and a $1,000 cash prize. Second- and third-place winners receive $500 and $250, respectively. Applications or nominations must be emailed to *HorkheimerJournalism@astroleague.org.* Deadline: March 31.

MABEL STERNS AWARD

The Mabel Sterns Award acknowledges the important role of club newsletter editors. Club officers may nominate a newsletter editor by emailing a copy of the club's print newsletter as a .pdf file, or by emailing a link to an online newsletter, to *sternsnewsletter@astroleague.org* along with a nomination cover letter (.pdf) that includes the name and address of the nominee and an attached .jpeg photo. Nominees and nominating officers must be League members. Deadline: March 31.

WILLIAMINA FLEMING IMAGING AWARD

The Williamina Fleming Imaging Award, now generously sponsored by Explore Scientific, is open to female League members who are 19 years of age or older. Images submitted by professional astrophotographers as defined in the rules will not be accepted. Submissions are made by emailing the entry form and up to three .jpeg attachments not exceeding a total of 25 megabytes to *flemingaward@astroleague.org.* All submissions must consist of images taken and processed solely by the individual. Deadline: March 31.

WEBMASTER AWARD

The League's Webmaster Award recognizes excellence in the creation and maintenance of society web pages. Club officers may nominate a webmaster by emailing a newsletter link to *WebmasterAward@astroleague.org* along with a nomination cover letter (.pdf) that includes the name and address of the nominee and a .jpeg photo. Nominees and nominating officers must be League members. Deadline: March 31.

SKETCHING AWARD

The League's Sketching Award recognizes the fundamental role that sketching plays in observing. The award, open to League members of all ages, provides cash prizes for first place ($250), second place ($125), and third place ($75). Sketches should be submitted as high-resolution .jpeg files (10 megabytes maximum) along with a .jpeg photo of the applicant to *Sketch@astroleague.org.* Winning sketches may be published in the *Reflector* and on League social media sites. Deadline: March 31.

—Chuck Allen

CALL FOR OFFICER NOMINATIONS

The current two-year terms of the League president and League vice president expire on August 31, 2022. Nominations for these offices must be received by the Nominating Committee co-chair, John Goss, at *goss.john@gmail.com* no later than **March 31, 2022**.

The president is the chief executive officer of the League and has general charge and supervision of the business affairs of the League. The president has the power to execute and terminate all contracts, deeds, obligations, and other instruments in the name of the League as authorized by Council, presides over League Council, Business, and Executive Committee meetings, creates, terminates, and appoints persons to all League committees, and serves as an ex-officio member of all committees.

The vice president assists the president and assumes the duties of the presidency in case of the absence, death, disability, or resignation of the president. The vice president is responsible for managing and executing all League youth awards and all League general award programs not otherwise assigned, is responsible for future national convention host selection, planning, and coordination, and chairs (or co-chairs if a candidate) the League Nominating Committee.

Nominations should include two items for publication in the *Reflector* and on the ballots: (1) a background statement of up to 250 words indicating qualifications and/or reasons for seeking the position and (2) a photo of the nominee.

—Chuck Allen

Hunting Down Young Crescent Moons

By Kenneth Drake

In the late 80s, I became interested in locating and observing young crescent moons. It was not until August 1991 that I observed my first thin moon after attempting 14 (including a possible world record on May 5, 1989). For nearly 20 years I was an avid chaser of both old and young thin crescents, accumulating over 100 successful observations. Slowing down about 12 years ago, I now only chase opposing crescents and those under 10° of elongation.

Today, it is much easier to locate the position in the sky of a near-invisible thin crescent using software and computer-driven optics. Back when I first began, the calculations were done with pen and paper and the optics were limited to tripod-mounted binoculars.

Software and internet tools are extremely helpful in determining where and when to hunt a thin crescent. For many years I used Guy Ottewell's *Astronomical Calendar* to get briefed on upcoming possibilities. Software, including MoonCalc, Stellarium, AstroGrav, and Virtual Moon Atlas, has been helpful to determine data, simulations, and crescent graphics. A good tip is to always keep "refraction" turned on, as near the horizon it becomes part of the equation.

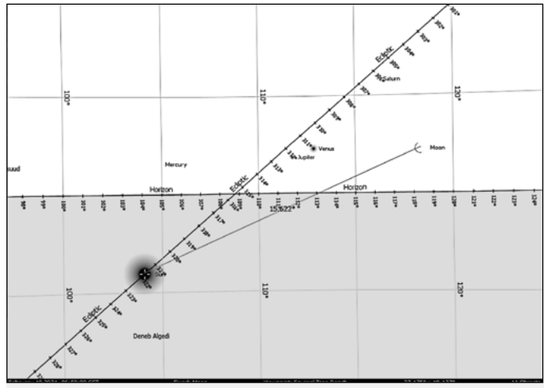


Figure 1. A simulation of the February 10, 2021, thin crescent as viewed from Squirrel Tree Ranch north of Willis, Texas. Generated by author using AstroGrav 4.4.1.

Even knowing where to look is no guarantee of success, as clouds, haze, twilight, elongation, and age from new are factors that affect visibility of the thin crescent. Another factor that I have discovered is the delta-T, the time difference between rise or set of the Sun and Moon. I've found 35–40 minutes to be a good delta-T. As it grows smaller, I've found that the elongation needs to be higher. It really depends on the slant of the ecliptic and whether the crescent is north or south of it. Figure 1 illustrates this issue on February 10, 2021, at 6:50 a.m.: the Moon–Sun separation was 15.6°, the age was over 30 hours before new, the Sun was at –4° altitude, and the Moon was only 2.5° up, including refraction. This should have been easy to see, except the delta-T was only 32 minutes. Low altitude and sky brightness also work against you.

Figure 2. Photograph by Charles Botkin (used with permission) of the October 11, 1996, morning thin crescent rising in a distant notch, Davis Mountains State Park, Texas, at end of Skyline Drive; one-second exposure on Ektachrome E1005W through a Takahashi FCT 65.

Try running a simulation on your own planetarium software, like Sky Safari Pro, to visualize a completely different scenario on May 1, 2022, about 20 minutes after sunset. The crescent is nearly directly above the Sun, at 12.7° elongation, with a delta-T of about 60 minutes. This should make for an easy find.

Often, careful study of the field of view is required to pull out that sometimes-thin line representing the arc of illumination. Early in my quest I picked up a few tricks. A small, low-contrast sliver that is moving will be far more obvious than one standing still. If the binoculars you're using have markings, gradations, or even a speck of dust, concentrate on that while slowly moving the field of interest about the view. This has helped many times snap a thin crescent into view. Another thing that I've found helpful is a low bank of clouds at the horizon. This often darkens the glare from the bright twilight and gives a reference point. Knowing the magnetic declination of the observing location is often highly beneficial. Since most of my planning is done at home, I use *www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml* to determine it.

A small, close group in our area began observing these thin moons and had set a few ground rules after seeing the "Moonwatch" article in the July 1988 issue of *Sky & Telescope*. No go-to or auto-finding allowed, and only binoculars can be used as optical aid.

Actually seeing one of these sub-10°-elongation moons can be rather difficult, as many times I failed under what appeared to be clear skies. One on April 3, 1992, a 10°, 19h 53m young moon, I attributed to the "Pinatubo effect" (the stratospheric aerosol cloud created by the 1991 eruption of Mount Pinatubo).

A remarkable and noteworthy morning sighting was made of a spectacular 25h 43m before new moon with an elongation of 11° 35'. A large group of experienced observers gathered atop a peak at the end of Skyline Drive at Davis Mountains State Park, Texas, on October 11, 1996, at 7:04 CDT. We have given this observation the name "Notch Moon" as the azimuth rise was predicted to be in a distant notch between a pair of mountains. All six observers spotted the earthshine in the notch simultaneously before seeing the illuminated crescent appear. It was my most beautiful thin moon ever.

The image (figure 2, previous page), with Mercury in the upper left, does not do justice to the awesome view that morning.

SELECTED UNSUCCESSFUL BATTLES

January 1, 1995, four miles east of Marathon, Texas, on U.S. 90, elevation 4157 feet

The original intent of this trip was to break what was then the documented record of 13h 28m by Robert Victor by going to the Pecos River near Del Rio and attempting the observation from either the Pecos River Overlook or the Silver Spike site. Don Pearce and I met up with Art Ciampi at Del Rio, and by late afternoon it was apparent that overcast skies were to be a major problem. We decided to head west, racing against time and an ever-persistent cloudy sky. Finally, near Marathon, with the Sun close to setting, we abandoned the race and set up our optics (100 mm Miyauchi binoculars) beside the highway, hoping to glimpse the Moon through murky (but not impossible) skies. Upon departing the vehicle, the temperature dropped from a pleasant 74°F inside the vehicle to 29°, and the northwesterly wind was whipping, probably bringing the windchill factor to near 0°! After a very short time, we abandoned the search.

Had we been successful at 18:20 local time, we would have gotten a 13h 23m crescent with an elongation of 7° 16' 59", which indeed would have been a world record at that time.

October 24, 1995, Summit of Mt. Locke, McDonald Observatory, elevation 6791 feet

This is, without a doubt, one of the most spectacular failures of all my observations of thin crescents. Three of us from the Houston Astronomical Society assembled at the summit of Mt. Locke. The sky was crystal clear except for the presence of red haze hugging the horizon, presumably pollution from a plant in Mexico. The distant Livermore Complex rose to about 1° near the sunset point with the haze extending about 1° higher. This suggested a narrow window of opportunity as the ecliptic slants far south this time of year and the crescent was only half a degree north of it. We never observed any hint of the 0.7% illuminated sliver. Although somewhat low, if we had acquired it at 19:25 local time, the 19h 48m young crescent would have had an elongation of 9° 36' 53" . The crescent altitude would have been 3.2° with a delta-T of 35 minutes. This was a shocking fail due to the high-altitude location and what appeared to be pristine skies. Although I have never spotted a sub-10° crescent naked eye, others have in worse conditions, which makes this fail hard to understand.

