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Journal

Le Journal de la Société royale d'astronomie du Canada

PROMOTING ASTRONOMY IN CANADA

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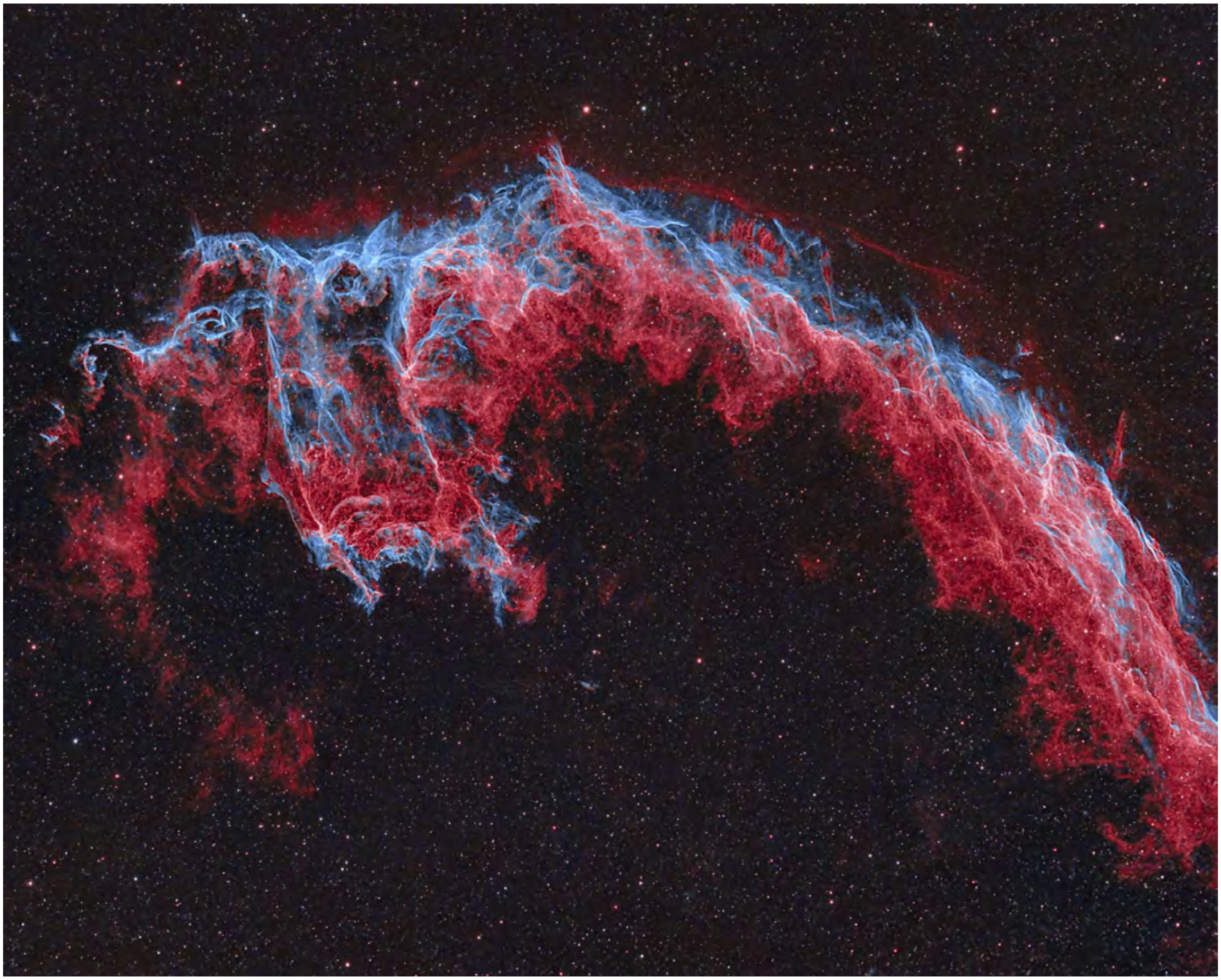
Photometric Timing and Fourier Orbital Modelling of the Eclipsing M-Dwarf Binary BX Trianguli

Wanted: Astronomer In Residence in Namibia—Apply Now!

Large Magellanic Cloud

Great Images

By Gary Crawford



Gary Crawford imaged the IC 1340 portion of the Eastern Veil Nebula (NGC 6992), known as the Bat Nebula. "This is an Hα OIII RGB image, one of my fall projects. I accumulated 20 h 25 min total integration, about half with an Antlia dualband filter and the other half with the Optolong quadband filter, the latter to cope with the moonlight to collect broadband data," he says. He used a William Optics 156-mm APO, iOptron CEM120 on a SkyShed pier, ASI2400MC Pro, Antlia 3-nm dualband filter, Optolong L-Quad Enhance filter, PrimaLuce Lab Arco rotator and Sesto Senso 2 focuser, WO Guide Star 61, and ASI120MM, all housed in his SkyShed in Lowbanks, Ontario.

