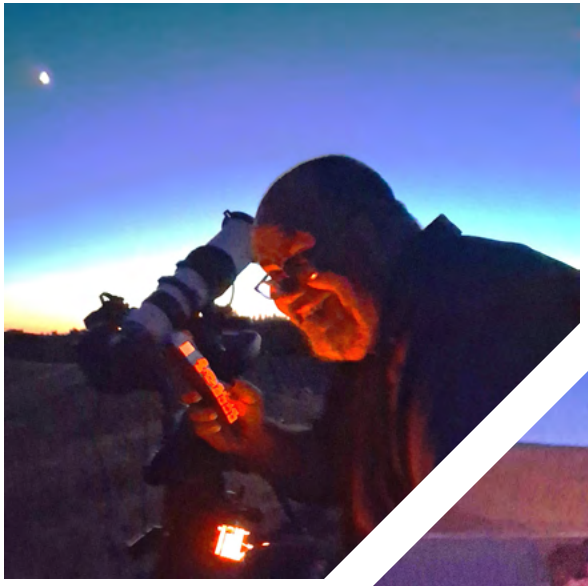
AOH Newsletter

Autumn 2025

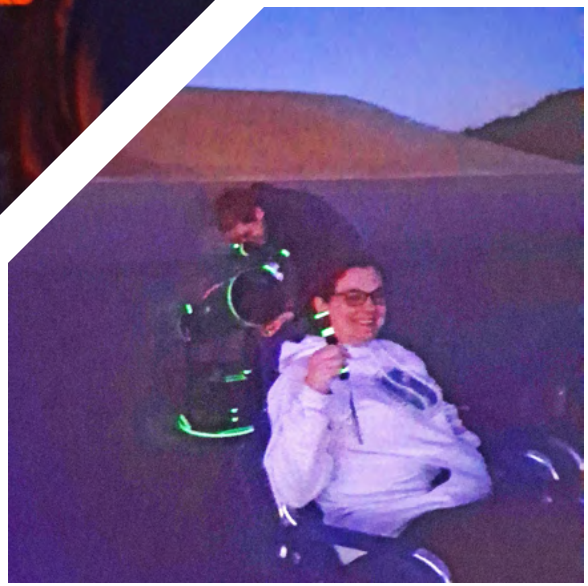
News and Notes

Kneeland, June



At Kneeland on June 28, we finally broke this year's string of consecutive observing cancellations.

Left: Oliver setting up his scope and camera. —KY



Right: Allison helping (?) Johann align the finderscope on their Dob. —KY

Albee Creek 1

The first 2025 Albee Creek Star Party was held July 5. There were over 200 people in attendance.

Above: Looking at the Moon in daylight. —GDW

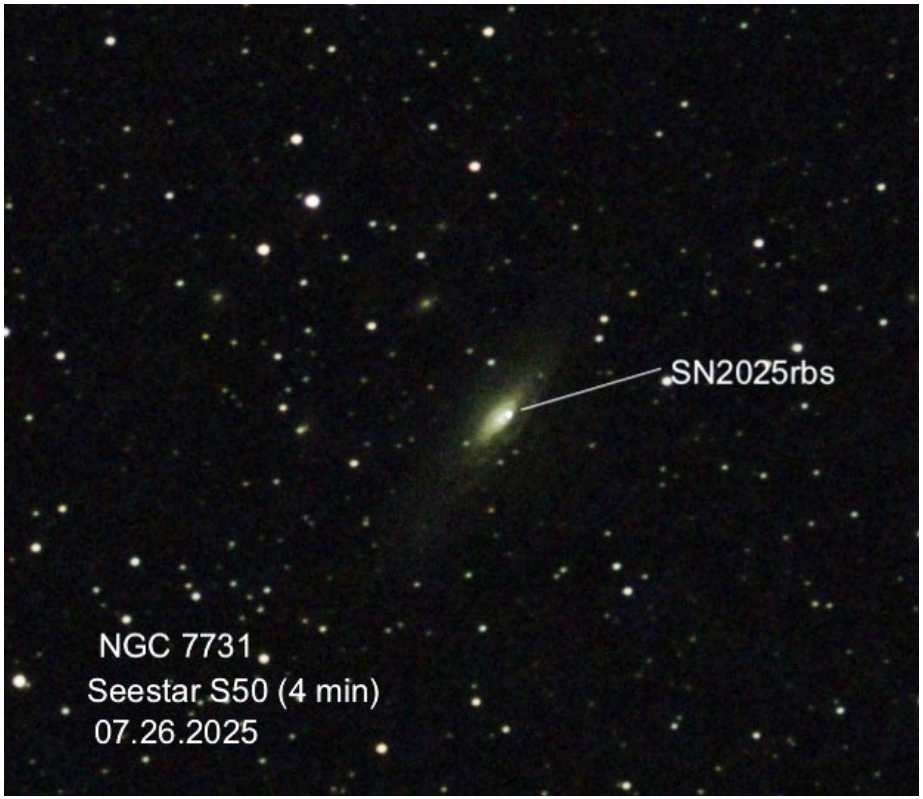
Right: Jeff sharing a look through his Dob; two of the HRIA volunteers who were there to help out. —GDW

Kneeland, July

Back at Kneeland on July 26, we had twelve club members and four guests enjoying a nice dark sky. We had good seeing and a couple of Seestars in action. The photos here are from Grace and Jeff.

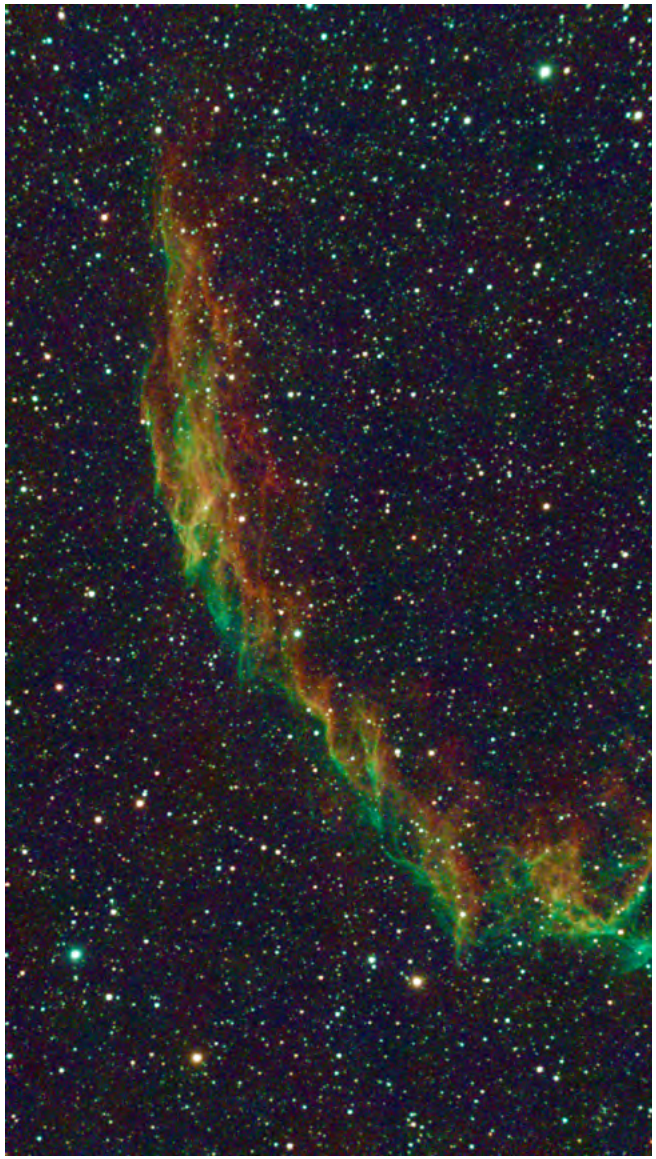
Far left: The two-day-old Moon was just setting as the sky got dark. —GDW

Near left: A set of 5's. The globular cluster is M5 in Serpens. The foreground star, by coincidence, has designation 5 Serpentis. And by a further coincidence, the star happens to have visual magnitude 5. —GDW



Bottom left: A supernova occurred in Galaxy NGC 7731. Grace photographed it during our meeting. See her article beginning on page 10. —GDW

Right: The supernova remnant NGC 6992 is part of the Veil Nebula, which is 2400 light-years distant, and forms a shell 130 light-years in diameter. Seestar stacked 229 10-second images. —JS



Albee Creek 2

The second Albee Creek Star Party on August 2 was attended by 320 visitors, who enjoyed views of the first quarter Moon and various multiple star systems and star clusters. Later on the group was entertained by Allison's excellent constellation tour.

