

The Journal of The Royal Astronomical Society of Canada

Journal

Le Journal de la Société royale d'astronomie du Canada

PROMOTING ASTRONOMY IN CANADA

October/octobre 2026
Volume/volume 120
Number/numéro 5 [840]

Inside this issue:

The Cycle That Never Repeats

Fenestratilis: Primary Proximus Theorem

The Other Veil

Great Images

By Mark Germani



Mark Germani captured and processed this image of the Andromeda Galaxy (M31) using an Astro-Tech AT92 triplet refractor telescope equipped with a 0.8 reducer, and a ZWO ASI533MC Pro camera. It is a two-panel mosaic, combining data from two filters for each panel: a broadband light pollution filter (Optolong L-Pro) to capture visible light, and dual-bandpass filter (Optolong L-eXtreme) capturing Hα and OIII (only Hα was used in the final image). Each panel consists of 12+ hours of broadband and 12+ hours of Hsy, with the final integration time of just over 49 hours. It was captured from his Bortle 7 backyard in Vancouver, Canada, during the autumn of 2024 and 2025. It was stacked with Astro Pixel Processor and processed in PixInsight and Photoshop.

Journal

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Société Royale d'Astronomie du Canada

contents / table des matières

Feature Articles / Articles de fond

183 The Cycle That Never Repeats
by Alister Ling

Research Article / Articles de recherche

187 Fenestratilis: Primar Proximus Theorem
by Glenn Hunter

Pen & Pixel / Stylo et pixel

196 Rho Ophiuchi / Milky Way / Cygnus / Star Trails
By Gary Crawford / Nishat Khan / Rob Lyons / Shelley Jackson

Columns / Rubriques

201 Art & Artifact: Agnes Mary Clerke's Manuscript Annotations in her Personal Copy of A Popular History of Astronomy During the Nineteenth Century (1885)
by Randall Rosenfeld

207 Mostly Variable Stars: It's Been a Summer of SETI
by Hilding Neilson

211 Keep Calm and Orbit On!: Space Mirrors Incoming
by Samantha Lawler

213 John Percy's Universe: Asteroseismology: The Music of the Stars
by John R. Percy

215 Dish on the Cosmos: 75 Years of 21-cm Astronomy
by Pamela Freeman

Departments / Départements

178 President's Corner
by Brendon Roy

179 News Notes / En manchettes
Compiled by Jay Anderson

197 What's Up in the Sky?
Compiled by James Edgar and Nicole Jiang

217 Blast From the Past!
Compiled by James Edgar

220 Astrocryptic and Previous Answers
by Curt Nason

Great Images / Superbes images

ii M31
by Mark Germani

195 Total Solar Eclipse
by David Hoskin

202 NGC 1333 / LDN 1450
by Carl Fleck

iii Sadr Region
by Liala Halawa

iv Aurora
by James Edgar



Thin tendrils stretch finger-like across this stunning image by Katelyn Beecroft. SH2-96 is part of a supernova remnant in Cygnus, and is often dubbed "the other veil," Katelyn says. "This image shows only part of the expanding shell of gases. To me, the red Hα and SII region on the right side of the image resembles the trunk of a tree, with the blue OIII filaments like ridges of a hilly terrain it is seated on." Katelyn used an Askar FRA400, 72mm aperture, ƒ/5.6 on a Sky-Watcher HEQ5-Pro mount with a ZWO ASI2600mm pro, gain 100, 26 MP. Total integration time: 50h 55min. Processed in PixInsight and Adobe Photoshop.

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



Light Pollution is Changing

Brendon Roy (Thunder Bay), President
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Autumn offers many of us the opportunity to get out under the stars in weather that is particularly favourable to amateur astronomers. It's the time of year when the nights start reasonably early, and temperatures are comfortable for both observer and equipment alike. It's a great time to get out under a dark sky and witness the transition from the stars of summer to the stars of winter—all without having to fight off mosquitoes.

I am fortunate to have a quiet observing location where I can enjoy the autumn sky. Living north of the 49th Parallel means that many of the spectacular objects in the southern Milky Way remain frustratingly low on the horizon during the summer and set early in the evening in autumn. I chose this site—just south of the 49th parallel—to take advantage of the local topography and give myself the best possible view of those southern constellations for as long as possible.

For now, this remains my personal observing site. However, I hope that, through hard work and a healthy dose of astronomer-inspired determination (a story for another article), it can eventually be developed into a place where members of my local Centre, and others with an interest in astronomy, can join me under dark skies.

Even from this location, however, I can still see the glow of distant city lights above the horizon. It is a constant reminder that our work to protect the night sky from light pollution is far from over.

The fight against light pollution is a never-ending one, and it is a responsibility that astronomers must embrace whenever the opportunity arises. Increasingly, however, that battle is changing. The threat to our night sky no longer comes solely from human activity on the ground—it is now coming from human activity in space.

Recently, the FCC, the American regulator responsible for licensing commercial space activities, approved a company to launch a test satellite designed to demonstrate the ability to reflect sunlight onto the Earth's surface on demand. Quite literally, the goal is to bring daylight to darkness. If the technology proves successful, the long-term vision is to deploy

a constellation of up to 50,000 such satellites over the coming decade.

The implications for both professional and amateur astronomy could be profound. Astronomers depend on naturally dark skies, whether conducting scientific research or simply enjoying the beauty of the Universe. While this first satellite is intended as a technological demonstration for the purpose of collecting data on its capabilities and potential impacts, I worry that the environmental and astronomical concerns may not receive the weight they deserve if the project proves commercially viable.

Now is the time for our community to become organized. Get involved at your Centre. Share your knowledge with others. Advocate for responsible lighting and responsible stewardship of the night sky wherever you can. History has shown that committed individuals working together can make a real difference. If each of us carries our passion for astronomy beyond our telescopes and into our communities, we may be surprised by just how much we can accomplish.

The night sky is one of humanity's oldest shared treasures. It is our responsibility to ensure that future generations have the opportunity to experience it much as we do today. ✶

News Notes / En manchette

Compiled by Jay Anderson

Jupiter's moon Io has a fever

NASA's *Juno* mission has provided the first measurements of the temperature below the surface of Jupiter's moon Io, revealing significant heating within the shallow subsurface of the most volcanically active world in the Solar System. Collected during two close flybys, the data also show that most of Io's surface is remarkably smooth and composed of material with very low density.

Io's extreme volcanism is powered by tidal heating. The moon is constantly stretched and squeezed by Jupiter's immense gravity as it travels in a slightly elliptical orbit, generating an internal heat many times greater than Earth's. Until now, virtually everything known about that heat came from infrared observations, which sense only the temperature of the surface. Using the Microwave Radiometer (MWR) instrument on NASA's *Juno* spacecraft, researchers made the first spatially resolved measurements of Io's thermal emission at microwave wavelengths. These data revealed a significant—greater than 20 °C—temperature increase in the upper few metres of the Moon's surface.

"The *Juno* Microwave Radiometer directly observed Io's heat output by looking below the surface," said Scott Bolton, study co-author and *Juno*'s principal investigator at Southwest Research Institute in San Antonio. "The surprising discovery that we could see below a rocky moon's surface has important implications for studying Earth's volcanoes. *Juno* has taught us that if we look with an MWR-type instrument near a volcano on Earth, we might see a similar signature in the subsurface temperature gradient, providing new information on how terrestrial volcanoes work."

Juno's Microwave Radiometer was designed by Bolton to peer beneath Jupiter's cloud tops to investigate the dynamics and composition of the gas giant's deep atmosphere. The MWR's six microwave antennas serve as a single instrument, simultaneously detecting microwaves at a wide range of wavelengths, from 1.3 to 51 centimetres. During the mission's extended phase, the MWR instrument has provided the opportunity to observe three of the planet's Galilean moons: Ganymede, Europa, and Io.

"The technique is novel in that each wavelength explores different depths, providing a new way to characterize the deep atmosphere of giant planets and the subsurface crusts of icy and rocky moons," said Bolton. "At Ganymede and Europa, we explored tens of miles below the surface, assuming their ice shells were mostly pure water, but the ability to probe volcanic rock on Io was an unexpected discovery."

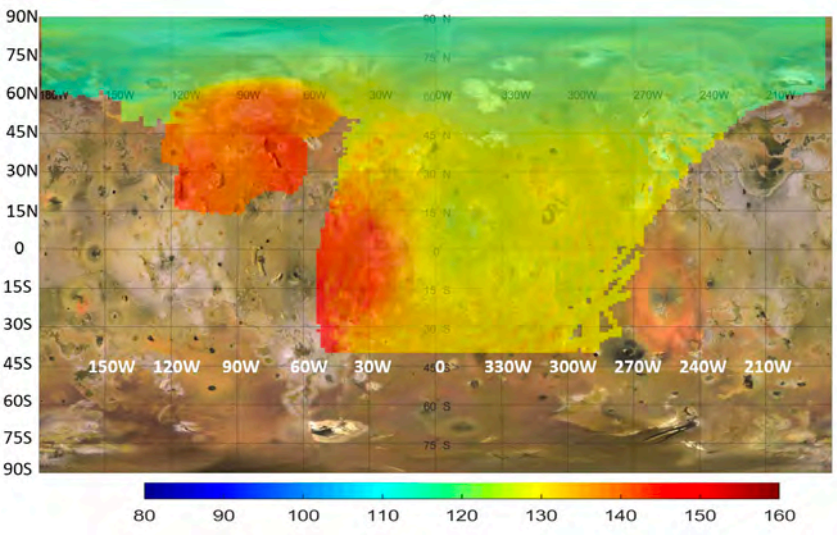


Figure 1 — This map represents data captured by the Microwave Radiometer instrument aboard NASA's Juno, *indicating heat rising from just beneath the surface of Jupiter's moon Io. The colors illustrate a distinct temperature gradient across the moon, with the most extreme, localized heat output in red. Credit: NASA/JPL-Caltech/SwRI/USGS*

During flybys on 2023 December 30, and 2024 February 3, the solar-powered *Juno* spacecraft came within about 1,500 kilometres of the moon's surface.

"The instrument measured Io's thermal emission at depths ranging from a few inches to tens of feet. Everywhere we looked, we found the temperature rising by more than 40 degrees Fahrenheit [4.4 degrees Celsius] just several feet into the surface—a gradient far steeper than solar heating alone can explain," said Shannon Brown, the paper's lead author at NASA's Jet Propulsion Laboratory in Southern California.

The data suggest two possible explanations. First, heat could be rising steadily through a conductive crust. While this background heat flow—measured at 1 to 3 watts per square metre—is relatively gentle on a local scale (roughly equivalent to a small nightlight glowing under every square yard), across the entire moon it represents a release of energy up to 30-times Earth's average. Alternatively, the signal could be coming from cooling lava flows, capped by roughly 9 to 11 metres of solidified crust, that cover about 10 percent of the moon's surface at any given time.

"Io provides a unique window into how tidal heating works throughout the cosmos, a fundamental process that provides energy and heat to worlds that are far from their parent star," said Bolton. "This process can not only create the most volcanic body in the Solar System, in the case of Io, but also fuel the subsurface oceans on the moons of giant planets, such as Europa and Ganymede. Until this point, we could only observe the heat escaping at the surface or through eruptions. Now we can characterize how the heat is moving from the interior toward the surface."

Though Io is known for its tall mountains and active lava flows, the radiometer measurements also indicated that the surface features extensive smooth patches stretching across distances of 100 kilometres or more. "Away from its mountains, the surface is more like the Great Plains of North America, and even though Io is a rocky body, the surface material has a very low density—more like pumice or a fluffy volcanic ash than solid rock," Brown said, in an interview with *Pasadena Now*.

Compiled with material provided by NASA.

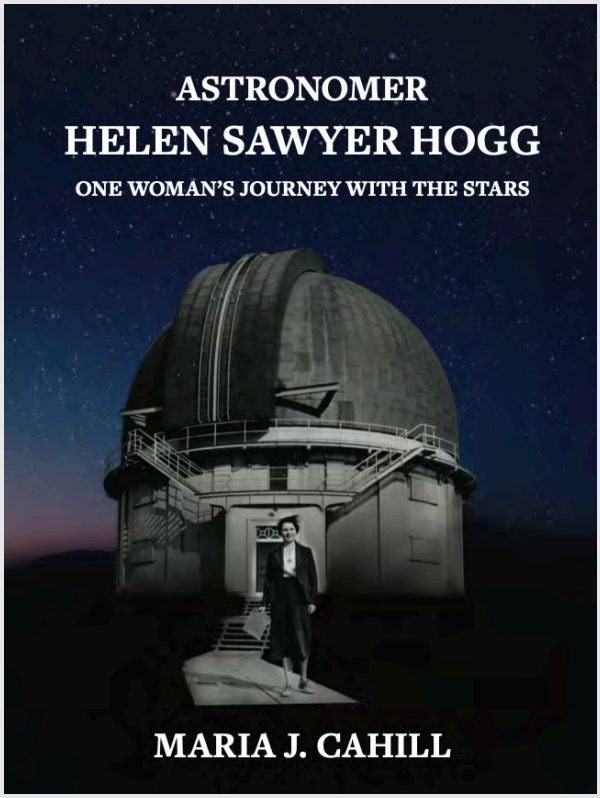
V445 Puppis spits out helium outflow

Mysterious high-speed "bullets"—clumps of possibly oxygen-rich gas travelling at up to 32 million kilometres per hour—have been discovered shooting out of the rarest stellar explosions in our galaxy. They were spotted after a dust of debris surrounding the Milky Way's only known helium nova, V445 Puppis, finally cleared after more than 20 years, revealing that an unusual stellar system was to blame for the extraordinary explosion.

But the origin of the "bullets" is an enigma that has left astronomers puzzled—nothing of their kind has ever been observed in other novae.

Using observations from multiple telescopes spanning two decades, John Mills, a researcher and Ph.D. student at the University of Warwick, showed that V445 Puppis, which disappeared behind a cloud of its own debris at the turn of the century, consists of a white dwarf that is accreting material from a helium star—a star that lost its outer hydrogen envelope, probably through previous interactions with its companion. Helium stars are extremely rare: there are estimated to be only a few thousand stripped helium stars among the hundreds of billions of stars in the Milky Way. The discovery confirms for the first time the nature of the binary system responsible for the Milky Way's only currently confirmed helium nova, providing an unprecedented opportunity to study one of the rarest types of stellar explosions.

"V445 Puppis has long stood out amongst novae for its complete lack of hydrogen, making it astronomers' sole opportunity currently to investigate this unusual class of explosion in detail. How could such an event be completely devoid of the most abundant element in the Universe?" said Mills.



The story of Helen Sawyer Hogg, a pioneering leader in Canadian astronomy and a trailblazer for women in astronomy. Price is $39.95 CAD.

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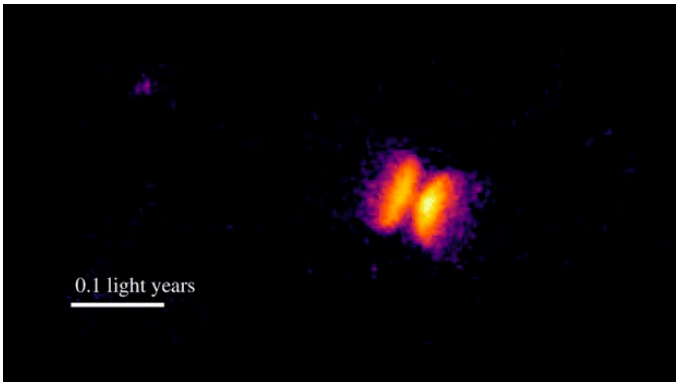


Figure 2 — Image from the Hubble Space Telescope *showing the bipolar outflow of material ejected by the helium nova V445 Puppis. The progenitor binary star system lies in the centre of the outflow. Image taken in 2013 with the F502N filter on Hubble's Wide Field Camera 3. Credit: John Mills / University of Warwick*

A nova occurs when a white dwarf pulls gas from the nearby companion star, and, as this material accumulates on the white dwarf's surface, rising temperatures and pressures trigger a runaway thermonuclear explosion. V445 Puppis was discovered by Kazuyoshi Kanatsu of Matsue, Shimane, Japan, who recorded a peak magnitude of 8.5 on 2000 December 18. The system lies at a distance of 8.2 ± 0.5 kpc. The white dwarf in the system has an estimated mass of more than 1.3 times the mass of the Sun. It was thought the white dwarf was increasing in mass because of recurring helium shell flashes and that it would explode as a Type Ia supernova after it passes the Chandrasekhar limit of about 1.38 solar masses, the mass limit of a stable white dwarf. It was later found that this white dwarf ejected more than a Jupiter mass in the 2000 eruption and it continues to lose mass over each eruption cycle, thus ruling out the hypothesis that it will explode in a Type Ia supernova.

When V445 Puppis erupted in late 2000, it launched an enormous bipolar outflow, which, in infrared observations, stretched more than a tenth of a light-year. The eruption created a thick disc of dust that completely obscured the stellar system. For the past two decades, astronomers could study the expanding debris but could not directly determine what kind of stars had produced it. Finally, the veil of dust thinned enough for the hidden system to emerge.

Combining infrared observations from the European Southern Observatory's Very Large Telescope, optical imaging from the *Hubble Space Telescope*, long-term spectroscopy from the Southern African Large Telescope, and photometric observations from NASA's *TESS* mission, Mills was able to reveal the binary system in unprecedented detail.

Also embedded within the nova's outflowing debris cloud were high-speed "bullets" of possibly oxygen-rich gas.

"The origin of these 'bullets' is a mystery. We suspect that these originated post-outbursts, but 'bullets' of this kind have not been observed in any other nova," said Mills.

He also found that the system is actively transferring material once again, indicating that the pair have resumed the process that eventually led to the original explosion. The observations suggest that the two stars orbit each other every 3.7 days, about twice as long as previously thought. Astronomers suspect that repeated helium-rich eruptions may represent one pathway toward producing Type Ia supernovae—some of the brightest explosions in the Universe.

"Because these supernovae shine with remarkably consistent brightness, they are special in their use as 'standard candles,' used to measure distances to galaxies," explained Mills.

"The culprits behind this galactic eruption have been an enduring mystery over the past 25 years, which is why it is very exciting to confirm that this helium nova was the result of a helium star accreting onto a white dwarf. I look forward to seeing how this result may help us uncover what powers other similar hydrogen-poor astronomical explosions, such as the famous Type Ia supernovae," said Mills.

Although many questions remain about whether helium novae can ultimately produce Type Ia supernovae, V445 Puppis now provides the clearest laboratory yet for testing that possibility.

Compiled in part from material provided by the Royal Astronomical Society

Galactic "atmospheres" hold missing matter

Physicists have good estimates of how much matter was present in the early Universe. Shortly after the Big Bang, roughly 83 percent of all matter in the Universe was composed of invisible dark matter, with ordinary matter making up the rest. And yet, these estimates exceed the amount of ordinary matter seen in stars and galaxies today. Where, then, did all the missing ordinary matter go?

Now MIT scientists, as part of the Canadian Hydrogen Intensity Mapping Experiment / Fast Radio Bursts Collaboration (CHIME/FRB), are using far-off radio signals to reveal missing matter in the vast space between galaxies. The team has developed a new method to search out missing matter by combining locations of galaxies with detections of fast radio bursts.

CHIME is a large radio telescope located in British Columbia, Canada, that is designed to scan the entire northern sky for incoming radio waves. The telescope is sensitive to ultrashort, ultrabright radio signals, and since it began observing, CHIME has detected about 4,000 fast radio bursts across the sky. DESI is an instrument mounted on the Mayall Telescope at Kitt Peak National Observatory, near Tucson, Arizona. The instrument makes detailed measurements of the light coming from more than 30 million galaxies to provide estimates of dark energy—the mysterious force that drives the expansion of the Universe.

A fast radio burst, or FRB, is an ultrabright, millisecond flash of radio waves emitted by extremely energetic phenomena in the distant Universe. As it travels through space, the signal from a fast radio burst undergoes dispersion, a process in which lower-frequency wavelengths are delayed more than those with higher frequencies. By cross-correlating the dispersion of background FRBs with the locations of over 6 million foreground galaxies, the MIT team was able to study the relative spatial distributions of plasma and galaxies on scales of 0.1 to 50 Mpc, which are strongly affected by feedback processes in galaxy formation.

The MIT-led team measured the degree of smearing experienced by thousands of FRB signals arriving at Earth. Then they cross-correlated each FRB smear with locations of galaxies to determine how much of an FRB's smearing was due to matter in galaxies versus other missing matter.

The new method revealed not only whether missing matter was present, but also where it was located: in very diffuse clouds surrounding groups of galaxies. These clouds extend out from the galaxies to much farther distances than had been predicted. "We find that, overall, where there are more galaxies, there tends to be more missing matter around them," says Haochen Wang, a graduate student in MIT"s Kavli Institute for Astrophysics and Space Research.

The results, reported in the journal *Physical Review Letters*, support the idea that matter is flung outward by way of black-hole jets, exploding stars, and other highly energetic processes within a galaxy. What's more, the findings suggest that such processes are more energetic than scientists had thought.

"We're finding missing matter that is pushed out to larger scales," says Kiyoshi Masui, associate professor of physics at MIT. "These measurements indicate that star activity, and activity from black holes, is stronger and much more violent than predicted. A galaxy is maybe a few hundred thousand light-years across, and we found missing matter out to about 4 million light-years. That's farther than the simulations predict, by quite a bit."

The vast majority of ordinary, observable matter in the Universe is built from baryons—a type of subatomic particle that includes protons and neutrons and makes up most of an atom's mass. Scientists estimate that just 17 percent of the early Universe was made from this "baryonic" matter, shortly after the Big Bang.

Some of that early matter was forged into every substantial thing we see today, from planets, stars, and galaxies to our own bodies. But as scientists have realized, this matter doesn't quite add up. The total mass of all the stars, galaxies and galactic clouds is about 10 percent of the baryonic matter that existed

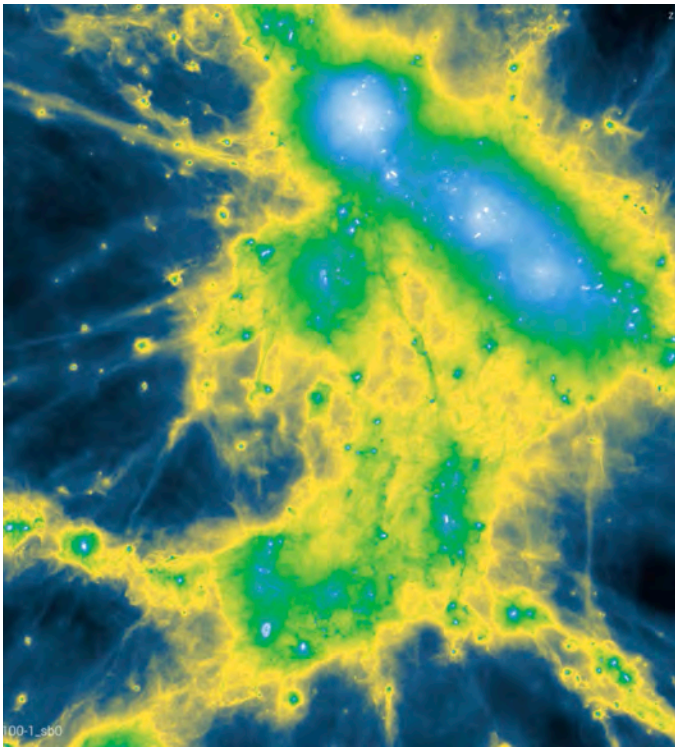


Figure 3 — Simulated gas distribution around galaxies. Credit: IllustrisTNG

in the early Universe. There must be more matter, likely in the spaces between galaxies.

But the Universe is vast. Any leftover matter likely exists at extremely low densities, of around a single proton per cubic metre, making it extremely challenging to detect.

"We're not just probing if the gas is with the galaxy or not, but we are seeing the shape of the missing matter that's around the galaxies," Wang says. "By mapping the shape of missing matter, we can understand how galaxies form and how they interact with their environment."

Their analysis revealed a pattern: Missing baryonic matter tended to be found around galaxies and galaxy clusters. But rather than gathering close to galaxies in a dense ball, missing matter was scattered over a large radius, similar to a diffuse puff.

"We are finding that the activity in galaxies is messier than we thought," Wang says. "They're more like fountains, and really push out gas to very large distances."

The new results show that fast radio bursts can be a reliable method for searching for missing matter. As CHIME continues to detect more FRBs, the team says its method can only improve. "We got it to work for the first time and will get it to work even more precisely as data get better," Masui says.

Prepared with material provided by MIT. ✶

The Cycle That Never Repeats

by Alister Ling, Edmonton Centre RASC

In casual glances, one clear night is the same as the next, but to an avid watcher of the skies, differences become noticeable. For an observer in the mid-latitudes, it's not easy to get a sense of the rhythm, the continuity, the sliding orbital movements, and changing transparency while juggling a gamut of responsibilities, waiting haphazardly for clear skies, and starting sessions at different times. A number of RASC members have now had the chance to experience long runs of nights as Astronomer in Residence at the Sossusvlei Desert Lodge in Namibia (Ling, *JRASC* February 2026). This article discusses some of my experiences from 2025 May 15 to July 30: 77 nights of observing in a row, with only a couple being partly cloudy.