Journal

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Société Royale d'Astronomie du Canada

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This image of the Large Magellanic Cloud was obtained over four nights, 2025 April 25 to 28, by Greg Lisk of the Belleville Centre from the Atacama Desert in Chile. He used an Askar FMA180 Pro astrograph, ASI2600MC PRO Camera ZWO AM3; Processed with Siril/Graxpert/SetiAstro Suite

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

The Value of Outreach

Brendon Roy (Thunder Bay), President
novationheart@hotmail.com

I was recently invited to join a local group of Beaver and Cub Scouts for a night under the stars—of course, to help show them the night sky.

I have considered myself an amateur astronomer for a very long time. Throughout much of my "career" as an amateur astronomer, I have focused on educational outreach as a way to promote the science of astronomy, The Royal Astronomical Society of Canada (RASC), and the importance of being a well-rounded member of society. Over time, as my career progressed, I was fortunate enough to upgrade my equipment as increased disposable income allowed.

Gone are the days of using equipment held together by hope—thinking, "It'll be fine" (it often wasn't). Those days have been replaced with better equipment, owned by someone who understands how to plan and evolve an observing setup responsibly. Many of my fellow amateur astronomers have followed a similar path as they grew into the knowledgeable and dedicated individuals I know today.

When you live and breathe astronomy day in and day out, it can be easy to forget that not everyone has the same access to the night sky. I'm not only referring to the constraints imposed by light pollution, but also to social and economic barriers.

For this outreach event, I set up under less-than-ideal observing conditions using a simple, easy-to-deploy telescope. As I assembled it, the excitement of both the children and the chaperones grew. Slowly but surely, the standard questions began—questions I was more than happy to answer and expand upon. One by one, everyone took a turn at the eyepiece, viewing the Moon and the brighter objects in the sky, accompanied by sounds of delight and curiosity.

As the event drew to a close, I was thanked for my time and for helping the troop learn about the night sky. Then, from the darkness, came a single comment that surprised me and instantly took me back to the first time I looked through an RASC member's telescope at M42. It was a simple, honest statement—one that lingers long after you hear it:

"I have never had the opportunity to look through a telescope."

This is why I do outreach. This is why I value the work of the RASC—to give people the opportunity to see the world from a new perspective, one they might not otherwise experience. I hope those moments contribute to personal growth, and if we are fortunate, to lifelong supporters of the causes the RASC champions. Above all, it is about giving others the chance to see and do something they simply haven't had access to before.

I hope this story reminds you of a time when your own interest in astronomy was first kindled—or rekindled—under dark, clear skies.✶

News Notes / En manchette

Compiled by Jay Anderson

Surprising, stable neighbourhood around Sagittarius A*

Over the past few decades, high-resolution studies of the core of the Milky Way—Sagittarius A*—have revealed a dynamic high-density environment with old and young stellar associations, spiralling streams of ionized gas, a dust-and-gas circumnuclear disk, and a 4 million-solar-mass, flaring black hole. Though an image of the 1-au black hole has been constructed from radio and infrared observations, the characteristics of the nearby surrounding environment are still being disentangled.

One denizen of the core's neighbourhood is the "S-star" Cluster, a group of relatively young (6–20 My) stars orbiting around Sgr A* with elongated orbits and short periods. The S-cluster consists of two discrete populations: a young, main-sequence group of hot B stars and a collection of dusty "G" objects that have so far eluded identification. G objects behave like stars but look like clouds of gas and dust. The presence of the young B stars was unexpected, as the tidal forces of Sgr A* were thought to be too strong to permit the formation of stars from a dust and gas environment. The G-object circumnuclear disk may be a remnant of an original star-forming molecular cloud that once provided the material to build the B stars.

Recently, an international research team led by PD Dr. Florian Peissker at the University of Cologne has used a new observation instrument, ERIS (Enhanced Resolution Imager and Spectrograph), at the Very Large Telescope (VLT) facility in Chile to show that several of the "dusty objects" follow stable orbits around Sagittarius A*. This is surprising as earlier studies had surmised that some of these objects would be swallowed up by the black hole. The new data refute this assumption.

The researchers focused on four of these unusual celestial bodies, which have been the subject of much discussion in recent years. In particular, one object, G2, was long regarded as a pure dust and gas cloud. It was thought to have been initially elongated by the gravitational pull of Sagittarius A*, a process known as "spaghettification," before heading to destruction. However, the specific observations made with ERIS, which captures radiation in the near-infrared range, show that G2 follows a stable orbit. This is an indication that there is a star inside the dust cloud. These results also confirm that the centre of the Milky Way, though occasionally destructive, can also be surprisingly stable.

