The Journal of The Royal Astronomical Society of Canada

# Journal

Le Journal de la Société royale d'astronomie du Canada

PROMOTING
ASTRONOMY
IN CANADA

August/août 2025
Volume/volume 119
Number/numéro 4 [833]

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*Aurora*

# TOTAL SOLAR ECLIPSE
## TOURS FOR 2026 AND 2027

### AUGUST 2026
### GREENLAND & ICELAND CRUISE

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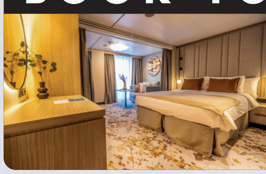

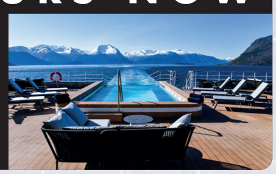

### AUGUST 2026
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Royal Astronomical Society of Canada

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## Great Images / Superbes images



*A bit of a throwback to one of the most memorable auroral displays of 2024. Kerry-Ann Lecky Hepburn photographed the northern lights from her home in Grimsby, Ont., on 2024 October 10. She writes, "The northern lights from October 10th last year were absolutely amazing. I sacrificed my sleep and took pictures all night long. This view is from my back yard, taken with the Sigma 15-mm fisheye on my Canon R6 … I really hope we get another night like this before we head into a solar minimum." Kerry-Ann used a Canon R6, with a Sigma 15-mm fisheye lens @ 2.8 at ISO 6400. This is a one-second single exposure on a tripod.*

Journal

The *Journal* is a bi-monthly publication of The Royal Astronomical Society of Canada and is devoted to the advancement of astronomy and allied sciences. It contains articles on Canadian astronomers and current activities of the RASC and its Centres, research and review papers by professional and amateur astronomers, and articles of a historical, biographical, or educational nature of general interest to the astronomical community. All contributions are welcome, but the editors reserve the right to edit material prior to publication. Research papers are reviewed prior to publication, and professional astronomers with institutional affiliations are asked to pay publication charges of $100 per page. Such charges are waived for RASC members who do not have access to professional funds as well as for solicited articles. Manuscripts and other submitted material may be in English or French, and should be sent to the Editor-in-Chief.



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# President's Corner

## Old-Fashioned Observing—and in Praise of Star Hopping

*by Michael Watson, President*
*Michael.Watson@gowlingwlg.com*

By the time you read this column in the August 2025 issue of the *Journal*, my term as RASC President will be over as of the Society's annual meeting at the end of June, although I will still be on the Board of Directors for another two years. But it's customary for the outgoing President to write the President's column for the August issue, mainly because the publication schedule for a journal such as ours requires a submission deadline of two months before the publication date; that is, June 1 for the August issue.

So, what to write about following my June 2025 column, which was titled "Thoughts at the End of my Term as President"? I have decided to go back to the early days of my membership in the RASC, in 1970, and remember what it was like teaching myself basic astronomy and learning how to use my new telescope. My first column as President, in the October 2023 issue of the *Journal*, was titled "A Journey in Astronomy and the RASC." In it I wrote a couple of paragraphs about my first telescope and about looking up into the night sky for the first time with real astronomical intent.

This was an era long before computerized GoTo telescopes, when even many equatorial (as opposed to altazimuth) telescopes had no motorized clock drives to counteract Earth's rotation and keep the observer's desired target object centred in the eyepiece. That's difficult to imagine now, isn't it? That was also an era when many amateur astronomers ground and polished their own parabolic mirrors for Newtonian telescopes. The McLaughlin Planetarium in Toronto had a mirror-grinding shop in its basement where dedicated Toronto Centre members turned out high-quality optics for the telescopes that they built themselves, as did other Centres.

Of course, in that era, computers were not available outside of institutions. Computer-operated telescopes, with their vast databases of objects, and automated pointing, were long into the future.

So how did we learn what was above us in the night sky, and how to find various objects in the small fields of view of narrow-angle eyepieces of the day? When I started, the classic and best known of atlases of the sky was *Norton's Star Atlas*, first published in 1910, with charts drawn manually by British schoolmaster Arthur Philip Norton (1876–1955). Apart from attractive and easily understood charts that showed stars down to magnitude 6.2 (later extended to 6.35), Norton's charts included deep-sky objects such as galaxies, open and globular star clusters, and diffuse nebulae. Because the charts were arranged in vertical slices, or gores, covering four hours of right ascension, it was easy to use just a couple of charts for a night of observing in a particular season. Studying *Norton's Star Atlas* in the winter of 1969–70 was how I learned where things were in the sky, before the spring observing season began. A PDF scan of the original 1910 version of this atlas can be found here: https://openlibrary.org/books/OL6544650M/A_star_atlas_and_telescopic_handbook_(epoch_1920)_for_students_and_amateurs. Note that because official constellation boundaries were not established by the International Astronomical Union until 1930, the divisions between the constellations were shown in early editions of *Norton's* as gently meandering curved lines, denoting more or less where one constellation ended and an adjacent one started!

But moving from the illuminated desk in the house with my trusty star atlas to the dark sky outside was an entirely different matter. How to find objects overhead in the sky, where the convenient lines of right ascension and declination imprinted on Mr. Norton's charts didn't seem to exist, and everything was dark? Remember too that this was before red LED astronomer's flashlights were devised, so it was a challenge to use a star atlas in the dark without ruining one's night vision with a white flashlight. Creative observers taped red acetate or translucent red tissue paper over their white flashlights to preserve their night vision while they consulted their star atlases for the locations of their observing targets.

How often do we hear enthusiastic newcomers to observational astronomy ask, "What magnification telescope should I get? I'm just starting in astronomy." In reply, we often gently explain the importance of lens or mirror diameter and focal length, and how any telescope can yield a broad range of magnifications depending on the eyepieces used. And we also often urge the beginner to invest in good binoculars before taking the more expensive plunge into the purchase of a telescope.

My end-of-high school enthusiasm couldn't be restrained, however. After I had spent some months studying *Norton's* and reading other books about the sky, I straight away ordered a Criterion 6″ *f*/8 (48″ or ~1220 mm focal length) Newtonian reflector from Connecticut. It took agonizing weeks for the scope to arrive in the late spring of 1970.

The first night out with a telescope, and no one to show you how to use it, can be a jarring and quite sobering experience. It sure was for me. The main challenge was figuring out how to get the telescope pointed at an object that I wanted to observe. The then-standard 6×30 finderscope took some getting used to, for two reasons: First, everything was inverted from what one sees with direct vision; I didn't realize how discombobulating that can be to a neophyte. Second, using a straight through (rather than right angle, which I have always hated) finderscope requires bodily contortions seen mainly in circus performances, especially for high-altitude objects.

But it didn't take long for me to get comfortable using the finderscope to get the main telescope pointed at a reasonably bright star that was close to a deep-sky object that I wanted to see. I still remember my first star through that old new telescope: Vega, high in the June evening sky as darkness fell. I also learned how to align the finder with the main scope, using a 40-mm Kellner eyepiece in the telescope, which produced a field of view of about 1.5 degrees (about three times the apparent diameter of the Moon or Sun).

After that began the "star hopping" to the target object: 1. Turn the star atlas in your hands so that the bright stars shown in the chart that you are using are aligned in the same orientation as those same stars in the sky above you; 2. Now turn the star chart 180 degrees, to replicate the view that you will get through the inverted-view finderscope; 3. Moving the telescope by hand in both axes, point the finderscope at a bright star (say, third magnitude or brighter) that is as close as possible to your deep-sky target. 4. Going back and forth from star atlas to finderscope, move the telescope by hand in both right ascension and declination to move the view first in the finderscope and then in the eyepiece of the telescope from star to star, as shown in the star atlas, toward your object. Eventually—this can take less than a minute, or a frustrating half hour, accompanied by some colourful language when you are starting out—your desired deep-sky object will slide into view.

This star-hopping method, which I still use sometimes to keep in practice, and because I have soft-hearted nostalgia for a bygone era of star-gazing, teaches the observer many things: patience, how everything in the sky is based on right ascension and declination, the fields of view of various eyepiece and telescope focal length combinations, how fast (when magnified through a telescope using even moderate magnification such as 30×) Earth rotates and carries an object right across the field of view, and the magnitude or apparent brightness of stars and other objects as they appear in both a finderscope and your main telescope.

Star-hopping one's way to a desired object has one other benefit that should not be discounted: producing a sense of real accomplishment that you yourself—with nothing more than a simple star atlas, some knowledge, accumulated experience, and effort to get out into a dark sky and look up—have become comfortable and a life-long friend with the sky above and all of its glorious celestial spectacles. That certainly describes my more than half century long life in astronomy, and in the RASC.

Good luck, best wishes, and clear skies to all of my fellow RASC members.

*Quo Ducit Urania,*

Michael, FRASC ✶

# News Notes / En manchette

*Compiled by Jay Anderson*

## So long, Planet X

A team led by Sihao Cheng, with colleagues Jiaxuan Li and Eritas Yang (Institute for Advanced Study at Princeton University), has discovered a large and unusual trans-Neptunian object (TNO), named 2017 $OF_{201}$, at the edge of the Solar System. Trans-Neptunian objects are minor planets that orbit the Sun at a greater average distance than the orbit of Neptune. The new TNO is special for two reasons: its extreme orbit and its large size.

With an estimated diameter of 700 km, the authors suggest that the new discovery is highly likely large enough to achieve hydrostatic equilibrium and qualify as a dwarf planet, though small compared to others in that category [the smallest icy body known to be nearly round and thus in hydrostatic equilibrium is Saturn's satellite Mimas, which has a diameter of about 400 km]. The new object is one of the most distant visible objects in our Solar System and suggests that the empty section of space thought to exist beyond Neptune in the Kuiper Belt is not, in fact, empty at all. The new object was officially announced by the International Astronomical Union's Minor Planet Center on May 21.

"The object's aphelion—the farthest point on the orbit from the Sun—is more than 1,600 times that of Earth's orbit," explains Cheng. "Meanwhile, its perihelion—the closest point on its orbit to the Sun—is 44.5 times that of Earth's orbit, similar to Pluto's orbit." 2017 OF201 made its latest closest pass to Earth in November of 1930, and it will come back again in about 24,256 years. It is currently at a distance of 90.5 au.

"It must have experienced close encounters with a giant planet, causing it to be ejected to a wide orbit," says Yang. "There may have been more than one step in its migration. It's possible that this object was first ejected to the Oort cloud, the most distant region in our Solar System, which is home to many comets, and then sent back," Cheng adds. "Many extreme TNOs have orbits that appear to cluster in specific orientations, but 2017 $OF_{201}$ deviates from this," says Li.

This previous clustering has been interpreted as indirect evidence for the existence of another planet in the Solar System, "Planet X" or "Planet Nine," that could be gravitationally shepherding these objects into their observed orbits. The existence of 2017 $OF_{201}$ with a longitude of perihelion that deviates significantly from the other TNOs challenges this hypothesis. Further work by the discovery team shows that the presence of a large object such as the hypothetical Planet X in the Kuiper Belt would have caused 2017 $OF_{201}$ to interact more closely with Neptune and be ejected from solar orbit within 100 My.

Cheng and his colleagues estimate 2017 $OF_{201}$'s diameter would make it the second largest known object in such a wide orbit. Further observations, potentially using radio telescopes, are needed to determine the object's size more precisely. The area beyond the Kuiper Belt, where the object is located, has previously been thought to be essentially empty, but the team's discovery suggests that this is not so. 2017 $OF_{201}$ was only observable because it was near perihelion, leaving open the prospect of a vast region of the outer Solar System with similar-sized objects.

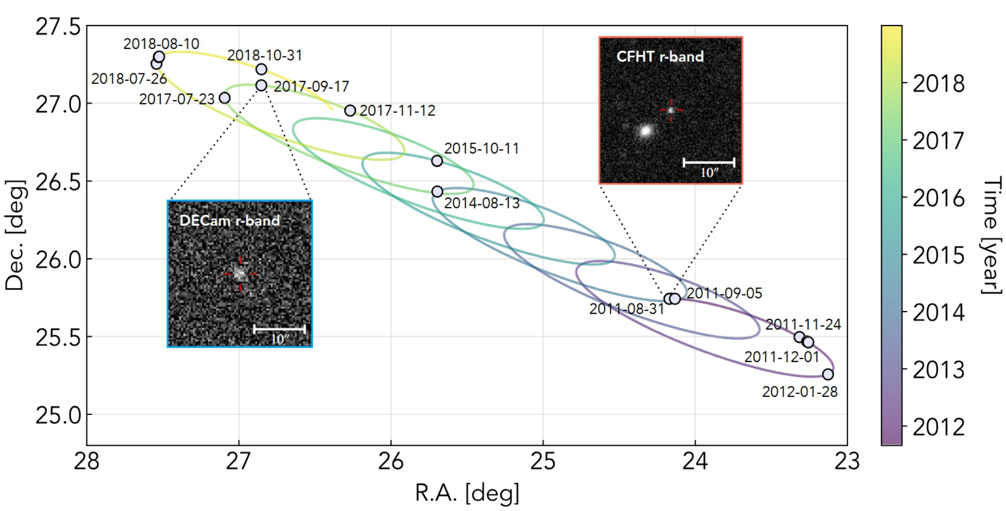



*Figure 1 – Trajectory of 2017 $OF_{201}$ on the sky from 2011 to 2018. Individual detections from 13 nights are shown on top of the predicted trajectory based on the best-fit orbit, which describes the detections very well with a scatter of 0.13 (DECam) and 0.03 (CFHT) arcsec in each component, consistent with the estimated astrometric error. The insets show example images from DECam (r-band on 2017-09-17) and CFHT (r-band on 2011-08-31). The oval pattern reflects the parallax of 2017 $OF_{201}$ due to the Earth's orbit. Credit: Institute for Advanced Study.*

"2017 $OF_{201}$ spends only 1 percent of its orbital time close enough to us to be detectable. The presence of this single object suggests that there could be another hundred or so other objects with similar orbit and size; they are just too far away to be detectable now," Cheng states.

Cheng discovered the object as part of an ongoing research project to identify TNOs and possible new planets in the outer Solar System. The object was identified by pinpointing moving objects in an astronomical image database derived from observation by the Victor M. Blanco (VMB) and Canada France Hawaii Telescopes. (CFHT). Ten detections of the new object were first identified in images acquired between 2014 and 2010 by the DECaLS (Dark Energy Camera Legacy Survey) instrument at the VMB. After connecting the individual images with a tentative orbit using a computationally efficient algorithm produced by Cheng, a further, focused search found other images 2017 $OF_{201}$ in the CFHT archives for 2011 and 2012. The additional images allowed a more precise calculation of the orbit of the new TNO. Ultimately, they identified 2017 $OF_{201}$ in 19 different exposures, captured over 7 years. "Even though advances in telescopes have enabled us to explore distant parts of the Universe, there is still a great deal to discover about our own Solar System."

The detection also demonstrates the power of open science. "All the data we used to identify and characterize this object are archival data that are available to anyone, not only professional astronomers," says Li.

"This means that groundbreaking discoveries aren't limited to those with access to the world's largest telescopes. Any researcher, student, or even citizen scientist with the right tools and knowledge could have made this discovery, highlighting the value of sharing scientific resources."

*Compiled in part with material provided by the Institute for Advanced Study, Princeton, NJ.*

## Hubble Tension gets an Aspirin

For the past decade, scientists have been trying to get to the bottom of what seemed like a major inconsistency in the Universe. The Universe expands over time, but how fast it's expanding has seemed to differ depending on whether you looked early in the Universe's history or the present day. These two results have presented a major problem to the gold-standard model that represents our best understanding of the Universe.

But thanks to the *James Webb Space Telescope*, scientists from the University of Chicago have been able to take new and better data—suggesting there may be no conflict after all.

"This new evidence is suggesting that our Standard Model of the Universe is holding up," said UChicago Prof. Wendy Freedman, a leading figure in the debate over this rate of expansion, known as the Hubble constant.

"It doesn't mean we won't find things in the future that are inconsistent with the model, but at the moment the Hubble constant doesn't seem to be it," she said.

There are currently two major approaches to calculating how fast our Universe is expanding. The first approach is to measure the remnant light left over from the Big Bang, which is still traveling across the Universe. This radiation, known as the cosmic microwave background, informs astronomers about what the conditions were like at early times in the

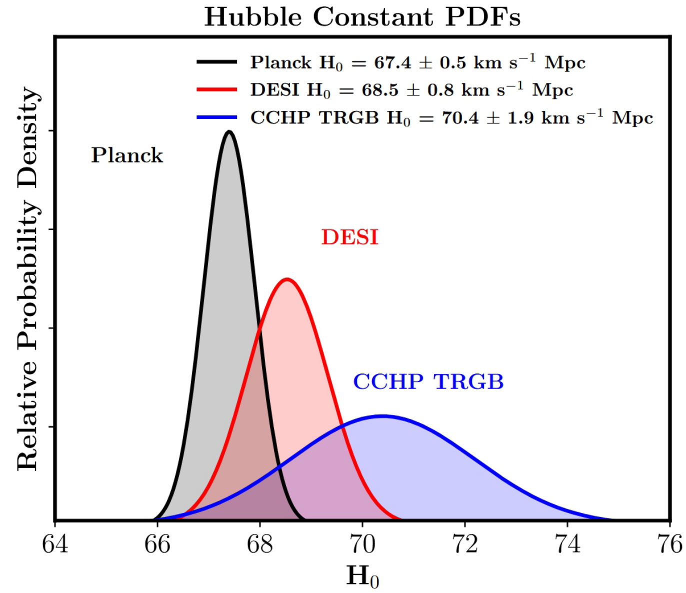



*Figure 2 – Relative probability densities for $H^0$ values from Planck (Planck Collaboration et al. 2020), DESI (DESI Collaboration et al. 2024) and the CCHP TRGB measurement (from this study). The results are all consistent, to within their uncertainties. Credit: Freedman, et al., arXiv:2408.06153, 2025.*

Universe. Freedman, the John and Marion Sullivan University Professor in Astronomy and Astrophysics, specializes in a second approach, which is to measure how fast the Universe is expanding right now in our local astronomical neighborhood. Paradoxically, this is much trickier than seeing back in time, because accurately measuring distances is very challenging. To refine the local measurement of expansion, Freedman and her team collected and calibrated three different methods:

- The brightness of stars at the tip of the red-giant branch in the Hertzsprung-Russell (H-R) diagram (TRGB)
- J-band luminosity (1.25 micron near-infrared) of carbon-rich asymptotic giant-branch stars (JAGB)
- Traditional Cepheid stars

The TRGB distance indicator uses the luminosity of the brightest red-giant stars in a galaxy as a standard candle; it is the point at which helium in the core is able to undergo nuclear fusion, creating a sharp directional change in the H-R diagram as the star increases in luminosity and moves to the left. The JAGB technique uses the brightness of carbon-rich stars on the asymptotic giant branch of the H-R diagram, observed in a narrow near-infrared atmospheric band in the Earth's atmosphere. Cepheid stars are well-studied variable stars whose intrinsic luminosity is a function of their period.