Top row: Susan C. showing Seestar views of the Moon; families lining up for a look through Ken's Dob; early arrivals studying the Moon while awaiting their turn at the telescopes. —KY

Bottom row: one of the HRIA volunteers setting up; Mark giving a welcome talk to the visitors. —KY

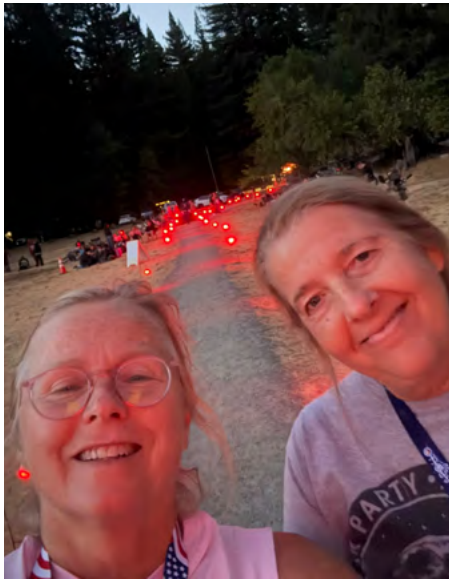
Kneeland, August

On August 23 we held our annual work party at Kneeland Observatory. Thanks to all who participated.

We applied rags and brooms to clear out accumulated debris. Later we brought out our picnic dinners and enjoyed the good food and good company. —KY

Albee Creek 3

The third Albee Creek Star party of the summer gathered 378 visitors. We looked at the Moon, Saturn, and many deep space objects like the Hercules Star Cluster (M13), the Owl Cluster, the Ring Nebula, and the Double Cluster, to name a few. As usual, Allison gave a great constellation talk.



Clockwise from above:

Astronomers of all ages had a good time. —GDW

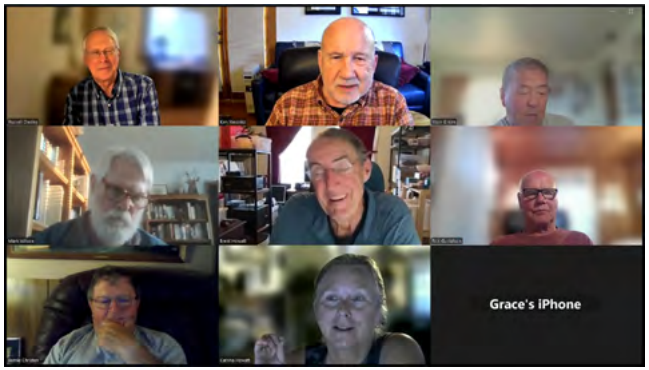
Big girls had fun too. —CWH

And a Baby Yoda fan came out to see the sky. —GDW

And other species were interested.—CWH

Zoom Meetings

We continued our monthly online get-togethers in between our observing sessions. This gives us an opportunity to exchange news, ideas, and plans. (Sometimes it's even about astronomy!) Below are Allison, Bernie, Brent, Catrina, Chris, Grace, Greg, Johann, Ken, Mark, Mary, Rick, Roger, Russ, and Yoon.



Outreach at Three Rivers

Roger and Susan went to Three Rivers Charter School in late June and spoke about the Sun, handed out astronomy stickers and book markers, and looked through a telescope at the sun. The students also colored their favorite planets on the sidewalk and looked at the Sun on the Seestar app. There were about 17 students.

Above: Roger in the classroom and at the telescope.
—SC.

Left: kids drawing planets on the sidewalk.
—SC.

Outreach at Cal Poly

Brent, Catrina, Mark, Russ, Grace, Yoon, and Ken went to the CPH Natural History Museum summer day camp in August for solar system studies. The kids learned about the planets and made planet masks. Then they went outside and learned about safe solar viewing and got to view sunspots and prominences. There were 18 students.

Left: Russ and Brent help the kids view the Sun in both white light and hydrogen-alpha light. —KY.

Below: The planets gathering around the Sun at the end of the lesson. —KY.

Upcoming: International Observe the Moon Night

International Observe the Moon Night is an annual world-wide public engagement program that encourages observation, appreciation, and understanding of our Moon and its connection to NASA planetary science and exploration. Everyone on Earth is invited to join the celebration.

AOH will be hosting an official event once again this year. The event will be "virtual"—any time from September 27 through October 11. Anyone can participate by going online to https://www.astrohum.org/moon.

All you will have to do is observe the Moon, take a photo or make a sketch, and submit your picture together with a brief report. All participants will receive an official certificate from the IOMN Coordinating Committee.

Upcoming: College of the Redwoods Science Night

AOH will participate in this annual event which is scheduled this year for October 3 from 5 to 8 pm. We will need half a dozen volunteers to set up and oversee our displays. No experience or expertise is necessary. Contact Brent if you would like to help out.

Upcoming: Kneeland School Trunk or Treat

AOH will participate in this event on October 26 at Kneeland School from 3 to 6 pm. We'll set up a scope or two for the crescent moon and hand out astronomical treats. Contact Brent if you would like to help out.

Upcoming: General Membership Meeting

Watch your inbox for announcements about nominations and elections for the Board of Directors and the general membership meeting (and pizza party) on November 8.

Outreach in the Press

AOH member Barry Evans writes a regular column for the North Coast Journal. The August 14 installment was about Deimos and Phobos, the moons of Mars. The article is available at https://www.northcoastjournal.com/life-outdoors/the-moons-of-mars-33618833.

Other News

On August 19 the Humboldt County Board of Supervisors approved an ordinance strengthening the county's dark-sky regulations. The text of the ordinance can be found at https://humboldt.legistar.com/View.ashx?M=F&ID=14598193&GUID=23D48D53-55E6-42CE-BF31-4D3C5F2C9A40.

Thanks

... to this issue's contributors: Allison, Catrina, Grace, Jeff, Susan C, and Susan F.