As an interesting note to go with this failed attempt, we had actually gone to Skyline Drive in the Davis Mountains State Park the morning of October 23 to attempt a very difficult morning crescent. This was an attempt to acquire 35h 38m opposing crescents (observing both a slender waning and waxing crescent on either side of new moon). We believe the red haze near the horizon was the culprit.

I could go on with other interesting fails, but usually the weather can be blamed. I still find the chase exciting.

Here is a list of old and young thin crescents that might be of interest; think of this as a starting point, and be sure to run a simulator for your location, because all numbers will vary by location. The two that really interest me are the pair in June due to the possibility of testing the "Danjon limit" (an estimate of the limit of visibility of a slender crescent due to the angular separation between the centers of the Sun and Moon) and the chance of acquiring opposing crescents. The pair in August has a possible opportunity for 37h 26m opposing crescents and has very doable numbers. MoonCalc 6 *(mooncalc.moonsighting.org.uk)* was used to make these calculations; be aware that it may not run on your computer. The online version, *mooncalc.org*, can be used to check things for your observing location. ✶

THIN MOONS OF 2022, LOCAL TIME AT HOUSTON, TEXAS, SUN –4°

Date/Time	Altitude	Azimuth	Elongation	Moon's Age	Delta-T
Jan 1 7:00	7.9°	125.9°	16.8°	-1d 5h 33m	67 min
Jan 3 17:52	8.5°	234.8°	16.9°	1d 5h 19m	69 min
Feb 1 18:16	3.9°	245.7°	10.8°	18h 30m	40 min
Mar 1 6:32	1.0°	111.8°	16.3°	-1d 5h 3m	23 min
Mar 3 18:38	10.6°	258.7°	16.0°	1d 11m	71 min
Apr 1 19:56	3.8°	274.2°	8.8°	18h 32m	37 min
Apr 29 6:25	3.3°	84.6°	15.7°	-1d 9h 3m	34 min
May 1 20:15	8.1°	287.2°	12.7°	1d 4h 47m	61 min
May 29 6:05	3.6°	69.5°	10.6°	-1d 25m	38 min
May 31 20:34	11.9°	293.4°	16.7°	1d 14h 4m	85 min
June 28 6:06	2.9°	61.3°	6.9°	-15h 46m	37 min
June 29 20:43	5.9°	296.6°	10.3°	22h 51m	53 min
July 27 6:21	9.6°	65.6°	13.7°	-1d 6h 33m	73 min
July 29 20:33	8.5°	286.7°	14.7°	1d 7h 39m	63 min
Aug 26 6:39	5.4°	72.3°	10.1°	-20h 38m	47 min
Aug 27 20:05	3.6°	280.1°	8.4°	16h 48m	36 min
Sept 24 6:55	12.1°	85.6°	16.5°	-1d 9h 59m	78 min
Sept 26 19:28	5.0°	261.2°	12.9°	1d 2h 34m	42 min
Oct 24 7:13	7.0°	100.1°	11.1°	-22h 35m	53 min
Oct 26 18:55	7.3°	241.8°	19.4°	1d 13h 7m	57 min
Nov 22 6:35	13.0°	116.6°	18.0°	-1d 10h 22m	88 min
Nov 24 17:39	3.6°	237.0°	13.7°	1d 42m	40 min
Dec 22 6:56	4.2°	123.7°	12.1°	-21h 20m	44 min
Dec 24 17:45	11.6°	230.0°	21.9°	1d 13h 29m	90 min

Upcoming slender moon apparitions potentially visible from Houston, Texas. Data generated using MoonCalc 6 (mooncalc.moosighting.org.uk) and AstroGrav 4.4.1 (www.astrograv.co.uk).

Kenneth Drake is a member of the Houston Astronomical Society and North Houston Astronomy Club

On the occasion of the Astronomical League's 75th anniversary, a look back at the *Reflector*'s beginnings: the first issue of the *Astronomical League Bulletin*

ASTRONOMICAL LEAGUE BULLETIN

Vol. 1 No. 1 — Five issues annually — September 1949

* MRS. HELEN S. FEDERER, PAST PRES., INTRODUCES THE BULLETIN: This is the first of a series of regularly issued Astronomical League Bulletins which will appear bi-monthly through the year from September to May. Sent automatically to all member organizations and members-at-large, and available on request (plus a 2¢ stamped envelope) to any individual connected with the League, the Bulletin will provide a means for disseminating local, regional, and League news. The need for such a means of intercommunication has been felt during these first few years of the League's existence. But if you want to get the fullest benefit from this publication, remember that you must not only receive it in the mail, but you must give to it items of interest from your society and your region. Only if everyone realizes that this is essentially a "house organ," by and for the League, will it go forward to unqualified success.

* CHAS. H. LEROY, PRES., LOOKS FORWARD: We all agree with Dr. Shapley that there is no reason for paralleling the work previously undertaken by the AAVSO, ALPO, Solar Division, and American Meteor Society. However, Dr. Wagman tells me that everywhere he goes, the plea is for more and more concentrated work in these fields.

I therefore propose that we concentrate and direct our efforts this year toward throwing the League's weight behind these programs, so that by the end of the year, every member possible shall be participating in some organized observing. I estimate that we must have around 1000 to 1500 telescopes, which is no mean advantage in enlisting the full cooperation of the above mentioned societies. In addition, the activities of the TAC could be merged into this channel.

So far, it appears that everyone's effort has been directed toward helping the League get started. Now it is time to enlarge into a reciprocating proposition, wherein the amateur assumes more responsibility. I firmly believe that they will accept this responsibility and that by coordinating the work of amateur and professional, we can enter into an era of astronomic progress never before witnessed in any field. Then, the League will have attained the goal outlined in its constitution.

* THE CONVENTION IN A NUTSHELL as compressed by Wm. C. Oberem, Past V.P., and Treas.: The last convention, more than any that we have attended before, seems to point the right way for promoting individual club activities through the medium of the League. Of greatest importance was the establishment and bringing about of the proper functioning of the Activities Committee ably headed by Rolland LaPelle. It would seem to the writer that the interests of the League are best served if that Activity Section is expanded to its fullest extent and within limits of the funds of the League, all publications be supported and financed, because it is through that Committee that the real life of the League will flourish.

* ANNUAL CONVENTION OF THE NORTHWEST REGION AT PORTLAND, ORE., September 3-4. Doors were scheduled to open at 12:30 P.M. Saturday with registration and exhibits in the mezzanine gallery of the Portland Oregon Journal Building in downtown Portland. After 3:30 there was to have been a session for papers and a welcome to everyone. At 6:30, according to the notice, the convention convened at the YMCA for a banquet at $2 per plate.

The Saturday evening program took place at Library Hall in the Portland

Public Library and was to have featured a speaker, Mr. Fergus J. Wood, or in the event of his absence, three films--"The Story of Palomar," "Solar Prominences," and 400 feet of film showing the 1945 total eclipse of the sun and accompanying phenomena, taken at Wolseley, Saskatchewan, by Paul W. Stevens, Eastman Kodak Company.

Sunday's session began at 1 P.M. at the Journal Building. The afternoon was devoted to the business meeting, session for papers, and exhibits. A complete account of the convention will be mailed to interested parties of the Astronomical League.

* ALL MICHIGAN SOCIETIES are invited to Wolf Lake Lodge near Kalamazoo, on September 10 when the Kalamazoo AAA will be host at a pot-luck supper at 6 P.M. with observing to follow. The Cleveland convention will be reported. Then, to reciprocate, the Detroit AS will be host to all the Michigan societies on Sunday, September 18, when again reports of the Cleveland convention will be featured, also reports from everyone of observation work accomplished during the past summer. One of the DAS juniors, aged 15, will tell of his experience as astronomy councillor at a boys' camp.

The speaker will be Claude B. Carpenter, a former president of the DAS and regional director of the AAVSO in past years. He will show films of his trip to the west coast to visit the large observatories. Mr. Carpenter has a site at Elsinore, Calif., where he will erect an observatory to house his 18" reflector now in the mirror stage. At dusk there will be general observing.

* BUFFALO AT&SO HOLD STAR PARTY in conjunction with Explorers' Club of Museum of Science. The program opened with an address on astronomy by one of the AT&SO's which touched specifically on objects to be seen that night. A public address system made by a member aided considerably. More than 100 persons heard the address clearly in the open surroundings. A battery of ten telescopes was active and observations began. On display earlier in the program, the scopes ranged from 3½" to 12", both reflectors and refractors, of various types of construction.

Interest ran high and questions came thick and fast. Many amateur astronomers were on hand to operate telescopes and answer questions. It is planned to make this a yearly event.

* WELCOME TO the Cleveland Astronomical Society, Pontiac Astronomical Society, and junior section of the National Capital Astronomers, all new members of the League. The Palo Alto Astronomy and Telescope Club, and the ATM Astronomical Club of San Diego have resigned, and the Tulsa Astronomical Society has disbanded.