The three indicators are tightly correlated but independent methods of extracting the absolute magnitude of a distant star, which, when compared to its measured brightness, can be used to determine distance. The three also have the advantage of being associated with luminous stages in the evolution of their parent stars, making them visible across vast distances.

However, there are many corrections that must be applied to these measurements before a final distance can be declared. Scientists must first account for cosmic dust that dims the light between us and these distant stars in their host galaxies. They must also check and correct for luminosity differences that may arise over cosmic time. Finally, subtle measurement uncertainties in the instrumentation used to make the measurements must be identified and corrected for. Since the launch of the *James Webb Space Telescope* (JWST), astronomers have been able to increasingly refine these measurements.

"We've more than doubled our sample of galaxies used to calibrate the supernovae," Freedman said. "The statistical improvement is significant. This considerably strengthens the result."

The team's latest observations were used to refine measurements to nearby galaxies, as these provide the essential calibrations needed to extend distance estimates to the Universe at large.

Freedman's latest calculation, which incorporates data from both the *Hubble Space Telescope* and the JWST, finds a value of 70.4 kilometres per second per megaparsec, plus or minus 3 percent.

That brings her value into statistical agreement with recent measurements from the cosmic microwave background, which is 67.4, plus or minus 0.7 percent.

Webb has four times the resolution of the *Hubble Space Telescope*, which allows it to identify individual stars previously detected in blurry groups. It's also about 10 times as sensitive, which provides higher precision, and the ability to find even fainter objects of interest.

"We're really seeing how fantastic the *James Webb Space Telescope* is for accurately measuring distances to galaxies," said co-author Taylor Hoyt of the Lawrence Berkeley Laboratory.

"Using its infrared detectors, we can see through dust that has historically plagued accurate measurement of distances, and we can measure with much greater accuracy the brightnesses of stars," added co-author Barry Madore, of the Carnegie Institution for Science.

Freedman explained that astrophysicists have been trying to come up with a theory that would have explained different rates of expansion as the Universe ages.

"There have been well over 1,000 papers trying to attack this problem, and it's just turned out to be extraordinarily difficult to do," she said.

Scientists are still trying to find cracks in the Standard Model that describes the Universe, which could provide clues to the nature of two big outstanding mysteries—dark matter and dark energy. But the Hubble constant increasingly seems not to be the place to look.

Freedman and her team will be using the JWST next year to get measurements in a group of galaxies called the Coma cluster, which should provide more data from a different angle, she said.

"These measurements will allow us to measure the Hubble constant directly, without the additional step of needing the supernovae. I am optimistic about resolving this in the next few years, as we boost the accuracy to make these measurements," she said.

*Compiled with material provided by the University of Chicago.*

## New galaxy erodes models of Universe

In what seems to be an almost-weekly sighting, a large astronomical team has announced a "stunning population of bright galaxies at surprisingly early epochs." The science paper pulls no punches—the title begins with "A Cosmic Miracle…." In this case, it seems that the discovery really is something significant, well beyond a mere distance record.

The new announcement focuses on just one galaxy: MoM-z14, a luminous (UV magnitude = −20.2) source at a redshift of 14.44, a result that places it in time to a mere 280 million years after the Big Bang. Its redshift is very well determined, as several emission lines of carbon, nitrogen, oxygen, and helium are readily identifiable in the spectrum. These lines have been redshifted by the expansion of the Universe into the microwave part of the spectrum. For the hydrogen Lyman-alpha line, that's a redshift from 121.5 nanometres in the UV to 1.88 microns in the infrared.

MoM-z14's name comes from the "Miracle or Mirage" name given to the observing project, a spectroscopic survey using the JWST to confirm the nature of very early galaxies. The larger survey has shown a surprising abundance of bright early galaxies, a result that was already known but is now being pushed to challenging limits. Current models of the Universe are unable to cope with the abundance of galactic forms and their early development, and MoM-z14 just increases the challenge.

Many if not most of those previous thoughts about the early Universe have had to give ground to the observation of MoM-z14. The galaxy is composed of second-generation stars, since the presence of elements such as C, N, and O speaks of element creation in a previous stellar generation. The fact that it is observable and bright suggests that it is actively forming stars, a characteristic shared by most of the very early galaxies detected by the JWST.

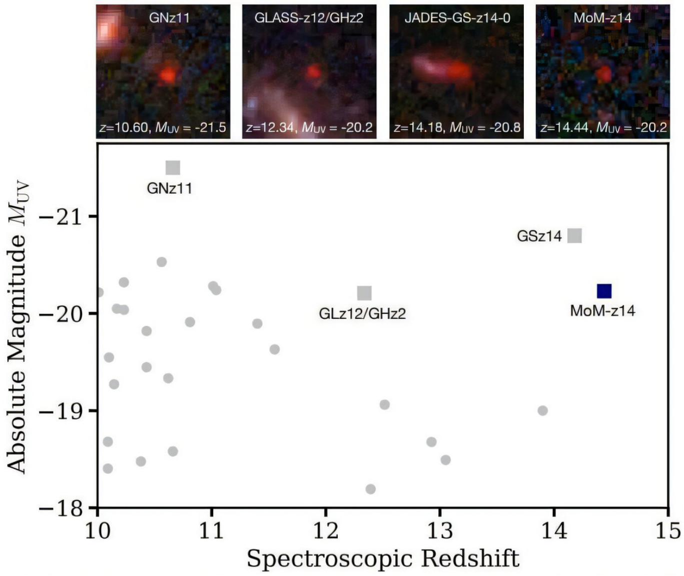



*Figure 3 – High-redshift galaxies on the cosmic frontier. On the top are images of the highlighted galaxies. Credit: R.P. Naidu et al., Open Journal of Astrophysics (submitted)/arXiv:2505.11263, 2025*

New stars produce UV photons, which ionize neutral atoms in the neighbourhood and it's those ionized atoms that produce the emission features seen in the spectrum as the lost electrons recombine with the nucleus and cascade down the atomic energy levels, emitting spectral lines along the way.

The derived age for MoM-z14, 280 million years after the Big Bang, is just 2 percent of the current age of the Universe, equal to a light-travel time of 13.53 billion years to reach our eyes. With our models of the Universe, we can determine that the galaxy is about 500 ly in diameter. It's concentrated in appearance and dust-free, as shown by the characteristics of its ultraviolet emission. It shows no signs of an active galactic nucleus (AGN) or light from a central black hole. Instead, there's plenty of light from a very high rate of star formation, likely the supermassive, luminous stars that theory predicts.

The star-formation rate seems to have jumped by a factor of at least 10 within the past 10 million years, and remained elevated for several million years. As a result, there's a high degree of ionization from UV radiation and must be a considerable amount of material to fuel star formation.

One of the biggest problems created by MoM-z14 is that we can see it at all. In the early years after the Big Bang, the Universe was a sea of ionized hydrogen. After about 379,000 years, the Universe had cooled to the point where neutral hydrogen could form. Such a Universe is relatively transparent but there were only two sources of photons: those created as neutral hydrogen formed, and those from the internal 21 cm radiation of hydrogen. Other photons that did form, from early concentrations of matter, were scattered or absorbed by the hydrogen. As expansion continued, visible wavelengths expanded into the infrared and the Universe became dark, an era known as the "Dark Ages." This time is visible as the cosmic microwave background.

As stars and other structures began to form under the influence of gravity in the interval between 150 million and 1 billion years after the Big Bang, newly created radiation began ionizing the hydrogen. Current models show the Universe becoming fully reionized about 550 My after the Big Bang, well after the creation of MoM-z14. The new galaxy is pushing hard against the boundary of the Dark Ages.

"JWST has revealed a stunning population of bright galaxies at surprisingly early epochs, $z > 10$, where few such sources were expected," the authors write. At a redshift of $z = 14.4$, this galaxy "expands the observational frontier to a mere 280 million years after the Big Bang." They point out that the JWST has found far more bright galaxies between $z = 14$ and 15 than the consensus showed before its launch.

The galaxy's nitrogen-to-carbon ratio is higher than that observed in the Sun. Its chemical composition resembles ancient globular clusters attached to the Milky Way. This means that the stars in the galaxy and those in globular clusters formed in similar environments with similar nucleosynthesis and metallicity pollution from previous stars.

"Since this abundance pattern is also common among the most ancient stars born in the Milky Way, we may be directly witnessing the formation of such stars in dense clusters, connecting galaxy evolution across the entire sweep of cosmic time," the authors write.

There seem to be two morphologies for these ancient bright galaxies: point source and extended. The relation between their morphologies and their chemistry is another potential link in galaxy evolution. "Furthermore, as noticed by Harikane et al. (2024b), these morphological differences are reflected in chemical abundance patterns, signaling a deeper connection between morphology and evolutionary pathways," the authors write.

As the JWST has found more ancient bright galaxies, a class of objects that are strong nitrogen emitters has become apparent, including luminous Little Red Dots. MoM-z14 could be among the most nitrogen-enhanced objects the JWST has ever found.

The space science community waited a long time for the JWST and its ability to observe the early Universe. While some of its findings have been unexpected, this study shows how astronomers are finding connections between the surprises revealed in the early Universe and the modern Universe.

"We interpret MoM-z14 and N-emitters through Galactic archaeology, connecting their abundance patterns to the most ancient stars born in the Milky Way at $z \geq 4$ as well as to globular clusters," the authors write in their conclusion. "The N-enhancement, brightness, hard ionizing spectra, stellar density, morphology, redshift dependence, and black hole fraction of these sources may be linked to globular cluster-like environments wherein runaway collisions may produce extraordinary objects such as supermassive stars."

If it survives repeated cancellation threats, the *Roman Space Telescope* should reveal hundreds more of these types of galaxies. A larger dataset is always desirable and would help solidify some of these findings, or maybe introduce new mysteries. Either way, it'll be progress. But for now, the *James Webb Space Telescope* deserves the spotlight for this discovery.

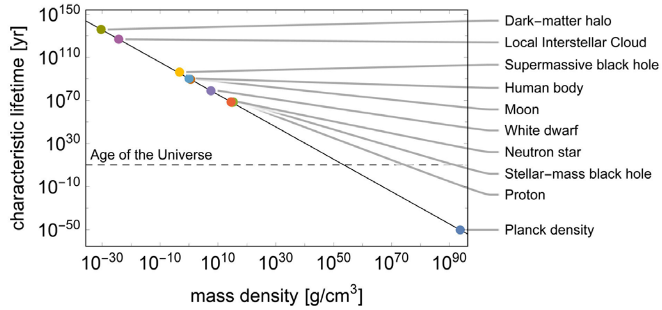



*Figure 4 – Researchers calculated from ten different objects how long the "evaporation" via Hawking-like radiation takes in an ideal environment without other influences. White dwarf stars dissolve in about $10^{78}$ years. The human body, if only Hawking-like radiation is involved, decays in $10^{90}$ years. Credit: Falcke, Wondrak & Van Suijlekom.*

## The end is closer than you think

The Universe is decaying much faster than thought according to calculations by three Dutch scientists on the so-called Hawking radiation. They calculate that the last stellar remnants will take about $10^{78}$ years to perish, much shorter than the previously postulated $10^{1100}$ years.

The research by black hole expert Heino Falcke, quantum physicist Michael Wondrak, and mathematician Walter van Suijlekom (Radboud University, Nijmegen, the Netherlands) is a follow-up to a 2023 paper by the same trio.

In that paper, they showed that not only black holes, but also other objects such as neutron stars, can "evaporate" via a process akin to Hawking radiation. After that publication, the researchers received many questions from inside and outside the scientific community about how long the process would take. They have now answered this question in the new article.

In a 1974 paper, Hawking showed that, in theory, a black hole radiates particles as if it were a blackbody, effectively draining energy from the black hole. Quantum fields in empty space obey Heisenberg's uncertainty principle, which means there is a limit to the certainty with which we can know their energy, or the time at which a specific energy can be assigned to them. Since a gravitational field bends space-time and affects the local passage of time, this means that regions of space-time with different gravitational curvatures cannot agree on the energy of the quantum fields. It is this difference in the energy of the vacuum at different locations in the gravitational field of a black hole that creates so-called "virtual particles," typically a photon but it also could be a particle. Quantum mechanics requires that two virtual particles must be created, one of which can be inside the event horizon of the black hole while the other lies beyond and escapes. The process results in a very slow evaporation of the black hole.

The researchers calculated that the end of the Universe is ≥about $10^{78}$ years away, if only Hawking-like radiation is taken into account. This is the time it takes for white dwarf stars, the most persistent celestial bodies, to decay via Hawking-like radiation.

Previous studies, which did not take this effect into account, put the lifetime of white dwarfs at $10^{1100}$ years. Lead author Heino Falcke commented, "So the ultimate end of the Universe comes much sooner than expected, but fortunately it still takes a very long time."

The researchers did the calculations dead-seriously and with a wink.

The researchers calculated that evaporation by Hawking radiation also applies to other objects with a gravitational field. The evaporation time depends only on the density of the object. Consequently, and to the researchers' surprise, neutron stars and stellar black holes take the same amount of time to decay: $10^{67}$ years. This was unexpected because black holes have a stronger gravitational field, which should cause them to evaporate faster.

"But black holes have no surface," says co-author and postdoctoral researcher Michael Wondrak, "They reabsorb some of their own radiation which inhibits the process."

Because the researchers were at it anyway, they also calculated how long it takes for the Moon and a human to evaporate via Hawking-like radiation: $10^{90}$ years. Of course, the researchers subtly note, there are other processes that may cause humans and the Moon to disappear faster than calculated.

Co-author Walter van Suijlekom, professor of mathematics at Radboud University, adds that the research is an exciting collaboration of different disciplines and that combining astrophysics, quantum physics, and mathematics leads to new insights.

"By asking these kinds of questions and looking at extreme cases, we want to better understand the theory, and perhaps one day, we will unravel the mystery of Hawking radiation." ✶

# Feature Article / Article de Fond

# The Sunrise Partial Eclipse of 2025 March 29—The Coastal Nova Scotia Experience

*by David M.F. Chapman, Halifax Centre (chapmandav@gmail.com)*

On 2025 March 29, there was a partial eclipse of the Sun, one year less 10 days (12 lunar months) after the total solar eclipse of 2024 April 9. Observing a partial eclipse would not normally excite me, but I realized early on that the 2025 partial eclipse would take place at sunrise along the northeast coast of North America, possibly a dramatic event. After the successful 2024 eclipse expedition to New Brunswick, I advised friends to hang on to their eclipse viewers in anticipation of the 2025 eclipse.

I wanted to observe the eclipse rising over the ocean, and had intended to observe from Hartlen Point (a 20-minute drive from my Dartmouth home). The Clear Sky Chart showed a serious band of cloud working its way up the coast from the southwest, and I worried about it covering the Sun, so I changed my mind at the last minute and drove along the Eastern Shore to the small village of Seaforth. It was an extra 10-minutes travel, but I know people there and had a spot clearly in mind that has a good ocean view.

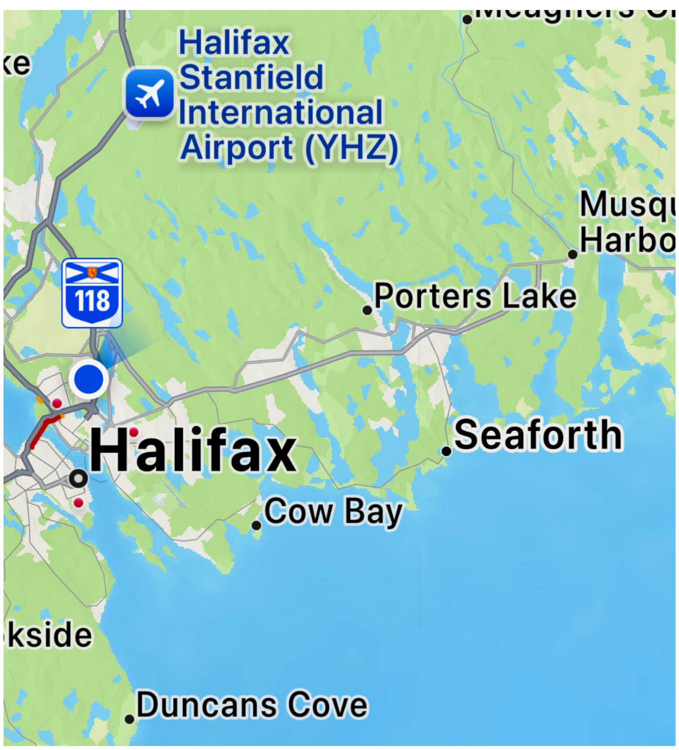



*Figure 1 — The drive from home (blue dot) to Seaforth was only 30 minutes. Hartlen Point (my original choice of observing location) is the point just to the southwest of Cow Bay.*

I arrived only minutes before sunrise and found a young couple in a truck already positioned there to watch the eclipse. I set my camera on my tripod, applied the settings, and waited. There was cloud to the south, but I could see that it would be clear where the Sun was rising in the east, as I saw a faint light pillar and bright reflections from scattered clouds. It was going to be a close call!

*Figure 2 — Seaforth resident Veronica is modelling the premium solar eclipse glasses the author loaned her.*

The young couple were Veronica and Mike, who (of course) were unprepared to observe a partial eclipse, so (of course) I supplied them some viewers that I brought for the very purpose of loaning to new friends.

The left horn of the Sun rose at 7:00 ADT, treating me to a lovely point-like green flash before I donned my viewers (the others missed it). It was incredible seeing the crescent Sun rise. In no time it was clear of the horizon.

I took dozens of photos with my Canon SL3 and stopped-down lens at various exposure times. I also observed in conventional viewers and a cool pair of 6×30 Lunt mini SUNoculars. Everything happened so fast. It was exciting to watch!


*Figure 3 — The Lunt mini 6×32 SUNocular viewer, ISO compliant.*

I shared my initial photos directly from my camera on social media, which earned some attention, but after I returned home, I looked into processing them more.

In Photoshop, I processed the RAW images from my camera and was able to improve the presentation. I used the tool to extend the dynamic range so that the images are not oversaturated. Here are the best two:

The approaching clouds finally moved in at 7:30 ADT, ending the eclipse for me. Many friends observed the event from high points within metro Halifax, and I reckon that observing from Hartlen Point would have been fine, but I'm glad that I chose Seaforth.