—*Ken*

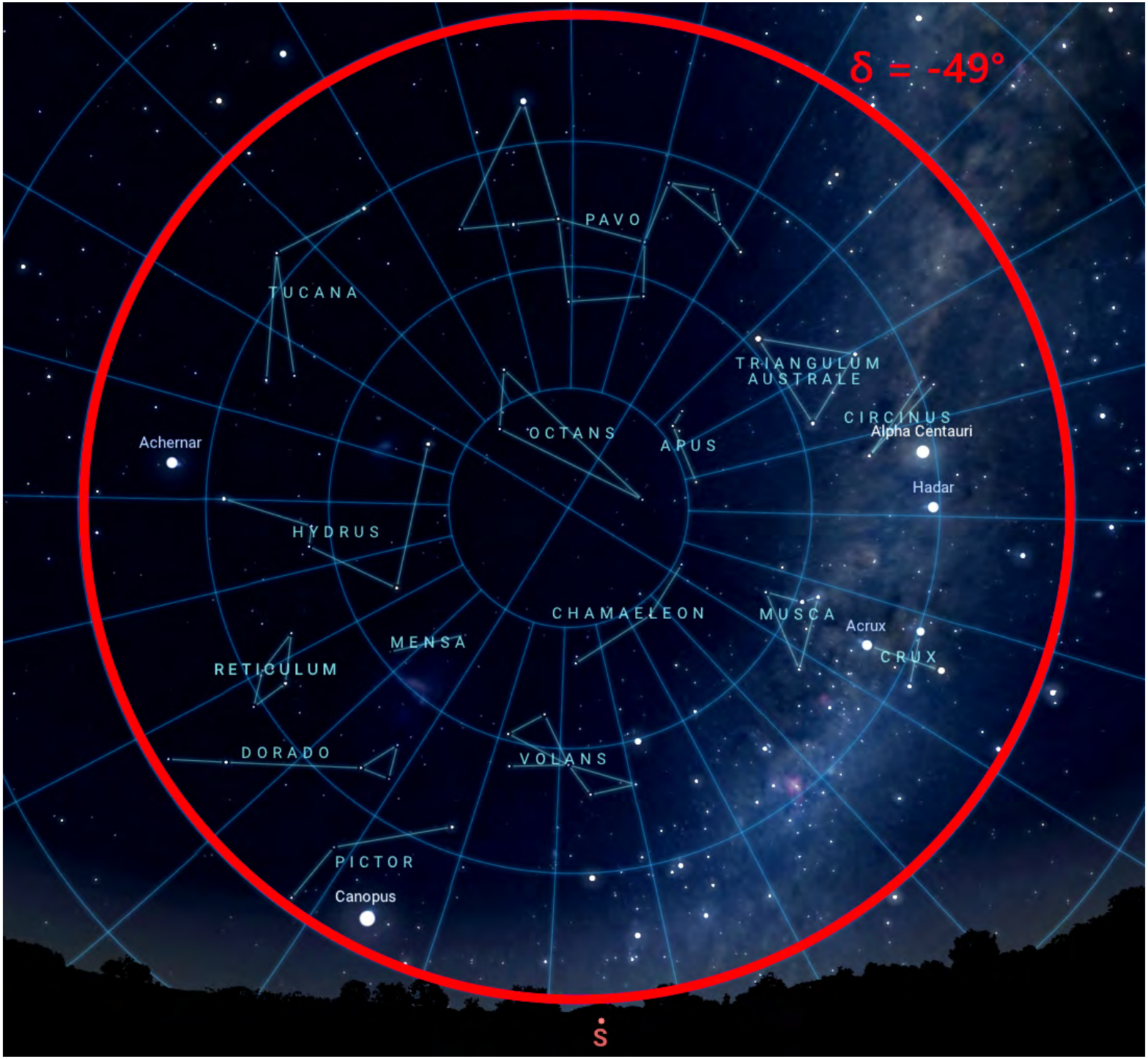
Southern Delights

by Allison Waltberg

Humboldt County is at a latitude of approximately 41° north. That means that Polaris permanently sits 41° above our northern horizon, and any stars less than 41° away from the north celestial pole – that is, those with declination (δ) at least +49° (the complement of 41°) – are circumpolar: they never rise or set, instead perpetually circling Polaris every night throughout the year. Alkaid, the last star of the Big Dipper's handle, has a declination of +49.3°, which coincidentally places it almost exactly on the edge of our circumpolar circle. At its lowest point in the sky, it would just graze the horizon (ignoring the slight shift upwards due to atmospheric refraction). The circumpolar constellations we see here include Ursa Major and Minor, Draco, Cepheus, Cassiopeia, and the perpetually-forgotten Camelopardalis. The further north you travel, the higher Polaris rises in the sky, and the larger the circumpolar region of the sky becomes. Eventually, at the North Pole, the entire Northern Hemisphere is circumpolar, and the visible stars will all circle endlessly overhead without rising or setting.

The belt of the sky between δ = +49° and δ = -49° contains the stars of our familiar seasonal constellations, which are visible in the night sky for a portion of the year, invisible in the daytime sky the rest of the time. The farther south they are, the briefer their seasonal appearance above the horizon in the southern sky becomes. This is why in the Northern Hemisphere we refer to Orion as a winter constellation and Sagittarius as a summer one: located in diametrically opposite positions in the sky, the sun is opposite Orion in December and Sagittarius in June. Remember, though, that "summer" and "winter" constellations are not universal – while Orion still shines in December and Sagittarius in June, December is midsummer and June is midwinter in the Southern Hemisphere.

South of the equator, the circumpolar circles are inverted as well. A stargazer at latitude 41° south (around Wellington, New Zealand) would draw their own circle 41° around the south celestial pole (δ < -49°)



to find the stars that are always up in their sky; these same stars never rise above the horizon here in Humboldt. Unfortunately for us, that circle includes a lot of astronomical novelties: the Southern Cross, Canopus and Alpha Centauri (the second- and third-brightest stars in the night sky, and our sun's nearest neighbor), both the Large and Small Magellanic Clouds (naked-eye dwarf galaxies orbiting the Milky Way), the Carina Nebula (larger and brighter than the Orion Nebula), and the Coalsack Nebula (a prominent dark nebula along the Milky Way), just to name a few.

Those southern constellations that never rise above the horizon posed a problem for ancient astronomers mapping the heavens. Ptolemy's Almagest, the 2nd century source of 48

Left: from Stellarium.

of the 88 modern constellations, had to leave a portion of the southern sky blank. (Interestingly, a few southern constellations such as Crux were actually known in Greece at the time, but due to precession of the Earth's axis, they haven't been visible from anywhere in Europe since before 400 AD.) Those southern reaches of the sky were mapped by European colonial explorers and formally defined as constellations beginning only in the 16th century. Cartographers on the first Dutch expedition to the East Indies created maps that led to the addition of 12 new southern constellations in the late 1500s, and another 14 were added by the French astronomer Lacaille at his observatory in the Dutch Cape Colony (now South Africa) in the mid-1700s.

Along with Crux, our Kiwi observer's other circumpolar constellations – those that never rise in Humboldt – are a wonderful collection of alien delights. The Dutch explorers favored naming theirs after exotic birds and animals: Tucana (the toucan), Apus (the bird of paradise), Pavo (the peacock), Volans (the flying fish), Chamaeleon (the chameleon, obviously), Dorado (a tropical fish), and Hydrus (the water snake); they also named the exceedingly uncreative Triangulum Australe (the southern triangle). Lacaille's constellations are instead named for scientific instruments, possibly whatever random objects were lying around in his observatory at the time: Octans (the octant), Circinus (the compass), Pictor (the easel), Reticulum (the telescope eyepiece reticle or crosshair), and Mensa (the table – though at least this was originally meant to commemorate Table Mountain, prominent on the horizon from his Cape Town observatory). These latter-day constellations can be an amusing break from the Greek history and mythology references that fill the northern sky.

Northern astronomers dipping their toes into the antipodean sky may also be amused by the total inversion of the constellations, moon, and sidereal motion from our familiar maps. Orion, Canis Major, Gemini, and Taurus all prance across the sky upside-down with their heads dangling away from the zenith, and Sagittarius's teapot dumps its Milky Way steam onto the horizon. Leo's "backwards question mark" and Scorpius's J-hooked tail have swapped shapes, and Boötes's "ice cream cone" looks more like a traffic cone. The moon's face is inverted and its phases appear to progress in reverse – I think of the northern moon phases like turning the pages of a book, as it waxes from a crescent lit on the right side to full and then waning down to a left-sided crescent, but south of the equator the waxing crescent is lit from the left and it wanes down to a right-sided crescent.