Readers of the *Journal* are all aware that our satellite moves about 12 degrees a day, circling the sky a little faster than a month. It's not rare to see it 3 or 4 days in a row, as a waxing crescent, stepping up the sky, helping us visualize its orbit. But the clouds put an end to that, our next occasion is to see it much farther around the sky, at first quarter or later. Viewing from –24 degrees latitude, a northern observer would say the ecliptic stands pretty much vertically. Under cloudless skies of the dry season, that daily 12-degree shift registers on one's neck muscles, along with the swiveling of the body as Luna goes up through the zenith and down the other side. It's easy to "connect the dots" to visualize half a lunar orbit at a glance. A key side-effect of being Astronomer in Residence is that the daily sleep/wake cycle hardly changes, effectively channelling one's look at the sky at 1 p.m. and 8 p.m. every day (and a lot of 6 a.m. times, too!). Back home at 53.5°N, the displacement can be nearly horizontal when the ecliptic lies at a very shallow angle, and that's a lot less striking.

A sky touched by Midas! We just don't get these colours in Canada with a few exceptions of retreating storm clouds over a harvest wheat field as the Sun drops into the horizon.

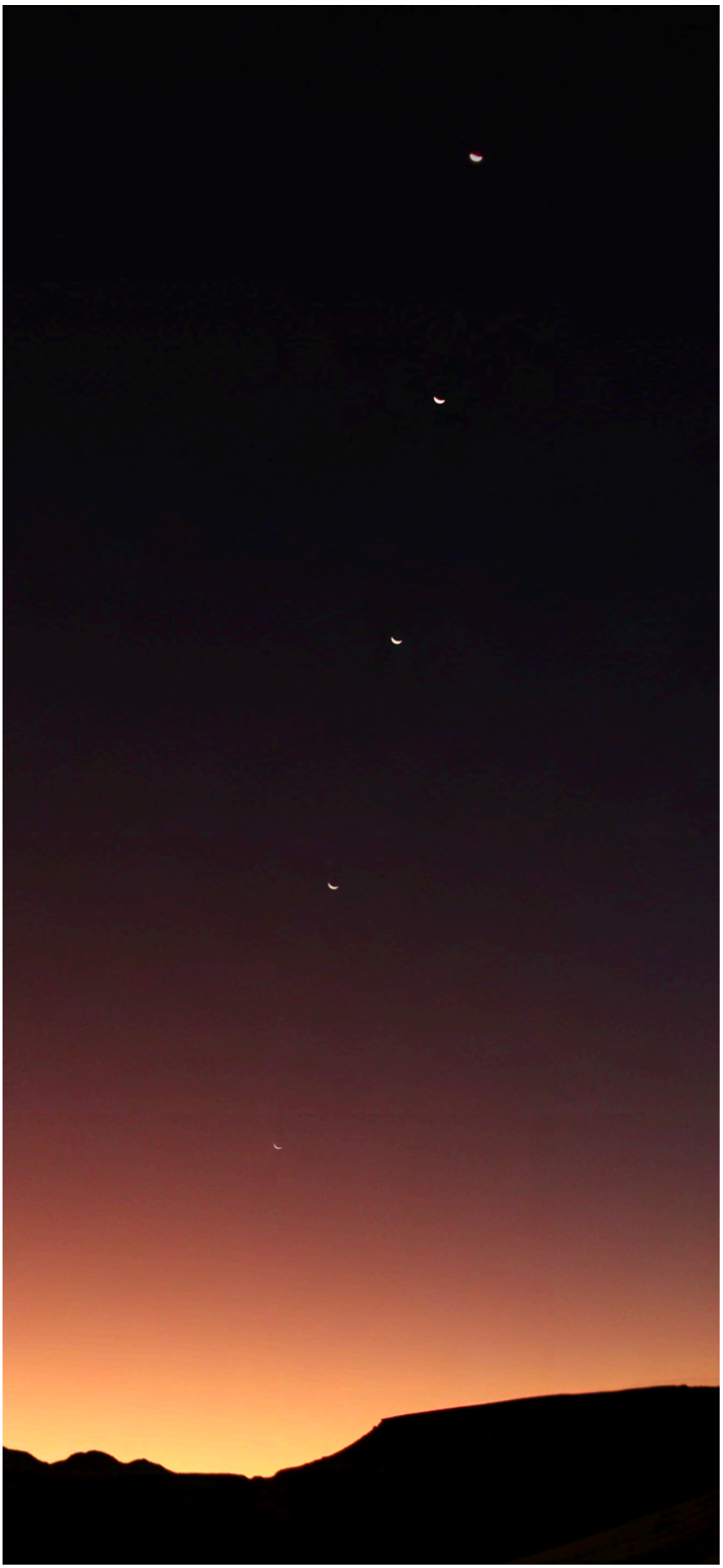


Figure 1 — Wide-angle twilight shots of the evening crescent.

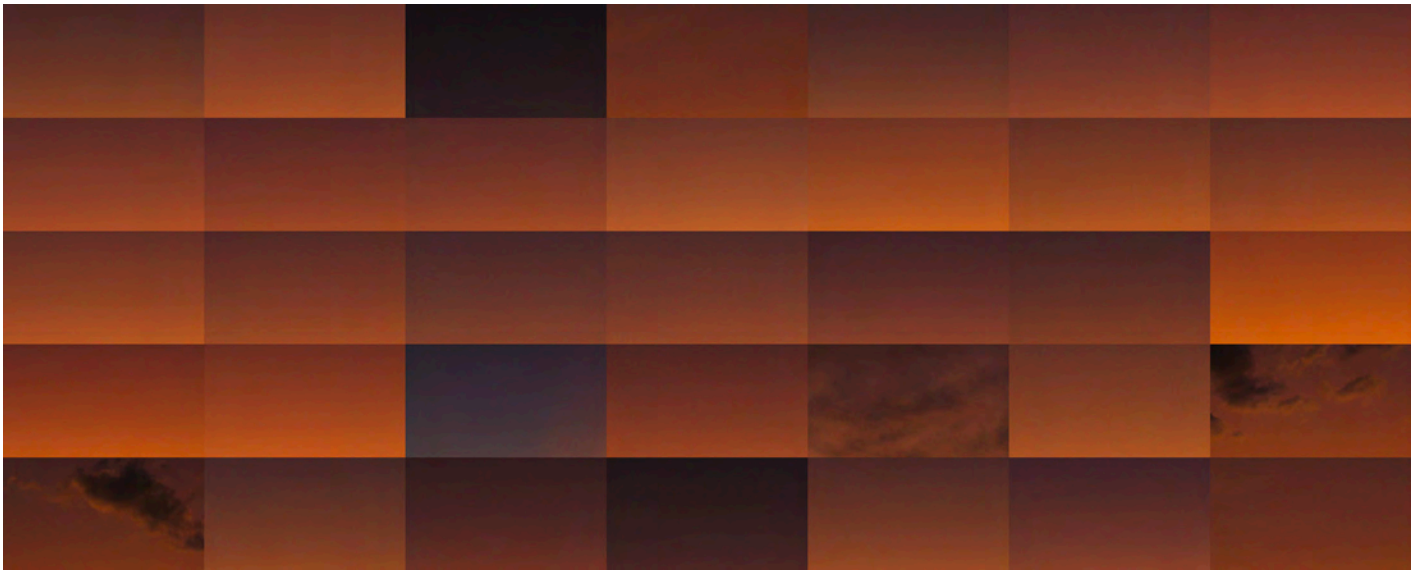


Figure 2 — A quilt of a month of dusks.

In Namibia, it was evening after evening of stunning gold. Inspired by a quilt of twilights I created for a Mercury apparition in 2019 (Figure 3), I resolved to take a month of high-dynamic-range triplet of exposures at the same solar depression to document how upper and lower atmospheric flows affect the dusk. I carefully positioned the camera and tripod each evening for the shots, then back home I used *Hugin* freeware to reproject each frame to correct minor pointing differences, cropping to the same spot in the sky, finally assembling them into a quilt using *ImageMagick*. From the outset I was disappointed that no white balance or colour temperature setting could remotely come close to capturing the intensity and palette of that golden sky. I tried hard to fix those twilights in memory, suspecting (correctly) that I'd be unable to match it using software.

What does one see? In common with skies back home, the more particulates that are suspended in the air, the brighter the sky. Crepuscular dark rays caused by distant clouds casting shadows allow the upper atmosphere's deeper purple to show. I should not have been surprised by the lack of variation, but a lifetime of "every evening is different" made it remarkable. In Namibia, there is little change day to day in the lower stratosphere and upper troposphere, leaving the variation to be decided by how much sand/dust had been whipped up in the previous day to the north. The most transparent nights came when a clean flow from the Atlantic swept in.

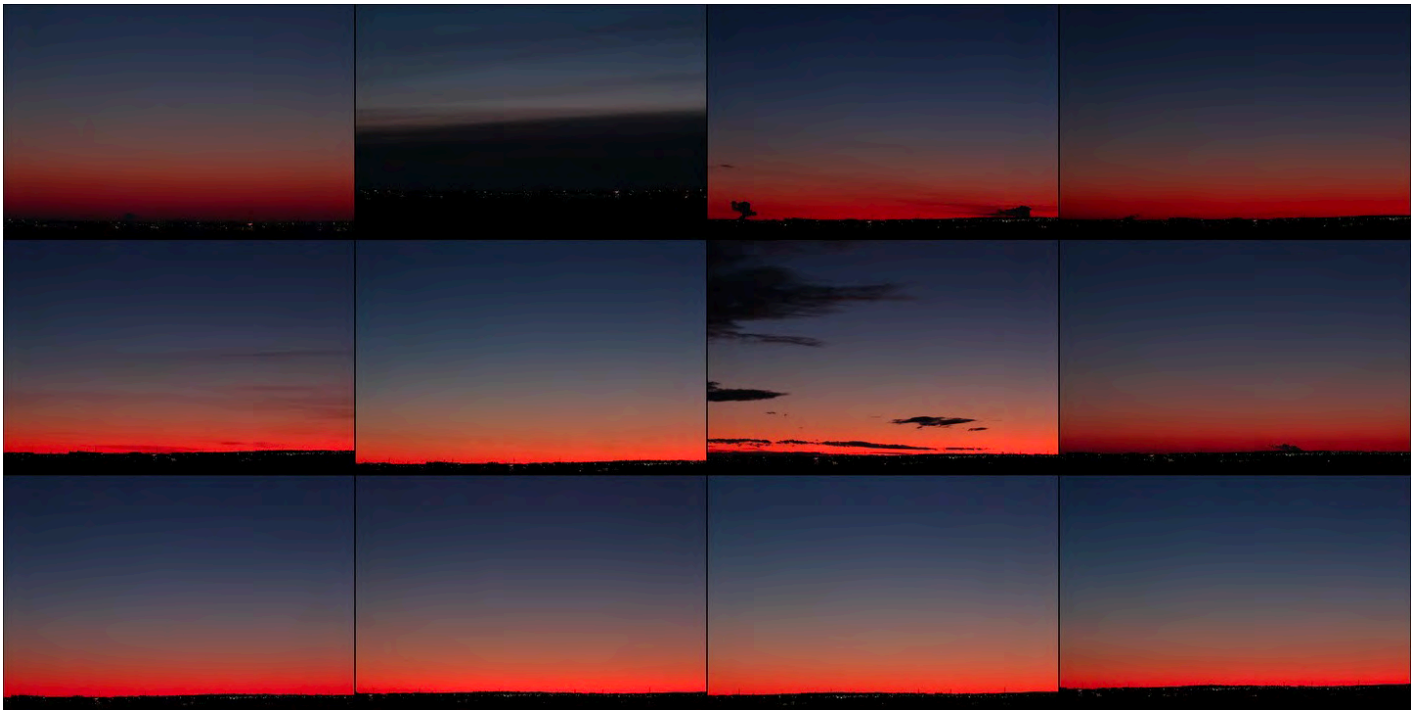


Figure 3 — A quilt of "Mercurial Skies."



Figure 4 — Mars moving up (eastward) in Leo.

In contrast, for the mid-latitudes, the key variable affecting night to night transparency is the amount of upper-level water vapour (look for that specific satellite imagery, sometimes labelled as "6u" or "7u"). Typically, immediately following a weather system, dry stratospheric air is entrained downward, producing "that remarkable deep blue" daytime sky, and shaving off a full Bortle unit from typical night-time values. As the next weather system approaches, the water vapour has significantly increased, creating the typical lighter "powder blue" colour. The large-scale swirling motions often create ribbons of low vapour that might last only 2 or 3 hours as they cross overhead. It's pretty common to hear observers stating how the transparency seemed to change during a session—it did!

What may look like an image of a *Starlink* chain, is a composite of the nightly positions of Mars. Each evening, I would point out the "not truly red" planet to the guests at the observatory and urge them to take a second look at their next lodge or back home, that by using two background stars as a reference it was obvious how much Mars shifted night to night once you knew what to look for. I've always enjoyed picking out the asteroid 4 Vesta with unaided eyes near opposition, but my stay at the lodge afforded me the chance to monitor its nightly shift for almost two weeks. Four 4–5th mag. stars provided the reference frame to do this. Not amazing but a personal first!

RASC member Alan Whitman (author of "Southern Hemisphere Splendours" in the *Observer's Handbook*) told me to look for the light bridge between the Large Magellanic Cloud and the Milky Way. This is a stream of stars, a tidal tail left over from the passage of the LMC through the galaxy. It's a very subtle glow! Once I detected it, I would check night after night, most registering a "nope," others a "sort of?" and only a handful "for sure!" Back home, one can gauge the Bortle

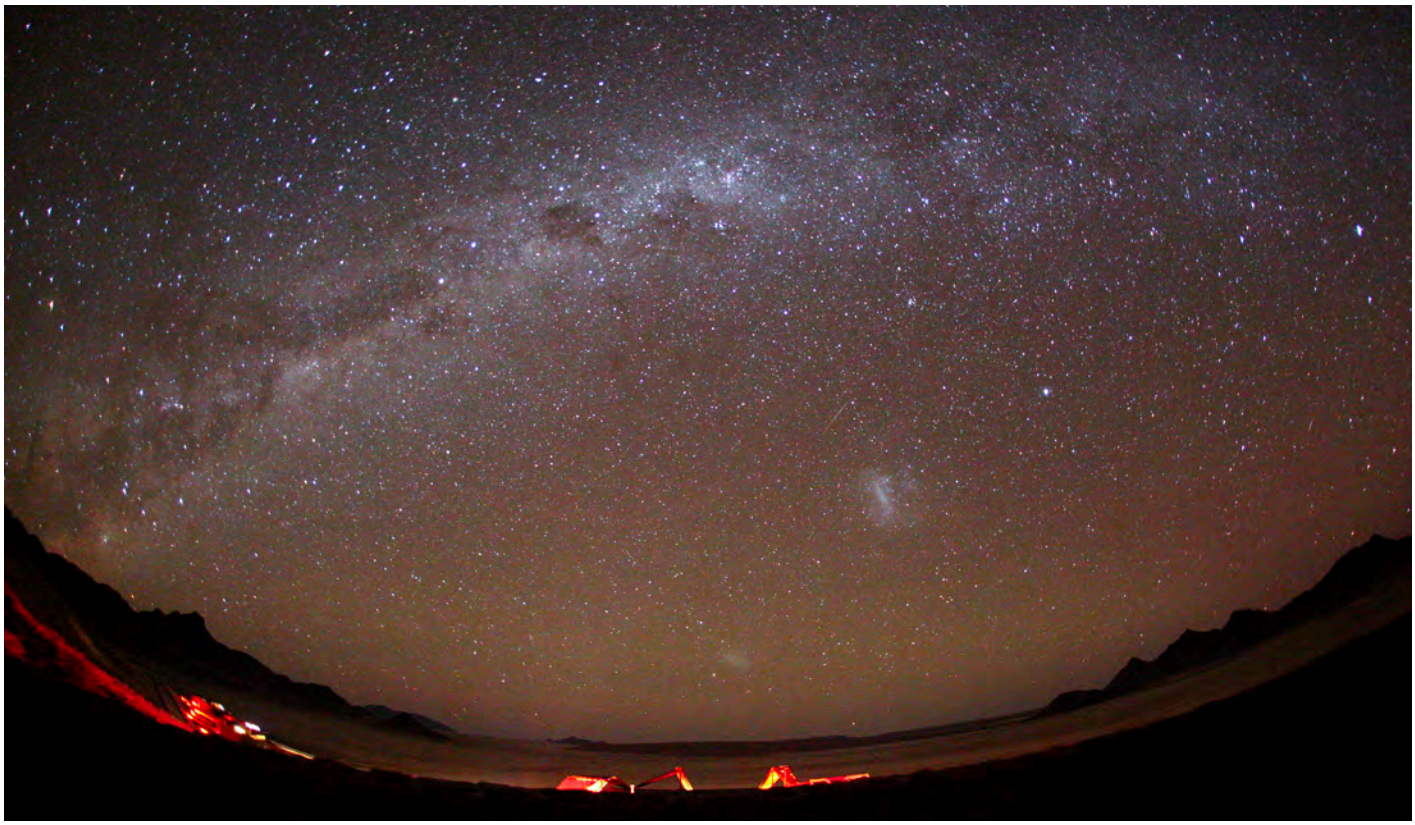


Figure 5 — The Large Magellanic Cloud light bridge and the Milky Way.

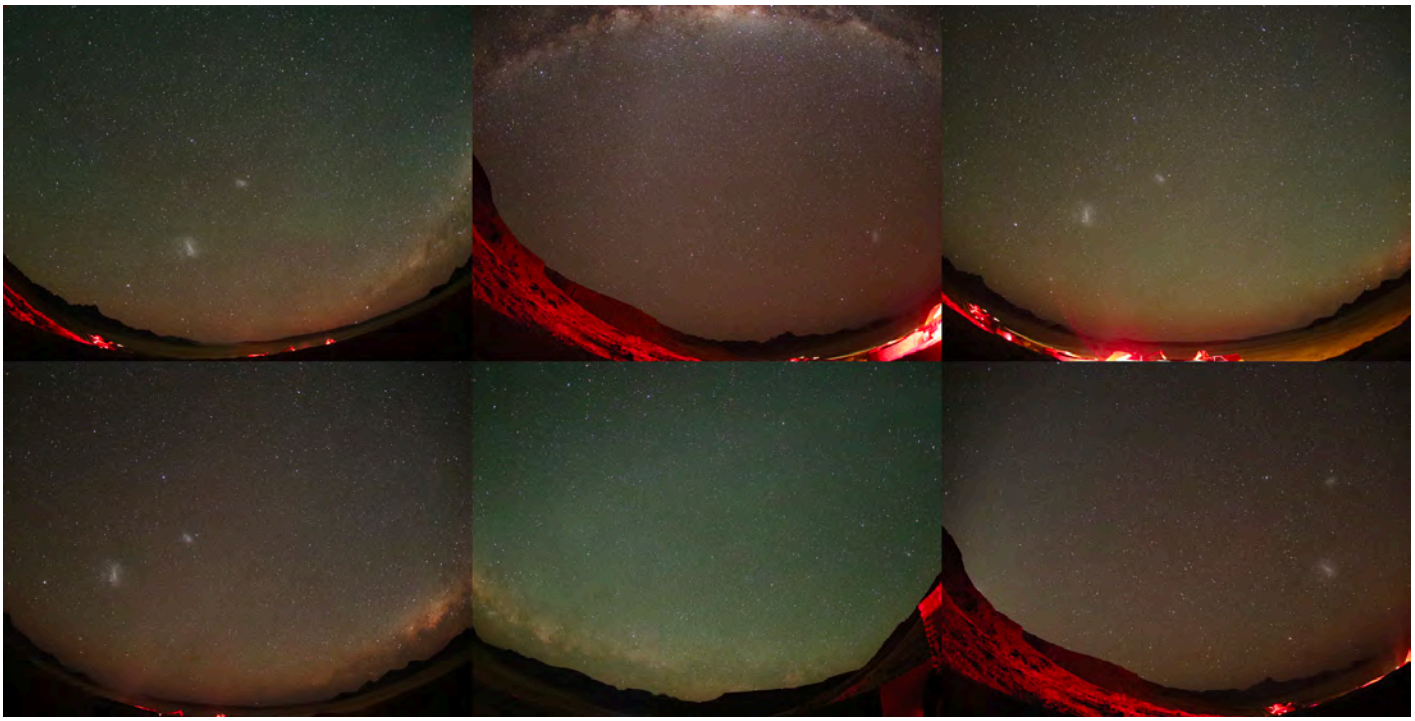


Figure 6 — A quilt of airglow.

level by the amount of detail and contrast in the Milky Way's dark lanes, yet every night I had in Namibia was the best it could be—a Bortle 1. With an incredulous broad smile, there were times I'd be thinking "this has to be a 0.8 then!" (5)

When told to notice a modestly obvious zodiacal pyramid, many beginner skywatchers just can't see it. I've found that it's best to start them looking well to one side, and while slowly scanning across the zone, note how the background sky gradually brightens then fades. Their response is usually "Oh, that! Yeah, no problem." Using this technique for the bridge, I would scan from horizon to Milky Way looking for the background to show that telltale variation. On the nights I did see it, I found it easier to notice the constant light level from Sagittarius to the LMC, with an abrupt drop on the farther side. It's cool to realize that the darker zone must be the leading edge of the LMC's motion.

To be honest, others looking at the image in Figure 5 told me they don't see the bridge, and I have to admit that maybe I don't either. But I think I see less light on the right side; scanning upward from the horizon there is a dip in the background glow that's not there on the left.

Airglow

A phenomenon more common than most people expect shows up in Alan Dyer's *AmazingSky.net* and Facebook widefield images: airglow. Pictures show bands of pale green and purple-pink covering large swaths of sky. The upper atmosphere is partially ionized during the day, then glows softly at night from the recombination of electrons to their atoms. I have visually seen them (colourless of course) from dark prairie skies only a handful of times and was keen to see more from this super dark location.

The first new-Moon period passed without a sighting. Puzzled, I asked experienced amateur astronomer Tom Polakis if there was any seasonality to airglow, his short answer being no, not really, but there is significant night-to-night variability. On a friend's all-sky camera in southern New Mexico, he sees them when watching the previous night in time-lapse, and suggested I do a similar thing: put the camera with a fisheye lens on low resolution and high ISO, shoot every 30 seconds, then review the capture at the end of the night. Be unbiased by first recording your impression a couple of times as the night progresses.

Sure enough, once an observer is sensitized to how a patch of sky normally looks, then the subtle differences between lighter, typical, and darker become recognizable. I had now become acquainted with the southeastern sky and the LMC climbing higher before dawn. I also keyed in on the quality of the sky through the "Great Square" of Pegasus, which I regularly use back home. From the city backyard, I see one or two stars inside the Square, 10–15 from a Bortle 4, and more than 70 from a truly dark location, at which point I joke "I can't count that high without losing my place." With these two mental references in place, I would guess if airglow was a factor. I soon realized there was a classic situation that a thin sheet crossing the sky would be invisible overhead yet be increasingly apparent as one approached the horizon thanks to the compression of foreshortening.

These images in Figure 6, with identical camera settings, show the variability of coverage and colour of airglow in July 2025. The two at upper right are a few hours apart on the same night! One can see that the zones closer to the horizon really lose contrast when airglow is present. As noted in the first article, the lodge uses red lights for travel zones, whose indirect glow scatters up the nearby slopes in widefield images but is totally invisible to the dark-adapted eye. The ever-present (somewhat annoying!) zodiacal glow can be traced out in several frames.

With the little time I had left, I wanted to bag the Eridanus Arc, one of Chris Beckett's "Wide-Field Wonders" listed in the *Observer's Handbook*. With what I thought was a pretty fine sky, I couldn't claim success. The northern mind boggles at observing Eridanus in July, but it's reasonably placed before dawn from down south. Once I was habituated and armed with a better sense of transparency and darkness, I could tell with a quick glance at the sky whether it would be worth the time to even try. Alas, between the approaching dawn and airglow-reducing transparency, I remained beaten.

What an experience, to witness the clockwork of the heavens, on repeat, yet never the same. Thank you, Alan Whitman, for the push: "Alister, you have to do this!" Likewise, you have to try this, too. ✶



Research Article / Articles de recherche

Fenestratilis: Primary Proximus Theorem

by Glenn Hunter (ORCID iD: 0009-0004-7444-3194)

Abstract

The Primary Proximus Theorem threads the borders of the abstract and the physical, as it describes a philosophical point in space leading the dynamic position of the planet Mercury by 0.1 percent. The Sun-Earth orbital relationship is expressed in ratio of the philosophical point that is derived from the Primary Proximus Theorem by utilization of the Earth's maximum Solar orientation angles empirically defined during an orbital period. A framework is developed to explore the tropical position (state) of Earth where gravitational mass and inertial mass agree with the General Postulate of Relativity, but are anomalous when two apparently equivalent tropical states are compared. A formula correlates Earth's gravitational escape velocity and the constant between Earth's sidereal and tropical time, and through the mathematical treatment of electromagnetic forces presents the notion of a frame regulating the observed constant velocity of light. Aggravating results deconstruct Einstein's thought experiment, of an observer in free fall, into two forces, where the observers experience is the mean of the upper and lower bounds of pi. Fenestratilis is the modality introduced.