It was truly a memorable experience. ✶

*Dave Chapman is a Fellow of the RASC and a lifelong skywatcher, in his 7th decade of observing. He is also Dave XVII of the Royal Astronomical Society of Daves. Learn more at https://linktr.ee/DaveChapman*

*Figure 4 — Eclipse at 7:06 ADT, 6 minutes after sunrise*

*Figure 5 — Eclipse at 7:17 ADT (maximum eclipse)*

# Reading Copernicus

*By Michael Levy, Vancouver Centre*
*(m.r.levy@me.com)*

## Abstract

Guided by astronomical historian Owen Gingerich, I examine the way Copernicus's book *On the Revolutions of the Heavenly Spheres* has been read and interpreted, both soon after its publication and in recent times. Along the way, I hope to give you some understanding of the work, and to clear up some common misconceptions about it.

## Preliminaries

I think you will agree with me that many of us in the RASC have certain obsessive traits. It is exactly what makes us either fascinating or boring dinner companions. Recently, I read—for the second time—a book by Owen Gingerich called *The Book Nobody Read*. The book describes Gingerich's obsessive hunt to examine, in person, as many copies as he could of Copernicus's *De revolutionibus orbium coelestium*, (*On the Revolutions of the Heavenly Spheres*). He spent three decades on this quest. Since I, too, share some obsessive traits, reading his book led me to an obsession with Copernicus and much that has been written about him since the publication of his landmark treatise in 1543. Join me as I journey—with Owen Gingerich as my guide—to discover more about reading *Revolutions*.

Wikipedia has an entry titled *The Copernican Revolution*, which it calls "a paradigm shift from the Ptolemaic model of the heavens." This might lead one to conclude that *On The Revolutions* was a drastic and radical departure from what we might call the Ptolemaic model of the Universe, Ptolemy being, of course, the author of the treatise known as *The Almagest*, written some one thousand years earlier. The reality is more complex.

## Retrograde Motion

Ptolemy and Copernicus both created geometric models of the Universe[1]. Their objective was to describe, as precisely as then-current and historical visual measurement allowed, the motion of the Sun, the Moon, the planets, and the fixed stars. From these models, it became possible to create tables that could be used to calculate heavenly body positions for any given date at any location. In addition, their models made it possible to predict various other celestial events such as rising and setting times, conjunctions, and eclipses.

Both *The Almagest* and Copernicus's *On the Revolutions* are lengthy treatises covering in detail the Sun, the Moon, the planets, and the stars. We can get a small sense of their approach by looking just at their treatment of the outer planets.

When I started writing this article, (2025 February 10), I wished that the clouds would clear so that I could see Mars, sitting close to opposition in the middle of the constellation Gemini. Luckily, my astronomy app *SkySafari Pro* is not bothered by clouds. Using the app, I plotted the path of Mars starting from December 20 going up to April 29 of this year. Table 1 for right ascension on some selected dates is below.

| Date | Right Ascension |
|---|---|
| December 20, 2024 | 8h 32m 8.27s |
| December 21, 2024 | 8h 31m 20.18s |
| December 28, 2024 | 8h 24m 8.25s |
| January 18, 2025 | 7h 51m 10.44s |
| February 8, 2025 | 7h 22m 24.19s |
| February 24, 2025 | 7h 15m 50.95s |
| February 25, 2025 | 7h 15m 55.06s |
| April 28, 2025 | 8h 30m 29.59s |
| April 29, 2025 | 8h 32m 21.54s |

*Table 1 — Right Ascension of Mars from 2024 December 20 to 2025 April 29*

If you look first at the last two entries, you will see that Mars moved (with respect to the stars) almost two minutes ahead in right ascension. Recall that right ascension increases eastward, meaning that Mars appears to have moved east by about two minutes between the 28th and 29th of April. Eastward with respect to the fixed stars is the normal progression of Mars whose orbit is about 1.88 Earth years. But notice what is happening on the earlier dates: Mars is moving west, and keeps doing this, slowing down until it reaches a so-called stationary point sometime between February 24 and 25. If the sky were clear, we might imagine it moving right up to Castor and Pollux, and then one of them stopped it and threw it back the way it came.

You no doubt know that the word planet comes from the Greek πλανητεσ (planetai) meaning "wanderers," because of the fact that they did not stay in the same position with respect to the stars.

The apparent westward movement of the planets is called *retrograde motion*. Of course, there are two so-called *stationary points*—the first when the planet begins its retrograde motion, and the second when eastward movement resumes. This first point occurred around 2024 December 7.

I am not recording the declination here: it varies slightly too, but always stays close to the ecliptic. If you plotted the projected retrograde motion of Mars over a period such as the one above, you would get a diagram much like the one in Figure 2 (on p. 145).

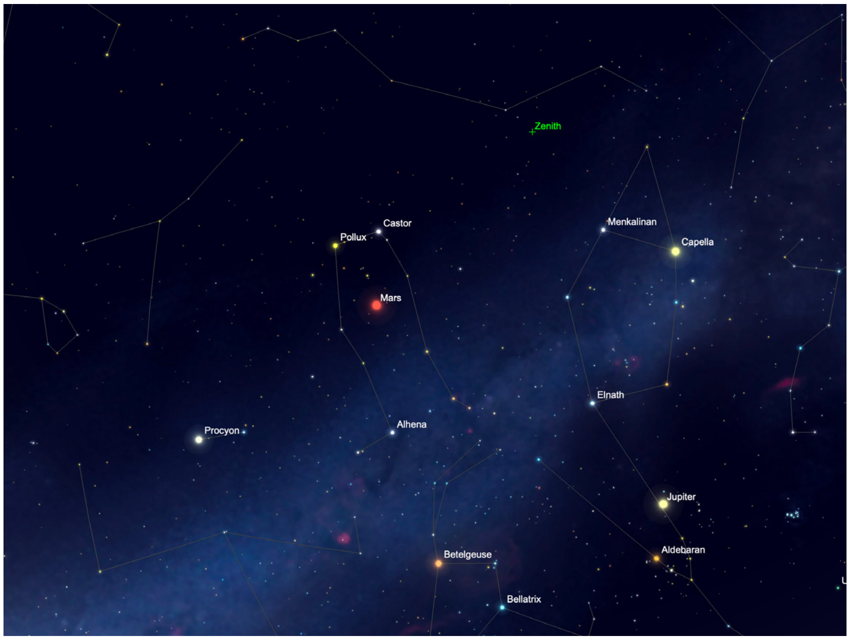



*Figure 1 — A sky map of Gemini and Mars.*

We can imagine that all ancient cultures noticed the unusual behaviour of the five wandering stars that were visible to the naked eye. Sadly, actual written records only exist in detail for Babylonian and Ancient Greek astronomy. The Babylonians developed what are essentially arithmetic interpolation techniques to try to predict the movement of the planets. Ptolemy, using many of the Babylonian observations, is the first person we know of who developed a predictive mathematical model based on geometry. The resulting document, *The Almagest*, written in about 150 CE, was so successful that it dominated astronomy until finally being upstaged by Copernicus in 1543.

Ptolemy, clearly influenced by Euclid, starts his treatise with some fundamental principles (much like Euclid's axioms). Foremost among these is the premise that Earth is at the centre of the Universe, and that the heavenly bodies, including the Sun and the Moon, travel along perfect circles, with uniform motion. It takes an incredible amount of sheer geometrical brilliance to get from these principles a model that works: that is, by using the model you can build a chart that can successfully predict solar, lunar, stellar, and planetary positions for any place, date, and time.

There is no space in this article to discuss the reasons why Ptolemy insisted on perfect circles and uniform motion other than to say that these concepts dated to the earliest known Greek attempts to describe the Universe using nested spheres. This is attributed to Eudoxus and later elaborated by Aristotle.

Actually, as I will discuss later, Ptolemy's model contained some aspects that later astronomers felt was a violation of these principles.

Even before Ptolemy's time, it was known that retrograde motion could be explained using a simple geometrical model with motion around two circles. The first circle, called the deferent, was a circle around the Earth. A second, smaller circle, called an epicycle, moves along the deferent. The planet moves along the epicycle. It may not be immediately apparent to you why this works, but if you play with a toy such as a Spirograph, you will be able to see a path similar to the one in Figure 2. (Search on YouTube for "Retrograde Motion" for some nice visualizations.)

Ptolemy also wanted the movements in his model—that is the angular velocity of the epicycles around the deferent and the angular velocity of a planet on the epicycle—to be uniform. A model that allowed non-uniform angular velocity would require mathematical sophistication that was just not available to him. Of course, the apparent velocity of the planets is not uniform—they move faster at apogee (furthest away from the Earth) and slower at perigee (closest to the Earth)[2]. One way to see how this works is straightforward: imagine that the movement is eccentric. That is, imagine that the Earth is not situated at the centre of the deferent circle, but is slightly offset from this position. This explains both the variable speed of the planets and their change in brightness.

Or does it? The problem arises when you try to attach numerical parameters to the model, namely the radius of the deferent, the radius of the epicycle, and their angular velocities. These numbers must match actual observations. It turned out that this simple eccentric model described above works reasonably well for the Sun, but not for the planets. In Ptolemy's model for any of the outer planets, there are two orbiting objects: the planet is orbiting on an epicycle, and the epicycle itself is orbiting on the deferent. His precepts required that both these orbits be uniform. That is (using modern terminology), the angular velocity in both cases should be constant. Unfortunately, this did not work in the simple eccentric model. Ptolemy solved the problem by introducing a new circle, called an equant circle, with the same radius as the deferent, but offset from its centre on the opposite side of the deferent centre but the same distance from it as the Earth. (Some writers call this point the equant; others call it the centre of the equant circle). Now imagine a line from this point to the centre of the epicycle. As the epicycle orbits the deferent, this line travels around the equant. It is this angular velocity that is uniform.

The introduction of the equant enabled Ptolemy to describe the motion of the planets very accurately. His parameters were used by astronomers, with the aid of various tables, to predict the position of the planets for any given date and location.

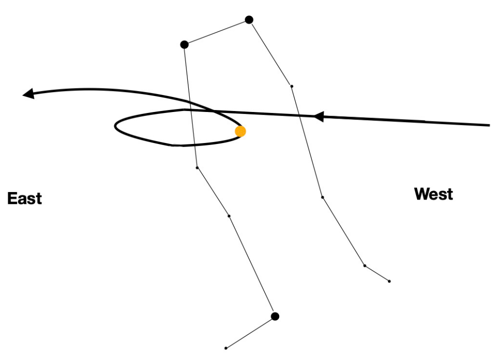



*Figure 2 — Mars retrograde motion through the Gemini constellation*

And, of course, other celestial events, such as eclipses, rising and setting times, and conjunctions.

You are probably thinking that Ptolemy would have found life much simpler if only he had chosen to place the Sun at the centre of the Universe. Enter Copernicus, who may have started with the same thought. Remember that astronomers at that time, including Copernicus, could be considered to be "Ptolemy-ists." That is, the mathematics they used was geometric, and they adhered to the principles of perfect circles and uniform motion. Using these methods, Copernicus spent many years developing a new model with the Earth rotating daily, and the Earth, the Moon, and the planets revolving around the Sun. Early during the work, in 1514, he wrote a brief outline of this. He called it *Commentariolus (Little Commentary)*, and circulated copies to friends and colleagues.

Finally, in 1543, at the urging of a young Austrian mathematician named Georg Joachim Rheticus, Copernicus agreed to publish his work.

His book is very similar in structure to *The Almagest*. It, too, starts with some fundamental precepts or axioms. But of course, one of his axioms places the Sun at the centre of the Universe, with the Earth and the planets orbiting the Sun. Only the Moon was left orbiting the Earth. I imagine that he thought retrograde motion would be fairly easy to deal with using this model, simply by imagining Mars (for example) to be moving more slowly and with a larger orbit than the Earth. As Earth overtakes Mars, its apparent movement shifts to westerly for a while, before resuming its easterly course. Was his model in fact simpler than Ptolemy's? Was he able to avoid epicycle upon epicycle?

## The Book that Everybody Read

In 1962, the philosopher Thomas Kuhn published a book called *The Structure of Scientific Revolutions* (Kuhn, 1962). In this book he made the claim that astronomy's complexity was increasing as astronomers tinkered with *The Almagest* in order to improve its accuracy. "But" he writes, "as time went on, a man looking at the net result of the normal research effort of many astronomers could observe that astronomy's complexity was increasing far more rapidly than its accuracy and that a discrepancy corrected in one place was likely to show up in another.[3]

To justify this claim he gives a somewhat vague reference to J.L.E. Dreyer's *A History of Astronomy from Thales to Kepler*, chapters xi-xii. I see no evidence of this in those chapters. Unfortunately, Kuhn's influential work (which popularized the term "paradigm shift") helped bolster the idea that epicycle upon epicycle had been added to Ptolemy's system until it was finally overthrown.

Flowing from this is the misconception that the Copernicus's heliocentric model is a lot simpler than the geocentric model of Ptolemy. For example, consider this from the *phys.org* website[4]:

"…*Copernicus proposed a model of the universe where the Earth, the planets and the stars all revolved around the Sun. In so doing, he resolved the mathematical problems and inconsistencies arising out of the classic geocentric model*."

Alas, this is simply not true. Copernicus thought that Ptolemy's equant was a violation of uniformity, and he was determined not to use it. He did allow the orbits of the planets to be eccentric—that is, that the Sun is not at the centre of a planet's orbit but is slightly offset. But this was not enough for the model to match observations. He therefore added epicycles to each planet's orbit. It turns out that both Ptolemy and Copernicus's models use a similar number of epicycles and have similar predictive capabilities.

There are other complications that Copernicus dealt with, requiring extra circles, including the observed changes in the so-called obliquity of the equinoxes caused by the fact that the Earth's axis of rotation itself revolves (like a wobbling top), and also his mistaken view that the precession of the equinoxes was not uniform.

There are aspects of the Copernicus model that are more satisfactory than Ptolemy. In particular, there is a uniformity to the treatment of the planets. The positions of the planetary orbits follow naturally from his model. Our guide, Owen Gingerich, argues that the appeal of the heliocentric model was not its simplicity or greater accuracy, but its aesthetic appeal[5]. Copernicus himself, in a preface to *Revolutions*, while not referring specifically to *The Almagest*, but instead to "the mathematicians," made this claim:

*"Also, they have not been able to discover or deduce from them the chief thing, that is the form of the universe, and the clear symmetry of its parts. They are just like someone including in a picture hands, feet, head and other limbs from different places, well painted indeed, but not modelled from the same body, and not in the least matching each other, so that a monster would be produced from them rather than a man."* [6]

Some 40 or so years later, both Galileo and Kepler believed that the heliocentric model was how the Universe actually worked. Galileo's telescopic observations undermined the Aristotelean and Platonic ideals of perfect spheres, perfect circles, and everything orbiting the Earth. But it was Kepler who finally eliminated the need for epicycles by realizing that the planets' orbits are elliptical.

To sum up, it should be clear that Copernicus could not claim that the heliocentric model was much simpler than the geocentric model. What was revolutionary about his book was its thoroughness in developing a model that not only placed the Sun at the centre of the Universe but retained all the predictive power of *The Almagest*. This book violated not only the Christian Bible, but also the centuries-long-held views of Aristotle, adopted by theologians and philosophers. Aside from its aesthetic appeal, we should note that the first edition of *Revolutions* was printed in 1543, during a time of great political, cultural, and social change in Europe. It was only 40 years since the pamphlet *Mundus novus* by Amerigo Vespucci announced the discovery of a new world and 26 years since Martin Luther published his *Ninety-Five Theses*, setting off a major political challenge to the authority of the Roman Catholic Church and the Papacy. For thinkers of the day, it was time to cast off the shackles of traditional visions of the world.

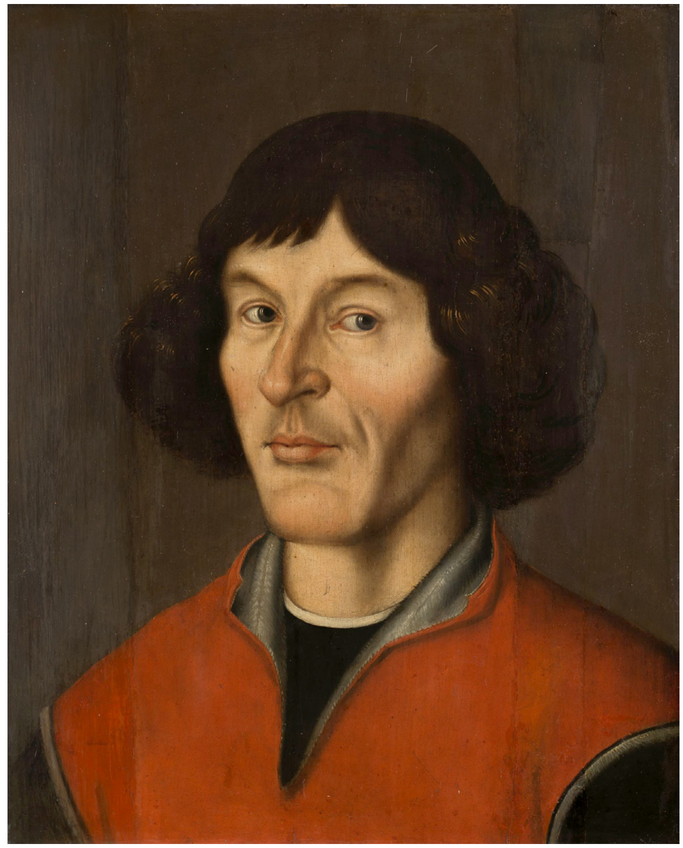


*Figure 3 — An image of Copernicus (Nicolaus Copernicus portrait from Town Hall in Toruń, 1580) Credit: WikiCommons*

It is therefore not surprising that, from the outset, Copernicus's book was seen by some as problematic. Copernicus died soon after it was published, and therefore he had no chance to challenge a preface added by an astronomer named Andreas Osiander. This preface, which was added without attribution, as if it had been written by Copernicus himself, suggested that the model in the book was not necessarily true, but merely useful for computational purposes. Presumably this was meant to deflect the wrath of both churchmen and Aristoteleans.

Copernicus's book is a challenging read. It is heavily mathematical and uses the same geometric approach used by Ptolemy. Although the book clearly bothered some prominent thinkers of the time, this does not mean they had actually read it.