Previous work by the research team shed some light on what the mysterious G objects could be. The team proposed that they might actually be a combination of binary stars that have not yet merged and the leftover material from already-merged stars.

In addition, a binary star system known as D9, which Peissker and his team discovered in 2024, is the first known double-star system to be observed so close to a supermassive black hole. D9 is estimated to be only 2.7 million years old, and it was thought that the strong gravitational force of the nearby black hole would cause it to merge into a single star within just one million years, a very narrow timespan for such a young system. Instead, D9 remains stable despite the enormous tidal forces of the black hole. Its current binary nature is evidence that gravitational forces around Sgr A* do not have the potency to completely disrupt nearby stellar-formation processes.

In theory, the stars involved in D9 could merge to form a single, more massive star due to the strong tidal forces. However, the ERIS data so far show that D9 remains intact. The same applies to other objects, nicknamed X3 and X7, which also orbit in stable orbits and are therefore less fragile than earlier models had suggested.

Figure 1— Image showing the location of the newly discovered binary star D9, orbiting Sagittarius A. It is the first star pair ever found near a supermassive black hole. The cut-out shows the binary system as detected by the SINFONI spectrograph on ESO's Very Large Telescope. While the two stars cannot be discerned separately in this image, the binary nature of D9 was revealed by the spectra captured by SINFONI over several years. These spectra showed that the light emitted by hydrogen gas around D9 oscillates periodically towards red and blue wavelengths as the two stars orbit each other. Credit: ESO/F. Peissker et al., S. Guisard.*

"The fact that these objects move in such a stable manner so close to a black hole is fascinating," says Peissker. "Our results show that Sagittarius A* is less destructive than was previously thought. This makes the centre of our galaxy an ideal laboratory for studying the interactions between black holes and stars."

The results also demonstrate that the processes at the centre of the Milky Way are more complex than previously assumed. "The supermassive black hole at the centre of the Milky Way has not only the capability to destroy stars but it can also stimulate their formation or the formation of pretty exotic dusty objects, most likely via mergers of stellar binaries," says Michal Zajaček from Masaryk University in Brno (Czechia).

Future observations from the ERIS and the Extremely Large Telescope (ELT)—which is currently under construction—should help to further track the evolution of these objects and to understand how stars can survive even in the extreme regions of the Universe.

Prepared in part with material provided by ESO.

Stellar clusters of clusters

Open clusters of stars are well known to every astronomer, a stellar configuration highlighted by the Pleiades cluster in Taurus, now a prominent part of the night sky. Clusters consist of dozens to thousands of stars that have formed from the same molecular cloud. Most are independent stellar collections, but some fraction forms in groups, typically as a binary pair like the Double Cluster in Perseus (*h* and χ Persei). Some, however, can form richer associations with several nearby partners.

Binary clusters (BCs) are defined as pairs of open clusters closely associated both by position and kinematics. They provide insight into how stars form within giant molecular clouds, making them important indicators of star formation and cluster evolution. In one scenario, cluster partners form from the same giant molecular cloud at the same time and so have related compositions, dynamics, and ages. In a different setting, one cluster may trigger the formation of another, perhaps through supernovae explosions or by stellar winds. These will have a small age difference, but more disparity between composition and dynamics. A third possibility is that clusters will interact gravitationally and become partners, having formed in different places and different times. At the end of the spectrum of binary clusters are those that are simply aligned in the sky and have no association beyond that.

This work was conducted by Ph.D. candidate Liu Guimei and her supervisor Prof. Zhang Yu from the Xinjiang Astronomical Observatory, together with their collaborators from the Shanghai Astronomical Observatory of the CAS. To begin, they used an existing catalogue of 7,167 star clusters reduced to a 4,084-member higher-quality sample that was then subject to further analysis.

For this ongoing analysis and to derive binary selection criteria, the team constructed and tested a randomized mock sample of clusters, from which they deduced that a separation of less than 260 ly and a velocity difference of 40 km/s would identify nearest neighbours in a sample. They then analyzed nearly 4,000 high-quality open clusters using *Gaia* DR3 astrometry and kinematic data, looking for clusters that shared even more stringent limits: differential tangential velocities <10 km/s and a close spatial proximity <160 ly. This reduced the sample to 400 potential binary clusters.

To further refine the identification of binary clusters, the research team extracted clusters for which spectral information was available, arriving at a "Golden" sample of 146 clusters with radial-velocity measurements. All of the 400 cluster candidates were then tested against age (<30 My) and differential velocity (<20 km/s) to separate primordial clusters from the sample. Those that had a large difference in age but a low differential velocity were assumed to be gravitationally captured systems, while those clusters that failed both the age and velocity limits were gravitationally unbound.