Introduction

To begin, an orbit of Earth will be defined by an observer geocentrically located, projecting a line representing the Earth's Copernican axis onto a secondary line representing the Solar rotational axis. The convergence of these two lines into a single parallel line is defined as *P* 0.0 degrees, representing the starting position of the body's orbit, where abbreviation P1T3 is used as shorthand to reference the position, see figure 1. The physical ephemeris data utilized is from the France IMCCE website that uses the letters (PA_N) NP at 360.0000 degrees or 0.0000 to denote the *P* position formerly described. One complete orbit is from P1T3 through P3T3 that creates a reciprocal P 0.0 degrees, then proceeds to close at P1T3 criterion. Thus creating the P1T3 orbital schema.

The representation of the horizontal dimension of Earth's orbit is the mean of two maximum P values difference from P 0.0, expressed in degrees, considered as positions P2T3 and P4T3.

The representation of the vertical dimension of Earth's orbit is the mean of two maximum βθ values difference from zero, expressed in degrees, P2T1 and P4T1 respectively. (IMCCE physical ephemeris δ SEP is equivalent to βθ described.) The value of βθ 0.0 degrees represents the energetic position of the Earth at equivalence to the solar equator if a Euclidean line were projected across space. If Earth is imagined to be at a descending node across the Euclidean βθ 0.0 degree line, this is the P1T1 state, while an ascending node across the Euclidean βθ 0.0 degree line is P3T1. See Figure 2.

The Primary Proximus Theorem (PPT), as detailed here, is used to solve for the mean vertical energy ratio of Earth as presented in the semi-major axis ratio (*Vsma*) of the philosophical point, by substituting in the mean maximum βθ degree at Observer degree (*Od*). Then, PPT is applied to solve for the mean horizontal energy ratio of Earth as presented in the semi-major axis ratio (*Hsma*) of the philosophical point, by substituting in the mean maximum *P* degree at *Od*.

$$Od^2 = \mathrm{H}$$

$$\sqrt[3]{H} = (p^2)$$

$$\sqrt[3]{(p^2)} = sma$$

The mean vertical and horizontal energy dimensions represented each by a single value, *Vsma* and *Hsma*, are merged using the Pythagorean Theorem (Britannica, 2025) to solve for what is termed the mean Terranomical Energy Plane ratio (*TEPsma*).

$$Vsma^2 + Hsma^2 = TEPsma^2$$

The *TEPsma* is inserted into the base of the PPT, which is fundamentally Kepler's third law (1618/2002) to solve for Earths period as presented in a ratio of the philosophical point orbital periods, referenced as Primary Proximus Periods (Ppp).

$$TEPsma^3 = Ppp^2$$

The Ppp ratio representing Earth's mean orbital period, is from P1T3 to P1T3 establishing a recursive cycle. To build a four-dimensional construct, we ought to consider only the mean span of time that approximates a singular track; thereby, seeding the idea of traveling over the mean P1T3 to P3T3, traditionally representing half an orbit. Ppp divided by two arrives at the mean span of time (MST). Then, we cube the MST to represent the three traditional Cartesian coordinates. We then take the square root of the three-dimension construct to solve for the two dimensions of horizontal and vertical energy. The x, y represent the mean horizontal energy dimension (ME) that is coplanar with x, y MST axes. The z represents the mean vertical energy dimension (ME) that is coplanar with z MST axis. Considered as a whole, we have a four-dimensional construct, with the Terranomical Couple representing mean span of time (MST) on the left and mean energy (ME) on the right.

$$Ppp \div 2 = MST$$

$$MST^3 = \square = ME^2 = (x, y) \cdot z$$

The PPT Mathematics

1) Earth's orbital ephemeris defined for analysis. The orbit begins at 2024-01-05T18:30:15.000 UTC equaling P1T3. The orbit ends at 2025-01-05T00:16:07.000 UTC equalling P1T3 closing. The sum UTC in seconds of this P1T3 orbital schema, as represented in Figure 1, is 31,556,752 seconds. Arriving at a value that is 156.8 seconds less than a mean Earth tropical year as calculated from Earth Fact Sheet, Orbital parametres (NASA, 2024 Jan.)
2) Solve for the mean maximum βθ degree within the P1T3 orbital schema. 2024-03-06T04:15:00.000 UTC at position negative maximum βθ 7.25203 degrees equals P2T1. 2024-09-08T06:30:00.000 UTC at position positive maximum βθ 7.25231 degrees equals P4T1.

$$(7.25203° + 7.25231°) \div 2 = 7.25217° \; Mean\; Max.\beta\theta$$

3) Solve for the mean maximum P degree within the P1T3 orbital schema. 2024-04-06T10:00:00.000 UTC at position negative maximum P 26.2601 degrees equals P2T3. 2024-10-09T21:30:00.000 UTC at position positive maximum P 26.2593 degrees equals P4T3.

$$(26.2601\,° + 26.2593\,°) \div 2 = 26.2597° \; Mean\; Max.P$$

4) Solve for the mean vertical energy ratio of Earth as presented in the semi-major axis ratio (*Vsma*) using PPT.

$$\beta\theta\ 7.25217^2 = 52.593,969,708,9$$

$$\sqrt[3]{52.593,969,708,9} = 3.746,668,916,492,85$$

$$\sqrt[3]{3.746,668,916,492,85} = Vsma\ 1.553,156,096,657,057$$

5) Solve for the mean horizontal energy ratio of Earth as presented in the semi-major axis ratio (*Hsma*) using PPT.

$$P\ 26.2597^2 = 689.571,844,09$$

$$\sqrt[3]{689.571,844,09} = 8.834,727,803,335,897$$

$$\sqrt[3]{8.834,727,803,335,897} = Hsma\ 2.067,272,485,967,788$$

6) Solve for Earth's mean Terranomical Energy Plane ratio (*TEPsma*) through the application of the Pythagorean Theorem (Britannica, 2025), by substituting in *Vsma* for "a" and *Hsma* for "b."

$$1.553,156,096,657,057^2 + 2.067,272,485,967,788^2 = TEPsma\ 2.585,712,550,115,04^2$$

7) Solve for Earth's period as expressed in ratio of the Primary Proximus Periods by placing the *TEPsma* in Kepler's third law equation (1618/2002).

$$TEPsma\ 2.585{,}712{,}550{,}115{,}04^3 = Ppp\ 4.157{,}864{,}815{,}427{,}175^2$$

8) Solve for the mean span of time (MST) by dividing the Ppp in two.

$$Ppp\ 4.157{,}864{,}815{,}427{,}175 \div 2 = MST\ 2.078{,}932{,}407{,}713{,}587$$

9) Solve for the four-dimensional construct and two mean energy dimensions (ME), represented by horizontal (x, y) vertical (z), by cubing the mean span of time ratio (MST) to equal a three-dimensional MST construct. Take the square root of the three-dimensional MST construct to find the two ME dimensions ratios. The formula considered as a whole reveals the four-dimensional construct and the Terranomical Couple.

$$MST\ 2.078{,}932{,}407{,}713{,}587^3 = \square\ 8.985{,}062{,}617{,}039{,}926 = ME\ 2.997{,}509{,}402{,}327{,}193^2$$

The PPT ratios: Analysis and conversion to metres and seconds

10) Analyze calculation result in item 7, regarding Earth's period as expressed in ratio of the Ppp, by solving for the equivalent format of Earth's tropical period 365.242 days divided by Mercury tropical period 87.968 days as per Mercury Fact Sheet, Orbital parametres (NASA, 2024 Jan.*) and solve for the difference of the two ratios:

$$365.242 \div 87.968 = 4.151{,}987{,}086{,}213{,}168\ NASA\ ratio$$

$$Ppp\ 4.157{,}864{,}815{,}427{,}175 - 4.151{,}987{,}086{,}213{,}168 = \Delta\ 0.005{,}877{,}729{,}214{,}007$$

11) Let the Terranomical Energy Plane ratio (*TEPsma*), solved for in item 6, equal one Astronomical Unit (au) in metres, as per the International Astronomical Union (IAU) 2012 Resolution B2. Solve for applicable Primary Proximus semi-major axis in metres (Ppam) with:

$$au\ 149{,}597{,}870{,}700 \div TEPsma\ 2.585{,}712{,}550{,}115{,}04 = 57{,}855{,}568{,}939.147{,}66\ Ppam$$

12) Solve for the conversion of the Terranomical Couple ratios, presented in item 9, to metres and seconds. Multiply the Proximus semi-major axis in metres (Ppam) solved for in item 11, by a mean energy dimension ratio (ME) presented in item 9, to result in a mean energy dimension in metres (MEm)

$$Ppam\ 57{,}855{,}568{,}939.147{,}66 \cdot ME\ 2.997{,}509{,}402{,}327{,}193 = MEm\ 173{,}422{,}611{,}872.084{,}2$$

Applying the four-dimensional construct equation in item 9, square the MEm to equal the four-dimensional construct and the cube root thereof equals the mean span of time in seconds (MSTsec).

$$MSTsec\ 31{,}098{,}335.780{,}280{,}03^3 = \square\ 3.007{,}540^{22} = MEm\ 173{,}422{,}611{,}872.084{,}2^2$$

As pure reference, the MSTsec above is 1.45% less then the mean Earth tropical period of 365.242 days (NASA, 2024 Jan.), arrived at by considering the standard metric of time with 60 seconds to a minute, 60 minutes to an hour and 24 hours in a day. The sum UTC of the P1T3 orbital schema defined in the PPT Mathematics section, item (1) is approximately 365.240 days.

Considering the βθ and P classifications as tropical phenomenon, this work becomes a modifying extension of Nicolaus Copernicus's work (1543/2002).

Discussion

(**D1**) It is important to recognize that the final section of the PPT, as detailed below, is considering approximately half of the traditional period of Earth. However, as results in item (12) show the MSTsec value is 1.45% below the average tropical period of Earth.

$$Ppp \div 2 = MST$$

$$MST^3 = \square = ME^2 = (x, y) \cdot z$$

Considering the apparent aberration, we have two ME dimensions of horizontal (x, y) and vertical (z) derived from axioms of geometric dynamics of the body through an association of patterns of symmetry. A standard of degrees placed on the symmetries, the bounds in two dimensions averaged, as the reduction of x & y Cartesian dimensions are in a singular dimension represented by the P degree, and placed in the PPT. The ratios are transformed to measures by associating the au (IAU, 2012). Only after the described procedure does a tacit axiom arise. The associative cumulative time (UTC), hereafter referenced as Keplerian time, does not match the expected MSTsec. Consequently, the reader is driven to seek an explanation as to why the MSTsec does not reflect an observer's experience in half an orbital period on the body in Keplerian time. The resulting MSTsec is not required to represent half a year in seconds simply because of an antecedent argument, rooted in the imaginative work of Johannes Kepler (1618/2002). The task, then becomes to disassociate the mind from the idea that Kepler's 1618 harmonic law is "retroactively functional" when fractionally manipulated, a task that is compounded by Isaac Newton's interpretation of it in his gravitational formulas of 1687. Considering the MSTsec as a representative state of Earth's orbital continuum is a considerably simpler task.

(**D2**) The experience of the observer is specific to the body's orbital continuum, which is inescapable with conventional distances from the body. Complementary energy of other bodies within the system have definable communicability within the continuum, as derived from the observer's body of origin. Numerous relatable body physical standards arise with an alternate handling of the Terranomical Couple. Consider a frame where there is no separation of the two ME dimensions and the MST. Imagine the two ME dimensions are summed, and then divided by the MST. Where energy in metres divided by time equals metres energy per time. Let the sum of two MEm divided by the MSTsec, as presented in item (12), equal the Earth's mean energy per time (EMET) in metres per second. Creating the EMET frame:

$$(MEm\ 173{,}422{,}611{,}872.084{,}2 \cdot 2) \div MSTsec\ 31{,}098{,}335.780{,}280{,}03 = EMET\ 11{,}153.176{,}369{,}138{,}98$$

By converting EMET metres per second into kilometres per second, we have EMET 11.153. The Earth Fact Sheet, Bulk parameters (NASA, 2024 Jan.), has the Earth escape velocity equal to 11.186 km/sec. Compared to the EMET value; we have a Δ 0.033 km/sec threshold. Where the traditional Newtonian escape velocity equation is:

$$v_{esc} = \sqrt{\frac{2GM}{r}}$$

The values of seconds and metres employed to create the EMET frame are finite, which results in a "Frozen Frame" value. Considering the three-dimensional construct, the three axes (x, y, z) each initially represent an MST. In contrast, within the EMET frame we have:

$$\frac{(ME + ME)}{MST} = \frac{[(x, y) + z]}{MST} = ME\ \&\ MST\ ratio\ in\ superposition\ on\ x, y, z$$

(**D3**) Probing the relationship of the speed of light (c), as per 2022 CODATA (NIST, 2024), within the body continuum, let us consider the MEm, as presented in section 12, as inflexible in relation to c with the following:

$$(MEm\ 173{,}422{,}611{,}872.084{,}2 \cdot 2) \div EMET\ frame\ c = \Delta sec\ 1{,}156.951$$

The Δ seconds converted into minutes equals 19.28. Presenting a value that approaches the mean time difference of 20.16 minutes that is equivalent to the phenomenon between Earth's tropical and sidereal year (365.256 days), as calculated from the Earth Fact Sheet (NASA, 2024 Jan.).

For the purposes of this paper, the difference in seconds of the Earth's tropical state, and associated sidereal state, collectively identified as the tropical-sidereal (ΔT) phenomena are utilized in nonspecific seasonal orbit position (NASA, 2024 May).

Let us allow an observer's perspective that enables freedom to consider a successive catalogue of positions associated with each second within Earth's orbital schema. Thereby, in essence, in every second of the body's orbit there is witnessed a continual opening of a new orientated tropical state; an opening of a conditional sidereal time delta, while simultaneously closing the prior second's tropical state, and the preceding period's orbital equivalent tropical state (Keplerian time), together with the closing of a conditional sidereal time delta.

(D4) Nature's function of Earth, regarding orbital angular velocity specific to tropical states, operates within a flexible band. An observer is led to deduce there is a dynamically inversely proportional relationship between the energy and time when expressed in body velocity. Perturbation theory (Laplace, 1798/1827) has body velocity amended by other Solar System Bodies encountered during a respective orbit. Subsequently altering the tropical year within a range of approximately 30 minutes (Hocken, 2025), and the associated sidereal time delta in an indirect minimal commensurate value.

(D5) Let us consider a hypothetical example, where the MSTsec representing the body's tropical value, increases due to a drastic decrease in energy due to body perturbative velocity change over the orbit. In an extended perspective of Mr. Albert E. logic, from his September 27 paper (Einstein, 1905), would it not suggest the inertial mass of the body has decreased from a prior state? Granted, we are dealing with a decrease in Newtonian angular velocity of an astronomical body rather than a constant velocity with a decrease in mass due to emission of energy from radiation; however, the energy is divided by the speed of light akin to how the Δ seconds is arrived at in section (D3). The argument becomes—the right side of the equation drives the left side:

$$\frac{E_0}{c^2} = mass = \Delta T = \frac{(MEm \cdot 2)}{c}$$

To orientate ourselves for the manipulations to follow, consider figure 3. The lower portion contains "Huygens Energy Pendulum." Let the far left position (Ê+) represent the body state as defined in item (12) and sections (D2), (D3). The manipulative action proposed of drastically increasing the MSTsec representing the body tropical value, due to a decrease in energy and increase in time by a hypothetical body perturbative velocity deceleration, is represented by "APM-" in top right of Figure 3. Applying the Albert Perceived Mass Decrease (APM-) will result in swinging the body state from (Ê+) toward, but not at, the ⊕MST bottom dead centre of Huygens Energy Pendulum. Solving for described decelerated state, let the P1T3 orbital schema in seconds equal the new positional MSTsec and solve for the body associated mean tropical-sidereal Δ seconds and the body effective escape velocity:

$$P1T3\ schema\ MSTsec\ 31{,}556{,}752^3 = \square\ 3.142^{22} = MEm\ 177{,}271{,}306{,}373{,}576{,}4^2$$

$$(MEm \cdot 2) \div EMET\ frame\ c = \Delta\ \text{sec}\ 1{,}182{,}626{,}858$$

$$\Delta\ \text{sec}\ 1{,}182.626 = \Delta 19.71\ min$$

$$\frac{(MEm \cdot 2)}{MSTsec} = v_{esc}\ 0.43\% > NASA\ Bulk\ v_{esc}$$

We find the tropical-sidereal Δ seconds is approaching the 20.16 minutes (NASA, 2024 Jan.). Secondly, if body gravitational mass and inertial mass are tied in an equivalence principle (Einstein, 1917), we find here a contradiction where the body gravitational mass has increased from the (Ê+) state, not decreased, as noted by an increased escape velocity, and that the body inertial mass has theoretically decreased due to a uniform deceleration within the frame. The P1T3 orbital schema is 0.0004% below the mean tropical time of 365.242 days (NASA, Jan. 2024). Then to locate the body state at the pendulum bottom dead centre ⊕MST representing 365.242 days, one might assume another small APM- adjustment rectifies the situation.

(D6) Retuning to Figure 3, let us establish logic of the body state (Ê-) at the far right of the Huygens Energy Pendulum. Solve for (Ê-) Terranomical Couple when the tropical-sidereal ΔT 20.16 min is required:

$$EMET\ frame\ c \cdot \Delta\ 20.16\ min = (\hat{E}^{-}MEm \cdot 2)$$

$$(\hat{E}^{-}MEm \cdot 2) \div 2 = \hat{E}^{-}MEm\ 181{,}314{,}478{,}598.4$$

$$\hat{E}^{-}MEm^2 = \hat{E}^{-}MSTsec^3$$

$$\hat{E}^{-}MSTsec\ 32{,}034{,}773.445 = 370.772\ Days$$

We find the tropical (Ê-) MSTsec body state is approximately 1.51% above the 365.242 mean days tropical observed (NASA, 2024 Jan.).

(D7) A solution proposed, requires entertaining that there are two altered "c" values from the 2022 CODATA standard (NIST, 2024), that act as research tools. Where "c #1" is appropriate to sidereal functions and "c #2" is appropriate to tropical and Solar System planetary phenomenon. In analyzing "c #1" in equations below, the value represents not metres per second as per c, but "ΔT packets" per sum of MEm considered. Solving first for the bottom dead centre state of Huygens Energy Pendulum (HEP) let the Earth mean tropical value in seconds (NASA, Jan. 2024) equal the state ⊕MSTsec. For:

$$365.242\ Days = \oplus MSTsec\ 31{,}556{,}908.8^3 = \square\ 3.142^{22} = \oplus MEm\ 177{,}272{,}627{,}620{,}549{,}2^2$$

$$\frac{(\oplus MEm \cdot 2)}{\oplus MSTsec} = 11{,}235.107\ v_{esc}\ 0.439\% > NASA\ Bulk\ v_{esc}$$

Solve for "c #1" to maintain tropical-sidereal 20.16 minutes (⊕ΔT) ratio as to sum ⊕MEm's:

$$\frac{(\oplus MEm \cdot 2)}{\oplus \Delta 1{,}209.6\ \text{sec}} = c^{\#1}\ 293{,}109{,}503.340{,}855{,}1\ \oplus \Delta T\ packets/(\oplus MEm \cdot 2)$$

$$c^{\#1}\ 2.22\% < c\ \text{NIST}$$

The "c #1" is applied at HEP states (E+) and (E–) to solve for applicable tropical-sidereal ΔT when⊕MSTsec is reduced and increased by 12.5 minutes in utilization of a 25-minute variation of the body tropical cycle.

(D8) In solving for "c #2," that is applicable to the body tropical states, the ratios solved for in item (1) thru (9) remain constant. However, the standard au (IAU, 2012) utilized in item (11) and (12) sees amendment by reversing calculations from the required ⊕MEm to the TEPsma. We arrive at "c #2" by recognizing the divisor of 499.004… seconds, that is the quotient when the standard au (IAU, 2012) is divided by c (NIST, 2024), but used as the divisor when the amended ⊕au is the dividend. Solve for "c #2":

$$\frac{\oplus MEm\ 177{,}272{,}627{,}620.549{,}2}{ME\ \ 2.997{,}509{,}402{,}327{,}193} = \oplus Ppam\ 59{,}139{,}973{,}833.916{,}61$$

$$\oplus Ppam\ 59{,}139{,}973{,}833.916{,}6 \cdot TEPsma\ 2.585{,}712{,}550{,}115{,}04 = \oplus au\ 152{,}918{,}972{,}555.833{,}2$$

$$\frac{\oplus au\ 152{,}918{,}972{,}555.833{,}2}{\left\{\frac{au}{c}\right\} = Q\ 499.004{,}783{,}836{,}156{,}4\ sec} = c^{\#2}\ 306{,}447{,}908.936{,}365{,}6\ meters/sec$$

$$c^{\#2}\ 2.22\% > c\ \text{NIST}$$

(D9) Solve HEP body state (E+), off ⊕MST state by application APM+ with subtraction of 12.5 minutes. For:

$$\oplus MST - 750\ sec = E^{+}MSTsec\ 31{,}556{,}158.8^3 = E^{+}MEm\ 177{,}266{,}307{,}910.263{,}9^2$$

$$\frac{(E^{+}MEm \cdot 2)}{E^{+}MSTsec} = 11{,}234.973\ v_{esc}\ 0.437\% > NASA\ Bulk\ v_{esc}$$

$$\frac{(E^{+}MEm \cdot 2)}{c^{\#1}} = E^{+}\Delta 1{,}209.55\ \text{sec} = 20.159\ \text{min}$$

Solve for effective "c #2" at body state (E+):

$$\frac{E^{+}MEm\ 177{,}266{,}307{,}910.263{,}9}{ME\ \ 2.997{,}509{,}402{,}327{,}193} = E^{+}Ppam\ 59{,}137{,}865{,}513.495{,}52$$

$$E^{+}Ppam\ 59{,}137{,}865{,}513.495{,}52 \cdot TEPsma\ 2.585{,}712{,}550{,}115{,}04 = E^{+}au\ 152{,}913{,}521{,}045.260{,}8$$

$$\frac{E^{+}au\ 152{,}913{,}521{,}045.260{,}8}{c^{\#2}} = \ 498.986{,}994{,}481{,}380{,}3\ sec$$

$$effective\ c^{\#2}\ 0.003\% < c\ \text{NIST}$$

(D10) Solve HEP body state (E–), off ⊕MST state by application APM- with addition of 12.5 minutes. For:

$$\oplus MST + 750\ sec = E^{-}MSTsec\ 31{,}557{,}658.8^3 = E^{-}MEm\ 177{,}278{,}947{,}405.933{,}9^2$$

$$\frac{(E^{-}MEm \cdot 2)}{E^{-}MSTsec} = 11{,}235.240\ v_{esc}\ 0.440\% > NASA\ Bulk\ v_{esc}$$

$$\frac{(E^{-}MEm \cdot 2)}{c^{\#1}} = E^{-}\Delta 1{,}209.643\ \text{sec} = 20.16\ \text{min}$$

Solve for effective "c #2" at body state (E–):

$$\frac{E^{-}MEm\ 177{,}278{,}947{,}405.933{,}9}{ME\ \ 2.997{,}509{,}402{,}327{,}193} = E^{-}Ppam\ 59{,}142{,}082{,}179.391{,}61$$

$$E^{-}Ppam\ 59{,}142{,}082{,}179.391{,}6 \cdot TEPsma\ 2.585{,}712{,}550{,}115{,}04 = E^{-}au\ 152{,}924{,}424{,}131.187{,}9$$

$$\frac{E^{-}au\ 152{,}924{,}424{,}131.187{,}9}{c^{\#2}} = 499.022{,}573{,}402{,}329{,}7\ sec$$

$$effective\ c^{\#2}\ 0.003\% > c\ \text{NIST}$$

Conclusion

(C1) The Primary Proximus Theorem, including subsequent manipulations in discussion, arrives at a puzzling conclusion. The body HEP states (E+, ⊕MST, E–) when compared, each contain a relationship where the body gravitational mass is inversely proportional to body inertial mass. If the body's energy kinetic (*Ek*) is equal to its inertial mass within the state considered, and both transition proportionally between states. The Fenestratilis mass-ΔT equation seeks to express this inertial mass relationship by recognizing the Newton-Hamilton vector perspective of Kepler's second law (1609), but pivoting methodology as the body has equivalent escape velocity on its x, y, & z axes, resulting in a equilateral stable point relative to the Sun. The "radius vector" has magnitude represented in light-seconds. Inertial mass is proportionally amended to gravitational mass, by reformulating the conception velocity is successfully gauged against time, when time is used as an independent scalar at velocities not approaching the "speed of light." Fenestratilis mass-ΔT equation applied to the ⊕MST state:

$$\frac{E_k = inertial\ mass}{\left[\underset{r}{\rightarrow} = \frac{\oplus au}{c^{\#2}}\right]} = \underset{V}{\rightarrow} \oplus body\ gravitational\ mass = \frac{(\oplus MEm \cdot 2)}{\oplus MST sec} = \oplus \Delta T = \frac{(\oplus MEm \cdot 2)}{c^{\#1}}$$

Rewriting the left side of above equation gives a product that is the constant inertial mass of body ⊕MST state, with resulting units in metre-seconds per second (m-s/sec), called Fasciculus Ignis:

$$\oplus inertial\ mass = \underset{r}{\rightarrow} \cdot \underset{V}{\rightarrow}$$

$$5{,}606{,}372.270{,}902{,}502\ m\text{-}s/sec\ = 499.004{,}783{,}836{,}156{,}4\ sec \cdot 11{,}235.107\ m/s$$

Considering the velocity vector as an equilateral stable point and the radius vector with magnitude toward the Sun, there is no resulting force to induce orbit within the state considered. Therefore, the movement of the body through space must proportionally mask a variance in the body gravitational field. With the movement proposed to be, the Earth orbital vector derived from Solar orientation angles. The force diametrically opposed to the radius vector is termed Tollomoles.