## Did Anyone Read the Book?

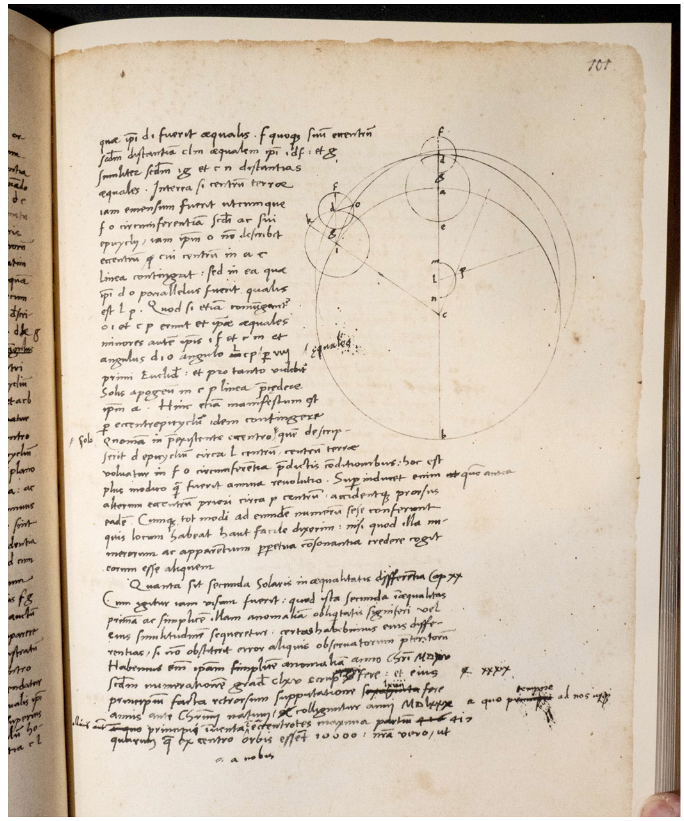
Author and journalist Arthur Koestler wrote a book called *The Sleepwalkers*, published in 1959. It traced the history of Western astronomy from the Babylonians to Newton. Part 3 of *The Sleepwalkers*, titled "The Timid Canon," is about Copernicus. Section 2 of this part is titled "The System of Copernicus," and its introductory section is titled "The Book that Nobody Read." He backs up this claim by pointing out that the first edition of 1,000 copies never sold out, and that there were only 4 reprints in 400 years. He claims that this is "a remarkable negative record, and quite unique among books that made history." Koestler was not a scientist, and there is no reason why popularity of a book should correlate with readership. Furthermore, I have no idea where Koestler obtained his figures for the publication and sales of the book—I'll talk more about this later.

## My Guide: Owen Gingerich

Owen Gingerich, my guide to reading Copernicus, was born to a Mennonite family, and he remained religious his whole life. He obtained a Master's degree from Harvard University in 1953, and his Ph.D. in astronomy there in 1962. The title of his Ph.D. Thesis was *Studies in Non-Gray Stellar Atmospheres*. During this time of his life, he was a frequent contributor to *Sky & Telescope* magazine.

After graduating, he was appointed as a professor of Astronomy at Harvard. In those days, Harvard was a pioneer of computers and had close ties with IBM. Indeed, my own Master of Computer Science supervisor, Derek Henderson, was a graduate student at Harvard around this time, and he told us that he had worked with a group of Harvard faculty and graduate students with IBM on the design of the IBM 360. Gingerich himself took to programming, and soon became adept at programming on an IBM 7094. He started writing programs to build ephimerides (tables of planetary and stellar positions) that spanned a period of several thousand years. This work led him to an increasing fascination with the history of astronomy. So much so that in 1967 he was appointed jointly to Harvard's History of Science department.

In 1970, while on a visit to the Royal Observatory, Edinburgh, he explored what he calls "a huge safe of rare astronomy books." Here he came across a richly annotated copy of Copernicus's book. He had read, and enjoyed, Koestler's *Sleepwalkers*, and thus was aware of Koestler's claim that nobody read *On the Revolutions*. Seeing the annotations in the edition in front of him made Gingerich question this assertion and set him on a 30-year obsessive quest to see if this statement was true. His method? Try to see, in person, as many copies of the first and second editions as possible. The result of this wild ride, covering visits to cities and libraries across the world, was that he became an expert on this subject, leading in 2002 to the book *An Annotated Census of Copernicus' De revolutionibus* (Gingerich 2002). Figures 4a, b, and c show a copy of one of the pages of *On the Revolutions* in a facsimile of the manuscript, a facsimile of the first edition, and a page from an English translation.



Figures 4a (above) — A facsimile of the original manuscript.

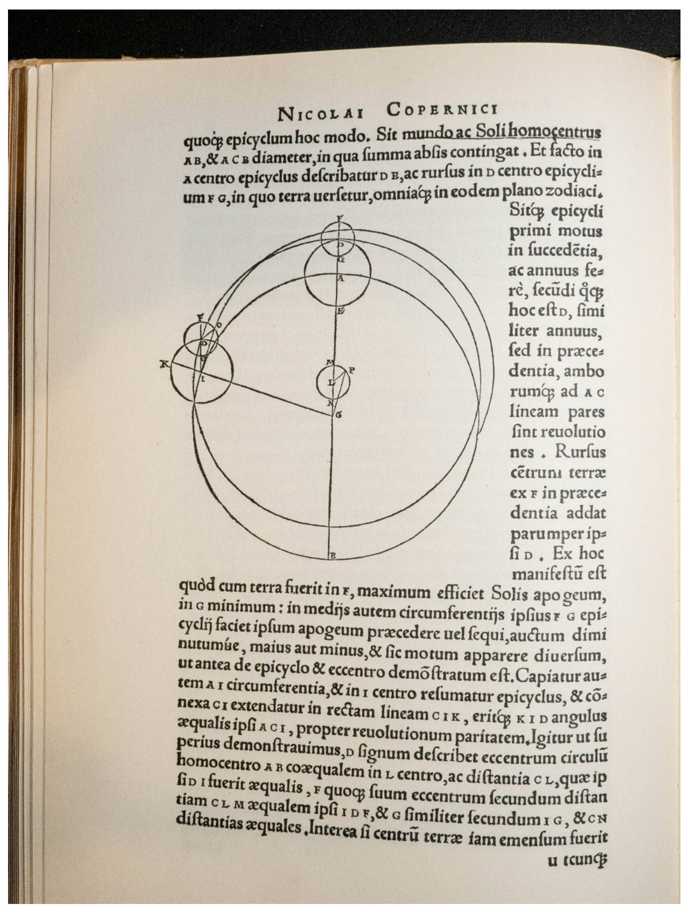
## The Book Nobody Read: Chasing the Revolutions of Nicolaus Copernicus

The Annotated Census is of course a book of interest probably only to collectors of rare books. The companion book by Gingerich, published in 2004, whose full title is *The Book Nobody Read: Chasing the Revolutions of Nicolaus Copernicus,* is written for a general audience (Gingerich 2004). It is a fascinating read. Chapter One starts not with a technical description of heliocentric astronomy, but with his account of the time that he appeared in court as a witness to a case against a thief who had stolen a first edition of *Revolutions* from The Franklin Institute in Philadelphia. Because of Gingerich's extensive knowledge and notes about almost every existing first and second edition, he was often able to match copies that showed up at dealers with known missing copies. Or indeed alert an institution to the fact that one of their copies might be missing.

Subsequent chapters cover his hunt for editions, his visits to libraries and institutions, as well as much information about rare books and their market. Surprisingly, he often worked with the renowned furniture designer Charles Eames. Eames accompanied him on some of his searches to take photographs of the manuscripts they were examining.

Included in Gingerich's book is his own attempt to try to deduce how many copies of the first and second editions of *On the Revolutions* were printed. After reading this, I was convinced that Koestler had made up his numbers for the sake of a good read. He was, after all, a popular writer and not a research scientist.

Figure 4b (below) – A facsimile of the same page in the first edition.



NICOLAI COPERNICI

quoq; epicyclum hoc modo. Sit mundo ac Soli homocentrus AB, & ACB diameter, in qua summa absis contingat. Et facto in A centro epicyclus describatur DE, ac rursus in D centro epicyclium FG, in quo terra uersetur, omniaq; in eodem plano zodiaci. Sitq; epicycli primi motus in succedẽtia, ac annuus ferè, secũdi q̃q; hoc est D, simi liter annuus, sed in præcedentia, ambo rumq; ad AC lineam pares sint reuolutio nes. Rursus cẽtrum terræ ex F in præcedentia addat parumper ipsi D. Ex hoc manifestũ est quòd cum terra fuerit in F, maximum efficiet Solis apogeum, in G minimum: in medijs autem circumferentijs ipsius FG epicyclij faciet ipsum apogeum præcedere uel sequi, auctum diminutumúe, maius aut minus, & sic motum apparere diuersum, ut antea de epicyclo & eccentro demõstratum est. Capiatur autem AI circumferentia, & in I centro resumatur epicyclus, & cõnexa CI extendatur in rectam lineam CIK, eritq; KID angulus æqualis ipsi ACI, propter reuolutionum paritatem. Igitur ut superius demonstrauimus, D signum describet eccentrum circulũ homocentro AB coæqualem in L centro, ac distantia CL, quæ ipsi DI fuerit æqualis, F quoq; suum eccentrum secundum distantiam CLM æqualem ipsi IDF, & G similiter secundum IG, & CN distantias æquales. Interea si centrũ terræ iam emensum fuerit

u tcunq;

Continues on page 154

# Pen & Pixel

Figure 1 – "Will you walk into my parlour?" said the Spider to the Fly,

"'Tis the prettiest little parlour that ever you did spy…" Thus wrote Mary Howitt in 1829. Today, we have two beautiful nebulae with the same names, IC 417 and NGC 1931, respectively. Steve Leonard imaged the pair using the Foraxx palette. Steve writes, "What makes this target so rewarding is the rich contrast between the chaotic, web-like outer nebulosity of the Spider Nebula and the bright high-energy and star-forming cores of the two nebulae. Steve used an AstroTech AT115EDT 4.5" triplet refractor at f/5.6 on an EQ6-R Pro mount, along with NINA, an ASI 1600MM Pro camera, Astrodon RGB filters, and Chroma 3-nm SHO filters. Processed in PixInsight and Topaz Denoise; imaged from Markham, Ontario, under Bortle 8/9, skies.

Figure 2 – From spiders and flies to fish. Kimberly Sibbald imaged the Fish Head Nebula (IC 1795) over seven nights in September and October 2024. She used a SharpStar 140PH Triplet with a 910-mm focal length lens, and a Mesu 200 MKII mount with a ZWO2600 camera. Total integration was 35 hours and 40 minutes.

*Continues on page 153*

# What's Up in the Sky?

## August/September 2025

*Compiled by James Edgar*

### August Skies

**The Moon** at the beginning of August is at first quarter and reaches apogee of 404,161 km. On the 3rd, Antares, the bright red star in Scorpius, is 0.6 degrees north of the Moon. Full Moon is on the 9th. August 12 finds both Saturn and Neptune 4 and 3 degrees south of the waning gibbous Moon, respectively. On the 16th, the last-quarter Moon is 0.9 degrees north of the Pleiades (M45). The 19th has Jupiter 5 degrees south of the waning crescent orb, while Venus takes up that post on the following day. The Moon and Mercury hover around the Beehive Cluster (M44) on the 21st. The Moon is new on the 23rd. Mars is 3 degrees north on the 26th; Spica is 1.2 degrees north on the 27th; and the Moon reaches first quarter on the 31st. Antares joins our satellite on the 31st, an occultation in the extreme south—for northerners, the bright red star in Scorpius is only 0.7 degrees away.

**Mercury** is in front of the Sun until mid-month, when it gradually becomes visible in the early morning eastern sky. Greatest elongation west occurs on the 19th, and then the speedy planet continues its orbit to behind the Sun.

**Venus and Jupiter** are poised to meet up in Gemini in the early dawn twilight in mid-August–a magnificent conjunction of the sky's two brightest planets. They pass within one degree of each other on the 12th, the night of the annual Perseid meteor shower (see below). On the 20th, the very thin crescent Moon joins up with the planetary pair in the dawn sky.

**Mars** is an evening object, hovering among the stars of Virgo, but you have to be quick about catching the Red Planet, as it's right near the horizon at sundown. The waxing crescent Moon slides by on the 25/26th.

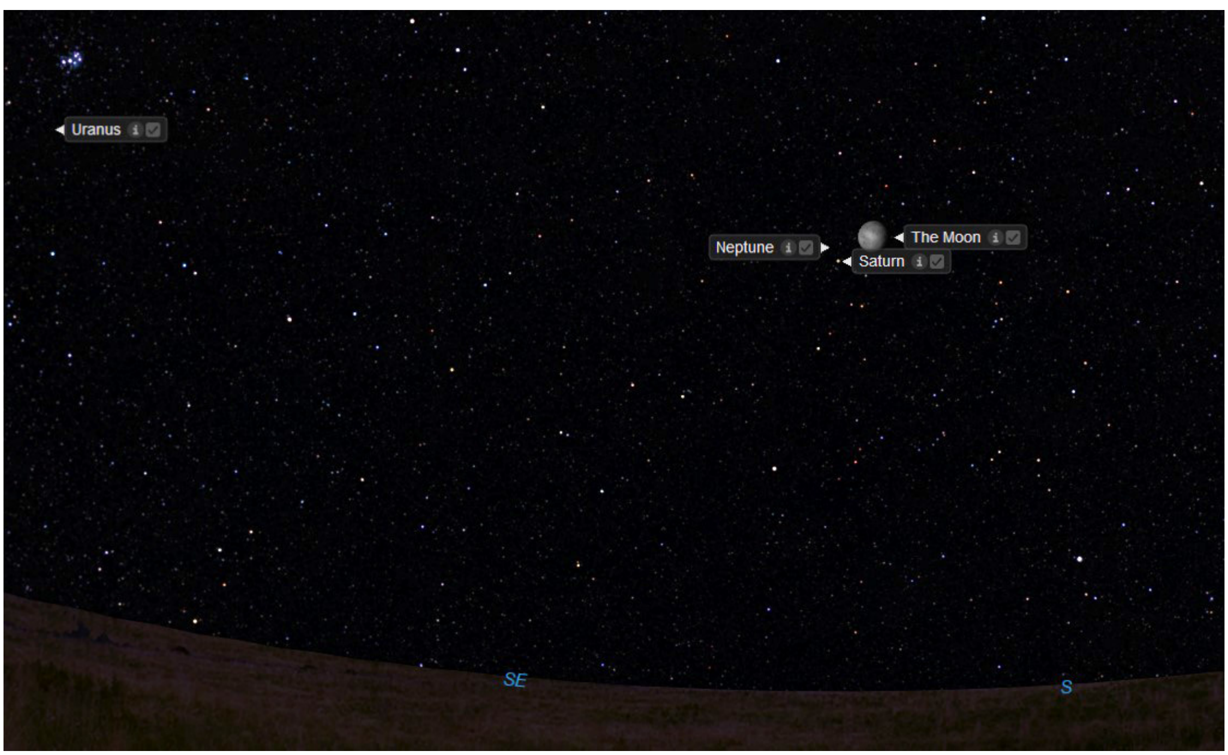
**Jupiter** is in Gemini with Venus, as described above–the two make a splendid pair for several days before and after the 12th.

**Saturn** is in conjunction with Neptune on the 6th–the second in a series of three, with the final one occurring in mid-February 2026. They might steal some of the Perseid meteor show when the Ringed Planet and Neptune join up with the Moon on the night of the 12th.

**Uranus** rises near midnight, remaining in the night sky until dawn's early light.

**Neptune** is a telescopic target all through the night–it rises at sundown and sets in the early morning. As stated above, Saturn joins up with the blue planet on the 6th.

**The Perseid meteors** peak the night of August 12. That's when Earth passes through the cloud of tiny particles left behind by Comet 109P/Swift-Tuttle in its many passes by the Sun. It has been confirmed that the earliest sighting was over 2100 years ago, returning approximately every 130 years. The comet is next due to appear in 2126.