* PITTSBURGH HOLDS STAR PARTY. More than 2500 visitors attended Pittsburgh's first Star Party held by the Amateur Astronomers Association in conjunction with the Pittsburgh Sun-Telegraph, on Flagstaff Hill, Schenley Park, the evening of August 1. While 25 telescopes were in use, the objects in focus were explained over the public address system by Dr. N. E. Wagman of Allegheny Observatory, Arthur L. Draper and C. V. Starrett of Buhl Planetarium, C. H. LeRoy, President of the Astronomical League, E. E. Lewis of the Sun-Telegraph, and operators of the telescopes.

Seven reels of sound motion pictures showing astronomical and related subjects contributed greatly to the success of the party. It was a successful inauguration of an annual affair.

* AFFILIATES WITH NATURE GROUPS. Battle Creek Amateur Astronomy Club voted to join the membership plan of the Kingman Museum where its meetings are held. The plan entitles them to Wild Life tickets, full participation in all educational activities sponsored by the Museum--Nature Club, Photographic Society, Amateur Astronomy Club--at dues of $1 for regular student, $1.25 senior student, $2.50 annual adult. The Kingman Museum in turn refunds $50 to the Club.

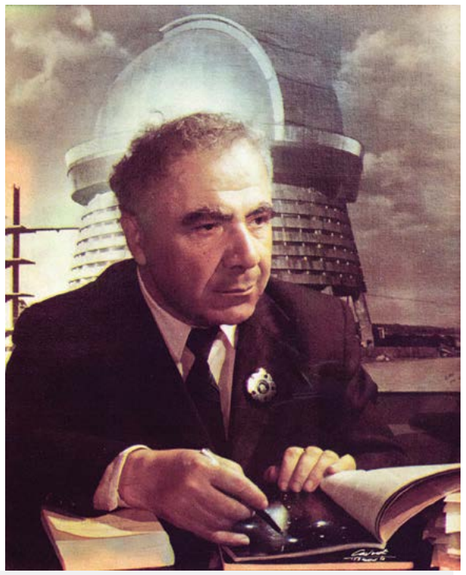
* FOR ADDITIONAL COPIES, send stamped envelope to Grace C. Scholz, Executive Secretary, 110 Schuyler Road, Silver Spring, Maryland.

VIKTOR AMBARTSUMIAN AND THE SCIENCE OF BYURAKAN

By Larry Mitchell

Armenia is not a country that most Westerners can pinpoint on a map of the world, nor are they aware of the many scientific accomplishments attributable to this country, located east of Turkey. Byurakan Astrophysical Observatory (BAO) is located near the village of Byurakan, located on the slope of Mount Aragatz, and home to one of the most prolific observatories in the world. It was founded in 1946 by Viktor Ambartzumian (1908–1996) and quickly became one of the main astronomical centers of what was then the USSR. Under Ambartsumian's guidance, Byurakan astronomers have been mainly concerned with the study of unstable and variable objects. Over the years the observatory has discovered thousands of galaxies, star clusters and stellar associations, flare stars, supernovae, Herbig-Haro objects, and nebulae. The largest telescopes have apertures of 2.6 and 1.0 meters.

Today, Viktor Ambartsumian is treated with reverence in Armenia as his contributions to astronomy are huge. He is less well-known in the West because many of his discoveries were made during the unfortunate Cold War. Ambartsumian got an early start by giving a lecture at Yerevan State University when he was only 16 years of age on Einstein's new theory of relativity. His first scientific article was published two years later in 1926. In 1930 he and Dimitri Ivanenko published a well-received paper demonstrating that atomic nuclei could not be made from protons and electrons, and two years later this was confirmed when neutrons were discovered. His 1958 textbook, *Theoretical Astrophysics,* became a classic, and solidified his reputation as a recognized expert in astrophysics, mathematics, and theoretical physics. He was a kind and modest man endowed with a great sense of humor, which won him many scientific friends worldwide. Ambartsumian was elected president of the International Astronomical Union from 1961 to 1964, at the height of the Cold War.



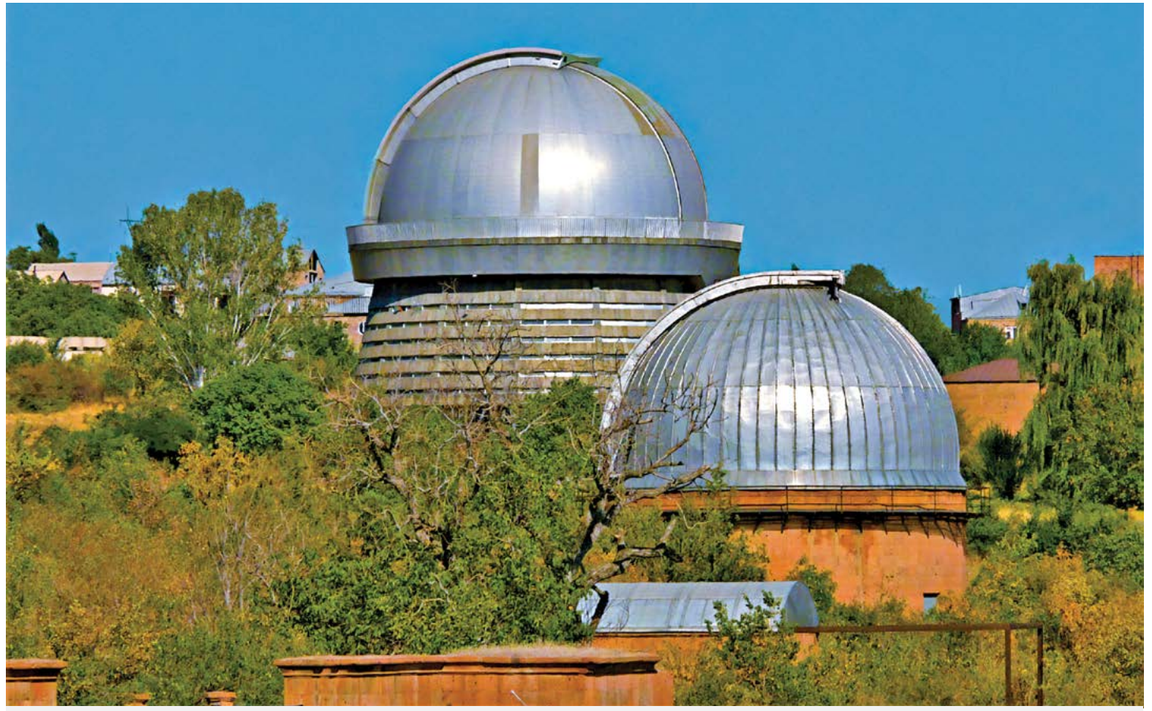
Victor Ambartsumian circa 1970s, unknown photographer, Wikimedia commons

While still in his twenties he reasoned that novae and planetary nebulae were expanding outward. Ambartsumian's 1932 paper, "On the Radiative Equilibrium of a Planetary Nebula," is today considered a cornerstone of the modern theory of gas nebula evolution. His first-ever evaluation of the gas mass ejected in the nebulae shells and the peculiarities of their spectra led to significant advances in stellar evolution. He was still a young man when his discoveries properly identified the changes in the life of a star. While the "established" astronomical community thought these nebulous structures were gravitationally collapsing, he boldly asserted that expansion, rather than contraction and condensation, were the "the basic evolutionary processes in the universe."

In 1947 Ambartsumian published a famous paper titled "The Evolution of Stars and Astrophysics" where he announced the discovery of a new type of astronomical system known as an OB or stellar association. Before his proposal, the predominant scientific opinion was that all stars were created simultaneously billions of years ago and they are currently only evolving. His proposal that new star formation is underway in the galaxy at the present time proved revolutionary in stellar cosmology circles, and he correctly stated these stellar associations were young, newly formed, and they were expanding. Proof of their youth was often the presence of nebulae and young massive stars which disintegrate in only about 10 million years.

This thought process led to his studies of flare stars, the physics of young stars and his concept of "protostars." He stated that protostars were super-dense protostellar matter in an early, unstable stage of star formation. He discovered that T Tauri stars produce Herbig-Haro objects, which are newly ejected material from the protostar. The T Tauri stage is short-lived and is followed by the star eventually settling down to become a main sequence star. He correctly reasoned that the formation of stellar associations owes itself to the disintegration of massive protostars. These were originally considered radical ideas, but they became universally accepted.

Ambartsumian is most widely known for his studies and discoveries in extragalactic

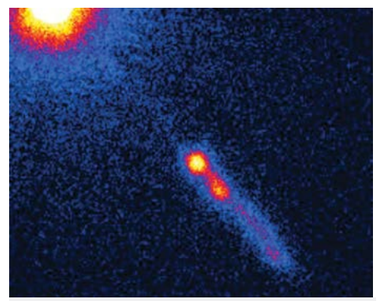


Part of Byurakan Observatory, Photo by Rita Willeart via Wikimedia Commons, Creative Commons Attribution 2.0 Generic License

astronomy. Before Ambartsumian, radio galaxies were thought to be the product of a collision, and the radio lobes were thought to be condensing inward. In 1956, he discovered that radio signals were coming from *outside* the Milky Way, the giant radio lobes could not happen due to the collision of two galaxies, and the lobes were expanding outward. He stated in his textbook *Theoretical Astrophysics* that radio galaxies may represent systems in close proximity that were formed from super-dense formations of stellar material. He did not say "black holes," a term not used until 1964, but he was getting close to the concept.