(C2) The Boundary SET equations introduced hereafter, offer proof the ⊕inertial mass correlates to the ⊕MST state experienced on the body, and subsequently other appropriate HEP states when applied to the Fenestratilis mass-ΔT equation. Consider the Earth volumetric mean radius 6371 km (NASA, Jan. 2024) in metres symbolized (Evr) divided by c (NIST, 2024) to represent the body's spherical radius (r) in seconds. Let the circumference solved for represent the distance in seconds of the body's equator and be equivalent to the x-dimension (Cx). A second circumference (Cy) that bisects the north and south Copernican axis of the body represents the y-dimension of the body. Imagine a figure eight has one side twisted 90 degrees and is folded 180 degrees into the other half resulting in a consecutive path, where the two dimensions summed gives one cycle of the spherical boundaries of the body in seconds (B1). Then we divide ⊕inertial mass by B1, resulting in a polyonymous value. Either referenced as, B1 cycles per inertial mass, or a fractional representation of the applied state, ⊕ in Mean Span of Time in seconds, as presented here:

$$\frac{Evr}{c} = r$$

$$[Cx = 2\pi r] + [Cy = 2\pi r] = B1$$

$$\frac{\oplus inertial\ mass\ m\text{-}s/sec}{B1} \approx {}^{2}/_{3}\ \oplus MST sec \text{ or } 66.52\%$$

(C3) The results of approximately two-thirds ⊕MSTsec, as calculated above reveals a captivating relationship. The divisor B1 is a "Speed of Energy Transfer" (SET) value. The B1 SET describes the three dimensions (x, y, z) creating a three-dimensional boundary of the body. Thus termed the B1 Boundary SET. The z-dimension in the circumference equations is the radius (r), and the z-dimension is parallel with the terrestrial force of gravity that acts perpendicular to the body surface boundary, which is defined by the summed x & y circumferences. Therefore, in analyzing the (C2) equation, we find the speed of light (NIST, 2024) is approximately one third below the SET required to satisfy a complete ⊕MSTsec, here after referenced as B2 Super Boundary SET. Refer to Figure 4. The conclusion emerges when the terrestrial force of gravity (g), that is the effective z-dimension, represented by approximately one third, is unburdened from the B1 Boundary SET, the B2 Super Boundary SET is realized. The Fenestratilis gravity effect expressed in reformulation:

$$[4\pi r] - [g \approx {}^{1}/_{3}] = B2\ seconds\ per\ cycle$$

$$[0.267{,}052{,}572{,}697{,}083\ sec] - [33.474{,}107{,}260{,}129{,}55\%] = 0.177{,}659{,}108{,}071{,}526\ B2$$

$$\frac{\oplus inertial\ mass\ m\text{-}s/sec}{B2} = \oplus MST seconds\ per\ second = E_p$$

(C4) The B2 Super Boundary SET is the "Timekeeping" reference state within the body continuum, as it is not only used to measure the B1 Boundary SET, but also sees the "speed of light" c (NIST, 2024) created therein. The speed of light represented by B1 is constant across varying body states as described in the HEP, because we are measuring a ratio between three dimensions (x, y, z) within the body's continuum, where the z-dimension is integral to the function of time defined by the Terranomical Couple. Referencing figure 4, we see the B2 Super Boundary SET also measures

the B3 Hyper Boundary SET that accounts for the observed sidereal phenomenon. Continuing to dissect the HEP ⊕MST state, solve for B3 Hyper Boundary SET:

$$\frac{\oplus E_k = \oplus inertial\ mass\ m\text{-}s/sec}{\oplus MST sec + \oplus \Delta T} = B3\ Hyper\ Boundary\ SET$$

$$\frac{5{,}606{,}372.270{,}902{,}502\ m\text{-}s/sec}{31{,}556{,}908.8\ sec + 1{,}209.6\ sec} = 0.177{,}652{,}298{,}525{,}583\ B3$$

$$B1 - \left[g \approx {}^{1}/_{3}{}^{+}\right] = B3$$

$$0.267{,}052{,}572{,}697{,}083\ sec - [33.476{,}657{,}149{,}791{,}33\%] = B3$$

An alternate perspective of the first equation in (C4): Let the ⊕Ek divided by the Keplerian time equal the SET and ⊕Ek divided by the SET equals Energy Potential (Ep).

(C5) The following is an overarching summation of the mathematics presented heretofore. The Fenestratilis mass-ΔT equation in section (C1) delineates one of the three observable and variable tropical period states defined in Huygens Energy Pendulum (E+, ⊕MST, E–). Freedom of substitution within the equation of values detailed in discussion sections (D9) and (D10) arrives at inertial mass appropriate to HEP states (E+) and (E–). Where upon further appropriate substitutions of HEP states within the Boundary SET equations as defined in conclusion sections (C2), (C3), and (C4) results in congruent values. The three Boundary SET equations work in concert in any one energy state analyzed. When the B2 SET and B3 SET are progressively compared in sequence from HEP state (E+) thru (E–) the values increase proportionally by approximately 0.002%, indicating agreement with the gravitational mass of the body states. Considering the division of the body inertial mass by respective B2 Super Boundary SET and B3 Hyper Boundary SET results in an impressionable reference value, considered the Energy Potential, as inferred in the discussion section (D3) closing sentence. Of course, there is a range of body energetic states observable and calculable within the swing of the HEP between (E+) and (E–), together with conceivable states slightly beyond the 25-minute escapement presented. Describing an alternative in-depth theory regarding phenomena identified as empirical maximums of tropical states from the mean is beyond the scope of this paper.

The altered c values introduced in sections (D7) and (D8) serve to unify empirical data and establish experimental tolerances from the ⊕MST state when the body oscillates between HEP (E+), and (E–) states. As the 'c #1' allows a tight tolerance in the tropical-sidereal ⊕ΔT, and "c #2" establishes a tight tolerance in deviation from the ⊕au.

Considering the PPT ratios as presented in PPT Mathematics section, item (7) through (9), the ratios are not perpetually fixed. As the βθ degrees and *P* degrees employed vary marginally over sequential periods.

(C6) The two gravitational values subtracted from the B1 Boundary SET to create the B2 Super and B3 Hyper Boundary SETs, establish the lower and upper bounds of a radius relationship to a circle, considered as pi (π 3.1415…) specific to body energy state analyzed. Visualize a Euclidian space created by an observer in free-fall along and within the effective z-dimension (g ≈ ⅓) required by the B2 Super Boundary SET. Let the fractional and subsequent percentage of the z-dimension become a decimal fraction value. To remain at relative rest the observer creates two dimensions x and y at equivalence to the z-dimension with multiplication. The resultant is reduced by subtracting the natural number giving a three dimensional remainder. Simplify further by dividing the remainder by three dimensions to locate the core remainder. Any nonzero radius the free-falling observer elects to implement to define a circle requires the recognition of the three dimensions by adding a three onto the core remainder, thus the lower bounds of pi is created. The upper bounds of pi follows the same formula with effective z-dimension (g ≈ ⅓⁺) applied in lieu. The following equations define the upper and lower bounds of pi within the HEP body ⊕MST state:

$$\left|\left[g \approx {}^{1}/_{3}\right] \rightarrow \% \rightarrow df\right| < \pi < \left|\left[g \approx {}^{1}/_{3}{}^{+}\right] \rightarrow \% \rightarrow df\right|$$

$$|(df \cdot 3) - N = 3\text{-}dR| < \pi < |(df \cdot 3) - N = 3\text{-}dR|$$

$$\left|\left(\frac{3\text{-}dR}{3}\right) = CR\right| < \pi < \left|\left(\frac{3\text{-}dR}{3}\right) = CR\right|$$

$$|CR + 3| < \pi < |CR + 3|$$

$$|3.140{,}773\ldots| < \pi < |3.143{,}323\ldots|$$

The presented lower and upper bounds of pi approximate limits as calculated by Archimedes (c. 287–212 BCE/1997).

(C7) The Fenestratilis Primary Proximus Theorem proposal of unification of time, energy, and gravity within Earth's orbital continuum state, asserts questioning the causality underpinning the Precession Theory as hypothesised by Copernicus in Book Three (1543/2002) and, later redefined as per IAU 2006 Resolution B1. Fenestratilis PPT also challenges the equality of inertial and gravitational mass as an argument of the general postulate of relativity (Einstein, 1917); not in the sense the two are unequal, but in the sense inertial mass and gravitational mass are proportionally equivalent, when two independent orbital period states of a body are compared. The argument being when one of the body states has an increase or decrease in inertial mass due to velocity change, from the comparable body state, the inertial mass is inversely proportional to the velocity, when velocity is gauged against time as an independent scalar.

The determination of pi is arguably linked to the body's orbital continuum. For, if a pi value attained through infinitesimals is let to represent the mean of (g ≈ ⅓) and (g ≈ ⅓⁺) in body ⊕MST state, we find utilizing $\oplus E_{\dot{k}}$ the quotient is 99.999,314% of the mean tropical and sidereal year (NASA, Jan. 2024) in Keplerian time:

$$\left[\frac{(\pi-3)\cdot 3+100}{3}\right]+\%=\odot$$

$$\frac{\oplus E_k}{(B1-\odot=B\#)}=E_p \text{ seconds per sec}^2 \approx E_p\left(\frac{\text{tropical sec}+\text{sideral sec}}{2}\right)\text{per sec}^{\ddot{u}}$$

Alternatively, if the mean percentage of (g ≈ ⅓) and (g ≈ ⅓⁺) as detailed in (C3) and (C4), is subtracted from B1, and the difference acting as divisor to $\oplus E_k$. The quotient sees a difference of eleven thousands of a second that creates a functionally effective energy potential equivalence.

$$E_p\,0 = E_p\,0$$

Finally, observing from the embankment, we find the experimental determination of the velocity of light is correct, yet the scope of its implementation in a Universal scale may aptly be refined to the experience within our broader environment.

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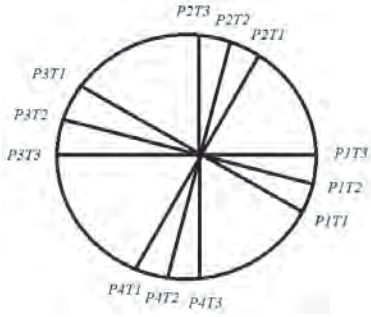
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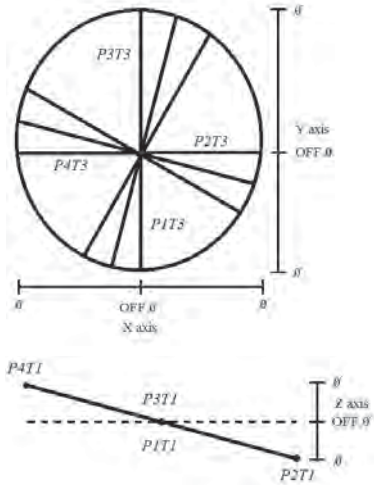
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Position & Triad Legend
P1T1 βθ Descending node 0.0°
P1T2 December Solstice
P1T3 P 0.0°
P2T1 βθ Maximum° (-)
P2T2 March Equinox
P2T3 P Maximum° (-)
P3T1 βθ Ascending node 0.0°
P3T2 June Solstice
P3T3 P 0.0°
P4T1 βθ Maximum° (+)
P4T2 September Equinox
P4T3 P Maximum° (+)

Figure 1



- Body at P1T3 has x off nominal & y at nominal
- Body at P2T3 has x at nominal & y off nominal
- Body at P3T3 has x off nominal & y at nominal
- Body at P4T3 has x at nominal & y off nominal
- Body at P2T1 has z at nominal
- Body at P1T1 & P3T1 has z off nominal
- Body at P4T1 has z at nominal

Figure 2 – General schematic representing Earth orbital dynamics

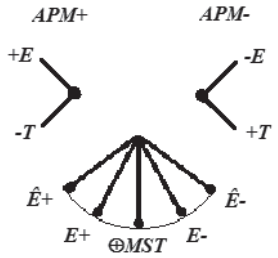


Figure 3

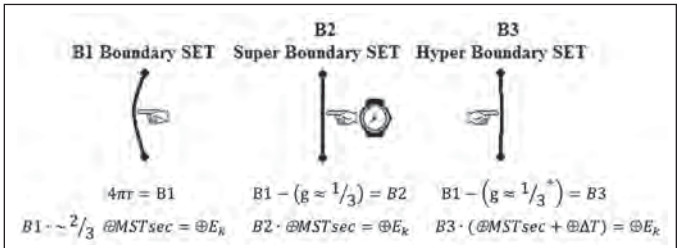
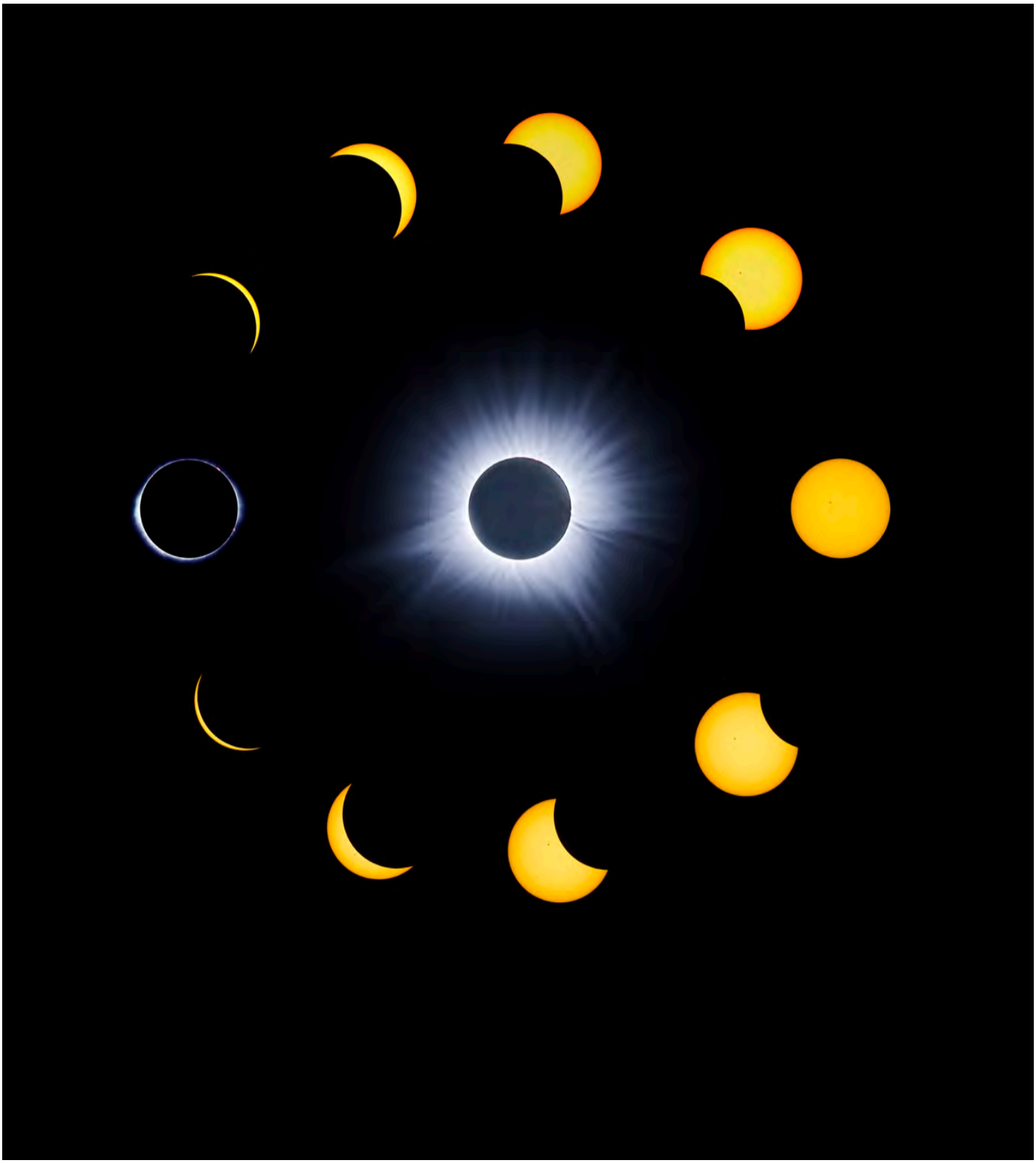


Figure 4 – Boundary SET Equations

Great Images

by David Hoskin



David Hoskin of Halifax writes "The images in the total solar eclipse sequence were obtained with a Canon EOS Rebel T3i DSLR, Canon 55-250-mm lens @ 250mm, ISO 100, and f/8 (exposure 1/800 sec to 1 sec starting from the start/end of the eclipse to totality) fitted with a Baader solar safety film filter, Sky-Watcher Star Adventurer star tracker on a Sky-Watcher tripod. Photoshop was used for post processing and the addition of false colour.

I drove to Rogersville, New Brunswick, to view and photograph the total solar eclipse on 2024 April 8, under a beautiful clear, blue sky, which was wonderful but very unusual for spring in the Maritimes."

Pen & Pixel



Figure 1 — Gary Crawford captured the beautiful and colourful Rho Ophiuchi Cloud Complex. As Gary notes, "This molecular cloud region is roughly 400 to 460 light-years away, making it one of the closest star-forming regions to us." Gary created a two-panel mosaic that includes both the Blue Horsehead Nebula (IC4592) and the Rho Ophiuchi Cloud Complex. Both panels have 1 hour and 48 minutes of integration. He used an ASI2600MC Pro camera with no filter, SV535 105mm ƒ/l refractor, mounted on an iOptron HEM15, and guided with a William Optics Uniguide 32 and ASI220MM Mini. He created the two master images in PixInsight, then composed the mosaic in Astro Pixel Processor. The rest of the processing was done in PixInsight."

Figure 2 — There's nothing like the summer Milky Way stretching across the sky above. Nishat Khan imaged the Milky Way over Clam Lake in Kearney, Ontario on July 12, 2026. She used a Nikon D750, Nikkor 20mm on a tripod. Acquisition: f/3.5, ISO 6400, 13-second exposures. Nishat processed the final image using Sequator, Siril, GIMP for a total of 98 images stacked and one foreground for the composite



Continues on page 201

What's Up in the Sky?

October/November 2026

Compiled by James Edgar

October Skies

The Moon is at perigee, closest to Earth, on October 1, and reaches last quarter on the 3rd. On the 5th, Mars is 1.2 degrees south of the Moon, which is an occultation in the high Arctic. That same day, the Moon is less than half a degree north of the Beehive Cluster (M44). Jupiter is occulted on the 6th for observers in southeastern Canada and most of the USA. For the rest of the northern viewers, it's a very close conjunction – 0.2 degrees separation. Of course, two outer planets so close together could make for good photo opportunities. Finding tiny Mars near giant Jupiter could be a challenge! Regulus is occulted on the 7th, but for North America it's a close conjunction of 0.6 degrees separation. New Moon is on the 10th, with Venus nearby the thin crescent Moon on the 11th. Mercury is 2 degrees north of the crescent Moon on the 12th. Look for the pair hugging the murky horizon in the evening twilight. Binoculars will be a great help locating them. By the 14th, Antares, the bright star in Scorpius, is 0.4 degrees north of the Moon; another occultation in the extreme south. The 16th sees the Moon at apogee of 404,643 km. On the 18th, the Moon is at first quarter, quite visible in the daytime sky. The Moon is full on the 25th, among the stars of the Pleiades on the 27th, reaching perigee once again on the 28th, and occulting Ceres, the large Minor Planet, on the 31st. It would be a fun exercise to watch with binoculars or a telescope as the Moon covers the tiny object, and which about 30 minutes later pop into view on the opposite side of the Moon.

Mercury suffers from the late-autumn ecliptic hugging the horizon, which is a boon for the Southern Hemisphere – not so much for the north. Nevertheless, it passes north of Venus on the 6th and 2 degrees north of the Moon on the 12th.

Venus begins retrograding after the 12th, reaching inferior conjunction (in front of the Sun) on the 24th. Experienced observers have viewed the bright planet through telescopes, being very careful not to have the Sun in the eyepiece! That would be a real challenge!

Mars is in the constellation Cancer, the Crab, well placed for observing in the very early morning. At the beginning of the month, Mars and Jupiter are close together – see the Moon section above. The waning crescent Moon occults Mars on the 5th. On the 11th, the ruddy planet is among the stars of the Beehive Cluster.

Jupiter rises in the east just before sunrise, and it's joined by Mars hovering nearby. Jupiter is occulted by the Moon on the 6th.

Saturn rises in the east after sundown, so is present in the sky all through the night. Opposition is when the planet is in the south while the Sun is in the north, behind the Earth. This is the best time to view the Ringed Planet, so be sure to give it a try. The view through a telescope is astounding, with the planet and its rings starkly outlined against the black of space.

Uranus is also in the sky for most of the night, also reaching opposition on the 25th. It's a so-called "naked-eye object," but you have to know where to look, and from a dark location, away from city lights, to see the blue-green planet.

Neptune is another object in the sky all night, but requires a telescope to be seen. Look for the blue disk among the stars of Pisces, the Fish.

The zodiacal light is visible before eastern morning twilight for the middle two weeks of October, beginning on the 8th.

The Orionid meteors peak on October 21.



October sky: On the 10th, Uranus rises just south of the Pleiades, while Saturn and Neptune are well up to the southeast. In spite of their closeness, Saturn is in Cetus, the Whale, and Neptune is in Pisces, the Fish.