*August sees the tight trio of Saturn, Neptune, and the Moon clustered in Pisces, The Fish, with Uranus far off to the east below the Pleiades. Image by Starry Night Pro Plus*

*Continues on page 152*

# The Sky August/September 2025

*Compiled by James Edgar with cartography by Glenn LeDrew*

**Celestial Calendar** (bold=impressive or rare)

Aug. 4 new Moon at 7:12 a.m. EDT (lunation 1257)

**Aug. 4 Venus 1.1° north of Regulus**

**Aug. 5 Venus 1.1° south of thin crescent Moon**

Aug. 8 Moon at apogee (405,297 km)

**Aug. 12 Perseid meteors peak at 10 a.m. EDT**

Aug. 12 Moon at first quarter

**Aug. 14 double shadows on Jupiter**

**Aug. 14 Mars 0.3° north of Jupiter**

Aug. 19 full Moon at 2:26 p.m. EDT

Aug. 21 Moon at perigee (360,219 km)

**Aug. 21 Saturn 0.5° south of waning gibbous Moon**

**Aug. 24 double shadows on Jupiter**

**Aug. 25 Moon in Pleiades (M45)**

Aug. 26 Moon at last quarter

Aug. 27 Jupiter 6° south of last-quarter Moon

Aug. 27 Mars 5° south of last-quarter Moon

**Aug. 30 Pollux 1.7° north of waning crescent Moon**

Sep. 1 Mercury 5° south of thin crescent Moon

Sep. 2 new Moon at 9:54 p.m. EDT (lunation 1258)

Sep. 4 Mercury at greatest elongation west (18°)

Sep. 5 Moon at apogee (406,211 km)

**Sep. 6 Spica 0.5° south of waxing crescent Moon**

**Sep. 8 Mars 0.9° south of M35**

Sep. 9 Mercury 0.5° north of Regulus

Sep. 11 Moon at first quarter

Sep. 17 full Moon at 10:34 p.m. EDT; partial lunar eclipse

Sep. 18 Moon at perigee (357,286 km)

**Sep. 22 Moon 0.2° north of Pleiades**

Sep. 22 Autumnal equinox

Sep. 24 Moon at last quarter

Sep. 25 Mars 5° south of Moon

**Sep. 26 Pollux 1.7° north of waning crescent Moon**

## Planets at a Glance

| | DATE | MAGNITUDE | DIAMETER (″) | CONSTELLATION | VISABILITY |
|---|---|---|---|---|---|
| Mercury | Aug. 1 | — | 9.3 | Leo | — |
| | Sep. 1 | 0.5 | 8.2 | Leo | Morning |
| Venus | Aug. 1 | — | 10.2 | Leo | — |
| | Sep. 1 | –3.8 | 11.0 | Virgo | Evening |
| Mars | Aug. 1 | 0.9 | 5.9 | Taurus | Morning |
| | Sep. 1 | 0.7 | 6.5 | Taurus | Morning |
| Jupiter | Aug. 1 | –2.1 | 35.5 | Taurus | Morning |
| | Sep. 1 | –2.3 | 38.5 | Taurus | Morning |
| Saturn | Aug. 1 | 0.8 | 18.7 | Aquarius | Evening |
| | Sep. 1 | 0.6 | 19.2 | Aquarius | Evening |
| Uranus | Aug. 1 | 5.8 | 3.5 | Taurus | Morning |
| | Sep. 1 | 5.7 | 3.6 | Taurus | Morning |
| Neptune | Aug. 1 | 7.8 | 2.3 | Pisces | Evening |
| | Sep. 1 | 7.8 | 2.3 | Pisces | Evening |


NORTH
AURIGA
LYNX
NW
PERSEUS
TRIANGULUM
Double Cluster
ANDROMEDA
CASSIOPEIA
CAMELOPARDALIS
URSA MAJOR
M31
Polaris
Little Dipper
URSA MINOR
CEPHEUS
Big Dipper
CANES VENATICI
LEO
DRACO
LACERTA
Deneb
COMA BERENICES
BOÖTES
Venus (August 19)
WEST
PEGASUS
Northern Cross
CYGNUS
M13
Vega
LYRA
CORONA BOREALIS
Arcturus
DELPHINUS
SAGITTA
VULPECULA
HERCULES
Altair
SERPENS CAPUT
VIRGO
SERPENS CAUDA
AQUILA
Spica
OPHIUCHUS
SCUTUM
LIBRA
CAPRICORNUS
M8
Antares
SW
SCORPIUS
SAGITTARIUS
M7
SOUTH

*Continued from page 149*

## September Skies

**The Moon's** orbit is tilted by about 5 degrees. When the orbit crosses the ecliptic, the imaginary plane where the planets orbit the Sun, it's termed a "node." So, on September 7, at 11:08 p.m. UT (5:08 p.m. CST), the Moon is at the ascending node. Ascending meaning moving from south to north, descending goes the other way. A node-crossing event brings about an eclipse season–twice a year, sometimes three times a year. Thus, on September 7, the Sun, Earth, and the full Moon line up such that Earth's shadow darkens the Moon–a lunar eclipse. The event lasts a couple of hours and can be seen from most of the Eastern Hemisphere; unfortunately not visible in the Western Hemisphere. Fourteen days later, a solar eclipse occurs during new Moon, only visible from the extreme South Pacific and Antarctica. In the meantime, we have some planetary and stellar close calls to observe. On the 8th, Saturn and Neptune are within 4 and 3 degrees of the Moon, respectively. The Pleiades are 1 degree away on the 12th. By the 16th, Jupiter is 5 degrees south of the waning crescent Moon, and the following day it's 2 degrees north of the Beehive Cluster (M44). The morning of the 19th sees a trio of the Moon, Regulus, and Venus. The 23rd sees Spica in Virgo only 1.1 degrees from a barely visible thin crescent Moon. Mars is 4 degrees north on the 24th and Antares (the opposite of Mars/Ares) is 0.6 degrees north on the 27th.

**Mercury** is behind the Sun, or too close to observe, all month.

**Venus** remains a Morning Star in the eastern dawn. Watch for a trio of Venus, Regulus, and the crescent Moon on the 19th.

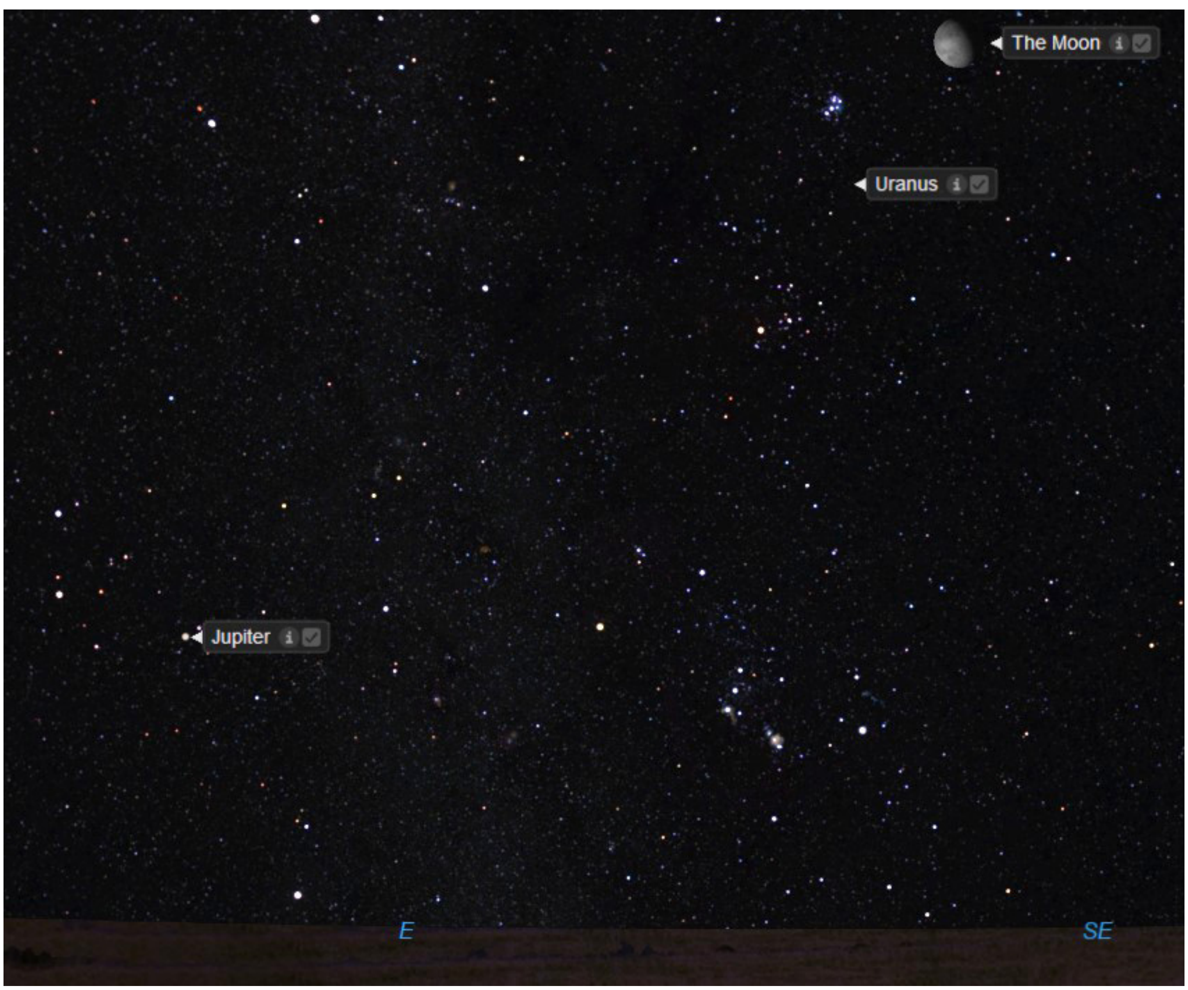
**Mars** is tiny but visible in the western evening twilight. It passes 2 degrees north of Spica on the 12th.

**Jupiter** is prominent in the evening sky and through the night. The waning crescent Moon passes 5 degrees to the north on the 16th. Toward the end of the month, a series of double shadow transits of two Galilean moons occur at 3.5-day intervals.

**Saturn** is at opposition in Pisces on the 21st, so the closest to us and furthest from the Sun, making for prime observing and astrophotography. The Ringed Planet will be in retrograde motion for most of the month. Watch for the Moon nearby on the 8th.

**Uranus** begins retrograde motion on the 6th among the stars of Taurus, just to the south of the Pleiades. Its apparent westward motion continues for nearly six months.

**Neptune** is in southern Pisces all month, along with Saturn, and reaching opposition on the 23rd. At its extreme distance from the Sun, the reflected light takes 4 hours to reach us. ✶




*September has Jupiter in Gemini, to the east of Orion, while Uranus is a few degrees below the waning gibbous Moon on the 12th.*

Continued from page 148

*Figure 3 – Mark Germani took this exquisite image of the Orion Nebula and he writes, "The iconic Orion Nebula (M42) is a region of diffuse nebulosity and star formation, and consists of both emission and reflection nebulosity, which inspired me to collect both broadband and narrowband data using multiple exposure lengths to prevent the brighter areas of the core from overexposing. With the smaller square sensor of my camera, a two-panel mosaic was necessary to capture the nebula in its entirety. In total, 9 different datasets comprising roughly 18 hours of data were combined to create this Hα RGB HDR image."*

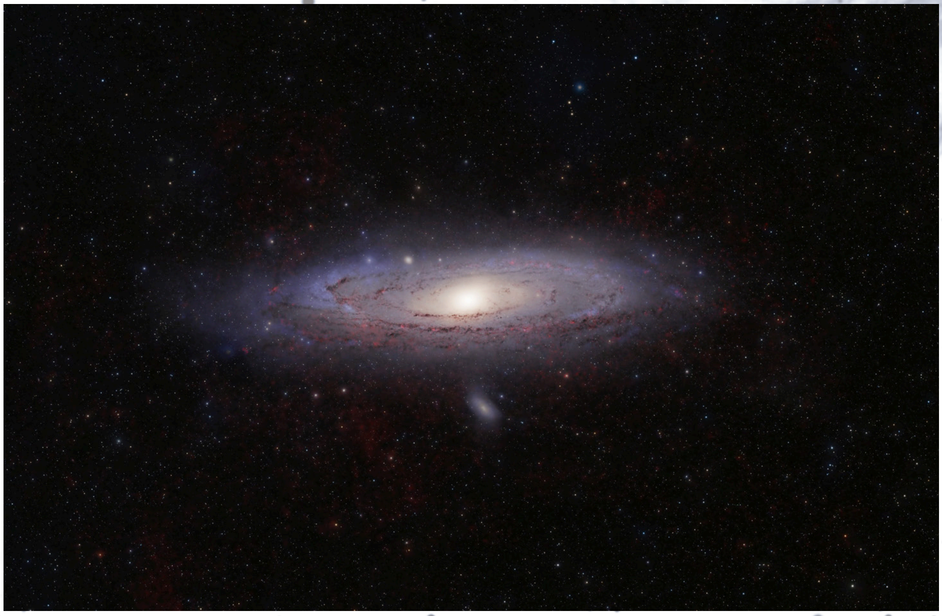
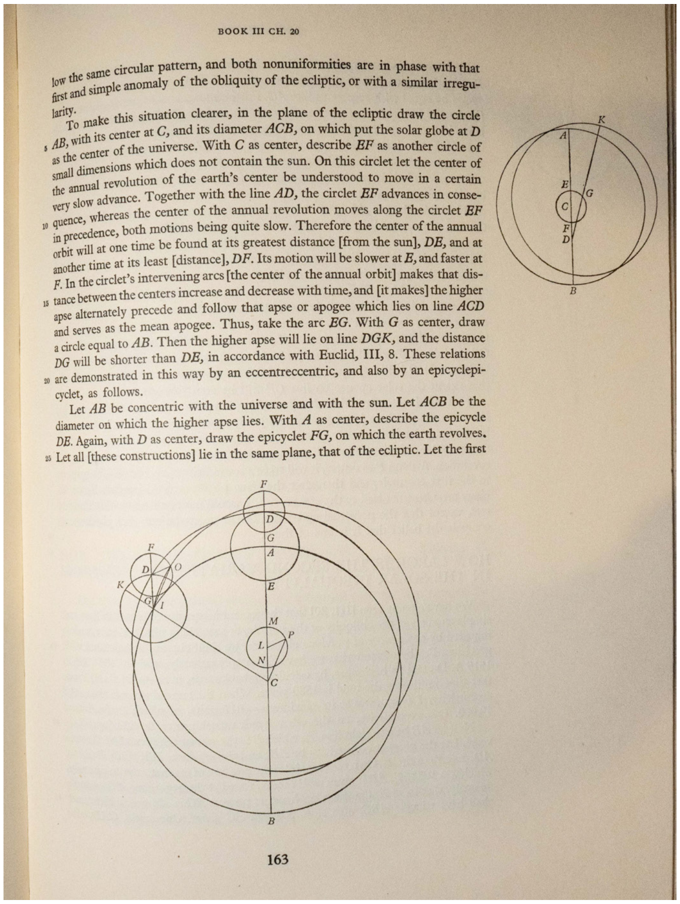


*Figure 4 – Our beautiful neighbour, and the closest spiral galaxy to our own Milky Way, the Andromeda Galaxy, was captured by Shelley Jackson under Bortle 4 skies from Athens, Ontario, using an Askar 200-mm astrograph lens with a ZWO 2600MC camera and a ZWO electronic filter wheel. She used a Sky-Watcher AZ EQ5 pro, with a ZWO EAF focuser and an Askar auto-focus kit. Acquisition software included NINA, ASTAP plate-solving, ASCOM device management, and PHD2 guiding. Stacked with PixInsight (WBPP). All processing and editing done with PixInsight for a total integration of 8.5 hours.*

*Continued from page 147*



BOOK III CH. 20

low the same circular pattern, and both nonuniformities are in phase with that first and simple anomaly of the obliquity of the ecliptic, or with a similar irregularity.

To make this situation clearer, in the plane of the ecliptic draw the circle *AB*, with its center at *C*, and its diameter *ACB*, on which put the solar globe at *D* as the center of the universe. With *C* as center, describe *EF* as another circle of small dimensions which does not contain the sun. On this circlet let the center of the annual revolution of the earth's center be understood to move in a certain very slow advance. Together with the line *AD*, the circlet *EF* advances in consequence, whereas the center of the annual revolution moves along the circlet *EF* in precedence, both motions being quite slow. Therefore the center of the annual orbit will at one time be found at its greatest distance [from the sun], *DE*, and at another time at its least [distance], *DF*. Its motion will be slower at *E*, and faster at *F*. In the circlet's intervening arcs [the center of the annual orbit] makes that distance between the centers increase and decrease with time, and [it makes] the higher apse alternately precede and follow that apse or apogee which lies on line *ACD* and serves as the mean apogee. Thus, take the arc *EG*. With *G* as center, draw a circle equal to *AB*. Then the higher apse will lie on line *DGK*, and the distance *DG* will be shorter than *DE*, in accordance with Euclid, III, 8. These relations are demonstrated in this way by an eccentreccentric, and also by an epicyclepicyclet, as follows.

Let *AB* be concentric with the universe and with the sun. Let *ACB* be the diameter on which the higher apse lies. With *A* as center, describe the epicycle *DE*. Again, with *D* as center, draw the epicyclet *FG*, on which the earth revolves. Let all [these constructions] lie in the same plane, that of the ecliptic. Let the first

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*Figure 4c — The same page in an English translation.*

After I attended the talk given by Owen Gingerich in 2003, I bought a copy of his book, and recently read it again. This led me to read further articles by Gingerich: a good collection of these is available as *The Eye of Heaven: Ptolemy, Copernicus, Keple*r (Gingerich 1993).

## Conclusion

It is not surprising that Owen Gingerich became a collector of rare astronomical books. He died in 2003, aged 93. In preparation for this article, I became curious about the fate of his likely collection of ancient astronomical books. I expected (perhaps) that these manuscripts were donated to Harvard or a museum. And possibly some were. But it turns out that in January of this year (2025), Christie's held an auction of rare books from three collections, one of which was from Owen Gingerich's private collection.

His books sold for a total of US$2,147,760. The most expensive of these was not *Revolutions*, but *Astronomia Nova* by Kepler. Its price estimate was $120,000–$180,000. The price realized was a whopping $327,600. (But take heart—you can buy a lovely translation of this book, translated by William H. Donahue, and with a foreword by Owen Gingerich, for a mere $59.95.) The fourth place in terms of value was *Revolutions*, which I think was a second edition—there is a photograph in his book of Owen Gingerich with his own second edition. It sold at more than double the estimate for $163,800. You may be lucky enough to buy a first or second edition yourself someday, and, if you do, please invite me to come and look at it. I will bring white cotton gloves with me. ✶


## Acknowledgements

Many thanks to Professor Christopher Friedrichs for his careful reading and thoughtful suggestions.


## Endnotes

1 Copernicus used the Latin word mundus, which is more commonly translated as world, but both English translations I have seen use the word Universe. Remember that it was only in the 20th century that people began to understand that the stars we see are confined to our very average galaxy in a much larger Universe.

2 Remember that Ptolemy placed the Earth at the centre of all heavenly body orbits.

3 Kuhn, 1962, page 68 of the paperback edition.

4 https://phys.org/news/2016-01-heliocentric-universe.html

5 Owen Gingerich. 1975. "'Crisis' versus aesthetic in the Copernican revolution". *Vistas in Astronomy 17(1)* (1975): 85-95.

6 Duncan 1976, page 25

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*The Royal Astronomical Society of Canada is dedicated to the advancement of astronomy and its related sciences; the* Journal *espouses the scientific method, and supports dissemination of information, discoveries, and theories based on that well-tested method.*

# Great Images

*By Bruce Hamilton*

*From Litchfield, Nova Scotia, north of Annapolis Royal on 2015 October 07, 9:18 p.m.*

*Using a Canon EOS Rebel T2ibr/ 25 sec., ISO 1600, 10-mm*

*To see the aurora this far south we need a clear northern sky with a low horizon. This shot is overlooking the Bay of Fundy and the lights in the distance are Saint John, New Brunswick, about 50 miles distant.*

*This image was a submission to the RASC Astroimaging Certificate Program.*

*By John Mirtle*

*The constellation of Auriga, showing several Messier clusters and a few nebulae from the Index Catalogue. An 8-point star filter was used to help avoid losing the bright stars marking the pentagon into the background! It also helped to bring out the star colours.*

*Details: 2000 November 19 near Cayley, Alberta*

*Olympus OM-2, 50-mm ƒ/1.8 lens Ektachrome E200, 15 minutes at ƒ/2.8*

*This image was a submission to the RASC Astroimaging Certificate Program.*

# Mostly Variable Stars

## The wild and wacky world of space conferences

*by Hilding Neilson*
*(hneilson@mun.ca)*

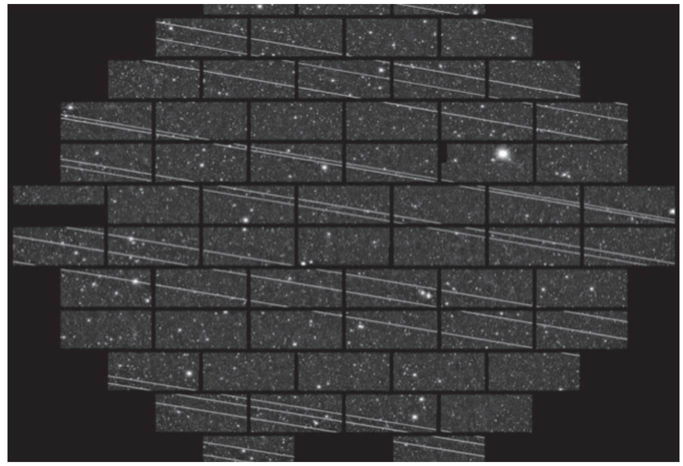

*Figure.1 — Starlink satellites visible in a mosaic of an astronomical image. Courtesy of NSF's*

*National Optical-Infrared Astronomy Research Laboratory/NSF/AURA/CTIO/DELVE)*

When Neil Armstrong set foot on the Moon in 1969, the world changed. It marked the end of the space race with the United States declaring victory over Soviet Union. After that the number of human-led missions began to decrease and the number of satellite missions grew. Today, we are in another space race, one driven by private interests and capitalist desires. Thanks to growing technology, we can observe the Earth with high precision, connect to the internet and track locations to within centimetres. The growth in these technologies has motivated a new generation of space companies to take the lead in outer space. But, this "leadership" has consequences for the night sky, astronomy, and the rights of various peoples. Many of the readers will note that these consequences came front and centre when the DESI team released a simple image contaminated by numerous streaks from satellites passing overhead, see Figure 1 for example. What is worse is that you don't even need a world-class telescope to see this, I took a ten-second exposure with my cell phone at Signal Hill in Newfoundland and picked out a handful of satellites overhead.