Crux over the braai

On my first journey to South Africa a few years ago, I was totally overwhelmed by safaris and hikes and Afrikaans; I barely even had a chance to get lost in the bewildering southern sky, although I do remember smiling at upside-down Orion before an early-morning hike. But I did have one magically unique Southern Hemisphere astronomy experience: admiring the Southern Cross setting over the famous Drakensberg Amphitheatre through the smoke of ostrich burgers on the braai ... and hoping that on my next trip I might actually recognize something in that alien night sky!

Renowned Astronomer Allison Waltberg lives in Kneeland and gives northern hemisphere constellation talks at AOH activities.

NGC 7331 and the Supernova

by Grace Wheeler

NGC 7331 is a spiral galaxy located in the constellation Pegasus, approximately 40 million light-years from Earth. Through a telescope, NGC 7331 appears alongside a group of smaller galaxies that are commonly referred to as the "Fleas." Despite their smaller appearance, these galaxies are actually much farther away—about 300 million light-years from Earth. The Fleas are also known as the Deer Lick Galaxy Group, a name given by amateur astronomer and writer Tom Lorenzin. He named it in honor of the Deer Lick Gap in North Carolina, where he spent a memorable night observing these distant galaxies. Below is an image of NGC 7331 and the Deerlick Galaxy group that was taken in September 2023 (Figure 1).

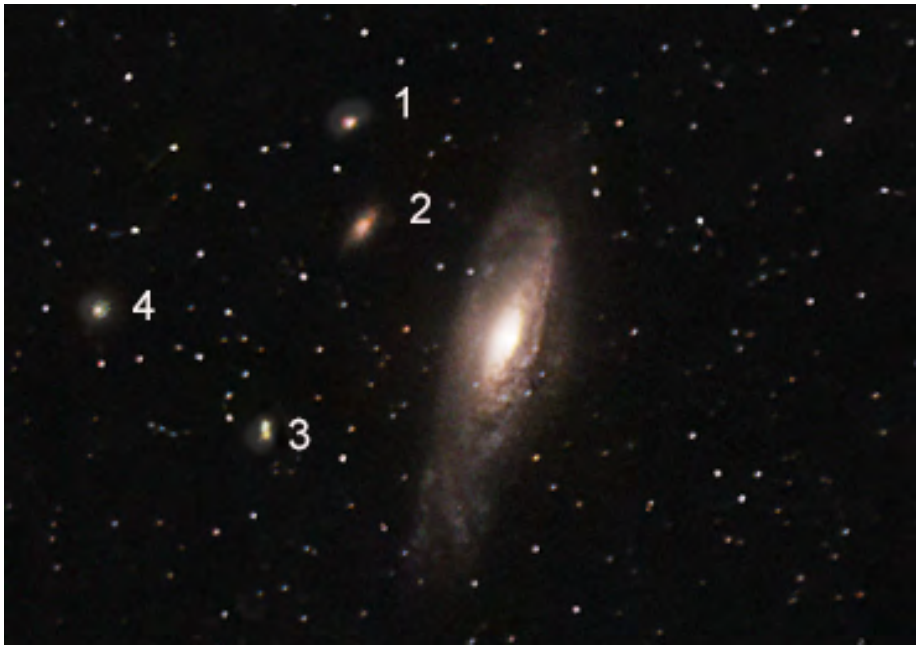


Figure 1. The spiral galaxy NGC 7331 and the "Fleas" from the Deerlick Galaxy Group. The "Fleas" are labeled in this image: (1) NGC 7336, (2 NGC 7335, (3) NGC 7337, and (4) NGC 7340. This photo was imaged with a 104 mm apo-refractor telescope and a Canon EOSRa. The total integration time was 1.5 hours (2-minute exposures x 90). (Image credit: GDW)

Supernova 2025rbs

On July 14, a new supernova was detected in NGC 7331 by the wide-field telescope arrays of the GOTO Observatory. (See the announcement at https://goto-observatory.org/bright-supernova-2025rbs-discovered-by-goto/ and the APOD post for July 31 at https://apod.nasa.gov/apod/ap250731.html.) While the primary mission of the GOTO (Gravitational-wave-Optical-Transient-Observer) is to search for electromagnetic events associated with gravitational waves, the telescope array does double duty by surveying the night sky for transient events such as supernovae, novae, outbursts from accreting binaries, variable stars, and near-earth asteroids.

The supernova was assigned the name 2025rbs, and based on spectral analysis, was classified as a type 1a supernova. Type 1a supernovae are associated with binary star systems in which at least one of the stars is a white dwarf. Instability occurs when the white dwarf siphons off the contents of its companion. The white dwarf gains so much mass that it starts to fuse carbon and oxygen. The fusion leads to a runaway chain and culminates in a supernova explosion. Type 1a supernovae are used as secondary standard candles for measuring cosmic distances. While the absolute magnitude is typically -19.4 at peak brightness, there can be variability. For now, if we assume that 2025rbs will be typical, then the apparent magnitude as seen from Earth should be around 11. (More about type 1a supernovae can be found here: https://lweb.cfa.harvard.edu/sdu/supernovae.html.)

Hunting for the Supernova

Supernova 2025rbs is located near the galactic core of NGC 7331, which makes it difficult to observe visually. Since its discovery on July 14, the supernova has brightened from its initial apparent magnitude of 17. By the end of July, amateur astronomers on the Cloudy Nights forum reported seeing a bright, starlike object near the center of the galaxy.

I searched for the supernova on July 26 during the AOH Kneeland Star Party (see page 2) using the Seestar S50 smart telescope. At

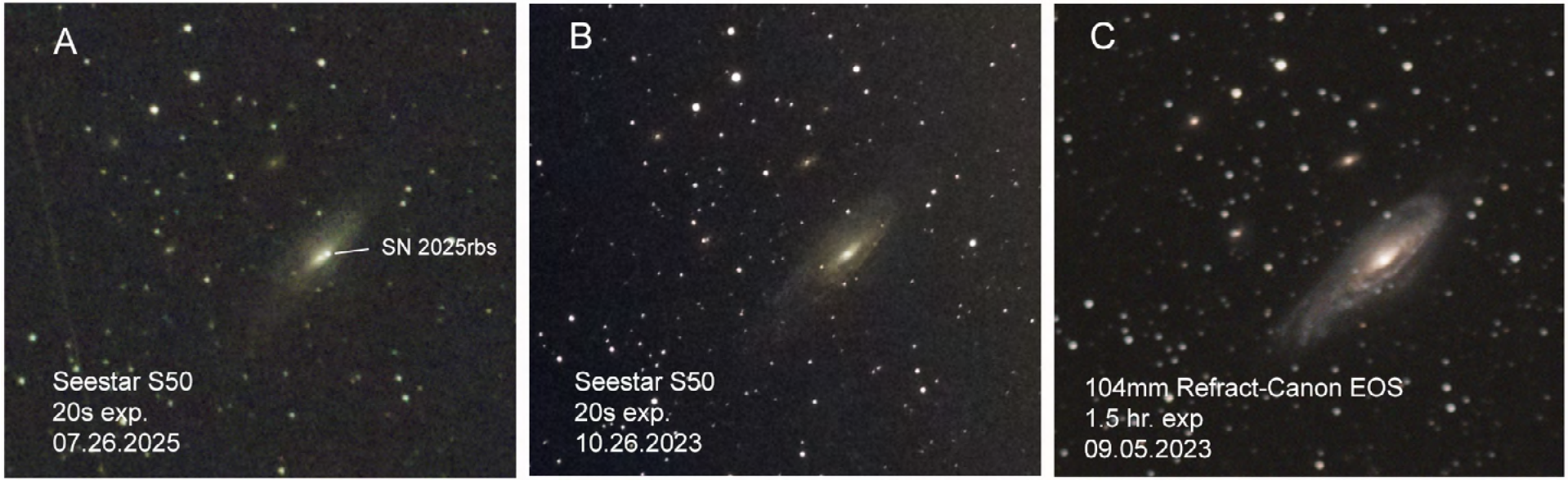
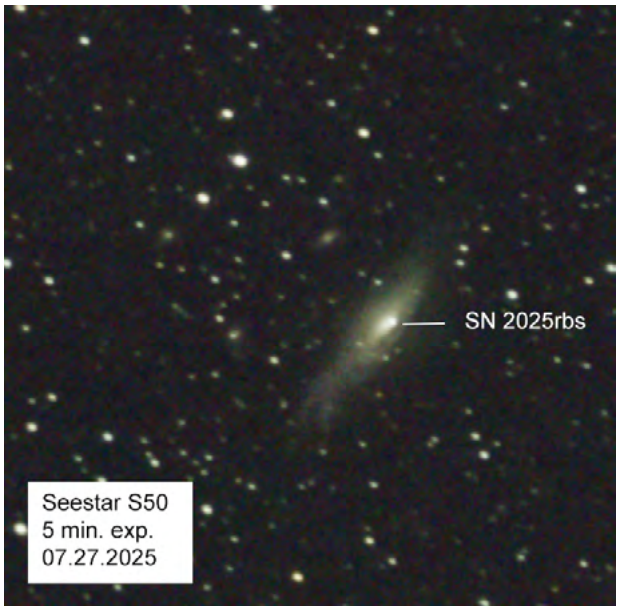