Continues on page 200

The Sky October/November 2026

Compiled by Nicole Jiang, Toronto Centre

Celestial Calendar (bold=impressive or rare)

October 2026

Oct. 1 Moon at perigee (369,334 km)

Oct. 3 Moon at last quarter

Oct. 4 Saturn at opposition

Oct. 5 Mars 1.2° south of waning crescent Moon

Oct. 5 Double Shadows on Jupiter

Oct. 5 Moon 0.4° north of Beehive (M44)

Oct. 6 Jupiter 0.2° south of waning crescent Moon, occultation

Oct. 7 Regulus 0.6° north of waning crescent Moon

Oct. 8 zodiacal light visible in east before morning twilight

Oct. 10 new Moon (lunation 1284)

Oct. 11 Mars 0.4° south of Beehive (M44)

Oct. 14 Antares 0.4° north of waxing crescent Moon

Oct. 16 Moon at apogee (404,643 km)

Oct. 18 Moon at first quarter

Oct. 23 Orionid meteors peak at 2:54 a.m. EDT

Oct. 26 full Moon at 12:12 a.m. EDT

Oct. 28 Moon in Pleiades (M45)

Oct. 28 Moon at perigee (364,407 km)

Oct. 31 Ceres 0.5° south of waning gibbous Moon

November 2026

Nov. 1 Daylight Saving Time ends

Nov. 1 Moon in Beehive (M44)

Nov. 1 Moon at last quarter

Nov. 2 Mars 1.1° north of waning crescent Moon

Nov. 2 Jupiter 0.5° north of waning crescent Moon

Nov. 3 Regulus 0.8° north of waning crescent Moon

Nov. 4 south Taurid meteors peak at 7:22 p.m. EST

Nov. 7 Venus 1.1° north of waning crescent Moon

Nov. 9 north Taurid meteors peak at 1:59 a.m. EST

Nov. 9 new Moon (lunation 1285)

Nov. 11 Antares 0.3° north of waxing crescent Moon

Nov. 13 Moon at apogee (405,619 km)

Nov. 15 Mars 1.2° north of Jupiter

Nov. 17 Moon at first quarter

Nov. 17 Leonid meteors peak at 7:00 p.m. EST

Nov. 19 Venus 1.8° north of Spica

Nov. 21 Mercury at greatest elongation west (20°)

Nov. 24 Moon in Pleiades (M45)

Nov. 24 full Moon at 9:54 a.m. EST

Nov. 25 Moon at perigee (359,347 km) Large tides

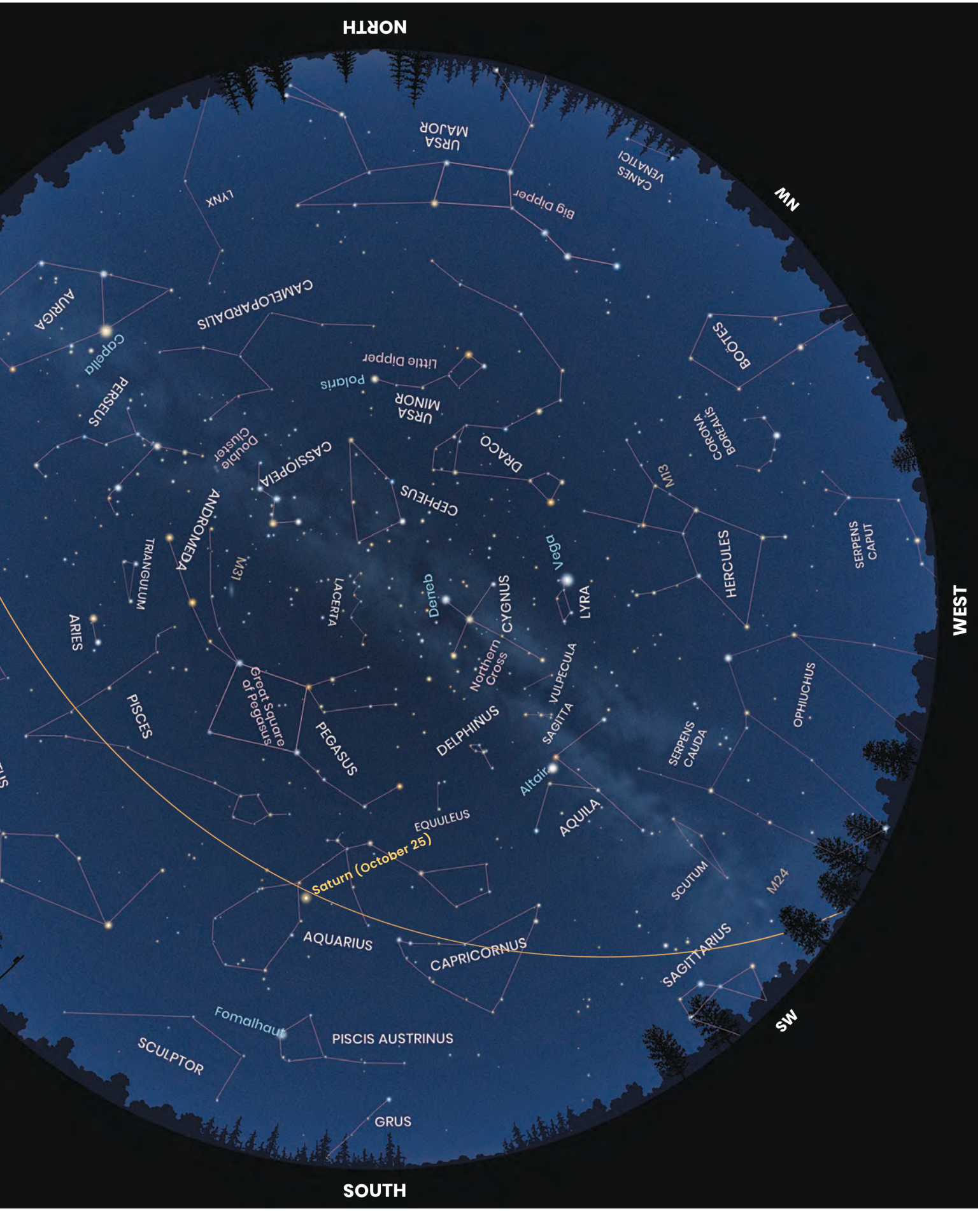
Nov. 29 Moon in Beehive (M44)

Nov. 30 waning gibbous Moon near Jupiter, Regulus, and Mars



Planets at a Glance

	DATE	MAGNITUDE	DIAMETER (″)	CONSTELLATION	VISIBILITY
Mercury	Oct. 1	—	5.7	Virgo	—
	Nov. 1	—	9.9	Libra	—
Venus	Oct. 1	—	48.0	Virgo	—
	Nov. 1	—	59.6	Virgo	—
Mars	Oct. 1	1.1	5.6	Cancer	Morning
	Nov. 1	0.9	6.5	Leo	Morning
Jupiter	Oct. 1	–0.9	33.3	Leo	Morning
	Nov. 1	–2.0	35.8	Leo	Morning
Saturn	Oct. 1	0.3	19.7	Cetus	Evening
	Nov. 1	0.5	19.4	Cetus	Evening
Uranus	Oct. 1	5.6	3.7	Taurus	Evening
	Nov. 1	5.6	3.8	Taurus	Evening
Neptune	Oct. 1	7.8	2.4	Pisces	Evening
	Nov. 1	7.8	2.3	Pisces	Evening


NORTH
NW
WEST
SW
SOUTH
URSA MAJOR
Big Dipper
CANES VENATICI
LYNX
AURIGA
Capella
CAMELOPARDALIS
PERSEUS
Double Cluster
Little Dipper
Polaris
URSA MINOR
CASSIOPEIA
CEPHEUS
DRACO
BOÖTES
CORONA BOREALIS
Mizar
HERCULES
SERPENS CAPUT
ANDROMEDA
M31
TRIANGULUM
ARIES
LACERTA
Deneb
CYGNUS
Vega
LYRA
Northern Cross
VULPECULA
SAGITTA
OPHIUCHUS
SERPENS CAUDA
PISCES
Great Square of Pegasus
PEGASUS
DELPHINUS
Altair
AQUILA
EQUULEUS
Saturn (October 25)
SCUTUM
M24
AQUARIUS
CAPRICORNUS
SAGITTARIUS
Fomalhaut
PISCIS AUSTRINUS
SCULPTOR
GRUS

Continued from page 197

November Skies

The Moon, at last quarter, is among the stars of the Beehive Cluster (M44). On the 2nd, Mars is 1.1 degrees north of the Moon, while Jupiter is 0.5 degrees north. This will be an amazing time to see the trio so close together. Both planets are occulted in distant parts of the globe. On the 3rd, Regulus is 0.8 degrees north. The 7th sees Venus 1.1 degrees away, another occultation, but in the extreme south. New Moon is on the 9th, while the following day sees Antares in close conjunction. Not much to see there, as the Moon in new phase is totally black and can't be seen. The Moon is at apogee on the 13th, at 405,619 km distance. The next phase after new is 1st quarter, which happens on the 17th – watch for the Moon in the daytime sky. By the 24th, the full Moon is among the stars of the Pleiades. Large tides occur in coastal areas. Perigee of 359,347 km occurs on the 25th, and we're back to seeing Luna in the Beehive again on the 28th. The 30th is a busy day, with first Jupiter at 1.2 degrees north, then Regulus 1.1 degrees north, and Mars 3 degrees north of the last-quarter Moon.

Mercury is in front of the Sun as the month begins, slowly appearing in the eastern dawn sky after the first week. This is a good opportunity to see the speedy planet, if you've never viewed it before. Venus is nearby, with Mars and Jupiter high in the south. Mercury climbs the ecliptic, getting ever closer to Venus.

Venus, the "Morning Star," shines brilliantly in the southeast at morning twilight. On the 8th, Spica, the bright star in Virgo, the Maiden, is to the east, right beside the planet.

Mars rises in the late evening, near midnight, alongside Jupiter. Orion is well up by then, as is the brightest star, Sirius. On the 30th, a quartet of objects gathers, with Mars, Jupiter, Regulus, and the last-quarter Moon in a tight group. Have your camera ready!

Jupiter is well placed all night for viewing. If you have binoculars or a telescope, this is a good time to follow the Galilean moons as they orbit around the giant planet. Their positions change every night, so it's fun to track their movements, much like Galileo did in 1610. Our Moon occults Jupiter twice in November, on the 2nd and the 30th.

Saturn has already risen before sunset, so is well placed for viewing all night. The Ringed Planet has been retrograding, and gradually slowing before becoming stationary in December.

Uranus is at opposition on the 25th, making for a good viewing opportunity all night.

Neptune is well placed all night. Get a telescope and have a look. You might even see its bright moon, Triton.

Daylight Saving Time ends on Sunday, the 1st; the south Taurid meteors peak on the 5th; and the north Taurid meteor shower peaks on the 12th. ✶



November sky: The gathering of four objects at the end of November is surely a great photo opportunity. Charge your batteries!

Continued from page 196



Figure 3 — This absolutely stunning wide-field image of Cygnus in all its glory was taken by Rob Lyons from Bortle 3 skies in Tofino, B.C. "Within this wide-field image, we have the North America, Pelican, Tulip, and Propeller Nebulae, as well as a couple of Wolf-Rayet stars, a supernova remnant or two, and even a black hole! This is a bucket list shot for me that took three years of practice and patience to finally get right," he says. He used a Sony A7R and 50MM f/1.4 GM lens with a UV/IR cut filter for the RGB and an STC Ha/OIII filter for the hydrogen and oxygen nebulosity. The total exposure time is 57 minutes.

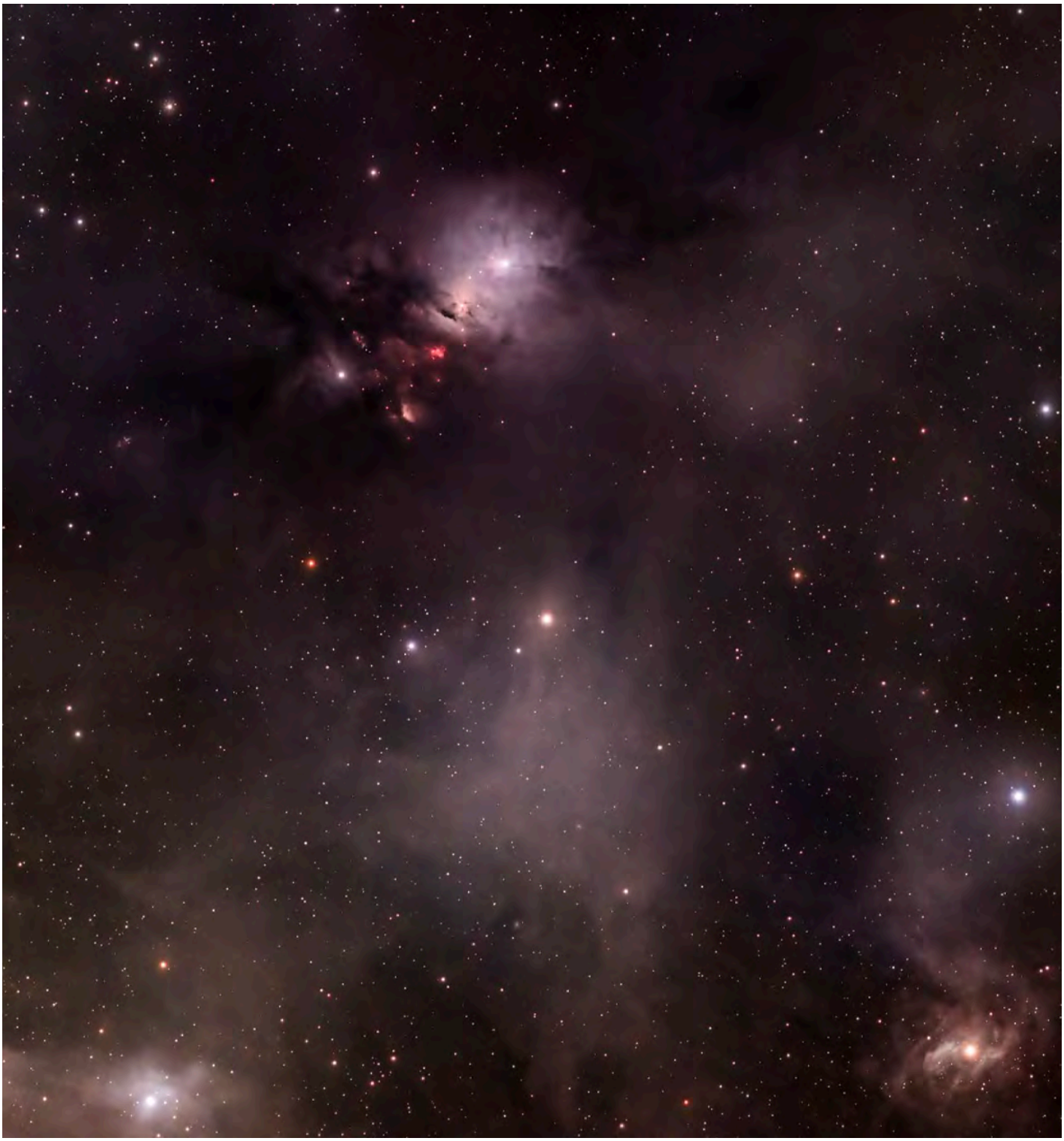


Figure 4 — Shelley Jackson captured star trails above her dome in Athens, Ontario. "I was blown away by how much the Moon lit up my dome. I really like the effect for this image. I think of my new-to-me dome as my little piece of heaven." She used a Nikon D5500 with a Rokinon 14mm lens at ISO 800. 1,400 10-second exposures.

Great Images

Continued from page 193

by Carl Fleck



Carl Fleck writes: This image contains the reflection nebula NGC 1333 and dark nebula LDN 1450 in Perseus. This region is a complex dust cloud and star-formation region about 1000 light-years out.

The image was compiled of frames taken over five sessions through January and February 2025 in my yard in Upper Coverdale, New Brunswick, under a Bortle 4 sky. Integration incorporated RGB × 90 frames, Hα × 63 frames and Luminescence × 98 for a total integration time of 20 hrs 55 min.

My rig includes the ZWO ASI1600 MM Pro camera (@-20C), ZWO EFW filter wheel (LRGB, Hα), Sky-Watcher Evostar 80ED telescope, Vixen SXD2 mount, and Orion 50-mm guide scope operated through APT and PHD2. Image processing was with PixInsight for stacking and post processing and Photoshop for minor adjustments.

Agnes Mary Clerke's Manuscript Annotations in her Personal Copy of *A Popular History of Astronomy During the Nineteenth Century* (1885)



by R.A. Rosenfeld, FRASC

Abstract

Agnes Mary Clerke (1842–1907) was an exceptional figure in the astronomical world during the rise of astrophysics. Well educated at home and grown into an effective autodidact, she mastered the professional astronomical literature to write *A Popular History of Astronomy During the Nineteenth Century*, the outstanding account of the development of the astronomy of her time. The book was accorded almost universal praise from knowledgeable reviewers for its accuracy, reasonable comprehensiveness, and balanced judgement. Professional astronomers were sufficiently impressed to send details of their latest work for inclusion in subsequent editions, and she even ventured assessments of possible future directions for research in astronomy in another work. The Rare Book Collection of the RASC possesses her heavily annotated personal copy of the first edition of her Popular History of Astronomy (1885). These glosses provide insight into how she interacted with her published text, and began to prepare for a second edition.

The Author & the RASC

The Astronomical and Physical Society of Toronto (A&PST, 1884–) represented the second coming of organized astronomy in Canada. When it seemed that this revival was not to end in an immediately ephemeral "dust to dust" and "ashes to ashes" sort of thing, incorporation followed (1890), and an embrace of the internationalism long characteristic of the learned world of national academies, which could make accommodation for foreign members (such as The Royal Society of London for Improving Natural Knowledge 1660–, the Académie royale des sciences 1699–, the Astronomical Society of London 1820–, among others).[1] This was most noticeable in the A&PST with the introduction of categories of honorary membership, "honourary [sic.] members," and "corresponding members." Among the most interesting such appointments was that of Agnes Mary Clerke (1842–1907, Figure 1); hers was also one of the best and wisest honorary appointments the Society ever made.



Figure 1 — Agnes Mary Clerke, portrait on magic lantern slide, 1890s. Image courtesy of the RASC Archives.

Clerke was born in Skibbereen, Co. Cork, to a well-respected middle-class family with mixed Catholic and Protestant affiliations.[2] Her father, who attended Trinity College, Dublin, was a man of wide intellectual interests. Whereas her brother followed their father's example and matriculated at Trinity, the two Clerke girls were home-schooled, but that did not necessarily have the connotation it has now. From the results it would appear that their father John (and very likely their mother Catherine as well) thought Agnes and her older sister Ellen (1840–1906) deserved an education in no way inferior to what males received, even if social strictures of the time meant they could not attend university. Agnes became highly proficient in Greek and Latin, as well as French, German, Italian, and other modern languages, and acquired some quite respectable mathematical skills. She reported that the fascination of astronomy had captured her early on, and by the age of eleven she could thoroughly comprehend John Herschel's *Outlines of Astronomy*, a text demanding more geometrical and trigonometrical competence than most amateur astronomers now can command (the edition she used had to have appeared before 1853, meaning it was either Herschel 1849, 1850, or 1851). If Agnes had the run of her father's library, as her modern biographer Mary Brück believes was the case, then she



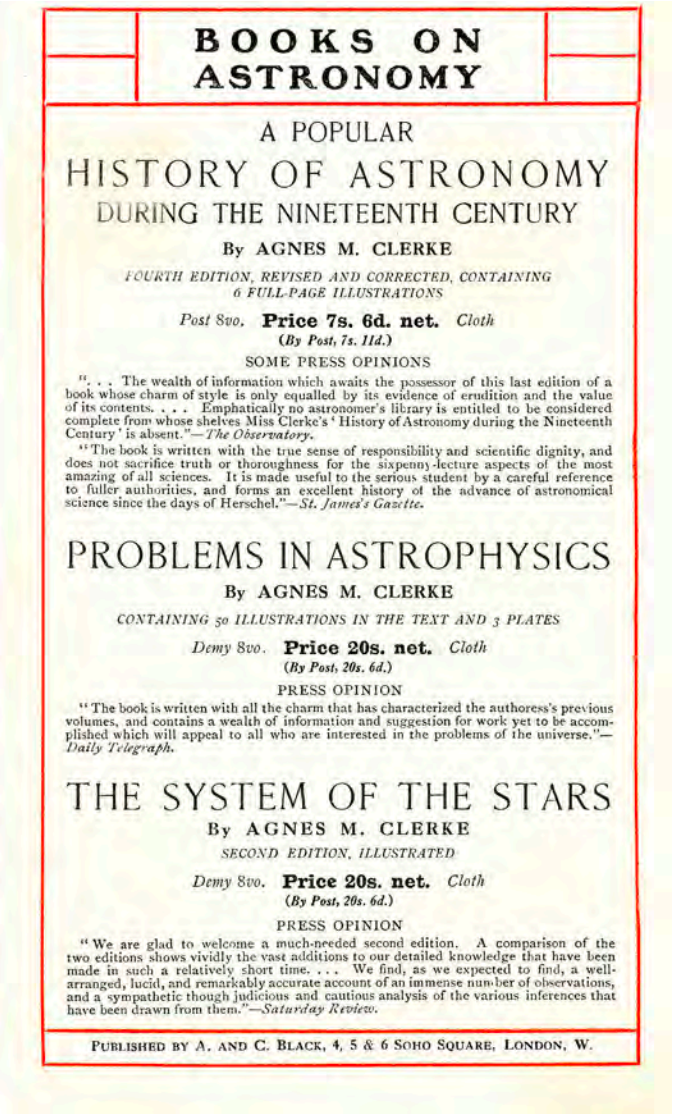
Figure 2 — Isobel Gill, Agnes Mary Clerke, H. Sawerthal, and David Gill in the library (or study) at the Cape Observatory, 1888, from Forbes 1916. Image courtesy of the Specula astronomica minima.

additionally had access to some uncompromising university-level mathematical treatments of the discipline (Brück 2002, 20–22).

Her father was also clearly competent in practical astronomy, and scientific apparatus was in the home, including a refractor with a 4-inch object glass (Brück 2002, 16). Astronomy was part of the fabric of domestic existence. She emerged from this educational setting with valuable autodidactic skills that served her for the rest of her life.

Agnes commenced her career as an author with anonymous essays in the *Edinburgh Review*, one of the major literary organs of the day. Her topics were varied, and included scientific subjects, as well other cultural areas, such as the history of the Mafia; all were characterized by thorough research. She also wrote a fair number of articles for the well-respected ninth edition of the *Encyclopaedia Britannica* (1875–1889, with her contributions starting with "G" entries in 1879), specializing in biographies of scientific figures such as Galileo, Kepler, Laplace, and Leverrier. These were signed, and brought her some notice and praise, and more importantly for this story, established a relationship with the publishers of Britannica, Adam & Charles Black, who would go on to publish her major books on astronomy.

In 1881, she began research for her first book, which was to be an account of modern astronomy rooted in the history of how that astronomy took form in the immediate past. This was sparked by her interest in the new discipline of astronomical spectroscopy, which aimed to probe the physical constitution of the Universe. This would require mastering the professional literature of astronomy. She accomplished that so well that the resulting book, *A Popular History of Astronomy During the Nineteenth Century*, garnered almost universal acclaim from the people whose work it set out to explain to an intelligent lay audience.



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PUBLISHED BY A. AND C. BLACK, 4, 5 & 6 SOHO SQUARE, LONDON, W.

Figure 3 — Flyer advertising the 4th edition of Clerke's A Popular History of Astronomy During the Nineteenth Century*, Adam & Charles Black, London, ca. 1902. Image courtesy of the Specula astronomica minima.*

Robert Ball (1840–1913), the Astronomer Royal of Ireland and Professor of Astronomy at Trinity College, wrote in his review for *Nature* that:

> "We have read this book with very great interest and with no little pleasure. The authoress (for this learned volume is indeed the product of a lady's pen) has modestly described her "History of Astronomy" as a popular work. We certainly hope that the book will be as popular as it deserves, and that it will be widely and extensively read. We think, however, that few men of science who use this book will think that it ought to be classed as a popular work in the ordinary acceptation. It might be more correctly described as a masterly exposition of the results of modern astronomy in those departments now usually characterised as physical" (Ball 1886, 313).

And E. Walter Maunder (1851–1928), First Class Assistant at the Royal Observatory Greenwich, was no less effusive:

> "The book will be full of interest to the general reader… but it will not be less highly valued by the student and the astronomer, on account of its completeness and accuracy, and the really remarkable skill with which the leading points on which our knowledge has been increased…are seized upon and set forth" (Brück 2002, 45–46).

Agnes Clerke's book made its mark due to her command of the literature, capacity to synthesise and organize information, and her ability to write clearly. Her success was reflected in the reaction of professional astronomers, who increasingly sent her reports of their work for inclusion in subsequent editions (Figure 2). And the fact that those editions followed in fairly quick succession, the second in 1887, the third in 1893, and the fourth in 1902 was an ongoing demonstration of the continued utility of the project (Figure 3).

The reputation she earned in the astronomical world as the author of *A Popular History of Astronomy During the Nineteenth Century* led to her election to an honorary class of membership in the A&PST (which became the RASC within her lifetime) on 1891 December 1:

> Miss Agnes M. Clerke, of London, England…wrote: "I have great pleasure in accepting the flattering offer which you have been so kind as to transmit to me. I shall consider it a high honour to be affiliated, in the manner you propose [i.e. as a corresponding member], to The Astronomical and Physical Society of Toronto, which already gives promise of being a powerful agency for the promotion of astronomical activity in your great country. The first Report, which I had the pleasure of receiving yesterday, is full of interest, and I hope on the first opportunity to offer some small contribution to it. I fear I can suggest little that might be effective for pressing the ladies of Toronto into the service. The means already adopted by you, of showing off the heavenly bodies, I should have thought most likely to be successful. Popular lectures might be a further help. The main thing is to kindle a spark, the rest might be left, comparatively speaking, to take care of itself—though, indeed, the really effective workers in astronomy are only a few out of many." (Lindsay 1892, 51).

The reality was that the Society benefitted from the honour reflected on it from Agnes Clerke's acceptance of honorary membership, rather than the other way around. She was as good as her word, sending two papers to be read at meetings of the Society, and then published in the *Transactions*, the first on "Nova Aurigae" in 1892, and the second on "Distance of the Nebulae" in 1893 (Clerke 1893; 1894). In the words of one member of Council: "Mr. Thomas Lindsay, in seconding the motion [of Arthur Harvey to thank Agnes Clerke], reminded the Society that the contribution of such a paper was no small compliment" (Clerke 1894, 112). He was right.

The Society acquired several of her books for its nascent library. In 1891, John Goldie of Galt donated several of Clerke's books, *The System of the Stars* (1890), and an edition of *A Popular History of Astronomy During the Nineteenth Century* (either the first edition of 1885, or the second of 1887; Miller n.d., 37). That particular copy of Clerke's history is no longer in the RASC's collections, and doubtless disappeared many decades ago. The Society does own a copy of the first edition, and it's a much more significant witness to Clerke's text than the now missing Goldie copy. That is because the book now in the RASC Archives Rare Book Collection is the personal copy which belonged to Ms Clerke, and it has copious manuscript annotations written in her hand.