I have been working with some organizations to think about how governments, companies, and academia should be thinking about how we govern outer space from low earth orbit (LEO) to the Moon and on to Mars. To that end, I had the privilege to participate in three conferences with different goals in the past year. The first conference was the 2024 Earth-Space Symposium on "Sustainability, Governance, Futures" www.planetstewards.eu/earth-space-symposium, then the United Nations World Space Forum "Sustainable Space for Sustainability on Earth" www.unoosa.org/oosa/en/ourwork/world-space-forum/2024/world-space-forum-2024.html, and most recently, the first Canadian Space Launch Conference www.spacelaunch.ca. I want to share some of the lessons learned at these three events.

You might see a theme in the first two conferences, that is "sustainability." This theme is largely motivated by the increase in orbital satellites in the past decade and expectation that this number will increase by a factor of ten in the next decade. The first conference was focused on an academic discussion of how we can think about governance of outer space in the future and how that governance should be connected to the Earth. This is a growing theme in the field, often connected with a concept of space environmentalism. If we continue to see outer space as some place other and not as part of the Earth system, then we risk legal frameworks to be determined solely by nation states acting in space along with private companies. We already have some experience with that kind of framework when colonialism in the Americas and elsewhere was driven by nation states and the private enterprises created to support that. During this first conference there were talks about space law, philosophy of space, space ethics, and so on.

One of the big issues that was discussed was the question of the legal rights and responsibilities of private companies in space. For example, if there were an incident in space where the activity of a company led to the damage of a satellite owned by a different company or nation state, how would they be held liable, if at all? In principle, the United Nations Outer Space Treaty says that nation states would be liable for incidents in space and one can infer that this means that that nation state where the company based or the nation state of the launch facility would be liable. This concept is the basis of maritime law with ships being of various national flags. But, it is not clear that this is true as there is no fixed law requiring this liability. Furthermore, it is unclear if there is any mechanism to hold the nation state responsible. That might sound depressing in a situation where companies are launching lots of satellites with growing numbers of launch failures leading to debris raining down to Earth as it did on Turks and Caicos www.nbcnews.com/science/space/spacex-starship-debris-littered-islands-turks-caicos-rcna188223 and in the airspace of the Bahamas www.cbc.bb/news/caribbean-news/spacex-starship-rocket-debris-falls-into-bahamian-airspace. But, we recognize the need for governance in space and the need for that governance to be equitable. Granted, this was just a bunch of academics talking, but it has motivated the need to build interdisciplinary resources to build the next generation of space policy.

The World Space Forum is a regular event hosted by the United Nation Office of Outer Space Affairs and includes participation of space agencies, industry, and academia hosted at the UN campus in Bonn Germany. The conference was very interesting, with talks from representatives from space agencies from around the world including Germany, United Arab Emirates, Peru, the United States, and Canada. There were also comments from representatives from Bhutan and Serbia. Altogether, there were a number of different views of outer space and our place in outer space, from the push to exploitation from some nations to the hope that building a space program will better humanity. Industrial partners also contributed significantly to the discussion, particularly with respect to issues of space debris and situational awareness in space. I was particularly surprised to hear a number of people cite the Kessler Syndrome in this discussion. The Kessler Syndrome is an idea coined by Donald Kessler and Burton Cour-Palais in 1978. The idea is that if orbital space becomes too congested with satellites, then the number of satellite collisions will increase, creating an increasing amount of debris of various sizes until the density of satellites is so high that the collisions cause other collisions and so on in a cascading event. While it is unlikely the number of satellites in low Earth orbit are at that point, we are getting closer and closer. Further, one industrial leader noted multiple times that we, currently, cannot track space debris smaller than one centimetre in size, implying that we do not really know how close we are to the Kessler Syndrome. As such there was discussion about how to safely remove satellites, with the current "best" option being to elevate non-functional satellites to a higher graveyard orbit.

Since this is an astronomy journal, one note of interest would be that a couple of representatives noted the need to include dark-sky protection and astronomy as space activities. The purpose of doing this is to require industry and national governments to consider how their space activities impact the dark skies and ground-based astronomy, both for enthusiasts and for research purposes.

The third conference was the first Canadian Space Conference in April 2025. This was a meeting primarily for the Canadian space industry with the goal of developing launch capacity in Canada. This is motivated by the recent announcement that the company NordSpace will build a launch facility along the south coast of Newfoundland www.cbc.ca/news/canada/newfoundland-labrador/nordspace-st-lawrence-1.7437531. This was a very different discussion than the first two conferences that focused on the goal of technology development, national defence, and sovereignty, and dealing with "red tape."

While the discussion was focused on the growth of the industry, there was a valuable anecdote discussed that does provide an argument for domestic space launch capacity: the story of RadarSat-2. The RadarSat satellites are widely considered one of the great successes of Canada in outer space. The purpose of the RadarSat Constellation of satellites is to monitor disasters, ice, oceans, and more. The second RadarSat satellite was launched in 2007 on a Soyuz rocket, however, NASA had originally agreed to launch the satellite but later declined because of concerns of the US intelligence community. This delay significantly increased the cost of the mission.

Overall, my takeaway from this conference is that it was a maple-flavoured manifest destiny because there was discussion about impacts on communities and the environment or how to be more inclusive. But, this conference is not unique and the space industry is growing one way or another.

Bringing the three conferences together, it is clear there is a lot to think and worry about going forward. Humanity is increasingly impacting the space environment, and regulations lag way behind, and this impact is having greater impacts on the Earth itself, from brightening the night sky to harming the ozone layer (Ferreira et al. 2024), to honestly an increased risk of things falling on our heads. While access to outer space, and the knowledge and learning that comes with that, will help communities around the world, we need to build the systems to protect humanity and nature from the same runaway industry that is continuing to make climate change worse. On the bright side, we still have a chance to do this. ✶

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# Keep Calm and Orbit On

## Saturn's 128 New Moons (Oops!)

*By Samantha Lawler, Regina Centre*
*(samantha.lawler@uregina.ca)*

One thing I love about astronomy is the general commitment to image sharing and open data policies. The Canadian Astronomy Data Centre (CADC)[1] is a vast repository of truly impressive quantities of data from many different telescopes, as well as tools to help sift through that data, open to anyone (even you!)

But this is really a story about how I accidentally helped discover some of the 128 new moons of Saturn.

Along with Dr. Wesley Fraser at NRC-Herzberg, I co-lead the Classical And Large-a Solar System (CLASSY) Survey, where we have spent nearly 500 observation hours over the past 3 years with the MegaCam instrument on the Canada-France-Hawaii Telescope (CFHT), trying to find the smallest and most distant Kuiper Belt objects (KBOs). Our technique is to take many short (5 minute) exposures over the course of 3 hours, and then using sophisticated software, combine the short exposures at different rates and angles of motion to find moving KBOs that are much fainter than we could find in a single exposure. The places on the sky we are searching for KBOs were carefully selected to look for any possible asymmetries in the distribution of the most distant KBOs, testing the "Planet 9" theory[2] and looking for other interesting patterns that may tell us about how our Solar System formed and evolved into its present state.

CFHT operates via queue-based observing. While this (disappointingly) means that I don't get to go to Hawaii every month when we have observing time, queue-based observing makes very efficient use of good weather conditions with flexible scheduling. Every astronomer who has been awarded time on the telescope submits the coordinates, exposure sequence, sky conditions, seeing, and airmass limits required for their science program, and the excellent queue team then executes the observations in a way that matches science requirements and fits in all the other observers. This type of observing works really well for Kuiper Belt science in particular: CFHT has already been used to discover and track close to 1300 Kuiper Belt objects before the CLASSY Survey even began[3].

Because CLASSY is such a large program, we have observed during nearly every dark run since mid-2022, and we have developed a pretty good rhythm. Before each observing run in the first year, I ran simulations of KBOs on orbits similar to what we expect to discover. For the second year, I used the same simulations to predict where on the sky most of the KBOs from the first year should be, effectively calculating the best place on the sky to point the telescope in order to measure the orbits of as many KBOs as possible. Because the KBOs in a given snapshot of the sky are all on different orbits and at different distances from us, they experience something called "Keplerian sheer," where the closer KBOs will move across the sky faster than the more distant KBOs. A block of KBOs on the sky will have spread out into a much bigger blob by one year later due to this effect. So calculating the pointing of the telescope requires not only careful orbital simulations, but prioritization of different targets.

In August 2023, the other CLASSY co-leader was on vacation during a dark run, and I was putting in the queue observing requests without my usual backup checks. The first few nights of the run went perfectly. I programmed the telescope, checked the images in the morning, and saw exactly what I expected: a few tiny galaxies and a bunch of random stars, a few of which would prove to be KBOs after careful measurements.

But one morning, I immediately saw something had gone horribly wrong. Our observations are focused right in the mid-plane of the solar system, and I had completely forgotten to check for photobombing planets. In the middle of my Megacam image was a horrible blob of hilariously over-saturated pixels bleeding across an entire CCD. Oh no! Saturn!!

Perhaps some of you have taken astrophotos of Saturn before? It's a great photography target. Single exposure times are recommended at a fraction of a second for an 8 inch telescope.

I had just requested 3 hours worth of 5 minute exposures with a 4 metre telescope. Of Saturn.

I felt *incredibly* stupid.

But remember how I started this article on a nice, hopeful note about how astronomers are so good at sharing data? Turns out that Dr. Edward Ashton, a postdoc at ASIAA in Taiwan and one of the members of the CLASSY research team, was already leading a survey specifically designed to look for new moons of Saturn. He's really good at finding new moons!

Dr. Ashton's survey kept the CFHT MegaCam fields a respectful distance away from painfully bright Saturn, which is the best use of telescope time: when you point a large telescope like CFHT at something as bright as Saturn, not only do you get saturation of pixels for a large fraction of your image, but reflections inside the telescope can make other parts of your image unreliable for photometry. Luckily, to discover new moons, the main piece of information required is the position on the sky over time, also called astrometry, which is not severely affected by internal telescope reflections, as long as the moon is not in the saturated portion of the image.

Thanks to Saturn photobombing my images, Dr. Ashton now had the ability to look for moons far, far closer to Saturn than he had originally planned.

Figure 1 — public in the CADC archives, from the CLASSY dataset (S. Lawler and W. Fraser, PIs), a horribly over-exposed, way too bright Saturn bleeds up and down out of the frame of the image, while several of its over-exposed, bleeding moons orbit nearby.

The motion of the Earth around the Sun, Saturn's much slower motion around the Sun, and the moon's orbits around Saturn causes the moons to follow flowing, random-looking curves across the sky relative to Saturn. Dr. Ashton took all these weird motions carefully into account, and discovered 128 new moons[4], bringing Saturn's grand total of discovered moons to a ridiculous 274.

The weirdest part about these new moons is that most of them are orbiting retrograde[5]. They are going backwards around Saturn! Retrograde moons have long been known, but to have such a large number be retrograde suggests that many of these moons were formed when a larger moon was destroyed in a large collision. This would have had to happen relatively recently (on Solar System timescales, at least)—Dr. Ashton's team calculates the collision would have had to occur less than 100 million years ago.

These new moons highlight how how dynamic our Solar System really is. We think about moons and planets being on fixed, unchanging orbits—but in reality, orbits are constantly changing by small amounts, and once in a while, dramatic, Solar System-changing collisions occur. The discovery of these moons also highlights the power of shared data in public archives!

And yes, thanks to the CADC and the open data policies that are standard on many telescopes with Canadian involvement, if you really want to, you can go download my horribly over-exposed Saturn images and giggle. ✶

## Endnotes


1 The Canadian Astronomy Data Centre webpage: www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca
2 Batygin & Brown (2016). Evidence for a Distant Giant Planet in the Solar System. *The Astronomical Journal 151*, 22 doi:10.3847/0004-6256/151/2/22
3 The Outer Solar System Origins Survey Discovery Database: www.ossos-survey.org/tnodb.html
4 Ashton, Gladman, Alexandersen, & Petit (2025). Discovery of 128 New Saturnian Irregular Moons. *Research Notes of the American Astronomical Society* 9, 57 doi:10.3847/2515-5172/adbf87
5 Ashton, Gladman, Alexandersen, & Petit (2025) "Retrograde Predominance of Small Saturnian Moons Reiterates a Recent Retrograde Collisional Disruption. *The Planetary Science Journal*, in press doi:10.48550/arXiv.2503.07081



*Sam Lawler is an associate professor of astronomy at the University of Regina. She studies the orbits of small bodies in the outer Solar System, and increasingly studies and advocates for regulation of the thousands of new artificial satellites streaking through her research images, crawling across her huge prairie skies, and crashing onto nearby farmland. She's active on Mastodon @sundogplanets@mastodon.social and BlueSky @sundogplanets.mastodon.social.ap.brid.gy*


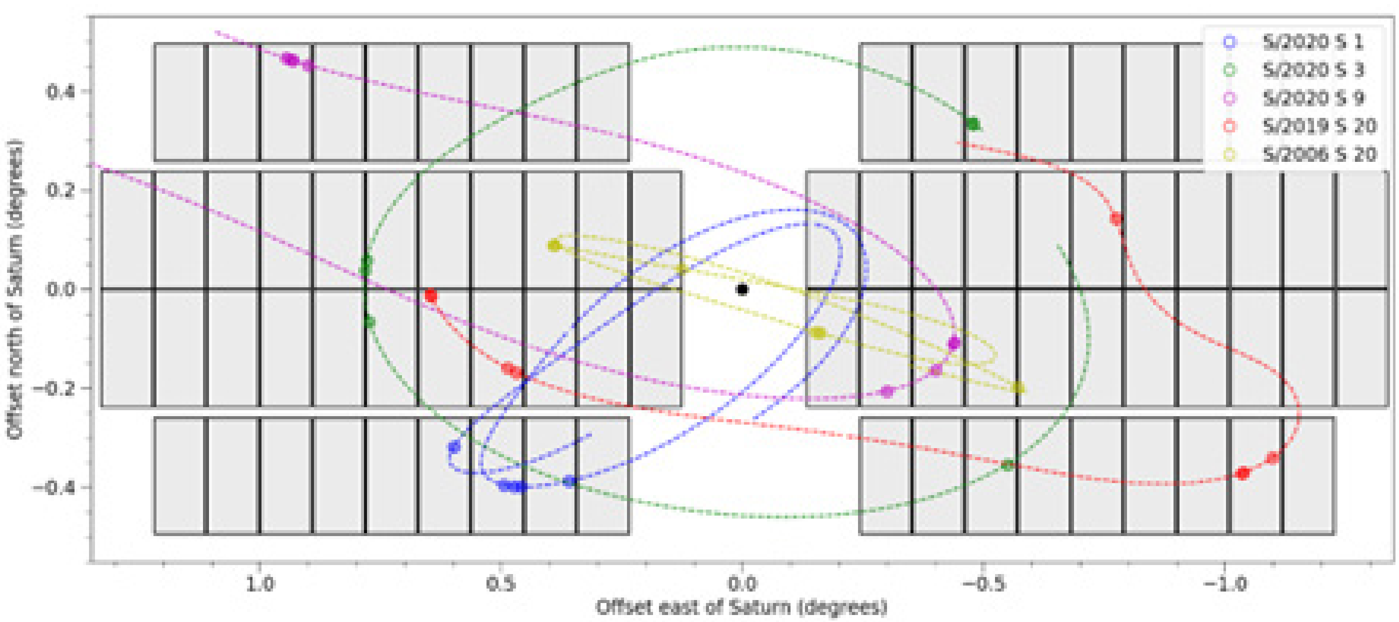


Figure 2 — from Ashton et al., 2025, arXiv 2503.07081. The grey boxes are the 40 individual CCDs of the Megacam instrument on CFHT, and show where the telescope pointed on each side of Saturn (black dot). The coloured dots are positions where each moon was measured, and the dashed lines show the orbits of the moons on the sky, including the motion of the Earth and Saturn.

# John Percy's Universe

## Six Decades in Astronomy Outreach

*John R. Percy,* FRASC
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For International Astronomy Day 2025, May 3, RASC National EPO Committee Chair Karim Jaffer organized a cross-country live-stream outreach event that reached thousands of astronomy enthusiasts across Canada and beyond (Figure 1). He asked me and a few others to speak for a few minutes about their work in astronomy outreach. In my case, that has included outreach to amateur astronomers and other astronomy enthusiasts, to schoolteachers and students, and to the public. For a longer and deeper reflection, a decade ago, see Percy (2012), an article based on my CASCA Qilak Award lecture.

It all started in 1961 when, as a lowly student, I joined the RASC. It was intimidating at first but, by 1965, I was National Librarian, then got even more deeply involved as a council member, National President (1978-80), *Observers Handbook* editor (1971-81), Honorary President (2013-17), and as *JRASC* columnist, starting in 2013. So, I have been actively involved in the RASC for 60 years! Question: how well does the RASC attract and serve students today?