Figure 2 (above). Supernova in NGC 7331. (A) Supernova 2025rbs and the galactic core is shown in a 20s exposure. Reference images of the galaxy NGC 7331 were taken in (B) September 2023 and (C) October 2023. These reference images show the absence of a bright object at the location of SN 2025rbs. (Image credit: GDW)

Figure 3 (below). A five-minute exposure of NGC 7331. The fainter regions of the galaxy are more apparent with this longer exposure, but the galactic core is over-exposed. SN 2025rbs can still be seen but the galactic core is beginning to blend in with the supernova.

that time, SN 2025rbs had reached an apparent magnitude of 12. To avoid overexposing the galactic core and the supernova, I reduced the gain and used short exposure times. Under these conditions, I was able to see the core and supernova as separate objects. I confirmed the presence of SN 2025rbs by comparing my July 26 image (Figure 2A) with reference images of the galaxy taken in 2023 (Figures 2B and 2C). I also did a 5-minute exposure of NGC 7331 in order to bring out more of the structure of the galaxy. The supernova is still apparent in the longer exposure (Figure 3), although the brightness of the core is beginning to encroach upon the supernova.



At the end of the night (July 26), I attempted to locate the supernova visually using an 8-inch SCT (Schmidt-Cassegrain telescope). While I was able to see NGC 7331, I was unable to detect any starlike object near its center. This might have been due to my eyes not being fully dark-adapted, as I had been looking at my tablet

screen during the Seestar imaging session.

On August 1, visual observers estimated the apparent magnitude of SNn2025rbs to be between 11.8 and 12 (https://rochesterastronomy.org/sn2025/sn2025rbs.html). Based on light curve data from the Transient Name Server, the supernova may have reached its peak brightness on August 2, with an apparent magnitude of about 12.2 (https://www.wis-tns.org/sites/default/files/astronotes_files/2274/lightcurve_sloan_obsn_sn25rbs_1.png).

On August 18, 2025, I did another observation of NGC 7331. This time my eyes were dark adapted. Using averted vision I was able to observe two loci of brightness which presumably correspond to the galactic core. The bright loci would only briefly come into focus. I also used the Seestar to image NGC 7331 and found that the supernova was still there, although the intensity seemed reduced. On August 18, the apparent magnitude of SN 2025rbs was 13.

Additional Images and Observations of SN 2025rbs

- Supernova 2025rbs in NGC 7331 Galaxy. https://www.cloudynights.com/topic/970931-supernova-2025rbs-in-ngc-7331-galaxy/.
- SN 2025rbs Light Curve. https://estelario.blogspot.com/2025/07/supernova-2025rbs.html.
- Masi, Gianluca (2025, August 1) Supernova SN 2025rbs in NGC 7331 Spiral Galaxy: An Image—1 Aug. 2025. https://www.virtualtelescope.eu/2025/08/01/supernova-sn-2025rbs-in-the-ngc-7331-spiral-galaxy-an-image-1-aug-2025/.
- TNS (2025, August 19) Early Multiband Photometry of the Type 1a Supernova SN. https://www.wis-tns.org/astronotes/

Amazing Grace Wheeler travels throughout the Universe seeking topics to write about for the Newsletter, and collecting photons with which to make pictures to go with those articles. Here she is 40 million light-years away in the Deer Lick Galaxy.

Saturn Ring Plane Crossing and Titan Transit Season

by Grace Wheeler

The following is an update to an article that I wrote in the 2024 Fall Edition of the AOH newsletter

For a brief period during Saturn's equinox, Earth aligns closely with Saturn's equator. At this time, Saturn's rings, also aligned with the equator, appear edge-on from our perspective. This alignment occurs during Saturn's ring plane crossing, when Earth passes through the plane of Saturn's rings and equator. The apparent tilt of the rings as seen from Earth is nearly zero, creating the illusion that the rings have vanished

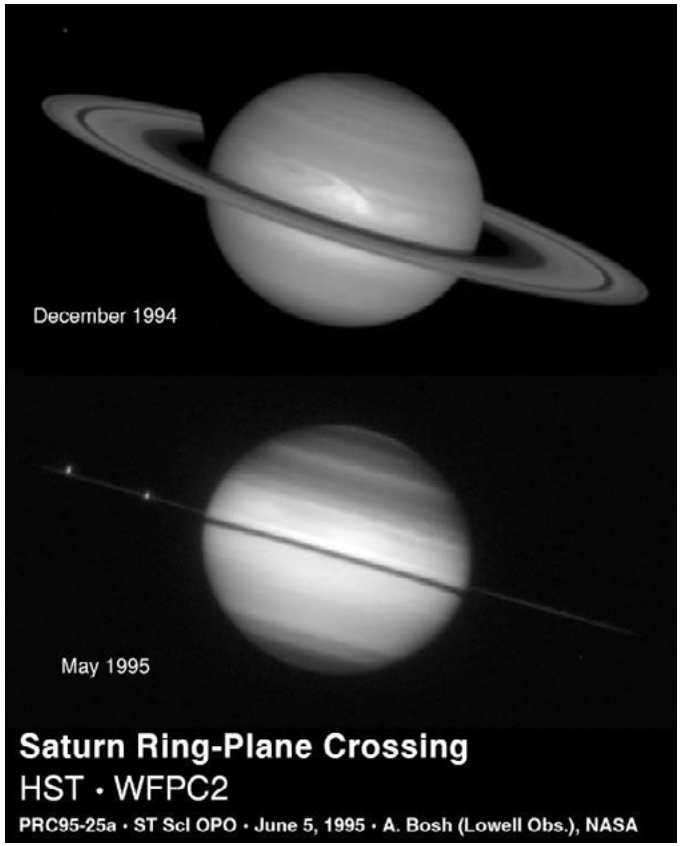


Figure 1. Saturn Ring Plane Crossing in May 1995 as captured by the Hubble Space Telescope. https://science.nasa.gov/missions/hubble/hubble-views-saturn-ring-plane-crossing/.