How the RASC Acquired the Book

Agnes Clerke's personal copy of the first edition of her most famous book also entered the RASC's collections as a gift. It was donated by one of the most singular characters inscribed as a member of the Society, Carl Reinhardt (1876–1962). He was a mining engineer and prospector (with degrees in

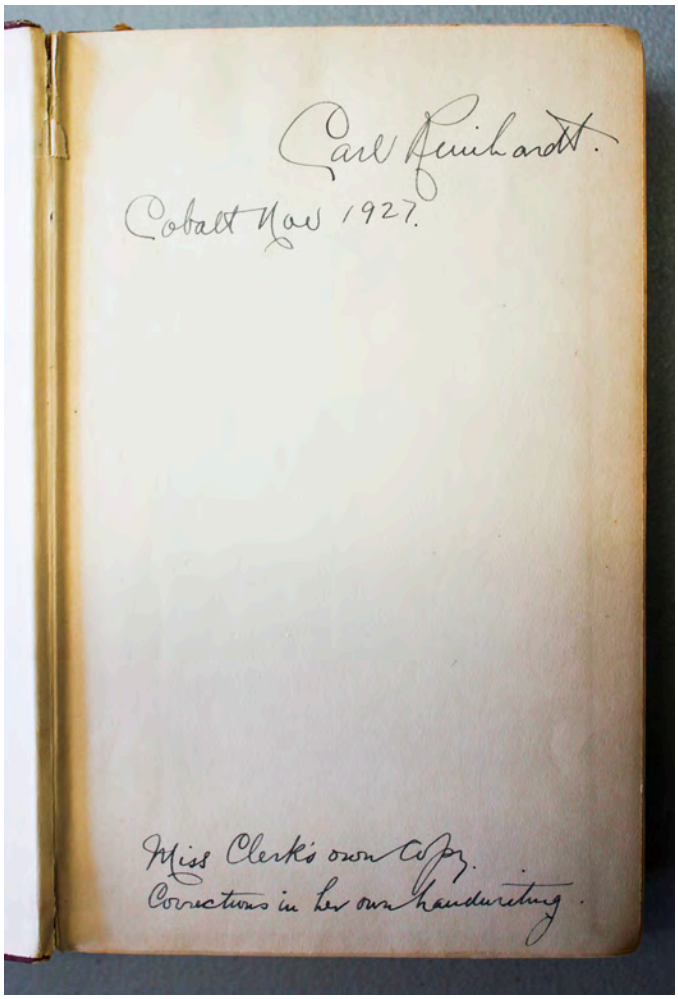


Figure 4 — Flyleaf of Agnes Mary Clerke's personal copy of her A Popular History of Astronomy During the Nineteenth Century *(1885). Image courtesy of the RASC Archives.*

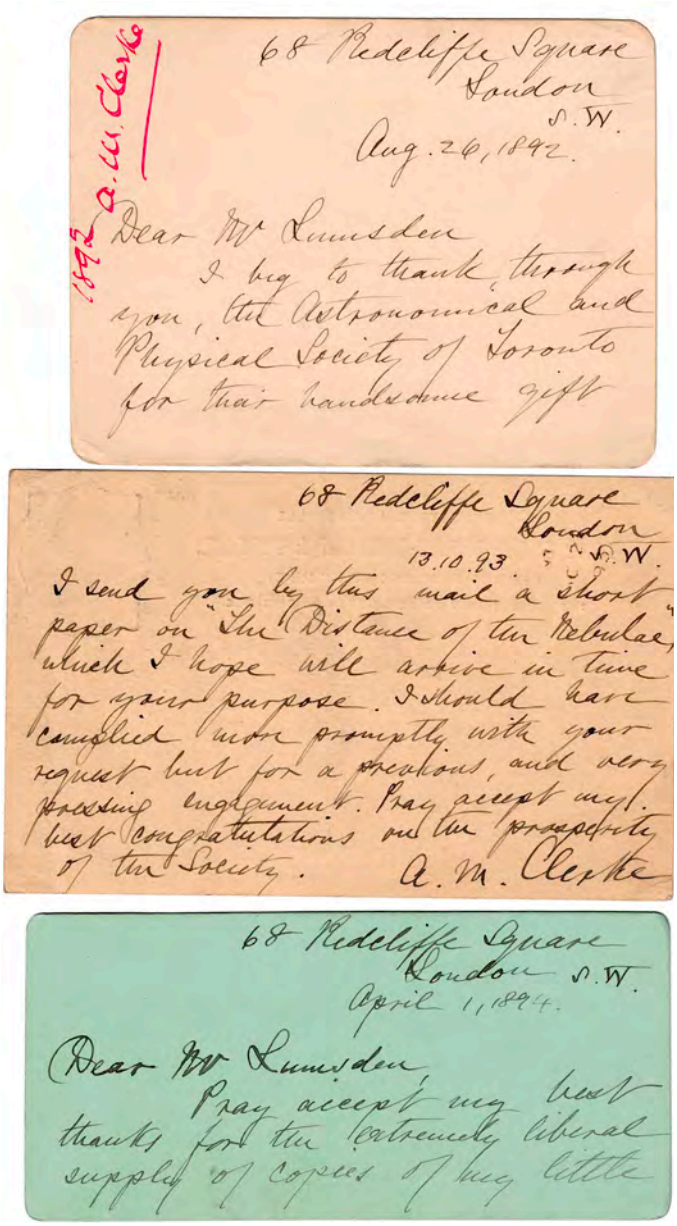
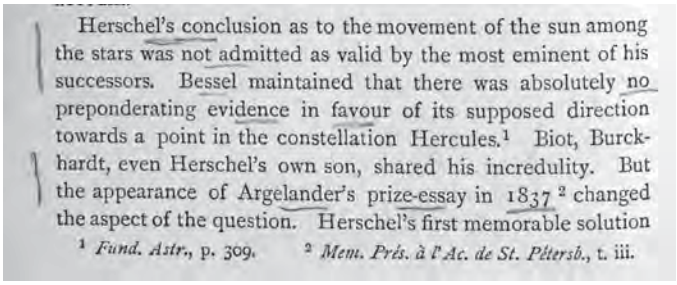


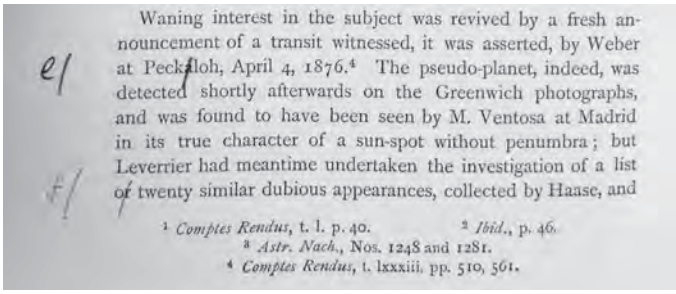
Figure 5 — Select correspondence from Agnes Mary Clerke to the A&PST/RASC, 1890s. Image courtesy of the RASC Archives.

Civil Engineering [1896], and Mining Engineering [1897] from McGill), and was a notable financial benefactor of the RASC (Broughton 1994, 78). In later life he lived in the RASC building at 52 College Street in Toronto. The present author remembers coming across a copy of a paperback from the 1940s or 1950s that dealt with the cosmology of the first half of the 20th century. It had belonged to Reinhardt, and bore his tersely and colourfully expressed pencilled disagreements with Einstein's theory of relativity! It's possible that the best sketch of him was penned by Jack Heard (1907–1976), a former Director of the David Dunlop Observatory (Heard 1979, 18–19). Reinhardt liked to collect books that belonged to famous astronomers, which is how the RASC acquired its present copy of *A Popular History of Astronomy During the Nineteenth Century* (Figure 4).


Herschel's conclusion as to the movement of the sun among the stars was not admitted as valid by the most eminent of his successors. Bessel maintained that there was absolutely no preponderating evidence in favour of its supposed direction towards a point in the constellation Hercules.[1] Biot, Burckhardt, even Herschel's own son, shared his incredulity. But the appearance of Argelander's prize-essay in 1837 [2] changed the aspect of the question. Herschel's first memorable solution

[1] *Fund. Astr.*, p. 309. [2] *Mem. Prés. à l'Ac. de St. Pétersb.*, t. iii.

Figure 6 — Detail of p. 50 of Agnes Mary Clerke's personal copy of her A Popular History of Astronomy During the Nineteenth Century *(1885). Image courtesy of the RASC Archives.*


Waning interest in the subject was revived by a fresh announcement of a transit witnessed, it was asserted, by Weber at Peckáloh, April 4, 1876.[4] The pseudo-planet, indeed, was detected shortly afterwards on the Greenwich photographs, and was found to have been seen by M. Ventosa at Madrid in its true character of a sun-spot without penumbra; but Leverrier had meantime undertaken the investigation of a list of twenty similar dubious appearances, collected by Haase, and

[1] *Comptes Rendus*, t. l. p. 40. [2] *Ibid.*, p. 46.
[3] *Astr. Nach.*, Nos. 1248 and 1281.
[4] *Comptes Rendus*, t. lxxxiii. pp. 510, 561.

Figure 7 — Detail of p. 294 of Agnes Mary Clerke's personal copy of her A Popular History of Astronomy During the Nineteenth Century *(1885). Image courtesy of the RASC Archives.*

Knowledge of its provenance is incomplete, as it is not known how Carl Rienhardt acquired the book (Mary Brück believes that Agnes Clerke's library was largely dispersed after her death; 2002, 17). The RASC has owned the book for over six decades.

The Glosses/Annotations

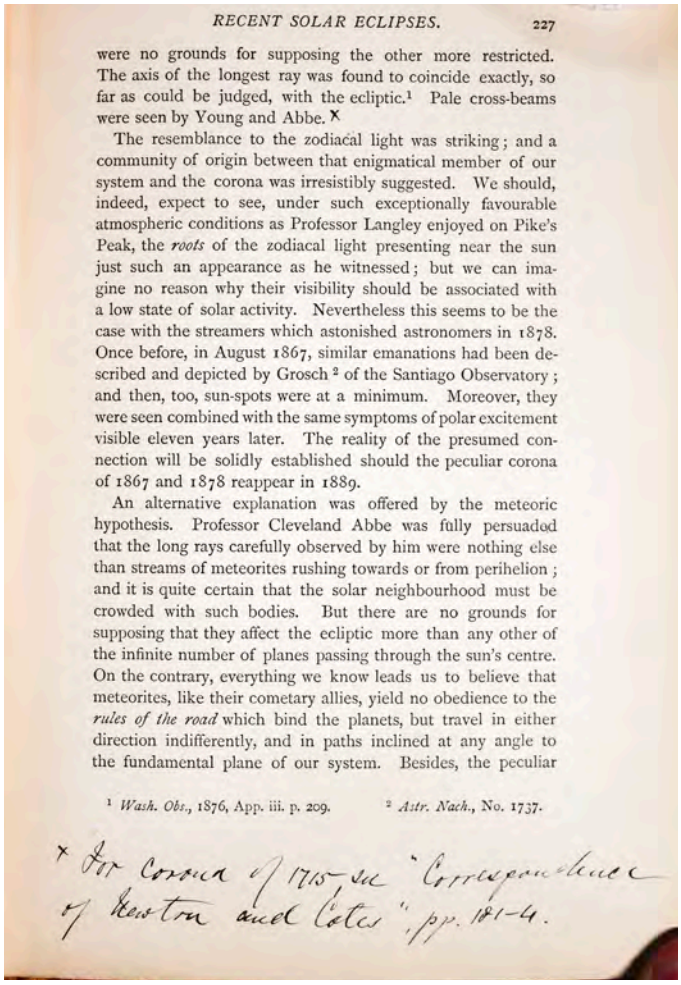
A comparison of the handwriting of the annotations in the book with that in the letters the Society received from Clerke confirms that the writing in the book is hers (Figure 5).

Clerke wrote 442 glosses of various sorts throughout the book, entering them either in the margins, or interlineally. The media she employed was either pencil, or pen & ink.

The vast majority of the glosses can be classified as notae bene; 368 of the 442 fall into that category. These annotations consist of short horizontal lines under words or phrases, or short vertical or diagonal lines (Figure 6). Their function seems to be to draw attention to statements and passages Clerke thought notable.

forty-two of the glosses are corrections of errors (Figure 7)—orthographical, numerical, or typographical (only 4 occur in the index).

twenty-three of them are additions to the text, which serve to improve the breadth or depth of presentation; the information they contain predates the 1885 date of publication (i.e. they are not the result of post 1885 advances in the field; Figure 8).



RECENT SOLAR ECLIPSES. 227

were no grounds for supposing the other more restricted. The axis of the longest ray was found to coincide exactly, so far as could be judged, with the ecliptic.[1] Pale cross-beams were seen by Young and Abbe. X

The resemblance to the zodiacal light was striking; and a community of origin between that enigmatical member of our system and the corona was irresistibly suggested. We should, indeed, expect to see, under such exceptionally favourable atmospheric conditions as Professor Langley enjoyed on Pike's Peak, the *roots* of the zodiacal light presenting near the sun just such an appearance as he witnessed; but we can imagine no reason why their visibility should be associated with a low state of solar activity. Nevertheless this seems to be the case with the streamers which astonished astronomers in 1878. Once before, in August 1867, similar emanations had been described and depicted by Grosch [2] of the Santiago Observatory; and then, too, sun-spots were at a minimum. Moreover, they were seen combined with the same symptoms of polar excitement visible eleven years later. The reality of the presumed connection will be solidly established should the peculiar corona of 1867 and 1878 reappear in 1889.

An alternative explanation was offered by the meteoric hypothesis. Professor Cleveland Abbe was fully persuaded that the long rays carefully observed by him were nothing else than streams of meteorites rushing towards or from perihelion; and it is quite certain that the solar neighbourhood must be crowded with such bodies. But there are no grounds for supposing that they affect the ecliptic more than any other of the infinite number of planes passing through the sun's centre. On the contrary, everything we know leads us to believe that meteorites, like their cometary allies, yield no obedience to the *rules of the road* which bind the planets, but travel in either direction indifferently, and in paths inclined at any angle to the fundamental plane of our system. Besides, the peculiar

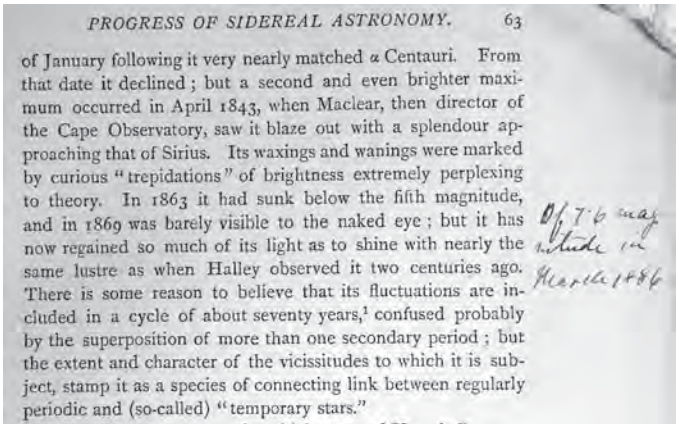
[1] *Wash. Obs.*, 1876, App. iii. p. 209. [2] *Astr. Nach.*, No. 1737.

× For Corona of 1715 see "Correspondence of Newton and Cotes", pp. 181-4.

Figure 8 — Detail of p. 227 of Agnes Mary Clerke's personal copy of her A Popular History of Astronomy During the Nineteenth Century *(1885). Image courtesy of the RASC Archives.*

Only 4 of them represent advances in knowledge (due to improvements in the values of constants, or new observational data, or new theories) post-1885 (Figure 9).

The final category comprises stylistic changes, of which there are 5 (Figure 10).

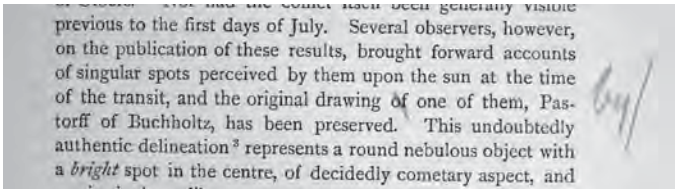


PROGRESS OF SIDEREAL ASTRONOMY. 63

of January following it very nearly matched α Centauri. From that date it declined; but a second and even brighter maximum occurred in April 1843, when Maclear, then director of the Cape Observatory, saw it blaze out with a splendour approaching that of Sirius. Its waxings and wanings were marked by curious "trepidations" of brightness extremely perplexing to theory. In 1863 it had sunk below the fifth magnitude, and in 1869 was barely visible to the naked eye; but it has now regained so much of its light as to shine with nearly the same lustre as when Halley observed it two centuries ago. There is some reason to believe that its fluctuations are included in a cycle of about seventy years,[1] confused probably by the superposition of more than one secondary period; but the extent and character of the vicissitudes to which it is subject, stamp it as a species of connecting link between regularly periodic and (so-called) "temporary stars."

Of 7·6 mag. at Greenwich 1886

Figure 9 — Detail of p. 63 of Agnes Mary Clerke's personal copy of her A Popular History of Astronomy During the Nineteenth Century *(1885). Image courtesy of the RASC Archives.*



previous to the first days of July. Several observers, however, on the publication of these results, brought forward accounts of singular spots perceived by them upon the sun at the time of the transit, and the original drawing of one of them, Pastorff of Buchholtz, has been preserved. This undoubtedly authentic delineation [3] represents a round nebulous object with a *bright* spot in the centre, of decidedly cometary aspect, and

Figure 10 — Detail of p. 131 of Agnes Mary Clerke's personal copy of her A Popular History of Astronomy During the Nineteenth Century *(1885). Image courtesy of the RASC Archives.*

The media used are remarkably constant in appearance, the pencil lead is sharpened to the same width and maintained there, the nib of the quill (if a feather) is cut to the same shape, angle, and width, the ink is the same consistency of blackness. These could represent Clerke's decided preferences in writing tools, or they may simply be relics of habit.

Is there anything special about the use of the different media? Of the 442 interventions, 394 are done in pencil, whereas 48 are in pen & ink. Clerke reached for a pencil an order of magnitude more often than she took up a pen. When using pen & ink, the majority of writers in her day would have used pens without reservoirs, meaning that an open inkwell had to be part of the apparatus as well as the pen and nib, and if the pen was a quill, then a quill knife (or possibly a mechanical quill cutter) was also necessary. A pencil involved less bother. The preference for the pencil may have been one of convenience. There is some evidence that the nature of the gloss may have partly determined which medium was used. Of the 42 corrections, 25 (well over half) are in pen & ink, revealing a preference for media based on function. It is more of a trend than an invariable practice, however.

What do these glosses tell us about Clerke's reading of her own text?

She is clearly concerned about the accuracy of what she has issued in print. It seems a sensible solution for an author to note desired textual changes within the physical text itself. There is a neatness about it. The corrections of error, addition of citations, textual expansions, and suggested changes due to advances in knowledge are what one would expect of an author contemplating a second edition. The *notae bene*, the least informative of the glosses are potentially the most interesting. They don't seem directly related to producing a second edition. What are they doing there? If they are indeed an author's response on re-reading her text, then they may allow a window into how she reads. To judge by the presence of the notations, reading is a very active engagement with the text, rather than a passive activity. More revealingly, the *notae bene* show us what Clerke found memorable in the ideas she chronicled. And that would certainly repay more careful reading.

Did Clerke do something similar with all her books and articles? There is some evidence that this was the case. A

private communication from Michael Hoskin to Mary Brück is directly relevant:

> "The successive editions of her *A Popular History of Astronomy during the Nineteenth Century* are goldmines of detailed and reliable information on almost every aspect of astronomy. We know how she did it: her copy of the fourth edition, the last to appear, is interleaved with blank pages, and on these she has begun in meticulous hand to record new discoveries as they appeared in scientific journals, ready to be incorporated in the fifth edition that she did not live to complete. She was a chronicler of her own times, widely respected by astronomers who thought time well spent on letters alerting her to the progress of their science" (Hoskin quoted in Brück 2002, 226).

This also revealed a change in the technology for glossing between the first edition of her *A Popular History of Astronomy During the Nineteenth Century* (1885) and her last (1902). It was an improvement because interleaved blank sheets could provide much more room for annotations (and if they were included when the copy of the book was bound they would be more secure than if they were just laid in between the bound pages). ✶

Acknowledgements

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Endnotes

1 The Paris Academy was founded in 1662, but regular provision for foreign members was introduced in the 1699 reforms; Tits-Dieuaide 1998, 97–98.

2 Many of the biographical details here on Clerke's life are taken from Brück 2002. It is a very positive thing that a book-length biography by a professional astronomer has been devoted to her life and work. The reader should be warned that the treatment is not entirely reliable, for example, nearly everything on Clerke's relationship with the RASC is inaccurate, and the witness of Clerke's manuscript glosses on her own copy of Clerke 1885 has been missed.

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Mostly Variable Stars

It's Been a Summer of SETI



by Hilding Neilson
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It's been a busy summer so far. I just wanted to share with you some recent work I have been doing based on papers presented at conferences. The first paper is based on a talk I contributed at the International Astronomical Union Symposium 399: Indigenous Astronomies in the Space Age held in Melbourne, Australia, in August 2025, and a second paper based on a talk given at IAUS 404: Advancing the search for Technosignatures from March 2026. You might wonder what these two conferences have in common, the first having a focus on cultural astronomies while the other on SETI and the search for technologies from alien civilizations.

Well, let me tell you about it. The first paper is called "Indigenizing the Drake Equation" where I work to bring together Indigenous methods and Western Science to understand the Drake Equation through an Indigenist Lens (Drake 1962). I am sure you all have heard of the Drake Equation, but a quick review is that this is a thought experiment that attempts to estimate the potential number of detectable civilizations in the Milky Way. When Drake came up with the thought experiment, astronomers were only considering detection via radio signals, and that, of course, became the basis for Carl Sagan's book and subsequent movie, *Contact*. In the thought experiment, he derived an equation to predict the number of detectable civilizations as a series of ingredients, but I find it easier to think of the Drake Equation as a nesting doll. The outermost doll is the number of stars created every year in the galaxy, i.e. the star formation rate. The next doll asks what fractions of the stars will host planets and the third doll is how many planets, on average, does a star host. The next doll, or term in the equation, is what fraction of planets are habitable for life, then it is the fraction of planets that can host life and will actually host life. Following that is a term asking what fraction of planets that host life will host intelligent life, then what fraction of those will host civilizations that create detectable signals. The final term asks how long those civilizations with detectable technologies last. When we put all the terms together, we are left with a number estimating how many detectable civilizations there are in our galaxy.

There has been a lot of work done in the past trying to understand this equation and come up with good predictions for the number. My contribution was to ask how the interpretation of the equation changes if we look at it through Indigenous methods. Indigenous peoples have lived and continue to live on the lands that today we call Canada, and the U.S. and many other parts of the world since time immemorial and, as such, have observed the night sky regularly, sharing stories of stars, planets, comets, and more that entire time. That knowledge was carried across generations through stories and learnings. As part of that knowledge, the understanding of the natural world was and is built through a number of methods that can differ from traditional western science methods in many ways. As shared by numerous Indigenous scholars such as Battiste (2013), Cajete (2000), Lipe (2019), Smith (2021), and more, some of these methods include: 1) what is above is a reflection of below; 2) knowledge is relational not objective, 3) Nature is familial and relational and not a hierarchy, 4) knowledge is (w)holistic and not separated into disciplines and more. But, it must be noted that there is no one pan-Indigenous knowledge system.

We can use these methods to explore various parts of the Drake Equation. The star formation rate and the fraction of stars with exoplanets are already measured by various experiments. The average number of planets per host star is not really understood because of all the challenges in finding small planets and long orbital periods, but could be from about one to maybe five, like the TRAPPIST-1 system. We really don't know what fraction of planets could be habitable, partly for the same biases and partly because we do not have a good definition of habitability. For instance, we can define the habitable zone in a stellar system as the region around the star where water can exist as a liquid on the planet. For our Solar System, that would include the Earth along with Venus and marginally Mars. However, there is evidence of liquid water on two of Jupiter's moons, Europa and Ganymede that would be outside the habitable zone. Furthermore, this definition of habitability is based on our understanding of life on Earth and is anthropocentric, even if it is the best idea we have. Then there is the question of the creation of life on a planet. The definition of life from NASA is something that is capable of Darwinian evolution, even though there exist microbacteria on Earth that do not seem to have changed in billions of years. I did not consider the definition of what is life when considered via Indigenous methods, but I have lots of thoughts on this and will write about it someday.

However, the question of the fraction of planets that form intelligent life and form civilizations with detectable technologies and their lifetimes is some of the most unknown, essentially because we define these quantities solely from our existence as humans. Well, that is not quite true. I would argue it is solely based on the presence of our western technosociety. I call it a technosociety because we tend to define progress and societal evolution through the development of technologies. Typically, we define intelligence solely as humanity, so in our galaxy we can say that there is one planet where we are certain there is intelligence. Similarly, we define our western technosociety as the detectable civilization so there is one again. However, we have no idea of what the fractions would

be, that is, we do not know how common intelligent life and civilizations are as defined. The lifetimes are also unknown as there are zero observations of this. During the time of Drake, the big fear was nuclear annihilation and it was suggested that this might limit our civilization to about a century or two. More recently and today, the big fear is climate change and its impacts on civilization; maybe that limits our lifetime as a civilization. All told, based on these western views, we would tend to conclude that advanced life in our galaxy would be relatively rare.

When we apply Indigenous methods to these terms, things change. The idea of intelligence has a long, dark history as noted in great detail by author Angela Saini (Saini, 2019). Further to that, if we consider nature as familial, kin and equal then we should consider that all life has intelligence regardless of whether humans choose to recognize it. By and large, there is no one good definition of intelligence, be it something about self-awareness, language, usage of tools, memory. None of these concepts are unique to humans so why do we think of intelligence as something only we have but not other species? In my work, I argue that we should stop using that term and simply treat all life as intelligent life.

The fraction of civilizations with detectable technology is a trickier issue because it raises questions of what a civilization is and what makes it detectable. Being detectable depends on the observer as much as the civilization. So, what then defines a civilization? We tend to think of the western civilization as the civilization, but Indigenous peoples have lived on the lands we call Canada since time immemorial, or, at least, 13,000 years. All of these Indigenous nations are civilizations in their own rights and ways. These Indigenous nations here, and elsewhere around the world, are civilizations so this might suggest that civilizations come about in many different ways and that the fraction of civilizations in the Drake Equation could be much greater than we might have expected from western methods. And if we consider these to be civilization lifetimes then the lifetime term could be orders-of-magnitude greater.

In all, thinking about the Drake Equation from Indigenous methods implies that there might be many tens of times more advanced civilizations in our galaxy than if we use western science methods only. Of course, the reader might have noticed that I dropped the detectability requirement which leads to a new issue: we are not searching for technology or technosignatures, we are looking for pollution.