Before Ambartsumian, mainstream astronomy assumed that "spiral nebulae" (galaxies) were fully formed quiescent systems originating with the Big Bang, which had a rich past and they would not change radically in the future. These structures were composed of millions of stars and were therefore huge gravitational centers where absolutely nothing could escape. In 1908, Edward Fath of Lick Observatory discovered that some galaxies (for example, M77) had unusually bright central regions, and this was followed up by Carl Seyfert of McDonald Observatory in 1943 who wrote a paper about galaxies whose spectra contained bright and unusually broad hydrogen emission lines. These were indications that gas clouds within the nuclei of these galaxies attain record velocities; these objects became known as "Seyfert galaxies." However, Seyfert said nothing about the cause of this activity. In a series of papers beginning in 1954, Ambartsumian proved that an explosion is occurring in the nuclei of these galaxies. His theory was based upon a newly formed young object he discovered which he posited was ejected from the core of the spiral galaxy NGC 3561, as it is being ripped apart by its nearby massive elliptical galaxy, NGC 3561A. This object has become known as "Ambartsumian's Knot" and is the progenitor of a new class of galaxies known as blue compact dwarf (BCD) galaxies.

He presented his findings at the scientific Solvay Conference in Liege, Belgium, in 1958 and it caused a huge sensation. It took courage to present these ideas to a group of influential astronomers who he knew would reject any idea of the origin of galaxies in any formation process other than the Big Bang. Not only was he stating that galaxies actually eject material, but he also proposed that new galaxies are being formed in our time. Some of the leading astronomers of the day, Jan Oort, Allan Sandage, and Subrahmanyan Chandrasekhar, all rejected his ideas. However, when an optical quasar (3C 273) was discovered in 1963 and a jet 200,000 light-years long of material being ejected from the core was seen, they recognized that Ambartsumian had been right all along, congratulating him on his monumental discovery. Sandage later reflected that "today, not one astronomer would deny the mystery



Chandra X-ray image of the 3C273 quasar and its jet of ejected matter. When first observed in 1963, this object served to vindicate Ambartsumian's theory. Credit: NASA

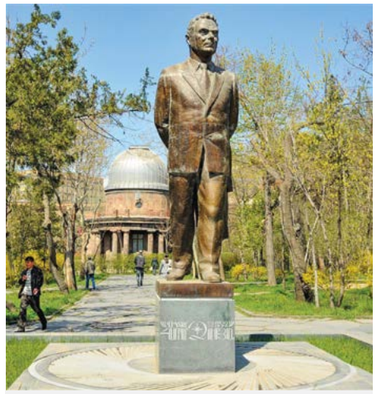
surrounding the nuclei of galaxies or that the first to recognize the rich reward held in this treasury was Viktor Ambartsumian." Today we know that this "active galactic nuclei" (AGN) phenomenon, which occurs in galaxies with active centers, is due to a feeding black hole or a super massive star-forming region.

As part of his explanation of what happens in the cores of Seyfert galaxies, Ambartsumian found that gas outflows were collimated bursts of material which sometimes formed young blue satellite objects, and that AGNs play a decisive role in the birth and evolution of galaxies. He also discovered that the emission of galaxies which contain AGNs frequently have an ultraviolet excess in their spectra. At the time, very few of these UV-excess objects were known, so he instructed Beniamin Markarian to conduct a prism survey for these objects, which he famously accomplished in a set of two surveys. In 2011 the Markarian Survey entered UNESCO's "Memory of the World" documentary heritage list.

Other areas in which Ambartsumian was active include the determination of the age of our galaxy, star formation in molecular clouds, the evolution of galaxies, pulsars, and studies of rarefied plasmas in gaseous nebulae. He wrote 20 books and booklets, published over 200 scientific papers, and was a member of 28 academies from all over the world. Every two years the $500,000 Viktor Ambartsumian Prize is awarded to an outstanding scientist from any country. Halton Arp recounts how Jan Oort once told him, "You know, Ambartsumian was right about absolutely everything." This true genius died in August 1996 in Byurakan and is buried next to the Grand Telescope tower.

A few words should be said about other BAO astronomers. Beniamin Markarian discovered in 1961 that the chain of galaxies emanating from M84 and M86 were gravitationally bound and became known as the "Markarian Chain" of galaxies. In doing so, he also discovered the heart of the Virgo Galaxy Cluster. He worked on the physics of stars and stellar clusters but is best known for his Markarian object surveys for UV-excess objects, conducted on the 1.0-meter Schmidt telescope. His first Byurakan survey lasted from 1965 to 1980 and was published in 1989. His second survey was conducted from 1978 to 1991 and published in 2005 after his death. He discovered 1,515 UV-excess galaxies, which became known as "Markarian galaxies," and to date over 2,500 professional papers have been devoted to these galaxies and stellar objects. Misha Kazarian extended the hunt for UV-excess galaxies which did not overlap Markarian's work, finding an additional 706 objects. Kazarian is also considered an expert in stars and nebulae and has published over 100 scientific papers.

Marat Arakelian was a brilliant astrophysicist who proved the extragalactic origin and evolution of quasars and analyzed approximately 800 faint galaxies and quasars. He published over 100 professional papers but is best known for his catalog of 621 Arakelian galaxies published in 1975. He wanted to know if there is a correlation between high surface brightness (HSB) galaxies and AGNs, and he proved there was. Unfortunately, Arakelian suddenly passed away at the height of his productivity at the young age of 54.



Statue of Ambartsumiam in Yerevan. Photo by Soghomon Matevosyan, Via Wikimedia Commons, Creative Commons Attribution-Share Alike 4.0 International license

A faint compact group of galaxies was found by Ambartsumian in 1957; these were so dim they were originally thought to be a faint compact group of stars. Ambartsumian instructed Romela Shahbazian to search for more of these objects. She examined over 200 Palomar Observatory Sky Survey (POSS) prints and discovered 377 of these groups, which came to be known as Shahbazian compact galaxy groups. They contain a high percentage of elliptical galaxies and are billions of light-years away.

Byurakan Astrophysical Observatory is also a center for the study of nebulae. In 1965, Elma Parsamian and Violetta Petrosian published a catalog of 106 cometary nebulae and Parsamian independently published a catalog of 534 hydrogen-alpha stars located within M42, the Orion Nebula. During her career she has published 136 professional scientific papers. Grigor Gurzadyan authored over 200 papers and ten books devoted to the structure of planetary nebulae, flare and binary stars, and gamma-ray repeaters. In the 1960s, Gurzadyan predicted the dynamics of magnetic fields within planetary nebulae, which were not officially discovered until 2005.

All of these people were inspired by the genius of Viktor Ambartsumian and today the discoveries continue. Areg Mickaelian, who has published over 300 scientific articles, is the director and lead scientist overseeing a huge curriculum, among which are the foundation of the IAU Regional Astronomical Center in 2015, the creation of the Armenian Virtual Observatory (ArVO) in 2005, and the well-attended regular Byurakan International Summer Schools for young researchers and students since 2006. The Byurakan Astrophysical Observatory may be the most prolific observatory for discoveries related to astronomy and theoretical astrophysics of any observatory anywhere in the world. ✶

The Megaconstellation Threat

By Dr. Paul A. Daniels, FRAS

Never since the launch of Sputnik 1 in 1957 has it been cheaper to make and launch satellites. It used to be the case that communication satellites were large and expensive to make and launch: typically 6,000–8,000 kg, costing $100–400 million to make and a similar amount again to launch. Those costs could only be borne by governments and large corporations.

Over time, more powerful launch platforms, such as SpaceX's Falcon 9 or Roscosmos' Proton M, capable of lifting larger payloads to orbit, arrived and further reduced the per-kilogram cost. The higher payload capacity coupled with the mass production of small, cheaper satellites led to the idea of constellations of multiple satellites being placed into orbit in one or more launches. A recent record was set by SpaceX for a single launch of 143 satellites of different types.

Exactly where the division between a constellation and megaconstellation lies is subjective, but a megaconstellation can be taken to mean several hundred or more similar satellites working as part of a single system. The sheer combined size of the several planned megaconstellations leads to a number of threats to astronomical observations.

TYPES OF ORBIT

Geocentric orbits can be divided into a few basic categories. Most traditional communications satellites are placed in a geosynchronous orbit (GEO) where they orbit at the same rate as the Earth rotates on its axis.

In GEO/GSO, a satellite can "see" about 40 percent of the Earth's surface, but the large distance requires more transmitter power. For GSO, the satellite's position is largely fixed in the sky and permits the use of fixed satellite dishes. Fewer satellites are needed for good coverage, with significantly fewer launches and less environmental impact. There is little to no impact on astronomy, a low collision risk, and they are easier to manage. However, there is greater financial risk at launch, additional design and engineering costs due to the long lifetime required, and "slots" in GSO are filling up.

In contrast, most low Earth orbit (LEO) constellations orbit the Earth every 1½ to 2 hours, can only see about 4 percent of the Earth's surface, but require less transmitter power. The satellites' rapid motion across the sky means receivers on the ground need complex phased-array antennae with beam-steering capabilities.

For GEO/GSO, the data's long round-trip takes about 250 milliseconds, but for LEO this is typically reduced to about 30 milliseconds. For streaming continuous, non-interactive data across the internet, for example, a Netflix film, this may not matter, but a GSO satellite solution won't work for time-critical communications operations, such as military use, banking, or gaming, where there's rapid back-and-forth data exchange.

TABLE 1. ORBIT CATEGORIES

DESCRIPTION	ABBR.	ALTITUDE(KM)[1]	ACTIVE SATELLITES[2]
High Earth Orbit	HEO	>35,786	18
Geosynchronous Earth Orbit Geostationary Earth Orbit	GEO GSO	35,786	560
Medium Earth Orbit	MEO	2,000-35,786	139
Low Earth Orbit	LEO[3]	<2,000	3,328
Elliptical		Varies	39

[1] Altitude refers to distance above the Earth's mean surface (not from the Earth's center).