The most recent ring plane crossing occurred on March 23, 2005; however, the phenomenon of the disappearing rings was not observable because Saturn was too close to the Sun (see Ken Yanosko's article on the tilt of Saturn's rings in the Winter 2025 issue of the AOH Newsletter).

If disappearing rings weren't interesting enough, Earth's close alignment with Saturn's equator also put the moons in the line-of-sight with Earth--most of Saturn's moons orbit along the equator. In the months surrounding Saturn's ring-plane crossing, observers can see transits of some of the larger moons and their shadows crossing Saturn's disk. Occultations and eclipses of the moons by Saturn are also visible. During the Saturnian equinox, the rings appear extremely thin, so they do not obstruct the view of the moons. Because the rings reflect less sunlight at this time, Saturn itself appears dimmer, allowing faint moons that would normally be washed out by its brightness to become visible.

The moon event I was most interested in was the transit of Titan and its shadow. Titan is a particularly good target for observing Saturnian moon transits due to its large size: it is Saturn's largest moon and it casts a shadow that is about 0.8 arc-seconds. This shadow is relatively large and can be detected with a moderately sized telescope.

The 2025 Titan transit season began in May, when Saturn emerged from solar conjunction and became visible in the predawn sky. During the spring and summer months, Titan transits were observable only from the western hemisphere. The early transits, occurring in spring and early summer, were challenging to view because they took place in the pre-dawn hours or in the middle of the night.

The transit on May 16 (Figure 2A) occurred shortly after Saturn's equinox on May 6 and about eight weeks after Earth passed through Saturn's ring plane. A Starry Night simulation shows Titan's shadow crossing Saturn's disk along the equator. Because the transit occurred before opposition, Titan appeared to trail behind its shadow. One month later, on June 16 (Figure 2B), the shadow transit had shifted slightly north of the equator. With each subsequent transit, the shadow will continue to migrate northward, eventually reaching the poles during the October 5 transit.

Observations of Titan Transits from Kneeland

Titan shadow transits were observed on July 18 and August 18-19 at Kneeland Airport. By that time, Saturn was rising just before midnight. On both dates, Titan's shadow was beginning its transit across Saturn's disk as the planet cleared the horizon. Using a planetary camera on an 8-inch SCT, I was able to capture the transits. During both the July 18 and August 18 events, Titan appeared to orbit just above Saturn while trailing its shadow. As shown in Figures 3 and 4,

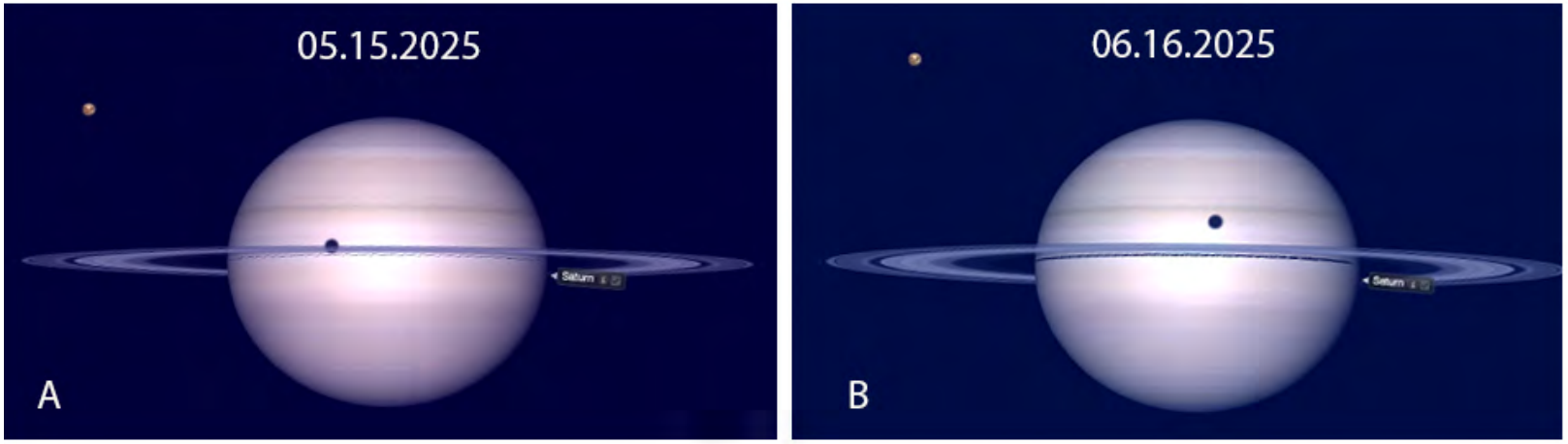


Figure 2. Simulation of the Transit of Titan's Shadow. Using the Starry Night Planetarium program, the transit of Titan's shadow on the Saturnian disk was created. The dates chosen (A) May 15, 2025 and (B) June 16, 2025 were transits that occurred shortly after the Saturnian Equinox on May 6, 2025.

Figure 3 (above). The Transit of Titan's Shadow on July 18, 2025. Titan (small and reddish) is seen orbiting above Saturn. Titan's shadow is seen on the disk migrating from left to right. Images from the transit was collected 10 minutes apart.
Figure 4 (below). The Transit of. Titan's Shadow on August 18-19, 2025. Titan is seen orbiting above Saturn. Titan's shadow is seen on the disk migrating from left to right. Images from the transit was collected 10 minutes apart.
Saturn was imaged with an 8-inch SCT, 2.5x Barlow lens, and a ZWO 294MC camera. Images were stacked in Autostakkert and sharpened in Registax.

Titan appears small, reddish in color, and somewhat dim. In contrast, its shadow is strikingly visible as a large, inky spot migrating from left to right across Saturn's disk.

The July 18 shadow transit began around 12:00 a.m. and ended at 5:00 a.m. (I imaged until 4:15 a.m. and did not capture the end of the event.) Images from the first hour were unusable due to turbulent air at low altitude. Figure 3 shows Titan and its shadow near the start, the midpoint, and near the end of the transit. A GIF of the event can be viewed here: https://www.youtube.com/watch?v=XL6Ub35A9hk.

The August 18-19 shadow transit began at 11:30 p.m. and

ended at 3:00 a.m. Its path was shifted northward compared to the July 18 transit and lasted about 90 minutes less. Figure 4 shows Titan and its shadow early in the transit, at the midpoint, and near the conclusion. A GIF of the full transit can be viewed here: https://www.youtube.com/watch?v=FrnXcOI2a9I.

Titan has an orbital period of about 16 days, so we can expect a shadow transit roughly every 16 days. As of this writing (September 1), the next three shadow transits are expected on September 3, September 19, and October 5. The September 19 transit will be especially interesting, as it occurs near Saturn's opposition. For the first time, Titan and its shadow will be seen transiting the disk together. This will also be a short transit since both will cross near Saturn's north pole. After October 5, shadow transits will no longer be visible in North America, though transits of Titan itself across Saturn's disk will still be observable. Weather permitting, I plan to observe and document the next three shadow transits and Titan's transits later this fall. Stay tuned for more.

References:

- King, Bob (2025, May 14) Titan Shadow Season Underway. https://skyandtelescope.org/astronomy-news/observing-news/titan-shadow-transit-season-underway/.
- Ford, Dominic (2025, May 5) Equinox on Saturn. https://in-the-sky.org/news.php?id=20250506_12_100#google_vignette.
- Whitt, Kelly Kizer (2024, August 4) Saturn's Rings are Disappearing! https://earthsky.org/space/saturns-rings-are-disappearing-march-2025/.
- Peach, Damien (2021, September 19) Rings and Seasons of Saturn. https://apod.nasa.gov/apod/ap210919.html.

For this article Grace is back in the Solar System just 80 light-minutes away at Saturn.