In the end of the first paper and for the second, I discussed how the search for technosignatures is not a search for technological advancement but of technological impact on nature. When astronomers search for radio signatures, it is something that clearly deviates from natural signatures and the greater the impact the more detectable it is. So, what if a civilization creates advanced, futuristic technologies but do not use them at significant scale to be detectable or the technology simply is very low impact. This would suggest that the current view of the Drake Equation is missing a significant number of worlds with life. Furthermore, if the search for technosignatures is the search for the impact, technosignatures are pollution. Following the work of Dr. Max Liboiron's book *Pollution is Colonialism* (Liboiron, 2021), then technosignatures are also colonialism. That is the thesis of the second piece and I am working on what it could mean to decolonize the search for technosignatures.

Whether or not these pieces are correct, I think they do illustrate some of the cultural biases that we have in the search for life beyond the Earth and how our assumptions can continue to limit our view. ✶

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Keep Calm and Orbit On

Space Mirrors Incoming



By Samantha Lawler, Regina Centre
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Note that this is an edited version of an article published in The Conversation Canada, with Aaron Boley as co-author.

A giant mirror to create "sunlight on demand" was just approved by the United States Federal Communications Commission (FCC), despite opposition from astronomers and the public, and real safety concerns. The FCC approved the company Reflect Orbital to test one satellite as a means of reflecting the sun's rays back to Earth for extra solar energy and wide-area lighting. The light is expected to cover an area of about five kilometres wide, and will require repointing every four minutes. And this is just the start. Reflect Orbital plans to have more than 50,000 satellites in action by 2035, which they claim will be used across agricultural, emergency response, and other industrial sectors.

There are many problems with this proposal[1], including impacts these satellites will have on human health and safety, including potential eye damage[2], as well as on astronomy and the low-Earth environment[3]. Flashes during mirror repointing could disrupt pilots and drivers. The light could also disrupt circadian rhythms of plants, animals and humans[4]. Sensitive detectors in research telescopes, as well as star-tracking cameras on lower altitude satellites, could be overloaded and fried.

The FCC said that the "risks of harm raised on the record regarding Reflect Orbital's solar reflector are unrelated to the Commission's role in authorizing use of radiofrequency spectrum."[5] Satellite proposals for "emergent space activities" in low-Earth orbit are becoming increasingly outlandish. The proposals have become so weird, in fact, that the FCC recently published a document called "Spectrum Abundance for Weird Space Stuff."[6]

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"Once the province of science fiction," this document states, "American companies are now upgrading, relocating and servicing satellites; manufacturing pharmaceuticals in space; building private inhabitable spacecraft; and conducting private robotic missions to the surface of the Moon." Millions of orbital AI data centres are also planned[7]. Corporations seem to be scrambling to launch anything that might persuade investors throw money at them: space advertising, hotels for billionaires, artificial meteor showers, space burials for cremated remains, solar-powered infrared beams to power data centres, and a variety of orbital missiles.

The phrase "weird space stuff" is refreshingly truthful. So, how did we get here?

There are over 11,000 SpaceX *Starlink* satellites[8] currently in orbit above our heads. Anyone who wants to launch into low-Earth orbit needs to carefully consider SpaceX operations, or directly co-ordinate with them. Otherwise they risk collisions, like the near-miss between a *Starlink* and Chinese satellite in December 2025. Even the *Artemis I* launch in 2022 and *Artemis II* launch in 2026 had small "cutout" windows in their launch timing to avoid satellites, including those belonging to *Starlink*.

Co-ordination is good. Forcing it because one corporation has effectively occupied low-Earth orbit is not. Indeed, the 1967 Outer Space Treaty, which was signed by more than 100 countries including the United States, China, and Russia, states that, "outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation."

Whether SpaceX's extensive use of Earth orbits violates this principle is now being tested in real time. In February, SpaceX filed with the FCC for one million additional satellites, for "AI data centers." One. Million. That is 40 times as many satellites as have ever been launched—for a single megaconstellation consisting of completely untested technology that may not even work in space.

Not only did the FCC accept SpaceX's filing[9], but they did so at ludicrous speed. Scientists worldwide then had just 30 days to model the effects with woefully incomplete information on masses, sizes, compositions, and orbital distributions. At the time of writing, four other copycat AI data centre proposals have been filed by rival companies, for tens of thousands of satellites each. And SpaceX just proposed another 100,000 satellites to interface with the million AI data centres that it already asked for.

The U.S. Federal Communications Commission was originally set up to regulate radio broadcasts. But it is now being asked to evaluate many non-radio effects, including orbital safety, which it may not have the required expertise for. It would make sense to move some of this evaluation to the U.S. Office of Space Commerce. However, recent budget cuts make that infeasible.

Consequently, the FCC will soon be asked to judge a daunting range of satellite proposals. They include a cluster of proposals to gather solar energy from space.

One idea is to send solar power down to earth through high energy beams. These could change atmospheric chemistry and kill birds and other wildlife that stray into the beam. They would also require no-fly zones around receiving stations for airplanes and also satellites on lower altitude orbits (such as the orbits SpaceX just requested for 100,000 more Starlink satellites).

While many of these projects claim to solve environmental problems by creating clean energy or capturing it in space, they function as a form of greenwashing. The solar energy generated is only clean if you ignore the environmental costs of building, launching, maintaining and burning satellites up in Earth's atmosphere. The daily operations of all these proposed systems will have huge environmental consequences.

There are companies that have tested plans for removing space debris from orbit. This is helpful for avoiding Kessler Syndrome—a runaway chain reaction of collisions. But where will the debris go once removed from orbit? It will fall into Earth's atmosphere, where it will deposit metal and possibly impact Earth's surface. It is unclear who is responsible for any resulting damage or deaths[10].

The majority of satellites in orbit today are American, and the main federal agency regulating satellites is not set up to do that well. We are now seeing the consequences. While outer space is effectively infinite, low-Earth orbit most definitely is not. Satellites orbit around the Earth once every 90 minutes. This means the collision potential between two objects in orbit is large[11].

The many satellites and rocket bodies that have burned up in Earth's atmosphere over the last few years have already measurably altered it. Preliminary studies show that using Earth's atmosphere as a crematorium for tens of thousands of satellites will have devastating effects on ozone and other atmospheric chemistry[12].

Astronomy is also under threat from some of the "weirder" ideas like space mirrors, solar sails and diffuse sky brightening from orbital debris.

We are not here to argue against satellites. Indeed, they provide a wide range of beneficial services to science and society. But each satellite comes with a cost that must be taken into account. Ultimately, this is an innovation challenge. Unfettered growth and exploitation of any environment comes with serious consequences, including to the long-term sustainability of the operations that depend on that environment. Doing more with less is the engineering challenge that needs to be met if we want to continue to use satellites in orbit.

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John Percy's Universe

Asteroseismology: The Music of the Stars



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Every few years, my department invites a distinguished woman astronomer to visit us for a few days and interact with faculty, students, and the public. This visitorship is in memory of Professor Helen Sawyer Hogg who, in her time, was Canada's best-known and most beloved astronomer (Percy 2025a).

Our 2026 visitor was Professor Conny Aerts, KU Leuven, Belgium[1]. Professor Aerts has won a score of prestigious national and international awards, including the Francqui Prize (the "Belgian Nobel Prize"). She also served for many years as her faculty's Vice-Dean, Outreach and Communication, and teaches a course there on outreach. She has many things in common with Helen Hogg. Indeed, her research in *asteroseismology* is a 21st-century version of Helen's research in variable stars, as you will see from this column. Her public lecture is freely available on our *YouTube* channel[2].

Asteroseismology—a challenge in a spelling bee—is the observation and study of oscillations (pulsations) in stars, in order to determine their properties and internal structure. It's the only way to probe the interiors of stars observationally. We need to understand stellar structure in order to understand stellar evolution and nucleosynthesis. In her public lecture, Professor Aerts used the analogy of ultrasound waves, which are used by medical personnel to study the interior of—us.

It has parallels to *seismology*, the study of the Earth's interior by using seismographs to observe earthquake waves that have traversed different layers of the core and mantle of our planet. *Helioseismology* is a specific example of asteroseismology—the study of oscillations of the Sun. Brightness changes and motions of different parts of the surface can be directly observed on the Sun, something not (yet) possible for other stars. Helioseismology began in the early 1960s with the work of R.B. Leighton and others and is still a vibrant field.

The most basic form of asteroseismology is the study of simple pulsating stars like Cepheids, discussed in my previous column (Percy 2026). Pulsations can be thought of as waves. The time for a pulsation wave to travel through the star from centre to surface—the period—is related to the radius and therefore the luminosity of the star—the famous Leavitt Law. Variable stars are studied by measuring their changing brightness and, in some cases, by using radial-velocity observations to study the motions of the stars' emitting layers—or both.

Cepheids pulsate *radially*—in-and-out. But there are stars that pulsate *non-radially*: for instance, the equator of the star could be moving inward as the poles move outward. Figure 1 shows a schematic "snapshot" diagram of one possible high-order mode in a non-radially pulsating star; the red areas are moving outward; the blue areas are moving inward. There are an infinite number of possible non-radial modes, and many can be excited at the same time, leading to the complex oscillations seen in some stars. And different modes probe different layers of the stars. Observations of these stars reveal the periods of these modes, which, by comparison with "models" of the stars, can reveal their properties and structure.

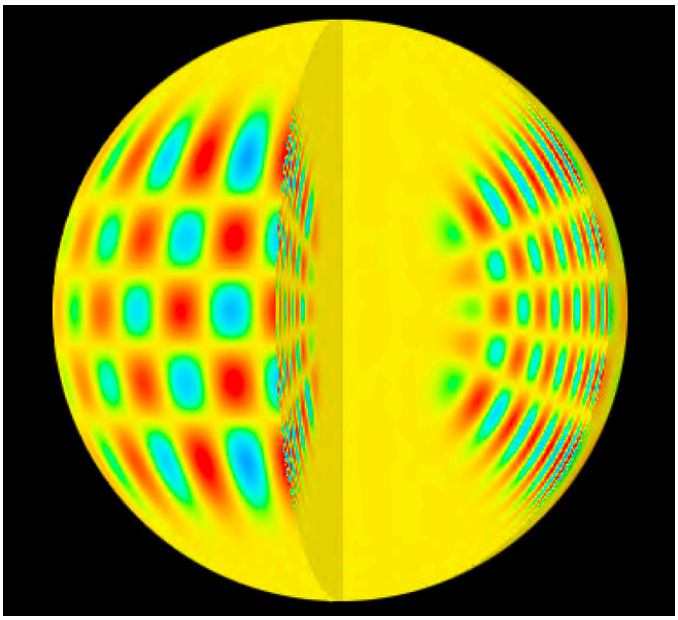


Figure 1 — A schematic "snapshot" diagram of a non-radially pulsating star. The red areas are moving outward; the blue areas are moving inward. Source: European Space Agency PLATO Mission.

As well as determining the interior structure of the stars, astronomers can also use asteroseismology to detect and measure their internal *rotation*. Rotation causes the observed oscillation frequencies to split, by an amount that depends on the rotation. With sufficient observations, the splits in different frequencies can be measured, compared with models, and used to determine the rotation rate at different levels in the star.

What causes these pulsations? In my previous column, I explained how the opacity and the ionization of hydrogen and helium—the two most abundant elements in stars—resulted in the pulsation of Cepheids. The Sun and stars like it pulsate due to a different mechanism: convective fluid motions in their outer layers. Motions of convection cells also produce the granulation observed on the solar photosphere.

Stars with a companion in a close, eccentric orbit can also develop tidally excited pulsations as the companion passes through periastron. These motions resemble the rising and falling of Earth's oceans, caused by the tidal effects of the Moon and the Sun.

Asteroseismology observations—both ground-based and space-based—have contributed to the study of more than just Sun-like stars. Wikipedia[3] lists various classes of such variable stars, other than Sun-like ones. They range from simple pulsators like Cepheids and RR Lyrae stars, to complex pulsators like white dwarfs, to stars like delta Scuti stars, which show a mixture of both simple radial pulsation and complex non-radial pulsation.

Much new understanding of stellar variability has come about from high-speed, high-precision ground-based photometry, starting in the 1960s—especially the discovery and study of rapid pulsational variability of white dwarfs and other compact objects. A few AAVSO (American Association of Variable Star Observers) photometrists have contributed significantly to this field.

But there is an advantage to doing photometry from space: long, uninterrupted runs of highly precise data. The first *satellite* to be dedicated primarily to asteroseismology was Canada's own MOST (Microvariability and Oscillations of STars), conceived by Slavek Rucinski and directed by Jaymie Matthews (Percy 2025b). A decade later, Canada's BRITE (BRIght Target Explorer)—a "constellation" of six nanosatellites—followed. As the name suggests, it was used to do asteroseismology of bright stars.

Several other satellites followed. WIRE (Wide-field Infra-Red Explorer, 1999–2006) was a failed infrared satellite whose star-tracker was redeployed for photometry. French-led CoRoT (Convection, Rotation, and planetary Transits, 2006–2012), NASA's *Kepler* (2009–2013) and TESS (*Transiting Exoplanet Survey Satellite*, 2018–) have made major contributions to both asteroseismology and exoplanet research. It helps that both require the same thing: long, dense, continuous series of high-precision photometric observations. For exoplanet research, asteroseismology can determine the mass and age of the host stars, which is essential for knowing the evolutionary context of the exoplanetary system. PLATO (*PLAnetary Transits and Oscillations of stars*) is a European mission, scheduled for launch in 2027, that will specialize in both exoplanets and asteroseismology. It will observe thousands of target stars, many *kinds* of stars, including clusters whose stars are all the same age. It will determine precise masses, sizes, and ages of these stars. It will probe the interior structure, rotation, and magnetic fields of some of them. So, discoveries will continue.

Analysis of the variability of complex pulsators is not trivial. Fourier analysis is a standard tool. The AAVSO's VSTAR package[4] comes with Fourier and wavelet analysis routines, and a good users' manual. It can help you to learn the basics of asteroseismological analysis. The result of such an analysis is a list of the periods present in the stars, and their amplitudes. These can be compared with models, to test how well they represent the interior structure of the star.

Finally: why did I refer to asteroseismology in the title as "the music of the stars"? It's not original. Others, including Professor Aerts, have used the term before me. There is also a partially unrelated reason: my favourite International Year of Astronomy 2009 project was the Tafelmusik Baroque Orchestra's "The Galileo Project: the Music of the Spheres" (Percy 2014); it is now freely available on YouTube[5]. In that case, the music referred to the motion of the planets, not pulsation. Rather, as I hope you have seen from this column, stars can vibrate and "sing" in many different frequencies, as a good violin or other musical instrument can. These frequencies are too low for our ears to hear, but our photometers and computers can detect and measure them. Our minds can then imagine them and understand and appreciate the fundamental knowledge that they can provide. ✶

Endnotes

1 Professor Conny Aerts's bio: fys.kuleuven.be/ster/staff/conny-aerts
2 Professor Aerts's public lecture: youtu.beZz8IVY3CixA?si=QOTyHenfmO6KamZ6
3 Other targets for asteroseismology: en.wikipedia.org/wiki/Asteroseismology
4 aavso.org/vstar
5 "The Galileo Project" on-line: www.youtube.com/watch?v=kTNAuPQSC1s

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John Percy is a Professor Emeritus, Astronomy & Astrophysics, University of Toronto, and a former President (1978–80) and Honorary President (2013–17) of the RASC. His research deals with "classical" variable stars, and what they can tell us about the structure and evolution of the stars.

The December 2026 *Journal* deadline for submissions is 2026 October 1.

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Dish on the Cosmos

75 Years of 21-cm Astronomy



by Pamela Freeman
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On 1951 September 1, scientists published results that offered us a way to study the Universe in a whole new fashion. Two teams, H.I. Ewen and E.M. Purcell in the United States, and C.A. Muller and J.H. Oort in the Netherlands, simultaneously shared astronomical observations of the 21-cm atomic hydrogen spectral line (Ewen and Purcell, 1951; Muller and Oort, 1951).

Oort, for one, had been searching for this line for years while at Leiden University. He was intrigued by Grote Reber's early work in radio astronomy as he understood that radio waves could provide unique observations—radio waves are not impeded by interstellar dust in the same way that visible waves are. The extinction of visible light by dust meant that astronomers had a very limited view of our own galaxy. In the early 1940s, Oort guided research into the theoretical and observational hunt for a spectral line in radio wavelengths.

One student, H.C. van de Hulst, visited Leiden after a fruitful colloquium in 1943. As documented by van Woerden and Strom (2006), Oort said to him, "radio astronomy can really become very important if there were at least one line in the radio spectrum. Then we can use the method of differential galactic rotation as we do in optical astronomy." By looking at the frequency shift of a spectral line in radio, caused by motion, Oort imagined determining how the galaxy was structured and how objects within it moved.

In 1944, van de Hulst presented his results considering hydrogen spectral line emission. One line was promising: the hyperfine transition in the ground state of atomic hydrogen. Atomic indicates it is a sole hydrogen atom (consisting of one proton and one electron) that we are interested in, the ground state means the electron is in its lowest energy configuration around the proton, and the hyperfine transition is a change in the orientation of the electron spin relative to the proton spin (these particles aren't actually spinning, but they have some intrinsic angular momentum; spin is just one of the ways these particles are quantified). If the spins are parallel, the atom contains a bit of extra energy—it is in an excited state. Releasing that extra, defined amount of energy leads to a photon with a frequency of 1420 GHz, or a wavelength of 21 cm.

This spectral line, this energy transition, is technically "forbidden." It is very unlikely to spontaneously emit; the lifetime of the excited state is on the order of 10 million years. There is an almost unfathomable amount of neutral hydrogen in the universe meaning that this line does occur often enough

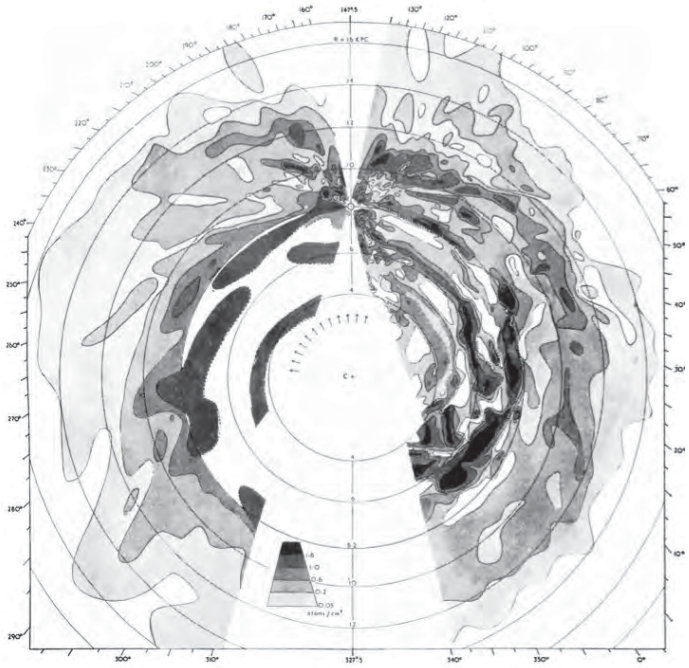


Figure 1 — One of the first maps of neutral hydrogen in the Milky Way, using data from both the Northern and Southern hemispheres. Image: Oort et al. (1958).

to be detectable. For us observers, it comes at a frequency that is just right. It's high enough that it is able to pass through the atmosphere without interference, and it is low enough that it can pass through the galaxy without extinction by dust. It's in a window we can clearly observe with ground-based telescopes, as long as they are sensitive enough.

That was one of the barriers to detection in the 1940s. Oort also had to search for funding and qualified engineers in order to even attempt making an instrument sensitive enough to detect this hydrogen line. In 1949, with the official start of what is now called the Netherlands Foundation for Radio Astronomy, he found backing for this project. As well, scientists and engineers had started using WWII military equipment for their research purposes. There were several Würzburg 7.5-m and 3-m antennae that radio astronomers co-opted. These antennae were lined along the European coast by Germany and used in the war to locate aircraft. After, one of these antennae was used at Kootwijk in the Netherlands and two others were used at Cambridge in England, at least.

In 1951, while the Netherlands team was in development of a sensitive receiver, they learned that a team in the U.S. was trying to detect the line using a technique called frequency switching. They would observe a source on the frequency of interest (1420 MHz) and then in another frequency (ideally that has no signal of its own), and measure the difference between those signals. This could improve the signal-to-noise ratio and reveal faint signals.

The U.S. team of Ewen and Purcell successfully detected the HI line in March 1951, using a large horn antenna. Those in the Netherlands, adopting this switching technique, observed the line in May 1951. This opened the cosmic doors to several

new areas of study. In the decades since, atomic hydrogen gas has been a workhorse in galactic and extragalactic astronomy and cosmology.

Quickly, astronomers began mapping out the Milky Way using the HI signal. In 1958, one of the first full pictures of galactic structure was released, combining data from both Northern and Southern Hemisphere data (Figure 1). It was further found that atomic hydrogen was structured in a thin, flat disk, and that it was densest in arms going around the galaxy.

It was also adopted as an important spectral line in the Search for Extraterrestrial Intelligence (SETI). The assumption was that any being with some knowledge of (radio) astronomy would recognize this spectral line and potentially use it for interstellar communications. They could send out an artificial signal to space, modified so it would stand out from the background of galactic HI signals. This produced one result of interest: the Wow! signal observed in 1977, a strong signal observed once and never again, with unknown origin. We performed our own version of sending a signal to space—the Pioneer 10 and 11 spacecrafts (now estimated to be billions of kilometres away from Earth) contain pictures depicting humans and our knowledge of space, just in case they're intercepted by extraterrestrial intelligence. These plaques include a graphic of the HI 21-cm transition (Figure 2).

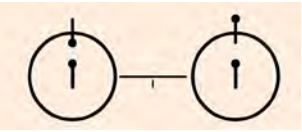


Figure 2 —A portion of the Pioneer Plaque placed on the Pioneer spacecraft. The two circles represent two hydrogen atoms, with the dotted lines representing the spin of the proton, in the centre, and the electron, on the edge. On the left, the spins are anti-parallel, and on the right, the spins are parallel. This represents the 21-cm spin-flip transition of atomic hydrogen. The centre horizontal line represents a unit length of 21 cm on the plaque. Image: NASA, vectorized by Mysid, Wikimedia Commons.

Atomic hydrogen is incredibly useful in extragalactic astronomy. Like in ours, it can be used to measure the motions and structure of an entire galaxy. Most gas in a galaxy is made up of atomic hydrogen, and structure like spiral arms or warps is easily seen. It can be compared spatially to molecular hydrogen, the type of gas that makes up star-forming clouds. It can reveal how galaxies may replenish their gas through interactions with other galaxies or the intergalactic medium.

Radio observations of galaxies can show an extended disk. There can be lots of atomic hydrogen gas outside the stellar disk (e.g. Figure 3). This finding contributed to the discovery of dark matter, as there was a larger diameter of motion to look at. Objects rotating around a galaxy should, in theory, move according to how much mass is contained within their orbits. Objects farther from the centre should move slower. Observations of stars showed that rotation didn't slow down as you looked farther out in the galaxy—the rotation curve was flat. Radio observations also showed a flat curve; the atomic gas behaved in a similar manner. There had to be something influencing the motion of "ordinary" matter. It



Figure 3 —From the WALLABY survey, this shows the atomic hydrogen in a galaxy (radio light, colored red) relative to the galaxy's stars (visible light). The white circle represents the stellar disk. Image: Legacy Surveys, D. Lang (Perimeter Institute), T. Westmeier.

was dubbed dark matter, as something that we can observe through gravitation but not through electromagnetic radiation. The NRAO notes it is "fair to say that radio astronomy truly revealed an invisible Universe, and then frustratingly provided evidence for an even-more-hidden Universe that even they can't see."

Atomic hydrogen is our key to the early Universe and understanding how it evolved. Right before the first stars and galaxies, before there was visible light to be seen, the Universe was a sea of atomic hydrogen gas. Radio light, then, is our key to seeing these cosmic dark ages. This signal has never been detected, as it would be very faint. It is also shifted, through the expansion of the Universe, down to frequencies that we use for FM radio. It would be very hard to capture even with modern technology. This has not stopped people from trying and going to extreme lengths to do so (see *JRASC*, February 2026, for more). Innovative instruments are floated on lakes, are being built in the Arctic, and are proposed to go to the far side of the Moon in order to try to detect the dark ages.

Along with dedicated cosmology experiments, next generation telescopes will continue HI astronomy for years to come. The Square Kilometre Array and its pathfinders will provide increased resolution and sensitivity to study the structure, evolution, and environment of far out galaxies, as well as dark matter, star formation, and much more. Stay tuned for the next 75 years of discovery. ✶

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.

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Blast from the Past!

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[This article is continued as Part 2 from the August 2026 *Journal*.]

Distribution of Radioactive Matter in the Earth's Crust.