[2] Operational satellite count correct up to April 30, 2021, UCS Satellite Database[1]

[3] Very Low Earth Orbit (VLEO) is sometimes used but the definitions vary and all have very different atmospheric drag considerations.

PROPOSED AND ACTIVE MEGACONSTELLATIONS

Table 2 shows the currently planned megaconstellations with those that are in early-stage planning shown in red. Some may not come to fruition but there will be others, still in planning, yet to be publicized. The total number of all such satellites *could* eventually grow to be several times greater than the size of the constellations proposed by SpaceX and most of the issues raised in this article will also apply to other satellite operators.

COLLISION AND EXPLOSION AVOIDANCE

Table 3 shows the current estimate of the amount of space debris orbiting the Earth. Adding thousands more satellites to LEO will dramatically increase the risk of collisions between satellites and debris. These collisions would then add to the debris and further increase the collision risk.

Even if the rate of collisions didn't reach the chain-reaction stage envisioned by Kessler and Cour-Palais in their 1978 research paper,[3] a few collisions could cause a temporary spike in the amount of debris sufficient to cause a lot of damage and to make both human habitation of space and additional launches extremely risky (insurance premiums could become prohibitive).

Similarly, precautions have to be taken to ensure that no part of the satellite might explode, for example, the battery, electronics, or pressurized gas components, as any collision or explosion might either directly cause an increase in the amount of orbital debris or cause the satellite to become "adrift" and/or unresponsive and so represent a threat of future collision.

TABLE 2: PROPOSED AND ACTIVE CONSTELLATIONS

COMPANY/COUNTRY	NO. PLANNED	ALTITUDE (KM)
SpaceX (USA)	16,518	325–350
Starlink	13,500	480–500
	11,908	515–580
Amazon (USA)	784	590
Kuiper	1,296	610
	1,156	630
Guo Wang (China)	3,600	508
	480	590
GW-A49	2000	600
	6,912	1,145
Samsung (Korea)	4,700	2,000
Boeing (USA)	3,116	1,030
Sat Revolution (USA)	1,024	350
Commsat (China)	800	600
Roscosmos (Russia)	640	870
AstromeTech (India)	600	1,400
Telesat (Canada)	512	~1,000
Others...	>2,000	550–1,500
European Union	?	?
OneWeb (UK)	6,325	1,200
	[2] 47,844	1,200
Lynk (USA)	Thousands?	500
TOTALS:		
(Excluding red) Total	**>47,853**	
(Including red) Total	**>>125,000**	

Clearly, failure to restrict or reduce the amount of orbital debris threatens the sustainable, long-term use of space. Satellite operators now have to give details of the end-of-life plan for satellites they plan to launch when applying for a license.

SpaceX and other operators wishing to operate in the United States have to provide the Federal Communications Commission with details of how they plan to remove defunct satellites from orbit once their mission life is complete or if they fail during service. Those in 290km orbits will re-enter, even if dead, in, at most, a few weeks due to atmospheric drag with little chance of collision because there are no active satellites that orbit at lower altitudes. However, re-entry from the higher LEOs due to drag alone could take decades or more, so reserved thruster fuel will have to be used to both reduce altitude and maneuver to avoid collisions on the way.

None of the above answers the problem of how to do that with a satellite that has become unresponsive. It's a requirement that all satellites are sufficiently protected against micrometeoroid or small debris impacts to prevent the systems required to complete a de-orbit from failing but such precautions aren't perfect.

REPLACEMENT SATELLITES AND THE ENVIRONMENT

The mission lifetime of a Starlink satellite is designed to be about 5 to 7 years. With current plans for about 12,000 Starlink satellites in orbit, that means approximately 150–200 of them will reach the end of their mission every month. If the total number eventually rises to 42,000, that will mean approximately 500–700 of them will need to be replaced every month.

The number of satellites re-entering each month and the number of launches to just maintain the number of satellites will have a serious impact[4].

POLLUTION FROM LAUNCHES AND RE-ENTERING SATELLITES

Starlink satellites that start in the interim 290 km check-out orbit take up to 45 days to transfer to a higher orbit, during which time they are significantly brighter than when in service. If there are 200 new satellites launched each month, that means up to 400 fairly bright satellites in the sky with the potential to affect both astronomical observations and the public view even *if* those in their target orbits do not.

Following the end of their useful mission, Starlink satellites will transfer to a low orbit prior to re-entry. During this time of transition there may be 200 or more satellites brighter than those at their target orbit.

SpaceX has said that, during the service time of the satellites, they will endeavor to orient the solar panels for minimum interference with ground-based observations. However, during the de-orbit phase the solar panels will be aligned to maximise atmospheric drag and this may not be optimal for reducing reflections.

PROBLEMS FOR ASTRONOMY

The pollution of the skies caused by megaconstellations of satellites will pose serious problems for both optical and radio astronomy, for professional and amateur astronomers, and for ground-based and orbiting observatories.

Optically, the very large number of satellites, when illuminated by sunlight, increases the risk of photographic images being spoiled by satellite trails, already being reported by both professional and amateur astronomers. Most professional observatories have a one-year embargo on the public release of their images so the amateur community and the public have been first to release images warning of the growing threat.

The damage to ground-based astronomy will be greatest for the wide-field camera telescopes such as the new Vera Rubin

TABLE 3: ESTIMATES OF SPACE DEBRIS

ESA ESTIMATES		NASA ESTIMATES	
>10 cm	34,000	Bigger than a softball	20,000
1 cm to 10 cm	900,000	Bigger than a marble	500,000
1 mm to 1 cm	128,000,000	Too small to track	>100,000,000

Telescope. Their large fields of view (FOV) means that it will be difficult to avoid trails and their sensitive CCDs mean the trails will likely be saturated and obliterate any chance to process images to recover the information that lies beneath the trail.

Images from orbiting telescopes, such as the Hubble Space Telescope (HST), are already being ruined by satellites passing through their FOV. A major advantage of an orbiting observatory is supposed to be that very long exposures are possible, but this advantage is now constrained by interference from LEO satellites, especially if the telescope is pointing to within a few degrees above the horizon.

Other recent research by Kocifaj and others[5] has assessed the growing contribution to the brightness of the night sky due to reflections and scattering from space debris. By averaging out the scattered light contribution from all the particles, they estimate there's been a 10 percent growth in night sky brightness (NSB). The authors warn that the number of planned megaconstellation satellites will increase the NSB further in the parts of the sky where debris is illuminated by sunlight.

For radio astronomers the problem is at least as bad: the satellites emit radio signals downward regardless of whether they're illuminated by sunlight. Given the sensitivity of radio astronomy telescopes and their receivers, it's the equivalent of a powerful downward-pointing searchlight!

Radio astronomy typically looks at specific emissions from celestial objects from, for example, H_2O, CO, or CN molecules. Some of these frequencies are protected for radio astronomy by the International Telecommunications Union (ITU) and satellite operators are not allowed to use those bands. However, the sources of those emissions are often not at rest relative to us and so those frequencies are (usually red-)shifted so that their signals may no longer be in a protected band.

SpaceX has said they will suspend their transmissions over the radio quiet zones (RQZs) that surround major radio astronomy installations, but that won't provide relief for radio observatories without statutory RQZs including the thousands of amateur radio astronomers. Whether other satellite operators will follow the same mitigation route remains to be seen. In addition, not only do all modulated radio transmissions produce side-bands (weaker signals at frequencies on either side of the principal frequency) but even well-designed antennae produce side lobes where some of the signal "leaks" in directions other than the antenna's aimed direction. There are also concerns about possible *unintended* transmissions from satellites produced by the digital noise of the satellite's own electronics.

To help mitigate the impact on astronomy, there will be online tools to help determine in advance the risk that an exposure of a given start time, duration, sky location, and FOV will be ruined by a satellite trail. It's also possible that a computer-controlled shutter could be used to interrupt the exposure for the duration of a satellite's passage through the FOV. With the large number of fast-moving Starlink and other LEO constellation satellites that will be crossing the sky, the opportunities for avoiding their pollution become almost vanishingly small.

SPACE LAW AND THE THREAT OF INTERNATIONAL TENSION

As with all big projects, there are supporters and detractors: those who see the megaconstellations as a sign of progress toward humans becoming space users and promoters of global internet access are very much in favor of the megaconstellations and what they will bring, but many in the astronomical community are outraged by the intrusion into their working domain and the pollution of what is seen by many as the common natural inheritance of all the people on Earth. There are some legal challenges, including on environmental grounds, to the megaconstellation satellites currently being launched, but they may be too little too late.

Sadly, there are few international treaties regarding the use of space. The principal one that has, until recently, stood the test of time is the non-armament *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies,* the Outer Space Treaty, OST, of 1967, signed by the United States, Soviet Union, United Kingdom, and sixty other countries, still in effect today (with extensions in 1968 and 1972).

The OST and its extensions agree there can be no claims of ownership of celestial bodies, that the exploration and use of outer space would be carried out for the benefit "of all mankind," that nations are liable for any damage caused by objects launched into space from their territories, and that all parties agree to conduct outer-space activities openly and in accordance with international law. Nations also have responsibility for controlling the activities of their own private operators.