The Helix Nebula

by Grace Wheeler

The Helix Nebula (Caldwell 63) is a planetary nebula located in the constellation Aquarius. It is one of the closest planetary nebulae to Earth, situated about 650 light years away. The nebula spans roughly 20 arc-minutes across, which is about 65% of the size of the full moon. Planetary nebulae are the remnants of dying stars that can vary in size from intermediate to low mass. For instance, our sun is considered to be of intermediate size and is expected to become a planetary nebula in about 5 billion years. As a star nears the end of its life, its fuel is exhausted, leading to inflation and the formation of a red giant. Eventually, the core collapses into a white dwarf, while layers of gas continue to expand outward. What remains is a planetary nebula, with a central white dwarf contained within a shell of expelled gas.

The Helix Nebula was imaged with a 71mm refractor telescope and a Canon EOS Ra. Integration time was 2.4 hours.
Light frames were taken at ISO 3200, 1 minute exposure. Stacking was done in Affinity Photo with 145 lights, 18 bias, and 18 flats. Processing was done in Photoshop.

In the image of the Helix Nebula, we can see the central white dwarf (in the center of the bluish disk) that is encircled by envelope of colorful, glowing gases. Although a white dwarf is no longer capable of fusion, it still emits heat and radiation. The ultraviolet radiation from the white dwarf ionizes gases such as hydrogen and oxygen, causing them to emit light. Planetary nebulae are transient objects and will eventually fade as the white dwarf cools and ceases to emit radiation. The lifespan of a planetary nebulae is thought to be 10,000 to 50,000 years.

The Helix Nebula is named for its distinctive double-ring appearance in astronomical photos and has often been likened to looking down a coiled spring. Astronomers believe that the nebula is an elongated helical tube, measuring about a trillion miles long. However, this helical structure isn't visible to us because we are looking at one end of the tube. Additionally, the Helix Nebula is frequently compared to an eye and is commonly referred to in popular culture as the "Eye of God" or the "Eye of Sauron." Personally, I have always found the Helix Nebula to have a somewhat eerie quality. I took this photograph of the Helix Nebula on October 10, 2024, and I've been saving it for the fall newsletter as my Halloween offering for 2025. While researching, I searched online for "Helix Nebula and giant creepy eyeball" and discovered this NASA video: https://www.youtube.com/watch?v=YLdnATv1eZM.

Happy Halloween!

References:

- Caldwell 63. https://science.nasa.gov/mission/hubble/science/explore-the-night-sky/hubble-caldwell-catalog/caldwell-63/.
- French, Sue (2006, July 28) Hunting Down the Helix. https://skyandtelescope.org/observing/celestial-objects-to-watch/hunting-down-the-helix/.
- NASA (2003, May 19) NGC 7293. https://apod.nasa.gov/apod/ap030510.html.
- Hubble (Sonifications of images from HST) https://www.system-sounds.com/hubble/.

And now she's 650 light-years away at the Helix!

Cosmology is at a tipping point – we may be on the verge of discovering new physics

by Andreea Font

For the past few years, a series of controversies have rocked the well-established field of cosmology. In a nutshell, the predictions of the standard model of the universe appear to be at odds with some recent observations.

There are heated debates about whether these observations are biased, or whether the cosmological model, which predicts the structure and evolution of the entire universe, may need a rethink. Some even claim that cosmology is in crisis. Right now, we do not know which side will win. But excitingly, we are on the brink of finding that out.

To be fair, controversies are just the normal course of the scientific method. And over many years, the standard cosmological model has had its share of them. This model suggests the universe is made up of 68.3% "dark energy" (an unknown substance that causes the universe's expansion to accelerate), 26.8% dark matter (an unknown form of matter) and 4.9% ordinary atoms, very precisely measured from the cosmic microwave background – the afterglow of radiation from the Big Bang.

This is article is part of our series *Cosmology in crisis?* which uncovers the greatest problems facing cosmologists today – and discusses the implications of solving them.

It explains very successfully multitudes of data across both large and small scales of the universe. For example, it can explain

things like the distribution of galaxies around us and the amount of helium and deuterium made in the universe's first few minutes. Perhaps most importantly, it can also perfectly explain the cosmic microwave background.

This has led to it gaining the reputation as the "concordance model". But a perfect storm of inconsistent measurements – or "tensions" as they're known as in cosmology – are now questioning the validity of this longstanding model.

Uncomfortable tensions

The standard model makes particular assumptions about the nature of dark energy and dark matter. But despite decades of intense observation, we still seem no closer to working out what dark matter and dark energy are made of.

X-ray: NASA/CXC/SAO; Infrared: (Herschel) ESA/NASA/Caltech, (Spitzer) NASA/JPL/Caltech, (WISE) NASA/JPL/Caltech; Infrared: NASA/ESA/CSA/STScI/Webb ERO Production Team; Image processing: NASA/CXC/SAO/J. Major, CC BY

The litmus test is the so-called Hubble tension. This relates to the Hubble constant, which is the rate of expansion of the universe at the present time. When measured in our nearby, local universe, from the distance to pulsating stars in nearby galaxies, called Cepheids, its value is 73 km/s/Mega parsec (Mpc is a unit of measure for distances in intergalactic space). However, when predicted theoretically, the value is 67.4 km/s/Mpc. The difference may not be large (only 8%), but it is statistically significant.

The Hubble tension became known about a decade ago. Back then, it was thought that the observations may have been biased. For example, the Cepheids, although very bright and easy to see, were crowded together with other stars, which could have made them appear even brighter. This could have made the Hubble constant higher by a few percent compared to the model prediction, thus artificially creating a tension.

With the advent of the James Webb Space Telescope (JWST), which can separate the stars individually, it was hoped that we would have an answer to this tension.

Frustratingly, this hasn't yet happened. Astronomers now use two other types of stars besides the Cepheids (known as the Tip of the Red Giant Branch stars (TRGB) and the J-region Asymptotic Giant Branch (JAGB) stars). But while one group has reported values from the JAGB and TRGB stars that are tantalisingly close to the value expected from the cosmological model, another group has claimed that they are still seeing inconsistencies in their observations. Meanwhile, the Cepheids measurements continue to show a Hubble tension.

It's important to note that although these measurements are very precise, they may still be biased by some effects uniquely associated with each type of measurement. This will affect the accuracy of the observations, in a different way for each type of stars. A precise but inaccurate measurement is like trying to have a conversation with a person who is always missing the point. To solve disagreements

between conflicting data, we need measurements that are both precise and accurate.

The good news is that the Hubble tension is now a rapidly developing story. Perhaps we will have the answer to it within the next year or so. Improving the accuracy of data, for example by including stars from more far away galaxies, will help sort this out. Similarly, measurements of ripples in spacetime known as gravitational waves will also be able to help us pin down the constant.

This may all vindicate the standard model. Or it may hint that there's something missing from it. Perhaps the nature of dark matter or the way that gravity behaves on specific scales is different to what we believe now. But before discounting the model, one has to marvel at its unmatched precision. It only misses the mark by at most a few percent, while extrapolating over 13 billion years of evolution.

To put it into perspective, even the clockwork motions of planets in the Solar System can only be computed reliably for less than 1 billion years, after which they become unpredictable. The standard cosmological model is an extraordinary machine.

The Hubble tension is not the only trouble for cosmology. Another one, known as the "S8 tension", is also causing trouble, albeit not on the same scale. Here the model has a smoothness problem, by predicting that matter in the universe should be more clustered together than we actually observe – by about 10%. There are various ways to measure the "clumpiness" of matter, for example by analysing the distortions in the light from galaxies, produced by the assumed dark matter intervening along the line of sight.