Using this framework, the researchers classified the 400 binary-cluster candidates into three categories: primordial binary clusters, gravitational-capture binary clusters, and optical pairs (chance alignments). Cross-matching with previously reported binary clusters shows that the method recovers a large fraction of known systems. Despite the stricter selection criteria, the study also added 268 newly identified physical binary clusters to the galactic sample.

Further analysis shows that 61 percent of the candidate binary clusters are highly consistent in age and kinematics, supporting formation from the same giant molecular cloud. Significant tidal interactions were displayed by 83 percent of the sample. The strength of the interaction clearly correlated with spatial separation—the closer the pair, the stronger the mutual attraction and perturbation.

Overall, the study suggests that about 17 percent of open clusters are currently in binary or multiple-cluster systems, and roughly 10 percent likely formed as primordial binary clusters. These fractions align well with theoretical and observational estimates. In a significant number of cases, binary clusters were also interacting with other clusters, either single or multiple, leading to systems with many members in a group.

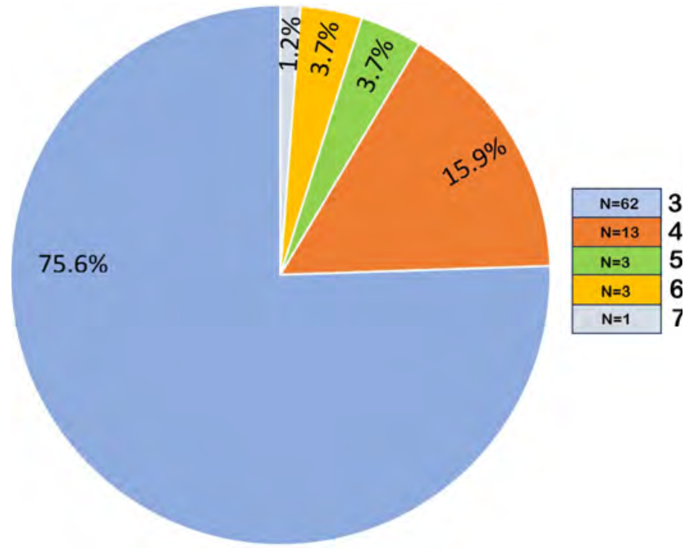


Figure 2 — Pie chart showing the number of star clusters that make up each multi-cluster group. The numbers along the right side show the number of samples (N) in the group. The values in the boxes show the number clusters in each group (i.e. 1 group with 7 associated open clusters). Image after the Xinjiang Astronomical Observatory.

Tidal interactions between binary clusters have a significant impact on their evolution. The results of the study suggest that many of these systems are interacting, so that a pair may be tidally distorting each other, exchanging stars, or facilitating the dissipation of the clusters.

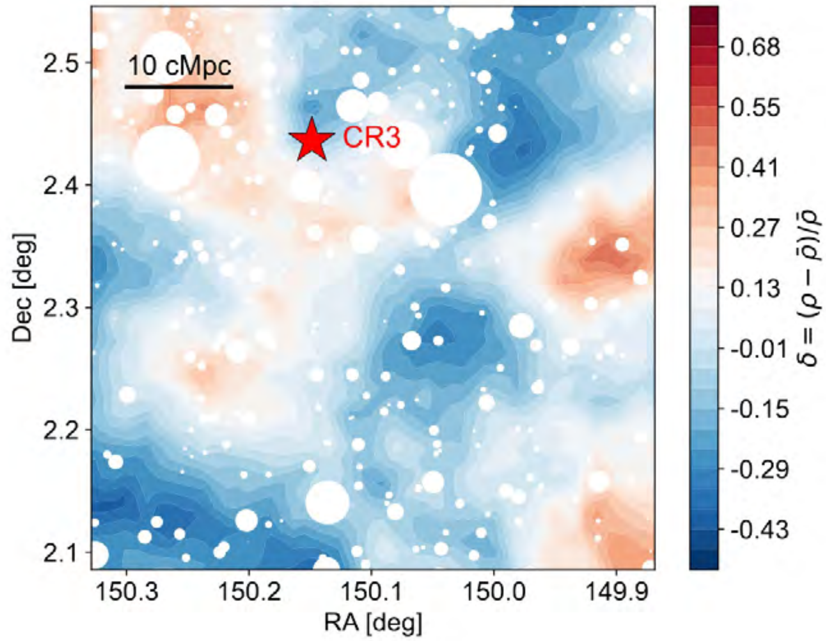
This study demonstrates that hierarchical cluster formation is an important process across multiple scales and provides key observational evidence for the formation mechanisms and dynamical evolution of multi-cluster systems.

Prepared in part with material provided by the Chinese Academy of Sciences.

The oldest stars, at last?