The OST never foresaw the significant growth of satellite numbers in LEO that we've seen over the past few years and are planned for the next decades; it's over 50 years old and badly needs updating. A problem, however, will be getting the spacefaring nations to agree to sign an update. There have been other attempts at treaties since the OST that have failed to gain such agreement and it's possible (if not likely) that powerful nations, striving to gain dominance of LEO for commercial and military advantage, will only want to water down the terms of such an update so that they can continue to exploit and pollute our skies.

Space is increasingly seen as a commercial resource to be dominated and exploited and not as a commons through which the people of the world view the Universe. Humans will be increasingly present in space, working there and living there – let's not see the pollution of space lead to it becoming a risky environment for human habitation nor a new arena for human conflict. ✶

Paul Daniels, PhD, is a Fellow of the Royal Astronomical Society, and is president of the Federation of Astronomical Societies, in the UK. A longer version of this article was originally published last year in that organization's newsletter (fedastro.org.uk/newsletter/pdf/FAS_118%20v2.pdf). *The opinions expressed are solely the author's.*

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The Coolest Place

By Dave Tostesen

As I wrote this, the air temperature outside my house sat at –30°F. The wind chill factor would have made exposed skin feel as if it was –52°F. Just for fun I looked up the coldest spot on Earth for the week, including the scientific communities in Antarctica who were experiencing summer and thus only at –11°F, and that dubious honor went to Oymyakon in eastern Russia at –80°F. This rural community of 462 people in Siberia's Sakha Republic is known as the coldest *inhabited* place on our planet. In 1983 the Vostok station in Antarctica recorded –128.6°F, the coldest then recorded by humans at ground level. The dome that crowns the East Antarctic Ice Sheet peaks near the Vostok station, and satellite data in 2018 measured even colder temperatures, what Ted Scambos of the National Snow and Ice Data Center in Boulder, Colorado, believes are the coldest possible for our planet. In the dead of the southern hemisphere's winter, long after the Sun has stopped warming the area and conditions have wrung all the moisture out of the air that could trap any heat radiated by the frigid ice, temperatures fell to the lowest ever measured.

Near the crest of that dome, Scambos's team found nearly a hundred small pockets into which cold air could sink. Their readings were –137°F near human head-height at two meters above the surface, but right at ground level dipped to –144°F! The scientists speculated this record may stand for a long time, as Earth's and Antarctica's conditions are changing with increased atmospheric moisture and global warming. A similar scenario explains why the low elevation of Embarrass, Minnesota, often reports the coldest temperature in the lower forty-eight states. It sits in a depressed hollow in the northeastern corner of the state. My state's record low temperature is a comparatively balmy –60°F, endured in 1996 by the residents of Tower, Minnesota, just a few miles north of Embarrass.

Certain parts of space, mostly near stars, are very hot. In relation to things we can observe in the Universe, let's take a look at the range of things visible with known temperatures and finish with the coldest. Mercury has a minimal atmosphere and boasts 427°C daytime readings, which plunge to –180°C on the night side. Temperatures on our Moon vary by three hundred degrees Celsius: +127°C where the Sun shines and –173°C where it doesn't. There are special places on our satellite that show up much colder down the list.

Certain celestial bodies studied by Spitzer are brightest in the infrared, but radiate just enough light in the longer wavelengths to make them visible to amateurs. These are the "failed stars" known as brown dwarfs. A select few can be seen with large reflectors, such as 18th-magnitude LP 944-20. The coolest one found so far is CFBDSIR 1458+10, at the temperature of very hot coffee: 100°C. Comet Halley was visited by the Giotto spacecraft in 1986, and measured to be 77°C at 0.9 Astronomical Units (AU) from the Sun. At its aphelion in the Kuiper Belt, our most famous cometary visitor drops to –220°C, or just 53 degrees above absolute zero.

Oymyakon, reputedly the coldest inhabited place on Earth. Note buildings in foreground, barely visible through fog. Photo by Maarten Takens, via Wikimedia; CC Creative Commons Attribution-Share Alike 2.0 Generic license

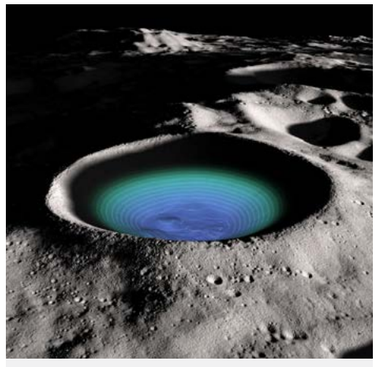
The impetus for this article was the polar vortex that swept down from the Arctic during the end of January 2019, what is on average our coldest week of the year. This cryovolution was impressively visible on NASA's satellite weather video. Climate change does not always mean warming, and the accelerating frequency with which both high and low temperature and rainfall records are being set show instability as a growing factor. The extremes of +159°F in the Iranian desert and –144°F in Antarctica span a range of more than 300°F, though the mean temperature of our planet is a livable 57°F (14°C). Mars carries an average temperature of –81°F (–63°C), and ranges from a high of 20°C to a low of –153°C. Now may be a good point in our journey to change to using only the Kelvin scale. One simply adds 273 to degrees Celsius (°C) to get kelvins (K); adding 459.67 to a Fahrenheit temperature and multiplying by 5/9 converts degrees Fahrenheit to kelvins. Saturn's largest moon, Titan, is an amazing world with liquid hydrocarbon rain and lakes, and water ice frozen hard as rock. Its atmosphere, thicker than ours, keeps it near a temperature of only 94 K. As amateurs we cannot visualize its surface because of the thick atmosphere, although the moon itself is easily spotted in a small telescope. Our imaginations have been fueled by pictures taken by the Huygens lander that accompanied Cassini. Mercury's night side has a temperature only one degree colder.

Clyde Tombaugh's discovery, 14th-magnitude Pluto, is now a body known to be tectonically active and that hosts a variegated,

Pluto, photo from the New Horizons mission. Credit: NASA/JHUAPL/SwRI

beautifully detailed surface we can appreciate and study thanks to the decades-long planning and execution of the New Horizons team. Its distance three times beyond Titan makes it that much colder, at 40–50 K. Evidence of former crustal motion of substances that would be soft or liquid much closer to the Sun mark an almost eerie circumstance that borders between the familiar and the totally alien.

The next coldest place in our exploration is not one more distant, as we might expect, but somewhere very near to us. The poles of our Moon have places deep within certain craters that have not seen Sunlight for over two



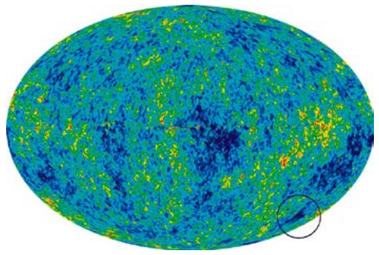
The Moon's crater Shackleton, near the Lunar South Pole and never illuminated within. The color codes for temperatures down to 33 K. Credit: NASA Scientific Visualization Studio

billion years. Areas estimated to cover about three percent of the Moon's southern polar region that are permanently shadowed have been found to contain water ice, an important discovery for future explorers. Without solar energy they stay at a frigid 33 K.

In the early 2000s, the race was on to find bodies in the Kuiper Belt beyond Pluto. These searches have been very successful, and two of the largest found to date are Eris and Sedna. I spotted 19th-magnitude Eris with my 32-inch scope from the 2006 Okie-Tex Star Party; this dwarf planet varies between 56 and 30 K depending on the position within its elliptical orbit. Sedna is farther out, fainter, and much darker than Eris. I was within a few arcseconds of seeing it several years ago from Okie-Tex, but needed a better ephemeris to nail it down. Stars right around it of the same magnitude (20.5) were visible in my large reflector, and someday I may be certain of its observation. It is presently 80 AU from the sun, near its 2075 perihelion in its 11,400-year orbit, and at a chilly 12–23 K.

There are colder places in our Solar System, such as the outer Kuiper Belt and the Oort Cloud, but no objects have been found there that we can observe with amateur equipment. So that leaves us with just a few things to see on our quivering quest. About 380,000 years after the Big Bang, the temperature of the expanding Universe had cooled to the point where recombination of protons and electrons from previously ionized hydrogen atoms produced photons. These photons have been traversing space ever since, stretched in wavelength by its expansion. They are now in the microwave portion of the spectrum, with a temperature of 2.73 K. The unevenness, or anisotropic nature, of this radiation at about one part in a hundred thousand has given us tremendous information about the structure and dynamics of the early Universe. Though not visible directly, old style television monitors with "rabbit-ear" antennas pick up the signals, with a significant fraction of their "fuzz" attributable to the cosmic microwave background radiation (CMBR). What things could be colder than that? There are apparently two.

Three satellites have measured the CMBR, each with a successive improvement in resolution. The latest is Planck, and it released data in 2015 showed larger areas of nonuniformity within the general fine-grained nonuniformity. The overall agreement of the initial data with theory was astounding, but several areas of the sky exceeded the average deviation of 18 microkelvins born of quantum fluctuations at the time of the Big Bang. The largest of these cooler areas was in the direction of Eridanus, and found to be 70 microkelvins below the mean CMBR temperature.