Elster and Geitel early observed that many caves and cellars, in which the air had been confined for long intervals of time, was unusually rich in the radium emanation. This was shown by the strong activity observed on negatively charged wires exposed in these confined places. Such a result is to be expected if the radium emanation continuously escapes from the soil, for the amount of it present must in-crease in such confined spaces. This led them to make an examination of the activity of soils. All were found to be active and many gave off the radium emanation. This effect was especially marked in clayey soils. J.J. Thomson and others showed that the water in many deep wells and springs was impregnated with the radium emanation. The presence of the radium emanation is especially marked in many of the hot springs distributed throughout Europe. Elster and Geitel observed that the sediment from certain hot springs in Italy was unusually rich in radium. Blanc showed that the sediment from certain hot springs gave off freely the thorium emanation. A very great deal of work has been done along these lines in the last few years, and radioactive matter has been found to be very widely distributed, in small quantity, over the earth's crust. The continent of North America has not been so systematically examined as Europe, but Boltwood has shown that a large amount of radium emanation is present in the waters from many deep-seated springs in various localities in the United States. McLennan and Burton have shown that the petroleum from the oil wells in Ontario contains a considerable quantity of radium emanation and also a trace of radium.

There appears to be no reasonable doubt that the earth is the source of the emanation in the atmosphere. This emanation escapes from the soil by the process of diffusion, or is borne to the surface in spring water and is then distributed by the winds. On account of the rapidity of the transformation of the emanations of thorium and actinium compared with that of radium, it is to be expected that the radium emanation will predominate in the atmosphere, and it is a matter of some surprise that the thorium emanation is present in such a large amount as is observed in some localities. The emanation of radium must diffuse slowly through the earth, disappearing with time, and it is to be expected, that, apart from deep-seated springs, most of the emanation observed in the air must be derived from a thin skin of the earth's surface not more than a few feet deep.

Internal Heat of the Earth.

It is thus natural to suppose that there is a. very large quantity of radium and other radioactive matter distributed over the surface of the earth. This radioactive matter must be continuously supplying heat to the earth, and it is of great interest to examine the magnitude of this heating effect and its probable bearing on the question of the origin and duration of the earth's internal heat.

In addition to the various properties I have enumerated, radium also gives out heat continuously and uniformly at a rapid rate. A quantity of radium supplies enough heat to melt more than its weight of ice per hour. A pound of radium in the course of a year will emit as much heat as that resulting from the combustion of 100 pounds of good coal. This heat emission of radium and of all the radioactive bodies is in reality a secondary property, for it is a consequence of the bombardment of the active matter by the α particles expelled from its own mass. The β and γ rays produce only a small percentage of the total heating effect. This heating effect of radium must always be proportional to the quantity of radium present and must persist, however sparse may be the distribution of radium throughout the earth's crust. Consequently, there must be a continuous supply of heat to the earth due to the radium and other radioactive matter distributed throughout it. But the heating effect due to a given quantity of radium does not last indefinitely. The radium breaks up into other forms and after 20,000 years only a small fraction of the radium would remain. This difficulty, however, is not serious, for it is now definitely settled that radium is produced from uranium and it is found that in old minerals the amount of radium is always proportional to the amount of uranium.

Now uranium is transformed extremely slowly in comparison with radium, and probably a period of at least one thousand million years would be required before the uranium was half transformed. Consequently, the supply of radium from the breaking up of uranium will keep up the amount of radium in the earth to a nearly constant value for periods measured by hundreds of millions of years.

We shall now consider briefly the ordinarily accepted theory of the origin of the earth's internal heat and of the age of the earth. It is known that the temperature of the earth steadily rises as we proceed from the surface inwards, and on an average rises 1° Fahr. for every fifty feet of descent. From the evidence of volcanic action, it is concluded that the interior of the earth is at a high temperature.

Lord Kelvin attacked this question of the age of the earth by supposing that the earth was originally at a temperature of molten rock and has since that time gradually been cooling by the radiation of heat through the surface into space. According to this theory, the temperature gradient near the surface of the earth has been gradually decreasing. Knowing the temperature gradient to-day, and the average conductivity and specific heat of the materials of the earth, it is possible by the aid of Fourier's celebrated analysis to deduce the interval that has elapsed since the earth was a molten mass. Some of the values of the quantities necessary in the calculation are uncertain within limits, but Lord Kelvin concluded that certainly not more than 100 million years can have elapsed since the surface of the earth was at a temperature capable of supporting animal and vegetable life. In later papers this estimate has been still further reduced, and the age of the earth is put as low as forty million years. I cannot here enter into the intermittent controversy that has raged for nearly half a century between Lord Kelvin on the one hand and the geologists and biologists on the other. The latter initially required a much longer period for the progress of geologic and biologic evolution than that allowed by Kelvin, but there appears to be a general consensus of opinion among geologists and biologists to-day, that a period of 100 million years allows sufficient time for the processes of evolution.

On the assumptions made by Lord Kelvin, there is no doubt of the general accuracy of the deductions. Let us however

examine these fundamental premises. The earth is assumed to be a cooling body isolated in space, and it is assumed that there has been no supply of heat to the earth since the cooling began; for Kelvin has conclusively shown that the heat supplied from ordinary chemical processes, that may be supposed to occur in the earth, is not sufficient to influence materially the conclusion as to the age of the earth's heat. But the discovery of the presence in the earth of active matter like radium which emits heat at a rapid rate, at once suggests the possibility that the earth is not a simple cooling body, but one in which heat is being steadily generated. In 1902, I made some calculations to determine how much radium (or other radioactive matter expressed in terms of radium) would be required to be uniformly distributed throughout the earth in order to maintain the present observed temperature gradient. In such a case, the heat supplied by the radium must exactly compensate for that lost from the earth by conduction to its surface and radiation into space. The calculations are simple, and show that a uniform distribution of radium amounting to only 1.7 x 10–13 gram of radium per cubic centimetre would suffice. From the data then available, I calculated that the amount of radium present in the earth was probably of the right order of magnitude to produce such a result.

Recently, the Hon. R.J. Strutt has made a number of systematic observations to determine the distribution of radium in the typical rocks of the earth's crust, and has obtained results of remarkable interest. Strutt collected a number of typical rocks, both igneous and sedimentary, obtained from widely different localities, and determined the amount of radium contained in them. The rocks were first of all obtained in solution and placed aside in closed vessels. After a definite time the emanation, generated by the radium contained in them, was boiled out, and passed into a suitable electroscope. The amount of radium in the solution was then determined by comparison with the effect in the electroscope due to the emanation from a standard solution containing a known quantity of radium bromide.

The following table shows the observed amount of radium in grams per cubic centimetre of rock for samples of igneous rocks.

No.	Name of rock	Locality	Density	Radium per gram in grams	Radium per c.c., in grams
1	Granite	Rhodesia	2·63	$9·56 \times 10^{-12}$	$25·2 \times 10^{-12}$
2	"	Lamorna Quarry, Cornwall	2·62	9·35 "	24·5 "
3	Zircon syenite	Brevig, Norway	2·74	9·30 "	25·5 "
4	Granite	Rosemorran, Cornwall (?)	2·62	8·43 "	22·1 "
5	"	Cape of Good Hope	2·67	7·15 "	19·1 "
6	"	Knill's Monument, near Carbis Bay, St. Ives, Cornwall	2·61	6·90 "	18·0 "
7	"	Shap Fell, Westmoreland	2·65	6·63 "	7·6 "
8	Elæolite syenite	Laurdal, Norway	2·70	4·88 "	3·2 "
9	Granite	Haytor, Devonshire	2·61	3·69 "	9·64 "
10	Blue ground	Kimberley	3·06	3·37 "	0·3 "
11	Leucite basanite	Mt. Somma, Vesuvius	2·72	3·33 "	9·07 "
12	Hornblende granite	Assouan, Egypt	2·64	2·45 "	6·47 "
13	Pitchstone	Isle of Eigg	2·41	2·06 "	4·97 "
14	Hornblende diorite	Schriesheim, near Heidelberg	2·89	1·98 "	5·73 "
15	Augite syenite	Laurvig, Norway	2·73	1·86 "	5·07 "
16	Peridotite	Isle of Rum	3·15	1·37 "	4·32 "
17	Olivine basalt	Talisker Bay, Skye	2·89	1·32 "	3·82 "
18	Olivine euchrite	Isle of Rum	2·97	1·28 "	3·80 "
19	Basalt	Victoria Falls	2·75	1·26 "	3·46 "
20	Hornblende granite	Mt. Sorrel, Leicestershire	2·71	1·25 "	3·38 "
21	Dolerite	Isle of Canna	2·95	1·24 "	3·65 "
22	Greenstone	Carrick Dû, St Ives	2·99	1·14 "	3·41 "
23	Basalt	Giants' Causeway, Antrim	2·80	1·03 "	2·89 "
24	Serpentine	Cadgwith, Lizard	2·60	1·00 "	2·60 "
25	Granite	Isle of Rum	2·61	0·723 "	1·89 "
26	Olivine rock	Isle of Rum	3·22	0·676 "	2·18 "
27	Dunite	L. Scaivig	3·34	0·664 "	2·22 "
28	Basalt	Ovifak, Disco Island, Greenland	3·01	0·613 "	1·84 "

I mentioned before that about 1.7 x 10–13 gram of radium per c.c. distributed uniformly throughout the volume of the earth, would keep up the earth's internal heat. An examination of the above table, however, shows that the surface rocks contain far more radium than this. As we should expect, the radium content varies considerably, but the poorest rock of all, Greenland basalt, contains more than ten times this estimate, while the average rock contains fifty or sixty times as much. An examination of the sedimentary rocks shows an average amount of radium somewhat smaller than that of the igneous rocks, but still of the same order of magnitude. Strutt considers that 5 x 10–12 gram of radium per c.c. is a fair average for the surface rocks of the earth—a quantity thirty times greater than that required to maintain the present temperature gradient. This is a surprising result, for although of necessity only a small number of rocks have been examined, yet we must consider that the results obtained by Strutt probably give the right order of magnitude for the distribution of radium in the earth's crust. It will be observed that very few rocks from the American continent figure on the above list. This omission will no doubt be soon rectified by other observers. It is of interest to note that Eve and MacIntosh of McGill University have recently examined the amount of radium in the typical rocks in the neighbourhood of Montreal, and have obtained an average value in substantial agreement with Strutt. By calculations based on the intensity of the penetrating or γ radiation at the earth's surface, Eve has deduced a value of the amount of radioactive matter in the earth's crust even greater than the average value found by Strutt. Not only therefore is the apparent amount of radium in the earth's crust sufficient to account for the maintenance of the earth's internal heat, but if uniformly distributed throughout its mass, there is far more than is required. The latter assumption would lead to the conclusion that the earth is growing hotter instead of colder—an explanation not likely to be regarded with favour. In order to get round this difficulty, Strutt suggests that the distribution of radioactive matter is not uniform throughout the earth, but is confined to a thin surface shell of the earth. Assuming the distribution of radium found by experiment to be uniform throughout this shell, it can readily be shown that its thickness is about 45 miles. In support of this explanation he cites the results of Milne, the seismologist, who concludes from an examination of the velocity of propagation of earth tremors through the earth, that there is a fairly abrupt transition of the material of the earth's crust at a depth of 30 miles. Below this depth, the material appears to be uniform, and transmits earth tremors at quite a different rate from the surface rocks.

On the assumption that radium is confined to a shell 45 miles deep, it is easy to calculate the temperature of the earth as we proceed downwards. The results are shown in Fig. 3.

The temperature should rise to about 1,500° C. at a depth of 45 miles. The temperature of the interior mass of the earth below this depth must be uniform and equal to 1,500° C.

It is difficult at present to advance satisfactory reasons why this superficial distribution of radium should occur. Temperature can have little if any effect, for Bronson has conclusively shown that the radiating power of radium is not altered by exposure to a temperature of 1,600° C.

There is another interesting point raised by Strutt in regard to the internal temperature of the moon. The latter is supposed

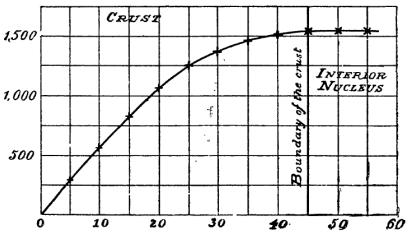


Figure 3

to have been initially separated from the earth's surface, and should thus contain the same average amount of radium as that found in the earth's crust. If this be the case, it can readily be deduced that the temperature gradient in the moon should be about eight times greater than in our earth. Taking into consideration that the force of gravity is small at the moon's surface, the conditions would appear to be very favourable for volcanic action in the moon. This is contrary to the general opinion that the lunar craters are extinct, but as Strutt points out, this view rests chiefly on an a priori conviction that the moon has no internal heat. Professor W.H. Pickering has pointed out that close students of the moon believe that changes are still occurring there.

I hope that I have made clear to you how the study of radioactivity has profoundly altered our views of the earth's internal heat. The conclusions advanced are by no means completely proved, but sufficient has been done to cast grave doubt on the validity of the older theories of the origin and variation of the earth's internal heat.

Age of Radioactive Minerals

This new point of view of regarding the supply of the earth's heat does not throw any definite light on the problem of the age of the earth. This want, however, is supplied by taking into account still another very remarkable property of radium. In addition to its property of radiating and of emitting an emanation, radium also steadily produces from itself another stable element, helium. This property of radium was first shown by Ramsay and Soddy, and has been amply confirmed by other investigators. The weight of evidence at the present time points to the conclusion that the a particle, expelled from radium and its products, is in reality a helium atom, which at the moment of its expulsion carries a positive charge of electricity. Whatever may be the position of helium in the general scheme of radioactive transformations, there is no doubt that radium produces helium at a slow but constant rate. The rate of production of helium has not yet been measured with accuracy, but it is probable that one gram of radium will produce per year about one tenth of a cubic centimetre of helium at standard pressure and temperature.

This rare gas helium, which next to hydrogen, has the lightest atom known to chemists, has had an unusually dramatic history. It was first discovered in the sun by means of the spectroscope by Lockyer in 1868, and hence its name. It was not found in the earth until 1895, when Ramsay showed that the gases liberated from the mineral cleveite, showed the spectrum previously attributed to helium in the sun. Now it is a very interesting fact that helium is· only found in quantity in the radioactive minerals. The presence of helium in these minerals was at first considered very remarkable, but is at once explained if the helium is produced in the mineral by the radium or other radioactive matter contained in it. Consider, for example, a very dense radioactive mineral from which the helium continuously generated by the radium cannot escape. The amount of helium in the mineral will steadily increase with time, and the total amount present should be proportional to the age of the mineral and the amount of radium contained in it. I have here some crystals of a new mineral, thorianite, found a few years ago in Ceylon, which contains about 12 per cent of uranium and about 70 per cent of thorium. This mineral on heating evolves a remarkably large quantity of helium—more than 10 c.c. per gram of the mineral. Now it is almost certain that the helium stored up in this mineral has been produced by the breaking up of the radium, contained in it since the formation of the mineral. Assuming the rate of production of helium by radium already mentioned, it can be calculated with some confidence that the mineral thorianite is at least 500 million years old, i.e., this interval of time must have elapsed since the formation of the mineral in the earth's crust. This is a minimum estimate, for probably some of the helium has in the course of ages escaped from the mineral. A similar result is obtained from consideration of other primary radioactive minerals. Most of them are apparently about 500 to 1,000 million years old.

When the constants involved in these calculations are accurately determined, I feel great confidence that this method will prove of the utmost value in determining with accuracy the age of the radioactive minerals and indirectly of the geologic strata in which they are found.

Conclusion

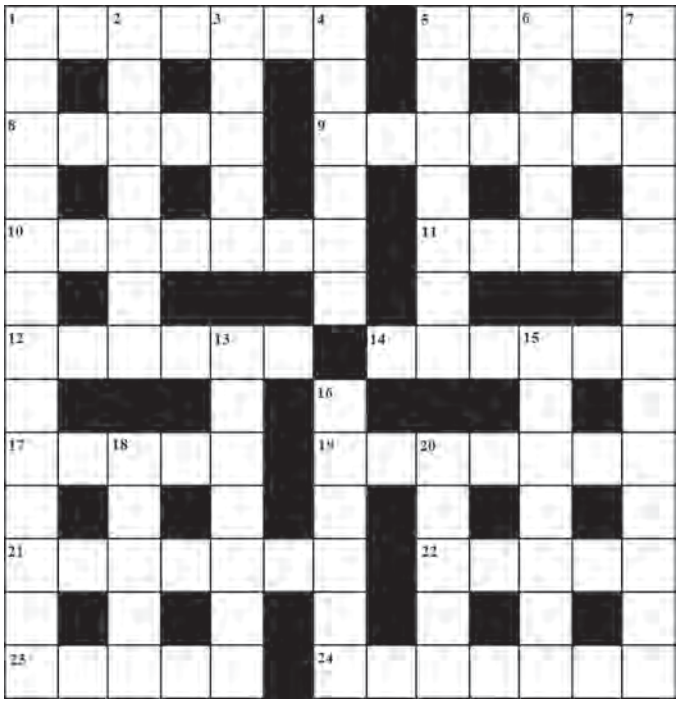
I have so far confined my attention to the earth and her satellite the moon. Is there any evidence of the presence of radium or other radioactive matter in the sun or in the stars? We may say at once that no definite evidence has yet been observed. From the similarity of the chemical constitution of the sun with our earth, we should expect the sun to contain radioactive matter also. The large amount of helium observed in the sun indirectly supports such a conclusion. Strutt found that stony meteors contained about as much radium as the surface rocks of the earth, indicating that these visitors from other systems also have their share of radium.

There is no obvious reason for supposing that the sun, at any rate during the initial stages of its condensation, contained much more radioactive matter than the earth. According to the condensation hypothesis of Kelvin and Helmholtz, the heat of the sun is derived from the gradual concentration of its material due to gravitation. On this hypothesis, Kelvin considers it improbable that the sun will continue to shine at its present brilliancy for a period more than 12 million years and probably much less. There is one possibility, however, which may greatly extend the estimate of the duration of the sun's heat. At the enormous temperature of the sun, it is possible that ordinary matter may become radioactive, i.e., it may break up into simpler forms, with the evolution of a great quantity of heat. If ordinary matter, in undergoing such change, emitted as much heat as radium in its transformation, this new source of heat would allow the sun to shine for a much longer period than the older theory allows. This is only a speculation, but one that must be taken seriously into consideration in coming to a decision of the probable duration of the sun's heat, and consequently of the time for habitation of our globe. ✶

[See https://en.wikipedia.org/wiki/Ernest_Rutherford, Ernest Rutherford held a professorship at McGill University, Montréal, at the time of this paper.]

Astrocryptic

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



ACROSS

1. Former president soundly led us to a constellation (7)
5. Toronto has absorbed many of these (5)
8. Much-peered-at star made of coral (5)
9. Double star in Libra, variable, with neon core (7)
10. Oddly close location of impacted quartz (7)
11. Martian winds turn a dune into these at Hyperboreae (5)
12. Nod off mean like Earth over a saros (6)
14. I left Artemis in confusion, rowing gently down it (6)
17. Earth rotates beneath queenly nebula (5)
19. First NEA particle charged with destroying ancient craters (7)
21. You once returned after north wind blew around western observatory (7)
22. Mars turns around western group of insects (5)
23. Around Jupiter rotates a real satellite (5)
24. Abundant in Moon rocks yet empty at TRIUMF before closure (7)

DOWN

1. Ron's preaching about dark clouds in Ophiuchus (8,5)
2. Like Musk, the field of an Astroscan (7)
3. Make a mistake by artificial intelligence? My star's in Cepheus! (5)
4. She has honorary role in a remake of Grease (6)
5. Comet Tuttle drops the French around falling tide (7)
6. Planet seen right in Harry Chapin's radio station (5)
7. First manmade moon, super or mini, arranged period of few sunspots (6,7)
13. Pedro's aunt ain't in orbit around Uranus (7)
15. After some hesitation, India roils from the river (7)
16. Layer you once saw on yellow track of the main sequence (6)
18. Back-ordered parts arrive in NASA's motto (5)
20. Beginning of the Moon setting (5)

Answers to previous puzzle

Across: **1** CANAL (Can+Al)); **4** OCCATOR (OC+anag); **8** RHOMBUS (2 def); **9** ORBIT (orb+it); **10** INERT (anag); **11** RANGERS (2 def); **12** INTERGALACTIC (anag+lactic); **16** COLOMBO (2 def); **18** G STAR (g(rev-n)r); **20** ANSER (hom); **21** ION TAIL (anag); **22** TROJANS (2 def); **23** BREIT (hid)

Down: **1** CIRCINI (hid, rev); **2** NIOBE (2 def); **3** LOBSTER (anag); **4** OBSERVATORIES (OB+anag+tories); **5** CROWN (2 def); **6** TUBBETT (Tubb+ET+t); **7** RATES (anag); **13** TELESTO (anag); **14** ALGENIB (anag); **15** CIRCLET (circle+t); **16** CHART (c(har)t); **17** MARIA (2 def); **19** TRACE (E(car)T, rev)

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- Discovery through the scientific method

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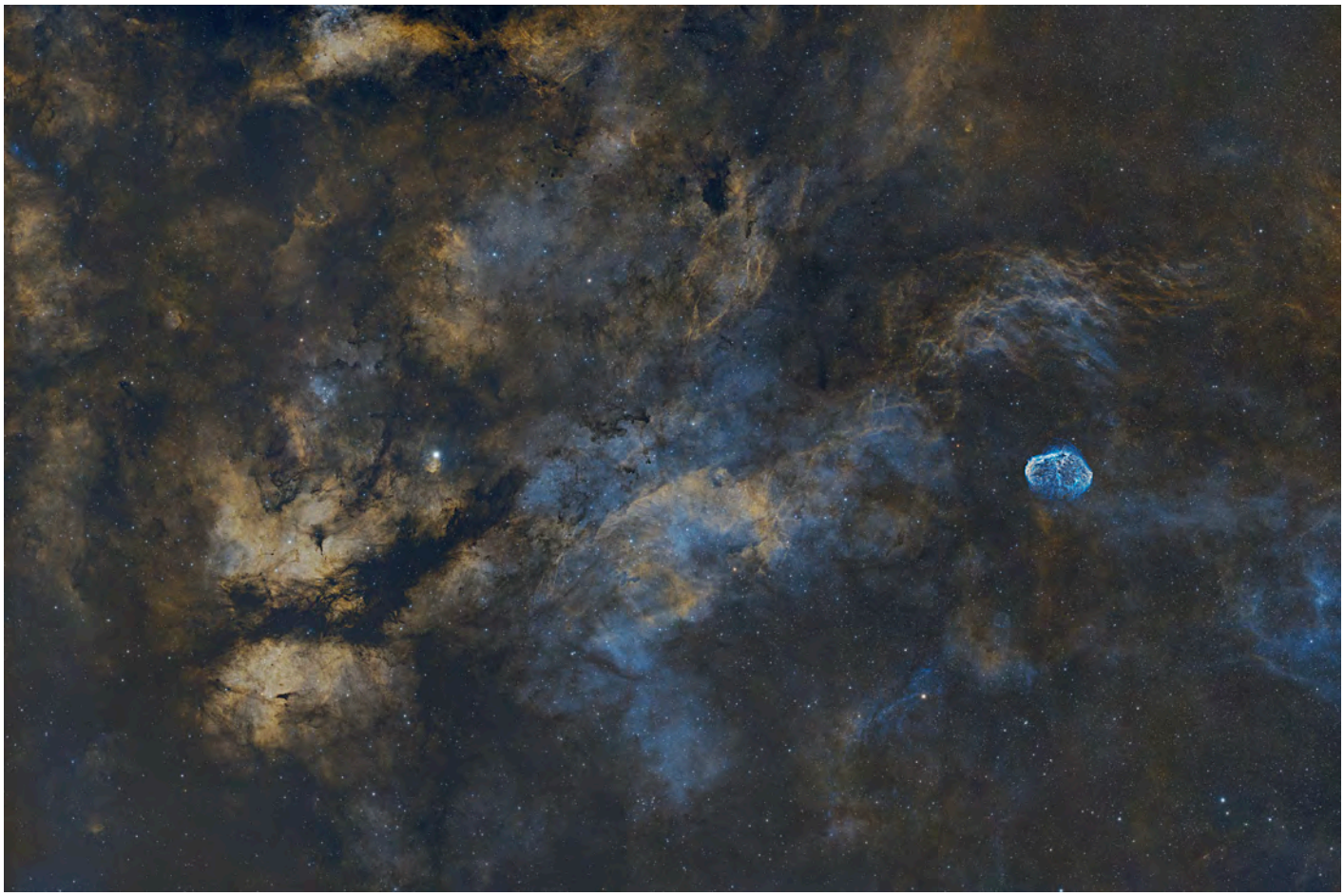
Journal
Nicole Mortillaro, B.A.A., Toronto

Observer's Handbook
James Edgar, FRASC, Regina and Halifax

Observer's Calendar
Chris Beckett, B.A. Philosophy, M.P.A., Kitchener-Waterloo

Great Images

By Liala Halawa



Liala Halawa imaged the Sadr region in Cygnus, also capturing the Crescent Nebula (NGC 6888). Liala used an AM3 mount, Redcat 71, ASI Air Plus, ASI 6200MC-P, ASI 120mm guide camera, ZWO 30F4 mini scope and Askar D1 (narrowband) filter for a total integration time of 12 hours.144x300s.



Journal

James Edgar snapped this image of the aurora from his back yard on the night of 2007 May 31. His Canon 20D was pointed straight up, capturing not only the aurora overhead but some star trails as well. Details: Canon EOS 20D ƒ/3.5 for 10s 18mm lens at ISO1600.