An international collaboration led by the Department of Astronomy at Tsinghua University, Haidian, Beijing, has discovered a galaxy extremely poor in metals, suspected to contain first-generation stars, by using combined observations from the *James Webb Space Telescope* (JWST), the Very Large Telescope (VLT), and the Subaru Telescope. The galaxy, named "CR3" is located in the "cosmic noon" period, dating back to approximately 11.5 billion years ago. CR3 has the distinction of being the galaxy with the lowest abundance of heavy elements found at cosmic noon, with an elemental content close to that theoretically predicted for first-generation galaxies. Stars in that era are composed almost entirely of hydrogen and helium and are known as Population III stars.

Figure 3 — Large-scale environment of the CR3. The background shows the galaxy overdensity field at z = 3.2 ± 0.3 based on COSMOS2025 LePhare photometric redshifts, with red (blue) indicating overdense (underdense) regions. Masked regions are shown in white. Image: Sijia Cai, et al., Department of Astronomy, Tsinghua University.



This discovery of such stars is akin to finding a living fossil in the middle-aged Universe, suggesting that pristine star formation may have persisted longer than previously believed, and revealing the inhomogeneity and complexity of cosmic chemical enrichment.

Cosmic noon is the period between 1 and 4 billion years after the Big Bang in which most of the Universe's stars formed—a time when new galaxies experienced very large rates of star formation. The period ended when a quenching process shut off the supply of dust and gas needed to manufacture stars. Some astronomers suspect that the formation of supermassive black holes in the cores of galaxies was responsible for the drop in star production.

Theoretical studies suggest the host galaxies of the first stars emerged only a few hundred million years after the Big Bang. They and their stars were composed almost entirely of hydrogen and helium, with the stars having extremely high masses, temperatures, and short lifetimes. Because they were metal-free (lacking elements heavier than helium), their host galaxies would show spectra very different from later and current generations: strong hydrogen and helium recombination lines, but almost no oxygen or other metal lines. Because these objects are both short-lived and extremely distant, they have escaped conclusive detection, though there are several candidates found in other research. Finding these "first galaxies" remains a long-pursued yet unrealized goal for astronomers.

How the Population III stars formed and died is a major unsolved mystery in the field of galactic cosmology. In particular, their existence serves as compelling fossil evidence supporting the Big Bang theory. Consequently, uncovering their history remains one of the core scientific objectives of the James Webb Space Telescope's (JWST) mission.

Conventional models predict that, as the Universe evolves, the intergalactic medium (IGM) becomes rapidly enriched with metals from successive supernovae, effectively ending the formation of first-generation stars after the reionization epoch ($z \sim 6$). In spite of this, the team has identified an exceptionally pristine galaxy, CR3, at redshift $z = 3.19$—about 11.5 billion years ago, during cosmic noon. Its spectrum only shows strong hydrogen and helium emission lines, but no detectable metal lines. The galaxy appears almost dust-free, extremely young (≈ 2 million years), and low in mass ($\approx 6.1 \times 10^5\ M_\odot$), displaying typical features of a theoretically predicted pristine system. The discovery of CR3 therefore provides observational evidence that Population III star formation may have continued well into the cosmic noon epoch, challenging existing theoretical frameworks.

Population III stars are predicted to be very massive and extremely hot ($>10^5$K), producing a strongly ionizing radiation that would in turn excite very strong hydrogen and helium emissions, as found in CR3. Cosmological simulations suggest that Population III star formation can continue at a low rate to more recent times, provided the host galaxy lies in a relatively sparse part of the Universe.

Based on current standard abundance calibration methods, CR3 stands out among currently known cosmic noon galaxies as the one with the lowest inferred heavy-element abundance.

The April 2026 *Journal* deadline for submissions is 2026 February 1.

See the published schedule at rasc.ca/sites/default/files/jrascschedule2026.pdf

CR3 is the only known isolated galaxy at $z \sim 3$ (11.5 Gy) with a gas-phase metallicity as low as that of the earlier, most metal-poor clumps or galaxies at $z \gtrsim 6$ (12.8 Gy), highlighting that such low-metallicity environments can exist well after the reionization era.

Why could such a primitive galaxy exist in a Universe already so evolved? Environmental analysis shows that CR3 lies in a slightly underdense region (its nearest neighbour is about 97 Kly distant) within the large-scale cosmic environment. The team hypothesizes that in such sparsely populated environments, metal-enriched outflows from nearby galaxies may not have reached CR3, and that galaxy mergers and interactions are relatively rare. This isolation could allow pockets of pristine gas to "survive" until later times, delaying the process of metal enrichment.

Future spectroscopic observations with higher resolution and signal-to-noise ratio will be crucial to confirm the true nature of CR3. Its discovery is expected to motivate the construction of a larger sample of similar first-galaxy candidates. Such a sample will provide key observational insights for understanding the history of star formation and the evolutionary processes of galaxies in the early Universe.