Map of the cosmic microwave background, with the "cold spot" circled. Perhaps surprisingly, this is not the coolest place in the known Universe. Credit: WMAP Science Team, NASA

So is that it? Is that the coldest spot in the Universe, at barely colder than the CMBR? Surprisingly, the answer is no. But what could possibly be more frigid than empty space? Something would have to be actively cooling an object to achieve this state. Think of your refrigerator or air conditioner. Chemicals that efficiently absorb heat, when expanded in a low-pressure environment, remove energy and heat from a system to cool it. As with the hottest temperature found at the Large Hadron Collider, the coldest artificially produced temperatures are in man-made laboratories. In 1995 Wolfgang Ketterle and his team produced a new state of matter when they used magnetic fields to hold atoms steady in a refrigerated module, getting the temperature to an almost unfathomable less than one billionth of a kelvin. This fifth state of matter, called a Bose-Einstein condensate, garnered them the 2001 Nobel Prize in Physics. It took the zero-gravity environment of the International Space Station to best this record. With magnetic containment easier to maintain sans Earth's pull, researchers in the Cold Atom Lab of the ISS produced a temperature of only one ten-billionth of a kelvin. In the *natural* world, the place with the lowest recorded temperature was found, paradoxically, within an object produced by the hottest stars in the Universe.

When medium-size stars like our Sun near the end of their lives, their cores become so hot their outer layers greatly expand, and they evolve into red giant stars. Eventually these layers are lost to the interstellar medium as wondrous varieties of structure known as planetary nebulae. In most cases this outflow of gas is relatively sedate and well-behaved, but in one pre-planetary nebula in southern Centaurus near its border

At 1 K, The Boomerang Nebula, LEDA 3074547, is the coolest natural place in the known Universe. Photo: NASA

with Crux there has been a puzzle for over two decades about why it was so cold. Discovered by researchers in Australia in 1980, the Boomerang Nebula was imaged by Hubble in the 1990s and found to be a beautifully symmetric bipolar object. The Swedish-ESO Submillimeter Telescope (SEST) measured its temperature at one kelvin, much lower than the CMBR, and no one could explain the reason. Present-day researchers, including a group headed by Raghvendra Sahai, used another Chilean telescope, the Atacama Large Millimeter Array (ALMA) that sits atop the Chajnantor plateau east of San Pedro, to discover several features that explain this cosmic cooler.

The nebula that surrounds this unique object is much larger than what was initially seen in visible light. It now extends to 120,000 AU, six times greater than previous estimates, and is expanding at a rate ten times faster than thought possible. Theorists suggest the system was initially a close binary, but the enlargement of the red giant's outer envelope caused its companion to be caught within its outer layers, lose momentum, and plunge into the other star, vigorously ejecting its outer material. The speed and force of this expansion is what's cooling it to less than half a kelvin. Its extremely low temperature helped us recognize this rare object, and the process that allows this cooling is thought to be a short phase in the life of a star becoming a planetary nebula. For observers at northern latitudes, its –54° declination makes it a difficult quarry. From my most southerly regular observing site of the Texas Star Party it just skims the mountaintops that define the southern horizon, and would have to be caught near culmination between peaks. But either there or in the Atacama, it would be a chilly highlight to glimpse the coolest place in the Universe. ✶

GALLERY

Images © their respective creators, 2021.

Left page top: ***Steven Bellavia*** *(Amateur Observers' Society of New York) captured this image of the Soap Bubble Nebula (PN G75.5+1.7) using a William Optics FLT 91 Triplet with a ZWO ASI294MM Pro camera.*

Left page bottom: ***Terry Hancock*** *(Western Colorado Astronomy Club) captured this image of IC 1396 from Grand Mesa Observatory using a Takahashi FSQ-130 with a QHY600 CMOS camera.*

This page top: ***Bernard Miller*** *(East Valley Astronomy Club) took this image of the Draco Trio with a PlaneWave 17-inch CDK and a FLI ProLine 16803 CCD camera.*

This page bottom: ***David Elmore*** *(Longmont Astronomical Society) captured this dusty wide-field image of M45 from his Dark Sky New Mexico observatory using a Vixen VSD 100 f/3.8 astrograph with a ZWO ASI6200MM Pro CMOS camera.*

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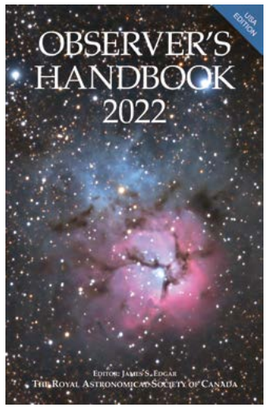

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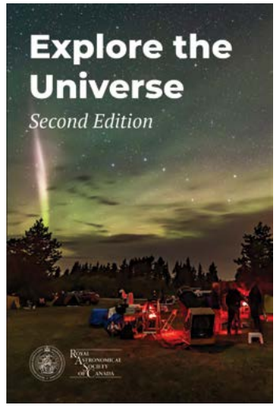

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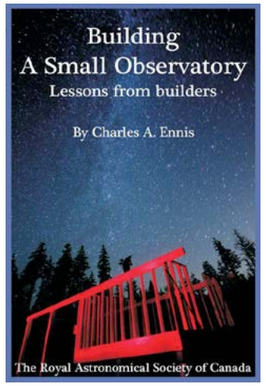

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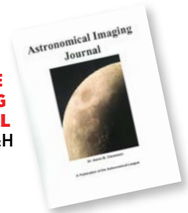

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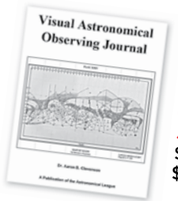

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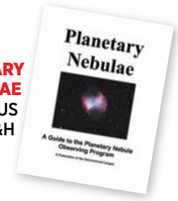

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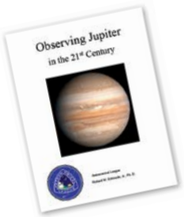

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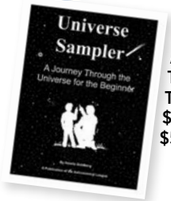

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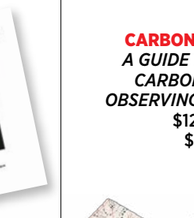

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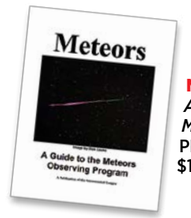

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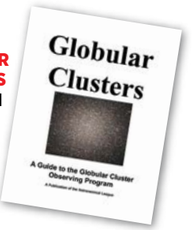

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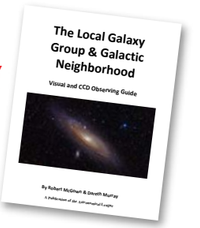

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No. 129, **Brook Belay,** Atlanta Astronomy Club

Citizen Science Special Program

Laurie Ansorge, Member-at-Large, Active Bronze, AstroQuest; **Marie Lott,** Atlanta Astronomy Club, Active Bronze, SuperWASP Variable Stars; **Brad Young,** Astronomy Club of Tulsa, Observational Gold, Class 18, Trusat EOS; **Pete Hermes,** Tucson Astronomical Association, Active Gold, Class 16, Gravity Spy; **Pete Hermes,** Tucson Astronomical Association, Active Gold, Class 30, Supernova Hunters; **Pete Hermes,** Tucson Astronomical Association, Active Gold, Class 2, Disk Detective; **Pete Hermes,** Tucson Astronomical Association, Active Gold, Class 2, Backyard World; **Pete Hermes,** Tucson Astronomical Association, Active Gold, Class 13, Planet Four Ridges; **Pete Hermes,** Tucson Astronomical Association, Active Gold, Class 10, Milky Way Project; **Dan Crowson,** Astronomical Society of Eastern Missouri, Active Gold, Class 4, Supernova Hunters; **Dan Crowson,** Astronomical Society of Eastern Missouri, Active Bronze, Dark Energy Explorer; **Dan Crowson,** Astronomical Society of Eastern Missouri, Active Gold, Class 1, Asteroids; **Dan Crowson,** Astronomical Society of Eastern Missouri, Active Bronze, Star Notes; **Dan Crowson,** Astronomical Society of Eastern Missouri, Active Gold, Class 1, Cosmological Jellyfish; **Anthony J. Kroes,** Neville Public Museum Astronomical Society, Active Gold, Class 16, Nova; **Al Lamperti,** Delaware Valley Amateur Astronomers, Active Gold, Class 10, Cosmological Jellyfish; **Al Lamperti,** Delaware Valley Amateur Astronomers, Active Gold, Class 48, Star Notes; **Al Lamperti,** Delaware Valley Amateur Astronomers, Active Gold, Class 8, Active Asteroids; **Rich Krahling,** Richland Astronomical Society, Active Gold, Class 7, SuperWASP Variable Stars

Comet Observing Program

No. 52, **Mark Bailey,** Gold, Member-at-Large;
No. 53, **Mark Simonson,** Gold, Everett Astronomical Society; No. 54, **Doug Bock,** Gold, Warren Astronomical Society; No. 120, **Brad Payne,** Silver, Northern Virginia Astronomy Club; No. 121, **Steve Boerner,** Silver, Member-at-Large

Constellation Hunter Northern Skies Observing Program

No. 271, **Viola Sanchez,** Albuquerque Astronomical Society; No. 272, **Conal Edwards,** Youth Member-at-Large; No. 273, **David Berish,** Greater Hazleton Area Astronomical Society; No. 274, **Peter Hermes,** Tucson Amateur Astronomers Association

Dark Nebulae Observing Program

No. 35, **Paul Harrington,** Member-at-Large;
No. 36, **Jeffrey Corder,** Ancient City Astronomy Club

Deep Sky Binocular Observing Program

No. 426, **Sean Smith**, Denver Astronomical Society;
No. 427, **István Mátis,** Member-at-Large;
No. 428, **Dan Chrisman Jr.,** Roanoke Valley Astronomical Society;
No. 429, **Mark Colwell,** Member-at-Large