*The cross-Canada event which motivated this column. Source: RASC.*

Formal outreach began in 1962 when, as a beginning MSc student at the University of Toronto, I held a scholarship which required me to lead school and public tours of the university's David Dunlap Observatory (DDO) and its "great" 74" telescope. I usually began the tour by showing *Universe,* a 27-minute National Film Board of Canada film which, in my opinion is still one of the best astronomy documentaries ever. It can still be seen for free (1). It "stars" DDO, the "74" telescope, and my favourite undergraduate professor Don MacRae.

Then, like many in my day, I took a detour: a year in teachers' college, and then on to high school science and math teaching. But the pull of astronomy and of the University of Toronto was too strong. A year later, it was back to graduate school for a Ph.D. and a career as a professional astronomer. But, unlike most university professors, I had actually learned to teach. My teaching career also led to a life-long interest in ensuring that there was good astronomy in the school science curriculum, and adequate support for those who had to teach it.

Even before I had finished my Ph.D., an exciting job opportunity beckoned, as a founding faculty member of a brand-new campus of the University of Toronto in Mississauga (UTM)—"the middle of nowhere" at the time. But that was an advantage for my geology colleagues, who were contracted to study the magnetic properties of moon rocks from the Apollo missions; "the middle of nowhere" was magnetically quieter than the downtown Toronto campus of the university. When the moon rocks went on display at the campus, 2,000 members of the public lined up to see them. Another early UTM outreach initiative was *Science Expo*, a one-day science extravaganza organized by my chemistry colleague (and amateur astronomer) Ulrich Krull. Years later, I was involved in a similar initiative *Science Rendezvous* (sciencerendezvous.ca), a one-day science festival, now held annually in early May at 25 sites across the country.

Since 2003, UTM has also hosted the RASC Mississauga Centre, which provides astronomy outreach on the campus and across the city, including a partnership with The Riverwood Conservancy, a megapark in the heart of Mississauga and an excellent location for star parties.

And speaking of partnerships—have you heard of the Science and Technology Awareness Network (STAN, www.stanrsst.ca)? You should. You can join—for free! It began two decades ago; the driving force was Vic Tyrer of the Ontario government; I was a co-founder. I am proud that my niece Dr. Sandra Eix, at Vancouver's Science World, is the immediate past president president. All in the family!

Meanwhile, my research was evolving. I began as a theoretician, modelling the structure and evolution of the Sun, and later of pulsating variable stars, to understand why they were unstable. But my theoretician supervisor Pierre Demarque left Toronto for the University of Chicago, halfway through my Ph.D. I was taken under the wing of Don Fernie, a photometrist and observer of variable stars (and later an RASC National President). I slowly caught the observing bug.

In the 1970s, I observed variable stars from Kitt Peak National Observatory in Arizona. But then I discovered the benefits of using archival data—specifically from the AAVSO, the American Association of Variable Star Observers. For over a century, they have archived millions of observations of variable stars, made by hundreds of skilled amateur astronomers—or citizen scientists as I prefer to call them. Much of their data awaits analysis and is especially useful for my students' projects—undergraduate students and, for 25 years, talented high school students in the University of Toronto Mentorship Program. They develop and integrate their math and science skills, do good science with real data—AAVSO data. They publish it in the *Journal of the AAVSO,* an on-line, open-access, refereed research journal that is read by, among others, the observers; they see how their work is contributing to both science and education – a win-win-win situation. "Citizen astronomers" contribute to many other areas of astronomical science and education; they deserve our appreciation and thanks.

For over three decades, starting about 1970, I was very active in international astronomy education, outreach, and development, primarily through the International Astronomical Union (IAU, iau.org). Among other things, I co-organized five international conferences in the topic, and co-edited the conference proceedings (e.g. *The Teaching of Astronomy,* Pasachoff and Percy, Cambridge University Press, 1990). I visited a variety of countries and met "kindred spirits" from all over the world. As of my "retirement" in 2007, I had given over 350 public lectures in 19 countries on five continents.

In 1992, I became (voluntary) Vice-Chair of the Board of Trustees of the Ontario Science Centre (OSC), one of the great science centres in the world at the time. It was the home of the RASC Toronto Centre until its unfortunate closing in 2024. The OSC is and was an agency of the Ontario government, rather than an independent entity like the provincial art gallery and museum. That made it extra-difficult for the board, especially when a new hard-right provincial government led by Mike Harris was elected in 1995 and introduced "the common-sense revolution". The future of Ontario's cultural institutions was in doubt. Nevertheless, we were able to oversee the completion of a new Omnimax theatre, and the installation of many new exhibits and programs. The closing of the OSC in 2024, due to neglected maintenance, was a blow to school and public education; the blame lies squarely in the hands of the government.

The 1995 election of the Harris government, and its "common sense revolution" also led indirectly to the closing of Toronto's world-class McLaughlin Planetarium in 1995. The Royal Ontario Museum, of which it was a part, abruptly closed it in the hope that it could be replaced by a money-making "cash cow." No way. It still sits, empty (as does the OSC). During its time, it was also the home of the RASC Toronto Centre, which is how I got to know it. At the time, I was serving as their second vice-president, responsible for finding interesting speakers for meetings—something I enjoyed and, with my interdisciplinary network of colleagues, was reasonably successful at.

In 2007, I "retired" i.e. went on pension. But, aside from classroom teaching, most of my activities continued, as a volunteer. Speaking of retirement: one of my most enthusiastic audiences has been later-life learners' groups such as Probus. They provide audiences of up to 200, excellent facilities, and even a small honorarium for the speaker!

Then came International Year of Astronomy 2009, a worldwide celebration of the $400^{th}$ anniversary of Galileo's development and first use of the astronomical telescope. Led in Canada by Jim Hesser (Hesser *et al.* 2010), it aimed to bring astronomy to large, new, and diverse audiences. It was a stunning success in Canada. And it led to three of my most memorable astronomy outreach projects – outreach to the arts, to the heritage community, and to the schools.

My favourite arts group for almost half a century has been Tafelmusik Baroque Orchestra. It is internationally known for, among other things, its multimedia programs, created by its long-time double-bass player Alison MacKay. I convinced her and music director Jeanne Lamon to create an astronomy-themed program for IYA. The result was *The Galileo Project.*

It toured Canada and beyond to great acclaim—full houses, standing ovations, and rave reviews—and won a major award in Australia.

Heritage is another of my long-time interests, especially Heritage Toronto and its walking tours of the city's historical neighbourhoods. So I created and led walking tours of astronomically-significant sites—of which there are many—on and around the University of Toronto's campus. This walk was held for many years, and has evolved into a year-round presentation given in libraries and other venues. And an article in *JRASC* in April 2014.

Prior to IYA, there had been a major revision of the school science curriculum in Ontario. One of my very long-time interests was school astronomy—the curriculum, and supporting those who teach it. So, I embarked on a project to create on-line resources for grade 6 and 9 astronomy, in partnership with my teacher-colleague Malisa Mezenberg of the Science Teachers Association of Ontario, another of my favourite organizations.

Now, my outreach activities are slowly winding down: this bimonthly column (feedback welcome!) and a library talk every month or so. Libraries have been great partners for 60+ years; they provide the locale, the A-V technology, the publicity, and the audience. I just provide the astronomer, and an interesting topic. The Toronto Public Library helps me to bring astronomy to the one hundred communities across the city—as they have been doing for 60 years. ✶

## Acknowledgements

I thank Karim Jaffer for inviting me to reflect on this aspect of my long career, and I apologize for the excessive use of the pronoun "I" and for the excessive blowing of my horn. Any success has been largely due to my mentors and hundreds of collaborators—amateur and professional astronomers and educators, and hundreds of students.

## Endnotes

1 https://collection.nfb.ca/film/universe

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Percy, J.R. 2012, "A half-century of astronomy outreach. Reflections, and lessons learned", *JRASC, 106*, 240.

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# Skyward

## Shakespeare and Time

*by David Levy, Kingston & Montréal Centres*

William Shakespeare is probably the greatest writer the world has ever seen. Was he capable of writing something poorly, if he really tried? I doubt that. He lived four centuries ago. Born in Stratford, he was successful in London, and he retired and died in Stratford.

Scholars have worked on every possible aspect of Shakespeare for centuries. My doctoral thesis dealt with an aspect the others largely ignored: Shakespeare and the night sky. Not so much science, or astronomy, but the simple majesty of the sky. When he was 8, his father probably showed him Tycho Brahe's brilliant *stella nova*. A new star it was not, but instead a massive old star blowing up. Years later, the star found itself in the opening lines of *Hamlet:*

> Last night of all,
> When yond same star that's westward from the pole
> Had made his course to illume that part of heaven
> Where now it burns, Marcellus and myself,
> The bell then beating one,--

Many critics have praised Shakespeare's curiosity about Nature—trees, flowers, animals —but I think he enjoyed a special and enduring interest in the night sky. The iambic pentameter lines point to where the supernova would have lit up the sky, around 1 a.m. in late autumn.

It is possible that Shakespeare, who as a youth developed interests in all of Nature, forged a particular thirst for the night sky. Thanks to his reference in the opening lines of Hamlet, I think it likely that Tycho's star led to that passion. But this concern did not begin and end with the simple beauty of the night sky. Especially in his later works, he also developed an inquisitiveness about the cosmos itself, and about how time, though carefully measured in seconds on Earth, passes unhurriedly throughout the cosmos, not in seconds or hours but over billions of years. In preparing my Doctoral dissertation at the Hebrew University, I found more than two hundred allusions to the night sky in Shakespeare's canon. But in Macbeth alone I counted 59 references to Time. Here are two of them:

Time, thou anticipat'st my dread exploits:
The flighty purpose never is o'ertook
Unless the deed go with it. (4.1.144-146.)

Shakespeare portends that the progression of time is not always linear. Macbeth addresses Time directly in this passage. Macbeth is continuing his murderous rampage, but time itself knows that the deed itself, to take p-lace in the future, will confirm the bloody purpose. The unity of time and space, which Einstein posited in his Special theory of relativity, in 1905, took place 299 years after Macbeth was probably written. In his essay on special relativity, Einstein added the dimension of time to the three dimensions of space, because the observed rate at which time passes for an object depends on the object's velocity relative to the observer. Einstein expanded his thought in general relativity, in which he demonstrated that a gravitational field can slow the passage of time for an object as seen by an observer outside that particular gravitational field.

To me you speak not.
If you can look into the seeds of time,
And say which grain will grow, and which will not,
Speak then to me, who neither beg nor fear
Your favours nor your hate. (1.3.55-61.)

In this passage Shakespeare has Macbeth speak directly to Time as if it had a personality, even seeds or parents and children. He` is asking time if it could tell him (like the weird sisters) whether his enterprise would succeed or fail. In the play, his enterprise clearly fails with the four-word rapturous stage direction "Dies. Fleance escapes." (3.3.17)

As the play nears its denouement, Macbeth is informed of the death of his wife. I like to imagine that the speech that follows is divinely inspired, as it is one of the finest scripts ever to touch paper: I quote it here, as it appeared in the First Folio published in 1623. I also take the liberty of adding two words at the end:

She should haue dy'de hereafter;
There would haue beene a time for such a word:
To morrow, and to morrow, and to morrow,
Creepes in this petty pace from day to day,
To the last Syllable of Recorded time:
And all our yesterdayes, haue lighted Fooles
The way to dusty death. Out, out, breefe Candle,
Life's but a walking Shadow, a poore player,
That struts and frets his houre vpon the Stage,
And then is heard no more. It is a Tale
Told by an Ideot, full of sound and fury
Signifying nothing.

[Signifying … everything.]

I am happy that the conclusion I reach here never made it to my dissertation, as I am certain that some scholars would have rejected it. But in this article, where I get to write what I like, I suggest that without being aware of it, Shakespeare anticipated Einstein's theory of general relativity by about three centuries. I also think that the culmination of the playwright's wording points to those final two words that quite possibly might have entered the poet's mind at the time, for surely his mind was aware of the status of that speech.

The next time you go out of doors and look at the evening sky, you may behold two of its features. One is the planets and stars that appear. The other is this collection of ancient words that potentially add a new dimension to our appreciation of the cosmos of which, for just an instant, we belong. ✶

*David H. Levy is arguably one of the most enthusiastic and famous amateur astronomers of our time. Although he has never taken a class in astronomy, he has written more than three dozen books, has written for three astronomy magazines, and has appeared on television programs featured on the* Discovery *and* Science *channels. Among David's accomplishments are 23 comet discoveries, the most famous being Shoemaker–Levy 9 that collided with Jupiter in 1994, a few hundred shared asteroid discoveries, an Emmy for the documentary* Three Minutes to Impact, *five honorary doctorates in science, and a Ph.D. that combines astronomy and English Literature. Currently, he is the editor of the web magazine* Sky's Up!, *has a monthly column, "Skyward," in the local Vail Voice paper and in other publications. David continues to hunt for comets and asteroids, and he lectures worldwide. David was President of the National Sharing the Sky Foundation, which tries to inspire people young and old to enjoy the night sky.*

The October 2025 *Journal* deadline for submissions is 2025 August 1.

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rasc.ca/sites/default/files/jrascschedule2025.pdf

# Dish on the Cosmos

# Is there anyone out there?

*by Pamela Freeman*
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The day scientists report findings of life on another planet will be historic. It will answer the long-standing question of whether we are alone in the cosmos, and it will change our view of our place in the cosmos. The search for life as a scientific endeavour has gone from the fringes to mainstream acceptance. There are thousands of confirmed exoplanets, some of which are potentially habitable. There are likely billions more star systems in our Milky Way. There are organic compounds abound in interstellar space, and evidence suggests there are oceans of liquid water on moons within our Solar System. With rovers and probes exploring our own Solar System and powerful telescopes observing distant exoplanets, it seems that day could be in our future.

A recent study highlights key challenges in the search for extraterrestrial life, and in this edition of Dish on the Cosmos I want to use it as a launch pad for bigger questions: What are the signs of life that scientists use? How does life on Earth influence these studies? How close are we to being able to detect these signs with our current technology?

## The saga of K2-18b

A team of astronomers recently claimed that the potential biosignatures, dimethyl sulfide (DMS) and/or a related species dimethyl disulfide (DMDS), were detected with their mid-infrared *James Webb Space Telescope* (JWST) observations of the exoplanet K2-18b. On Earth, DMS is mainly produced by phytoplankton in the ocean. It is released into the atmosphere where it is quickly destroyed—thus, if observed here, it is a distinct sign that life is present.

These were follow-up observations of a 2023 study by the same team. In this study, using... two near-infrared JWST instruments, they found hydrogen, methane, carbon dioxide, and tentatively detected DMS on K2-18b. The JWST, which can detect astonishingly faint and distant objects, observes how a planet's atmosphere absorbs light from the parent star as the planet transits in front of it. Each molecule or atom in the atmosphere absorbs light at unique wavelengths, creating a fingerprint on the light spectrum. This is a transmission spectrum. In the infrared frequencies of light that the JWST collects there are notable atmospheric molecules—if the JWST was looking at Earth, we'd see a transmission spectrum with molecules like oxygen, ozone, water, carbon dioxide, methane, and nitrous oxide.

The new DMS detections were reported at a 3-sigma level—a three in a thousand chance that it's noise. They explained the presence of these molecules through a "Hycean world" model, where K2-18b is an ocean-covered world surrounded by an atmosphere rich in hydrogen. These results, then, were reported to the media as the "strongest hints yet of biological activity outside the Solar System." Despite the headline, these results have major caveats. The claims are being disputed by the scientific community, by both astronomy communicators in popular outlets and researchers in pre-printed scientific papers.

One study performed a simple test to determine if the spectral lines, the features on the spectrum, from K2-18b are distinguishable from a flat line. Spectral lines, in these sorts of observations, can be assumed to have a certain kind of shape that distinguishes it from the background. When compared to a flat line, they should be significantly different and here, they were found not to be. A second study combined the data from both the near-infrared and mid-infrared JWST observations. They used a cohesive model on the data, collected at different frequencies, to have more confidence in their interpretation. They found no significant hints of the claimed molecules, and, by using a model with more molecules included, they were able to recreate the spectrum without using DMS or DMDS. The third study did a similar analysis. They expanded the catalogue of potential molecules observed in the spectrum, using species that could be potentially produced on an exoplanet, and found that numerous other models without these two species could produce equal or better results.

Overall, the signal detected might not even be real, or, if it is, is likely not DMS. If it is DMS, there is prior knowledge that DMS can be formed abiotically—it has been detected in a comet and in an interstellar cloud. These results emphasize a complexity that astronomers have been working on—any detections must be looked at holistically within the network of gases they exist in and within context of the planetary and stellar system they're a part of. Likely, no individual molecule is going to present a strong and clear sign of life.

These results represent key points needed when determining a true sign of life. A community effort has put together a helpful set of questions to think about when searching for biosignatures, paraphrased here: Is the signal authentically detected? Is it adequately identified? Are there abiotic origins for this detection? Is it likely to come from life in this particular environment? Are there independent signs to support a biological explanation?

## What are biosignatures?

Biosignatures are any feature or substance that indicates the presence of life. They are the signs that life is altering an atmosphere or surface: biological, like fossils or atmospheric molecules present due to biotic processes; or technological, like radio communications signals or atmospheric molecules due to industrial processes. The latter is referred to as technosignatures, a subset of biosignatures.

Biological signals are advantageous to study as they encompass the search for life, and not just intelligent, technologically advanced life. If we were to study Earth, there would be billions of years to study atmospheric signatures versus the last century or so of artificially produced signals.

Commonly, molecular signatures in exoplanet atmospheres are used as a convenient way to gather information about a planet—the molecular features in their atmosphere can be telling signs of activity lurking on them. And unlike with fossils or other geological features, we can collect this information comfortably from many light-years away. We can only send probes and rovers, or plan sample return missions, for relatively nearby bodies in our Solar System.

Techosignatures, on the other hand, are of interest as they can be strong and clear signals, and they are unambiguous signs of intelligent life. If we find a technologically advanced civilization, there are other implications—what could it tell us about our future as a species?

## What would Earth look like, as a reference?

Life on Earth is a natural starting point for figuring out what extraterrestrial signals could look like. While there are limitations—our form of life and our technology are not necessarily the only kind that can exist—we can start to determine what types of needles to possibly look for in the vast haystack of the cosmos.

In early days, molecular oxygen was viewed as a dependable biosignature. Its prevalence in our atmosphere is due to photosynthesis. Our atmosphere wasn't always oxygen-rich and became so over 2.3 billion years ago when cyanobacteria, or blue-green algae, started to produce enough of it for it to become a significant fraction of the atmosphere.