Composed in part with material provided by Tsinghua University.

Lightning on Mars—or at least a small spark

Scientists have detected what they believe to be lightning on Mars by eavesdropping on the whirling wind recorded by NASA's Perseverance rover. The crackling of electrical discharges was captured by a microphone on the rover, a French-led team reported in November. The researchers documented 55 instances of what they call "mini lightning" over two Martian years, primarily during dust storms and dust devils. Almost all occurred on the windiest Martian sols, or days, during dust storms and dust devils.

Just centimetres in size, the electrical arcs occurred within 2 metres of the microphone perched atop the rover's tall mast, part of a system for examining Martian rocks via camera and lasers. Sparks from the electrical discharges—akin to static electricity here on Earth—are clearly audible amid the noisy wind gusts and dust particles smacking the microphone.

Scientists have been looking for electrical activity and lightning at Mars for half a century, said the study's lead author Baptiste Chide, of the Institute for Research in Astrophysics and Planetology in Toulouse. The dusty atmosphere of Mars undergoes aeolian processes ranging from wind-blown dust and sand, metre-to-hundred-metre-sized dust devils to thousand-kilometre-scale dust storms, all of which, in Earth's deserts, can become electrified through triboelectric charging (electric charge transfer between two objects when they contact or slide against each other).

"It opens a completely new field of investigation for Mars science," Chide said, citing the possible chemical effects from electrical discharges. "It's like finding a missing piece of the puzzle."

The evidence is strong and persuasive, but it's based on a single instrument that was meant to record the rover zapping rocks with lasers, not lightning blasts, said Cardiff University's Daniel Mitchard, who was not involved in the study. What's more, he noted in an article accompanying the study in the journal *Nature*, the electrical discharges were heard—not seen.

"It really is a chance discovery to hear something else going on nearby, and everything points to this being Martian lightning," Mitchard said in an email. But until new instruments are sent to verify the findings, "I think there will still be a debate from some scientists as to whether this really was lightning."

Lightning has already been confirmed on Jupiter and Saturn, and Mars has long been suspected of having it too.

To find it, Chide and his team analyzed 28 hours of Perseverance recordings, documenting episodes of "mini lightning" based on acoustic and electric signals. Electrical discharges generated by the fast-moving dust devils lasted just a few seconds, while those spawned by dust storms lingered as long as 30 minutes.

"It's like a thunderstorm on Earth, but barely visible with a naked eye and with plenty of faint zaps," Chide said. He