Double Star Observing Program

No. 679, **John Strebeck,** St. Louis Astronomical Society; No. 680, **Nicholas Broman,** San Bernadino Valley Amateur Astronomers; No. 681, **Paul Olson,** Member-at-Large; No. 682, **Michael Grabner,** Rose City Astronomers; No. 683, **Jarret Lingle,** Member-at-Large; No. 684, **Ronan Kerr,** Austin Astronomical Society; No. 685, **Dan Crowson,** Astronomical Society of Eastern Missouri; No. 686, **Lewis Cason,** Lowcountry Stargazers

Flat Galaxy Observing Program

No. 40-H, **Steve Boerner,** Member-at-Large;
No. 41-H, **Mark Bailey**, Member-at-Large;
No. 42-H, **Jeffrey Corder,** Ancient City Astronomy Club

Foundations of Imaging Observing Program

No. 3, **Steve Boerner,** Member-at-Large;
No. 4, **Daniel Beggs,** Albuquerque Astronomical Society

Galileo's TOES Observing Certificate

Michael Hotka, Longmont Astronomical Society;
István Mátis, Member-at-Large

Globular Cluster Observing Program

No. 365-V, **Jeffrey S. Moorhouse,** La Crosse Area Astronomical Society; No. 366-I, **Alan Sheidler,** Popular Astronomy Club; No. 367-V, **Mark Colwell,** Member-at-Large; No. 368-V, **Richard Wheeler,** Northeast Florida Astronomical Society; No. 369-V, **Viola Sanchez,** Albuquerque Astronomical Society

Herschel 400 Observing Program

No. 633, **Daniel Beggs,** Albuquerque Astronomical Society; No. 634, **Tim Printy,** New Hampshire Astronomical Society; No. 635, **Sam Finn,** Central Pennsylvania Observers; No. 636, **Richard Wheeler,** Northeast Florida Astronomical Society; No. 637, **Steven Powell,** Houston Astronomical Society

Herschel Society

No. 15, **Matt Orsie,** Silver, Tri-State Astronomers

Herschel II Observing Program

No. 114, **Mark G. Bailey,** Device-aided, Member-at-Large

Lunar Evolution Observing Program

No. 16-I, **Paul Harrington,** Member-at-Large;
No. 17, **Brook Belay,** Atlanta Astronomy Club

Lunar Observing Program

No. 1148-B, **Viola Sanchez,** Albuquerque Astronomical Society; No. 1149-B, **Becky Ramotowski,** Albuquerque Astronomical Society; No. 1150, **Larry Bloom,** Longmont Astronomical Society; Nos. 1151 and 1151-B, **Jill Sinkwich,** Member-at-Large; Nos. 1152 and 1152-B, **Stephen Pavela,** La Crosse Area Astronomical Society; Nos. 1153 and 1153-B, **Michael James Vlcek,** Omaha Astronomical Society; Nos. 1154 and 1154-B, **James Goodwin,** Member-at-Large; Nos. 1155 and 1155-B, **Trena Johnson,** Minnesota Astronomical Society

Lunar II Observing Program

No. 121, **Robert J. Olson**, Member-at-Large

Mentor Awards

Michael A. Hotka, Denver Astronomical Society;
Dennis O'Day, Northeast Florida Astronomical Society

Messier Observing Program

No. 2799, **Gary Dietz,** Honorary, Astronomy Enthusiasts of Lancaster County; No. 2846, **Rick Ginanni,** Honorary, Greater Hazleton Area Astronomical Society; No. 2857, **Clariza E. Kern,** Honorary, Pontchartrain Astronomy Society; No. 2864, **Jason Wolfe,** Regular, Member-at-Large; No. 2865, **Michael Shaw,** Honorary, Atlanta Astronomy Club; No. 2866, **Mary Warren,** Regular, Ancient City Astronomy Club; No. 2867, **Michael K. Butler,** Regular, Member-at-Large; No. 2868, **István Mátis,** Honorary, Member-at-Large; No. 2869, **Wayne E. Frey,** Honorary, Central Florida Astronomical Society; No. 2870, **David Cooper,** Honorary, The Astronomy Connection; No. 2871, **Kelsey Yocum,** Honorary, Rose City Astronomers; No. 2872, **Angele Mott-Nickerson,** Honorary, Rose City Astronomers; No. 2873, **Viola Sanchez,** Honorary, Albuquerque Astronomical Society; No. 2874, **Chris Westphal,** Honorary, Northeast Florida Astronomical Society; No. 2875, **Mike Napper,** Honorary, Northeast Florida Astronomical Society; No. 2876, **John McLaren,** Regular, Seattle Astronomical Society

Meteor Observing Program

No. 76, **Steve Sauerwein,** 30 hours, Member-at-Large; No. 183, **Mark Colwell,** Honorary 76, Member-at-Large; No. 191, **Gregory T. Shanos,** 24 hours, Museum Astronomical Resource Society; No. 203, **Richard Benson,** Honorary 74, Member-at-Large; No. 204, **Lindsey Benson,** Honorary 75, Youth Member-at-Large

Multiple Star Observing Program

No. 10, **Steve Boerner,** Member-at-Large

Nova Observing Program

No. 14, **Peter K. Detterline,** Gold, Member-at-Large; No. 15, **Anthony J. Kroes,** Gold, Neville Public Museum Astronomical Society; No. 16, **Terry N. Trees,** Silver, Amateur Astronomers Association of Pittsburgh

Open Clusters Observing Program

No. 99, **Steve Boerner,** Basic Imaging, Member-at-Large; No. 100, **Jeffrey Padell,** Advanced Imaging, Skyscrapers, Inc.

Outreach Observing Award

Nos. 45-S and 45-M, **Dennis O'Day,** Northeast Florida Astronomical Society; Nos. 632-S and 632-M, **Bernard Venasse,** Lifetime Member; No. 1098-S, **Michael Napper,** Ancient City Astronomy Club and Northeast Florida Astronomical Society; Nos. 1226-O, 1226-S, and 1226-M, **George A. Reynolds,** Back Bay Amateur Astronomers; Nos. 1227-O, 1227-S, and 1227-M, **Ronan Kerr,** Austin Astronomical Society; No. 1228-O, **Byron Davies,** Popular Astronomy Club; No. 1229-O, **Hugh Holt,** Popular Astronomy Club; No. 1230-O, **Wanda Gacioch,** Popular Astronomy Club; No. 1231-O, **Paul Levesque,** Popular Astronomy Club; No. 1232-O, **Tim Holt,** Popular Astronomy Club; No. 1233-O, **Mike Gachoch,** Popular Astronomy Club; No. 1234-O, **Trena Johnson,** Minnesota Astronomical Society

Planetary Nebula Program

No. 2, **Steve Boerner,** Advanced Southern Imaging, Member-at-Large; No. 91, **Jeff Hoffmeister,** Advanced Manual, Olympic Astronomical Society; No. 92, **Brian Cudnik,** Advanced, Houston Astronomical Society; No. 93, **Michael Myer,** Astronomical Society of Kansas City

Radio Astronomy Observing Program

Nos. 31-B and 24-S, **Eric Edwards,** Albuquerque Astronomical Society; Nos. 32-B, 25-S, and 13-G, **Steven Powell,** Houston Astronomical Society; Nos. 33-B, 26-S, and 12-G, **Rodney R. Rynearson,** St. Louis Astronomical Society; No. 14-G, **Brad Payne**, Northern Virginia Astronomy Club

Sketching Observing Program

No. 48, **William Castro,** Central Florida Astronomical Society; No. 49, **Alfred Schovanec,** Astronomical Society of Eastern Missouri

Solar System Observing Program

No. 177, **Viola Sanchez,** Albuquerque Astronomical Society; No. 178, **Juan Velasquez,** Denver Astronomical Society; Nos. 179 and 179-B, **Jim Hontas,** Cincinnati Astronomical Society; No. 180-B, **Michael A. Hotka,** Longmont Astronomical Society

Sunspotter Observing Program

No. 200, **Karl A. Schultz,** Central Arkansas Astronomical Society; No. 201, **Brad Payne,** Northern Virginia Astronomy Club; No. 202, **Nikolay Kurtov,** Member-at-Large; No. 203, **Jeffrey A. Corder**, Ancient City Astronomy Club

Two in the View Observing Program

No. 46, **Rick Olson,** Rose City Astronomers; No. 47, **Kevin Nasal**, Neville Public Museum Astronomical Society; No. 48, **David Whalen,** Atlanta Astronomy Club; No. 49, **Bruce Bookout,** Colorado Springs Astronomical Society

Universe Sampler Observing Program

No. 156-T, **Ronald Birkhoff,** Telescope, Houston Astronomical Society

Urban Observing Program

No. 226, **Eric Edwards,** Albuquerque Astronomical Society; No. 227, **Ronan Kerr,** Austin Astronomical Society; No. 228, **Viola Sanchez,** Albuquerque Astronomical Society

Variable Star Observing Program

No 51, **Kevin McKeown,** Albuquerque Astronomical Society

Master Observer Progression

OBSERVER AWARD

Kevin Nasal, Neville Public Museum Astronomical Society

MASTER OBSERVER AWARD

No. 244, **Scott Cadwallader,** Baton Rouge Astronomical Society; No. 245, **Daniel Beggs,** Albuquerque Astronomical Society

MASTER IMAGER AWARD

Steve Boerner, Member-at-Large

BINOCULAR MASTER OBSERVER AWARD

Jim Hontas, Cincinnati Astronomical Society

MASTER OBSERVER AWARD – GOLD

Charles E. Allen III, Evansville Astronomical Society

Membership Secretary
Astronomical League
National Office
9201 Ward Parkway, Suite 100
Kansas City, MO 64114

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