Other potential biosignatures in our atmosphere are carbon dioxide, methane, or some nitrogen-bearing molecules. While these molecules have long existed on Earth—prior to the Great Oxidation Event, for about a third of Earth's entire life, and while single-celled organisms existed, methane and carbon dioxide were prevalent in our atmospheric makeup—their relative and unstable abundances could point to an environment affected by life. In modern times, agriculture and industry could have altered the atmosphere enough for these molecules to be viewed as biosignatures. Carbon dioxide can be seen as one example. Nitrogen dioxide is another, as it is primarily in our atmosphere from fossil fuel combustion. In a more extreme example, if an alien civilization could recognize chlorofluorocarbons, and happened to spot us in the late 1900s, then that could be a reliable biosignature.

There are also prevalent technosignatures: radio communications of all sorts, light pollution, urban heat islands, and the rovers and satellites we've sent into space. In order to explore what kinds of technosignatures are revealing of us on Earth, a team of SETI (Search for Extraterrestrial Intelligence) scientists took a theoretical approach to an important question: what would present day Earth look like to another planet with our modern observing capabilities?

To answer it, they made a detectability scale of a diverse set of technosignatures. Our best bet for observing Earth, they find, is through strong and directed signals like the Arecibo message—the first active message sent by humans to signal our existence. This message was sent in 1974 toward Messier 13, a dense cluster of stars 25,000 light-years away. (While relatively nearby in our Universe, we'll have to be patient for any reply.) It contained information on common elements, DNA, our Solar System, and the Arecibo radio telescope that was used to transmit the message. With our best telescopes today, we could detect this sort of signal from 12,000 light-years away.

The next strongest signal can only be seen from 65 light-years away. This is NASA's Deep Space Network (JRASC April 2024), the network of radio antennas that support interplanetary space missions like the JWST and *Voyager*. Earth-based communications, like radio and television, can be seen from 4 light-years away. For scale, our nearest stellar neighbour, Proxima Centauri, is just over 4 light-years away. In other wavelengths, optical communications lasers could be detectable at 5.9 light-years away, and atmospheric nitrous dioxide at 5.7 light-years away. The closer Earth is, the more diverse our technosignatures become.

Our modern radio environment, seen here as our most detectable signal, represents a unique era in human history. Radio transmitters were only created at the end of the 19th century and radio detectors a few decades later. If someone were looking for us through these signals, their timing must be impeccable.

## Listening to the Universe with radio telescopes

SETI research started in the mid-1900s with radio telescopes searching the sky for these technosignatures. Radio frequencies of light are quite useful for this purpose (see also JRASC February 2017)—they are almost unimpeded by the gas and dust of interstellar space. There is a useful frequency window between background galactic emission at lower frequencies and the emission and absorption of our atmosphere at higher frequencies. In addition, radio waves are also relatively easy to encode information in, and the transmitters needed to send them are easy to build, which is convenient for interstellar communication.

The first attempt to listen for extraterrestrial messages was Project Ozma, named after the Queen of a far away and exotic land, L. Frank Baum's Oz. In this project, Dr. Frank Drake

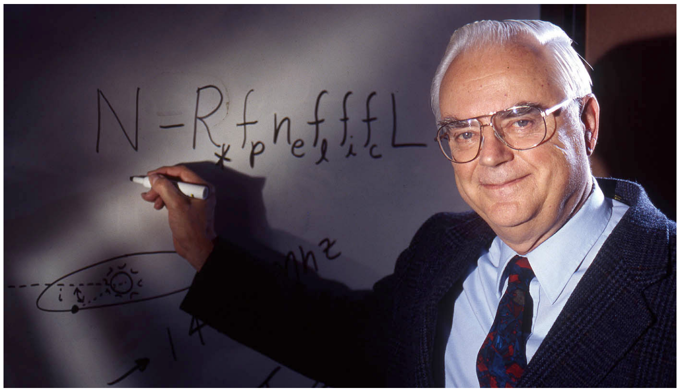


*Figure 1 — Frank Drake with the Drake equation. The number of civilizations in our galaxy (N) is based on the rate that stars form (R), the fraction of stars with planets ($f_p$), how many planets per star that can support life ($n_e$), the fraction of planets that develop life ($f_l$), the fraction that then produce intelligent life ($f_i$), the fraction that then give off detectable signs of life ($f_c$), times the amount of time these signals will be emitted (L). Image credit: SETI Institute.*

*Figure 2 — A composite of the MeerKAT telescope in South Africa with some of the astronomical signals it has detected. Image credit: South Africa Radio Astronomy Observatory (SARAO).*

attempted to detect radio transmissions towards two stars, each about 11 light-years from us, using the 1420 MHz line of neutral hydrogen. He assumed that this would be a universally known line that any intelligent and technologically capable civilization could use as a "hailing frequency." A year later, Drake came up with his famous equation (Figure 1) that forms an understanding of our odds of detecting alien life—how many planets could form intelligent life producing detectable signatures at any point in time? At the time, Time Magazine called Drake's work "a first small step in an effort that might take one year or 10,000 to turn a dream into reality."

Most SETI research since then has continued using radio telescopes to listen for messages from the Universe. These days, the SETI Institute (whose Centre for Research co-founder and former director, Dr. Jill Tarter, is the inspiration for Dr. Ellie Arroway of Carl Sagan's *Contact*) and the Breakthrough Initiatives are two main players with dedicated research programs for this cause. Breakthrough Listen, as a part of the Breakthrough Initiatives, is one of the programs investigating whether we are alone in this universe by searching for techno-signatures. Breakthrough Listen includes a broad range of observations and analyses across radio wavelengths to survey nearby stars and nearby galaxies for technological signs of life.

Breakthrough Listen has found a way to complete their work commensally with other research. On the MeerKAT telescope (Figure 2), an array of radio antennas in South Africa, they have found a way to produce multiple streams of the observed data. Listen can then use a stream of data from the telescope while other observations are occurring. This means they can have access almost 24/7 to the large area of the sky that MeerKAT observes, without needing their own dedicated telescope time. In these large sky scans they will hunt for interesting signals. This research will only become more promising: MeerKAT is a precursor to the Square Kilometre Array, an even larger array of antennas that will increase the volume of sky able to be observed, and on which commensal research will also be possible.

Depending on how you look at it, the odds are high or low for meeting cosmic neighbours. On one hand, there are billions of stars within our own galaxy, each potentially having at least one planet, as well as billions to trillions of galaxies within the Universe. That is a lot of space for life to inhabit. On the other hand, the Universe is very big, and very old, and we have no idea what life could potentially look like. No matter what comes in our lifetime, it seems that the search for extraterrestrial life has already started teaching us about our place in the cosmos. ✶

*Pamela Freeman recently finished her Ph.D. in astrophysics at the University of Calgary. Specifically, she studies the chemical make-up of star-forming clouds with radio telescopes. Generally, she loves to observe anything and everything about nature.*

# Blast from the Past!

*Compiled by James Edgar*
*(james@jamesedgar.ca)*

## SUMMARY REPORT OF THE WEATHER IN CANADA.

JUNE 1907.

*Temperature.*—The mean temperature was a little higher than average in the northern portions of Ontario, Manitoba and Saskatchewan and on Vancouver Island, while in other parts of the Dominion it was below average, the largest negative departure, about 4°, being in Southwestern Ontario. The month opened rather cool in nearly all parts of the Dominion, but within a few days the weather became warm and seasonable. In the West no very pronounced heat spells have occurred, but in Ontario and Quebec since the 16th the temperature has frequently exceeded 80°, and on several days 90° has been reached in many localities.

The following are the highest and lowest temperatures recorded at various stations:—

*British Columbia.*—Dawson, 86, 81; Atlin, 70, 32; Port Simpson, 66, 40; Victoria, 78, 43; New Westminster, 82, 40; Barkerville, 84, 34; Kamloops, 94, 43; Agassiz, 87, 38; Chilliwack, 85, 40.

*Western Provinces.*—Edmonton. 84, 35; Battleford, 88, 34; Prince Albert, 82, 32; Calgary, 80, 33; Medicine Hat, 86, 35; Swift Current, 84, 33; Qu'Appelle, 82, 84; Minnedosa, 80, 30; Winnipeg, 88, 32; Portage la Prairie, 87, 38.

*Ontario.*—Port Arthur, 86, 34; White River, 85, 30; Southampton, 89, 35; Parry Sound, 91, 40; Port Stanley, 80, 38; Toronto, 87, 44; Kingston, 82, 43; Rockcliffe, 94, 35; Ottawa, 94, 45; Sutton West, 91, 40; Paris, 89, 40; Haliburton, 91, 32; Bruce Mines, 90, 38; Port Dover, 82, 40; Welland, 90, 45; Peterboro', 89, 38; Huntsville, 85, 41; Kenora, 89, 37; Owen Sound, 92, 36; Uxbridge, 90, 40; Port Burwell, 81, 41; Bloomfield, 87, 41; Bancroft, 92, 33; Otonahee, 87, 44; Beatrice, 87, 35; Stony Creek, 92, 37; Stratford, 89, 39; Brantford, 88, 39; Agincourt, 89, 40; Barrie, 91, 42; Hamilton, 92, 44; Clinton, 89, 35; Lake Talon, 90, 35.

*Quebec.*—Montreal, 87, 44; Quebec, 89, 40; Father Point, 75, 33; Sherbrooke, 91, 36; Ste. Anne de Bellevue, 92, 43.

*Maritime Provinces.*—Charlottetown, 75, 35; Chatham, 94, 34; Sydney, 82, 28; Halifax, 84, 37; Yarmouth, 74, 33; St. John, 76, 38; Fredericton, 91, 34; Sussex, 85, 26; Moncton, 90, 30; Dalhousie, 84, 42; Pt. Lepreaux, 67, 40; Windsor, 87, 33.

*PRECIPITATION.*—Over the Dominion as a whole the rainfall of June was less than average, the most pronounced deficiencies occurring in Southern New Brunswick, New Ontario and in British Columbia. In Alberta the fall was nearly average, as it also was in Northern New Brunswick and Southwestern Ontario. Nearly all stations in the Province of Quebec recorded an excess approximating one inch; and Western Manitoba and Southern Saskatchewan also recorded an excess, and in some few localities the rainfall may have been as much as·double the average amount.

JULY, 1907.

*TEMPERATURE.*—A supernormal mean temperature was recorded in July over Vancouver Island and the Cariboo District of British Columbia; also very locally in Alberta, Saskatchewan, Ontario, and Southwestern Quebec, but over the greater portion of Canada the mean temperature was subnormal. Departures from average were not pronounced, except locally in Southwestern Saskatchewan, where a negative departure of five degrees was recorded at Swift Current.

*The following are the highest and lowest temperatures recorded at the various stations:—*

*Yukon Territory.*—Dawson City, 84, 36.

*British Columbia.*—Atlin, 80, 36; Port Simpson, 74, 46; Victoria, 88, 47; Vancouver, 90, 44; New Westminster, 92, 44; Agassiz, 97, 42; Kamloops, 98, 46; Barkerville, 82, 36.

*Western Provinces.*—Calgary, 84, 40; Edmonton, 81, 44; Medicine Hat, 92, 45; Battleford, 82, 44; Prince Albert, 80, 41; Swift Current, 86, 38; Regina, 82, 40; Minnedosa, 88, 40; Portage la Prairie, 86, 43; Carman, 87, 44; Winnipeg, 87 40.

*Ontario.*—Kenora, 85, 45; Port Arthur, 84, 40; White River, 80, 36; Bruce Mines, 84, 39; Cockburn Island, 82, 42; Copper Cliff, 86, 41; Parry Sound, 92, 40; Huntsville, 84, 40; Beatrice, 84, 40; Owen Sound, 90, 40; Southampton 86, 39; Meaford, 84, 44; Lucknow, 90, 32; Clinton, 86, 34; Sarnia, 84, 40; Port Stanley, 92, 40; Port Dover, 85, 41; Stratford, 86, 39; Port Burwell, 82, 41; Brantford, 89, 38; Paris, 87, 42; Uxbridge, 87, 39; Welland 88, 44; Stony Creek, 92, 43; Hamilton, 90, 48; Toronto, 90, 48; East Toronto, 86, 44; Agincourt, 87, 45 Sutton West, 85, 46; Peterboro', 86, 42; Bancroft, 86, 38; Haliburton, 85, 32; Kingston, 84, 47; Rockcliffe, 88, 38; Ottawa, 87, 48.

*Quebec.*—Montreal, 85, 51; Ste. Anne de Bellevue, 88, 51; Brome, 84, 45; Quebec, 87, 47; Father Point, 74, 44

*Maritime Provinces.*—Chatham, 90, 50; St. John, 76, 49; Fredericton, 88, 46; St. Stephen, 90, 44; Moncton, 87, 47; Sussex, 86, 47; Yarmouth, 72, 47; Halifax, 87, 49; Sydney, 83, 41; Charlottetown, 83, 51.

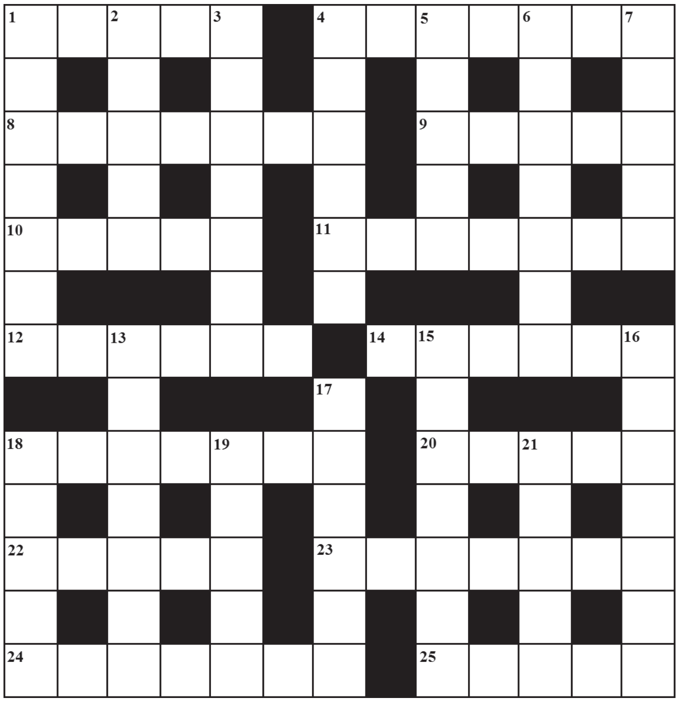
*PRECIPITATION*—Precipitation in July was deficient over a considerable portion of Canada, but an excess was recorded over large sections of Manitoba, New Ontario, Quebec, and the Maritime Provinces. Vancouver Island, in British Columbia, also recorded an amount slightly in excess of the average. Departures from normal were very marked, positive differences being as high as 95 per cent. in the Gaspé Peninsula of Quebec and Northern New Brunswick, and negative departures of from 55 per cent. to 64 per cent. were recorded in the southern portions of Alberta and Saskatchewan.

METEOROLOGICAL OFFICE, TORONTO,

August 5th, 1907. ✶

# Astrocryptic

*by Curt Nason (nasonc@nbnet.nb.ca)*



### ACROSS

1. Sawed-off limit of resolving power (5)
4. One depicted in the sky when seen through crosshairs (7)
8. Kelly pens monthly events but he is no saint in March (7)
9. Fail badly after Charlie checks abbreviated state of Lick Observatory (5)
10. British ground gave electrician a heart attack (5)
11. After morning, old English girlfriend studied monocells in a microscope (7)
12. Roman god runs around at high speed… (6)
14. and his father ran between the university and us (6)
18. Brightest rainbow seen reflected at the bottom of a Dob (7)
20. Fix the software before budget turnaround loses time (5)
22. Scatter first laser beam, then walk away casually (5)
23. Feline secured with CNSA grant money to visit a crater location (7)
24. Spooner says do stay for a time to honour Mars (7)
25. Observer leans toward the catalogues in the Handbook (5)

### DOWN

1. Couple very quietly rides around Polaris (7)
2. Element of surprise perhaps will be Shackleton (5)
3. Putting her slip on wrong, he was a star of Lowell Observatory (7)
4. Royal United Kingdom sport club is a star archer (6)
5. He was in pretty choosy company in Denmark (5)
6. Around Uranus a cabin holds fifty strangers (7)
7. Old wide-field eyepiece available for free around beginning of Lent (5)
13. Yes Virginia, there is dark matter in the belt rim (7)
15. Cardial failure arising from one's extreme views (7)
16. Addled genius sees first star in Boötes (7)
17. Five letters underlining after start of solar alignment at opposition (6)
18. It truly shines in a dove, so I've heard (5)
19. Comet discoverer was a nerd in disguise (5)
21. Brightest stars badly beat the second brightest (5)

### Answers to previous puzzle

**Across**: **1** ASTRONOMY (anag); **6** TEA (Galatea-gala); **8** GRAZE (2 def); **9** TAURIDS (tau+rids); **10** ELTANIN (re(anag)v); **11** GALLE (hom); **12** AUGUST (2 def); **14** MARTHA (anag); **18** COMET (come+T); **20** OCCATOR (rev+anag); **22** BRITAIN (Br(it)ain); **23** LIBYA (anag); **24** ARA (hid); **25** SEXTANTIS (sext+antis)

**Down**: **1** ALGIEBA (anag); **2** TRACT (E/T change); **3** OCEANUS (2 def); **4** OCTANS (Oct+ans); **5** YOUNG (anag); **6** TRIPLET (2 def); **7** ANSAE (2 def); **13** GOMEISA (anag+a); **15** ASCELLA (anag+rev); **16** AIRMASS (anag); **17** FORNAX (Fo(RNA)x); **18** COBRA (Co+bra); **19** TEARS (2 def); **21 (20)** TABIT (t(AB)it)

# Great Images

*By Shraddha Pai*

*Toronto RASC member Shraddha Pai witnessed a moonbow in Kauai's Northwest rainforest region in Hawaii, while on a trip during March 2025. She says, "At 4:30 a.m., the 90.7% waxing gibbous Moon was close to setting, and the misting rain and Bortle 2 skies collectively created the perfect condition for this rare phenomenon. To the eye, the moonbow appeared as a mysterious ghostly white arc; it was the camera that revealed the colours and its identity as a moonbow." She used a Sony A7IV with Sigma Art 24-mm lens, at ƒ/2.8 and at ISO 3200 with a 3.2 s exposure. Processed with Lightroom Classic and Topaz Denoise.*

Journal

*The Lagoon and Trifid nebulae are a favourite of many astrophotographers, and Tammy Foley is one of them. She captured the pair at the annual Starfest star party in Ayton, Ontario, in 2023 using her Redcat 51, 183-MC pro and the ASIAIR Pro with just 4.16 hours of integration, which she says is "a testament to the profound impact that access to darker skies can have."*