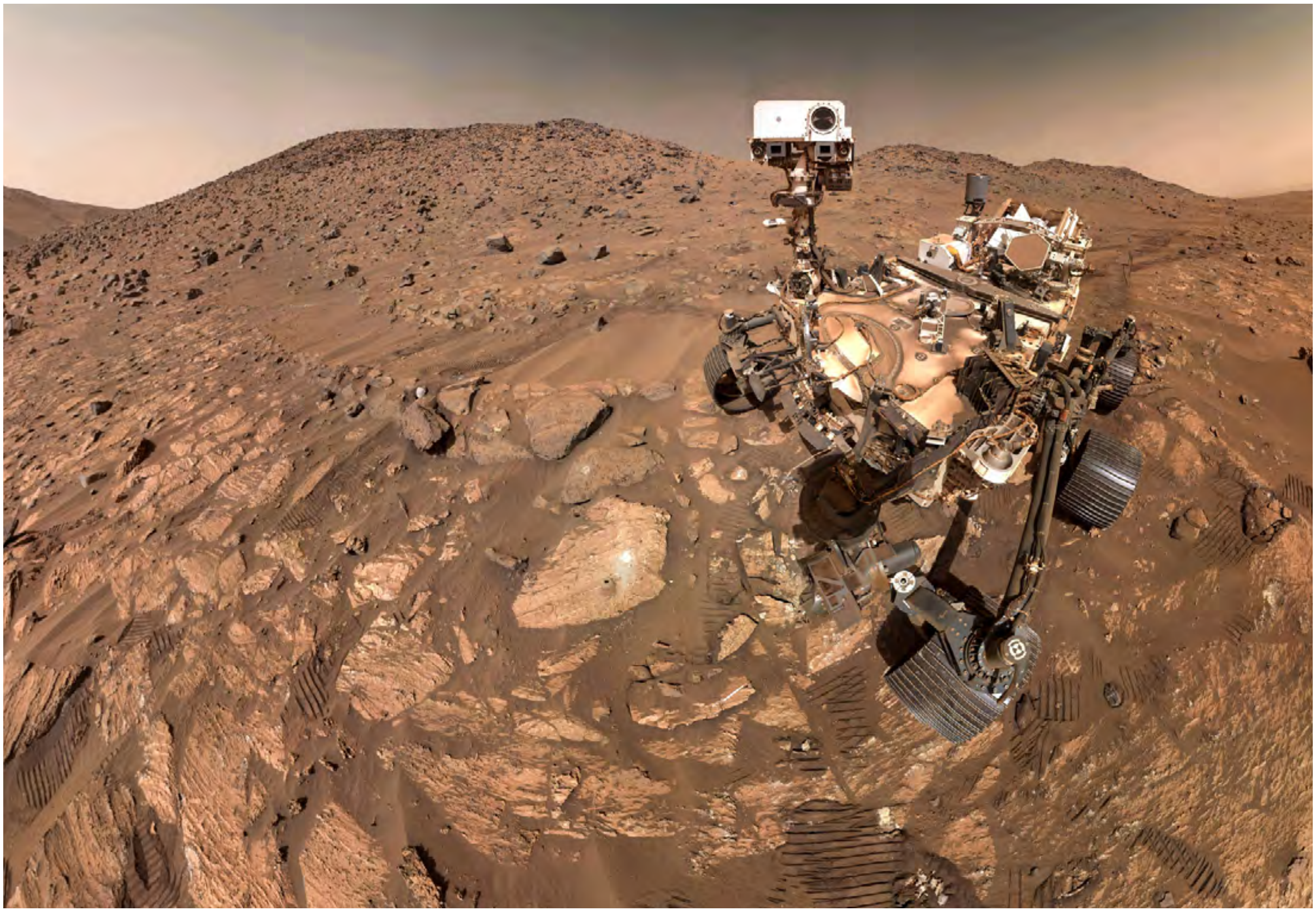


Figure 4 — A selfie of the Perseverance Mars rover, on 2024 July 23, stitched together from 62 individual images. Image: NASA

noted that the thin, carbon dioxide-rich Martian atmosphere absorbs much of the sound, making some of the zaps barely perceptible. However, Mars's atmosphere is more prone than Earth's to electrical discharging and sparking through contact among grains of dust and sand, according to Chide.

"The current evidence suggests it is extremely unlikely that the first person to walk on Mars could, as they plant a flag on the surface, be struck down by a bolt of lightning," Mitchard wrote in *Nature.* But the "small and frequent static-like discharges could prove problematic for sensitive equipment."

These aren't the first Mars sounds transmitted by Perseverance. Earthlings have listened in to the rover's wheels crunching over the Martian surface and the whirring blades of its no-longer-flying helicopter sidekick, Ingenuity.

Composed with material provided by NASA. ✶

Featured Article / Article de Fond

Wanted: Astronomer In Residence in Namibia—Apply Now!

by Alister Ling, Edmonton
(dawnskygaze@gmail.com)

Imagine soaking in awesome southern skies for 8 hours with an 11-inch (280 mm) SCT all to yourself in exchange for 1–2 hours of outreach-style astronomy...for 60 nights in a row!

Thanks to an enthusiastic recommendation from fellow RASC member Alan Whitman and the generous support from my wife Valerie holding down the fort back home, I was able to live this incredible opportunity from mid-May to the end of July 2025. The AndBeyond company runs several lodges in Africa providing high-end travellers interactive experiences with nature. They advertise that their Sossusvlei Desert Lodge in southwestern Namibia is adjacent to an internationally accredited Dark Sky Preserve, giving guests an unparalleled view of the sky guided by a knowledgeable astronomer.