Currently, there seems to be a consensus in the community that the uncertainties in the observations have to be teased out before ruling out the cosmological model. One possible way to alleviate this tension is to better understand the role of gaseous winds in galaxies, which can push out some of the matter, making it smoother.

Understanding how clumpiness measurements on small scales relate to those on larger scales would help. Observations might also suggest there is a need to change how we model dark matter. For example, if instead of being made entirely of cold, slow moving particles, as the standard model assumes, dark matter could be mixed up with some hot, fast-moving particles. This could slow down the growth of clumpiness at late cosmic times, which would ease the S8 tension.

JWST has highlighted other challenges to the standard model. One of them is that early galaxies appear to be much more massive than expected. Some galaxies may weigh as much as the Milky Way today, even though they formed less than 1 billion years after the Big Bang, suggesting they should be less massive.

A region of star formation seen by JWST and the Chandra telescope. Image credit: Credit: X-ray: NASA/CXO/SAO; Infrared: NASA/ESA/CSA/STScI; Image processing: NASA/CXC/SAO/L. Frattare, CC BY

However, the implications against the cosmological model are less clear in this case, as there may be other possible explanations for these surprising results. Key to solving this problem is to improve the measurement of stellar masses in galaxies. Rather than measuring them directly, which is not possible, we infer these masses from the light emitted by galaxies.

This step involves some simplifying assumptions, which could translate in overestimating the mass. Recently, it has also been argued that some of the light attributed to stars in these galaxies is generated by powerful black holes. This would imply that these galaxies may not be as massive after all.

Alternative theories

So, where do we stand now? While some tensions may soon be explained by more and better observations, it is not yet clear whether there will be a resolution to all of the challenges battering the cosmological model.

There has been no shortage of theoretical ideas of how to fix the model though – perhaps too many, in the range of a few hundred and counting. That's a perplexing task for any theorist who may wish to explore them all.

The possibilities are many. Perhaps we need to change our assumptions of the nature of dark energy. Perhaps it is a parameter that varies with time, which some recent measurements have suggested. Or maybe we need to add more dark energy to the model to boost the expansion of the universe at early times, or, on the contrary, at late times. Modifying how gravity behaves on large scales of the universe (differently than done in the models called Modified Newtonian Dynamics, or MOND) may also be an option.

So far, however, none of these alternatives can explain the vast array of observations that the standard model can. Even more worrisome, some of them may help with one tension but worsen others.

The door is now open to all sorts of ideas that challenge even the most basic tenets of cosmology. For example, we may need to abandon the assumption that the universe is "homogeneous and isotropic" on very large scales, meaning it looks the same in all directions to all observers and suggesting there are no special points in the universe. Others propose changes to the theory of general relativity.

Some even imagine a trickster universe, which participates with us in the act of observation, or which changes its appearance depending on whether we look at it or not – something we know happens in the quantum world of atoms and particles.

In time, many of these ideas will likely be relegated to the cabinet of curiosities of theorists. But in the meantime, they provide a fertile ground for testing the "new physics".

This is a good thing. The answer to these tensions will no doubt come from more data. In the next few years, a powerful combination of observations from experiments such as JWST, the Dark Energy Spectroscopic Instrument (DESI), the Vera Rubin Observatory and Euclid, among many others, will help us find the long-sought answers.

Tipping point

On one side, more accurate data and a better understanding of the systematic uncertainties in the measurements could return us to the reassuring comfort of the standard model. Out of its past troubles, the model may emerge not only vindicated, but also strengthened, and cosmology will be a science that is both precise and accurate.

But if the balance tips the other way, we will be ushered into uncharted territory, where new physics will have to be discovered. This could lead to a major paradigm shift in cosmology, akin to the discovery of the accelerated expansion of the universe in the late 1990s. But on this path we may have to reckon, once and for all, with the nature of dark energy and dark matter, two of the big unsolved mysteries of the universe.

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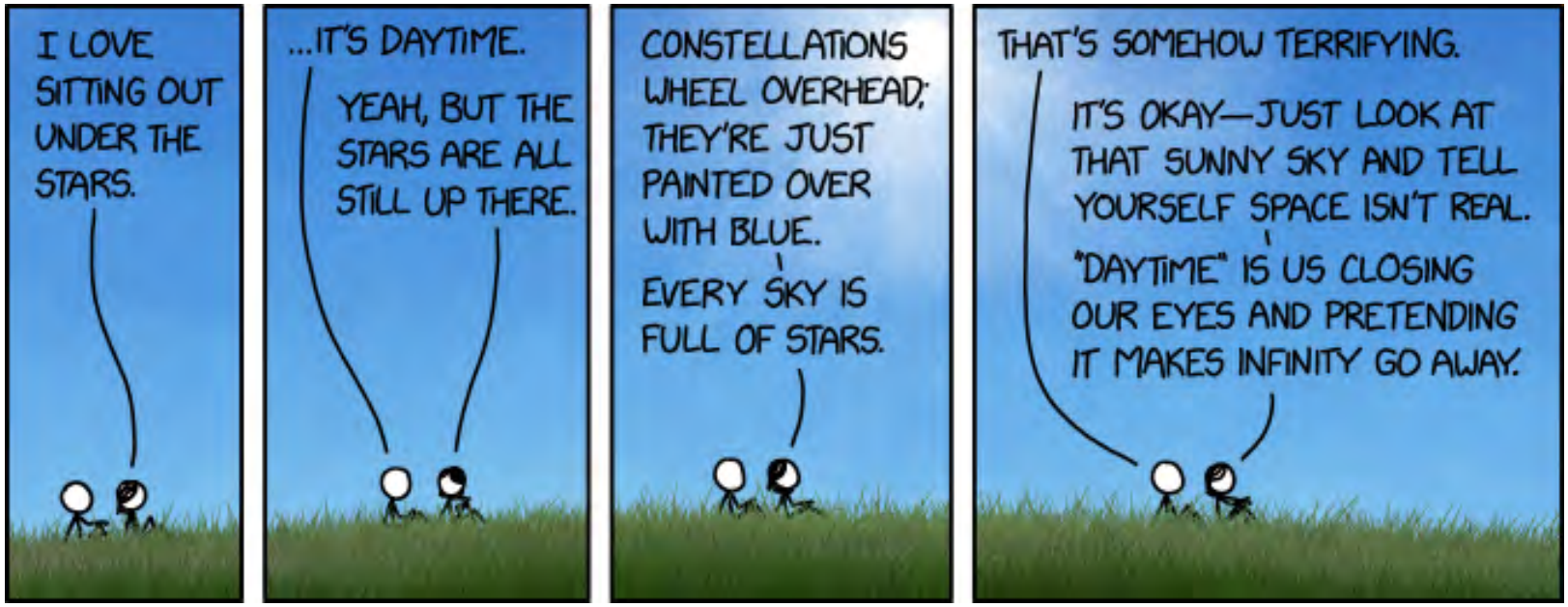
After Words

"This Voyager spacecraft was constructed by the United States of America. We are a community of 240 million human beings among the more than 4 billion who inhabit the planet Earth. We human beings are still divided into nation states, but these states are rapidly becoming a single global civilization.

"We cast this message into the cosmos. It is likely to survive a billion years into our future, when our civilization is profoundly altered and the surface of the Earth may be vastly changed. Of the 200 billion stars in the Milky Way galaxy, some--perhaps many--may have inhabited planets and spacefaring civilizations. If one such civilization intercepts Voyager and can understand these recorded contents, here is our message:

"This is a present from a small distant world, a token of our sounds, our science, our images, our music, our thoughts, and our feelings. We are attempting to survive our time so we may live into yours. We hope someday, having solved the problems we face, to join a community of galactic civilizations. This record represents our hope and our determination, and our good will in a vast and awesome universe."

President Jimmy Carter
The Voyager Golden Records, 1977



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