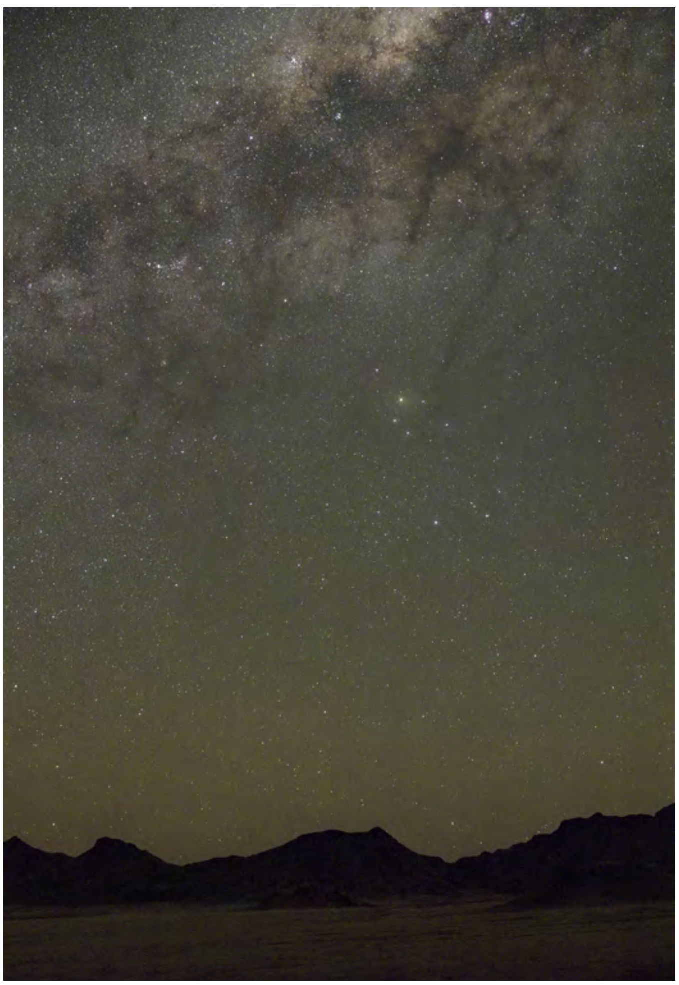


Figure 1 — Scorpius hanging in airglow. The ground here is not stacked separately, the stars light it up in this single unprocessed image, Canon Ra for 8 s, ISO 25600 with a 35-mm lens at f/3.5.

The lodge provides you with crew quarters (equivalent to a quiet Best Western style queen room), gourmet food and drink, laundry service, and chances to go out on excursions when guests free up their spot due to exhaustion. You pay your own airfare and travel insurance, but you actually save money because your personal expenses are basically nil while you're there—a mighty fine gig! AndBeyond is currently having trouble finding folk like us, to my surprise. The key hurdle seems to be getting the time off from work and/or being away from family/home for eight or more weeks. Six is less than ideal but could be negotiated. The Wifi is very good, allowing a "work from home" arrangement, best done near full Moon. Insufficient daytime sleep and caffeinated nights are a bad idea!

"Surreal" is the only word I can use to describe how I felt during my first two weeks. I kept expecting a *Twilight Zone* twist leading me to Purgatory! The sky is so dark that an OIII filter rarely improves the view, while the Milky Way seems absurdly bright, making the ground visible enough for me to walk the 150 metres to my room safely without a light. In May I was observing in shorts and a t-shirt until 2 a.m.—no insects, no dew. Record lows in July however are −3 °C, necessitating autumnal night clothing.

The lodge is decked out with red fixtures to keep white light to a minimum, but there is spillage from the dining area occurring for an hour or so after evening twilight and before breakfast. The wall of the observatory is just high enough that none of that is visible at the eyepiece. The worst source of light pollution is the zodiacal light. Seriously. It reduces contrast enough that should you want to chase fainter objects along the ecliptic you should plan to catch them in the darkest part, about 20 degrees from the antisolar point. Any closer gets you background light from the gegenschein.

Part of your outreach is helping the guests use their smartphones for Milky Way keepsakes, either at the start or end of their viewing session, providing you with a segue to talk about light pollution and eye function in the dark. Many of them have never even looked through a telescope let alone been outside of a metropolis. Several visitors from Australia and South Africa were familiar with the Southern Cross but hadn't seen more than a dozen stars before. A handful had been to Australia's outback, the Atacama Desert, Mauna Kea in Hawaii, or African game parks, but only a couple came explicitly to capture the iconic scene of the Milky Way above a lone tree. Many nights I endured a broken sleep cycle, encouraging guests to stop in from 5–6:30 a.m. for views of the Pleiades, Venus, and Saturn, but my true reward was spending the preceding two hours observing the Large Magellanic Cloud.

Plus-ones are welcome, but they need to be skywatchers or enjoy solo walks and e-bike rides in the desert wilderness while

Figure 2 — Observing the Large Magellanic Cloud. The local illumination was on only for the picture. Canon Ra, 35-mm lens f/2.8 for 10 s at ISO 25600, single unprocessed jpg.

you're sleeping after a long night. There is no TV. Consider having them stay during your last week then you head out together to the big game safaris or gorilla encounters elsewhere in Africa. This particular lodge focuses on the wilderness and desert isolation experience with the night sky playing a notable role. Upon arrival, I was greeted with "welcome to Mars!" While there are oryx, zebras, antelope, ostrich, jackals, and falcons that visit the waterhole directly out front, you won't see giraffes, elephants, lions, or exotically coloured birds. It's not easy for non-astronomy acquaintances and relatives to understand that the animals you've taken pictures of are Scorpius, Toucana, Grus, and Corvus but not elephants, hippos, or rhinoceros.

If you can handle being away from home and family for two months while being a service-provider on an unbroken string of day and night interactions with guests, send me a short run-down of your RASC outreach experience and I'll put you in contact with the lodge manager.

In future articles I will recount some of my unusual astronomical excursions and revelations, highs and lows during this fantastic southern sky observing adventure of 78 nights in a row. ✶

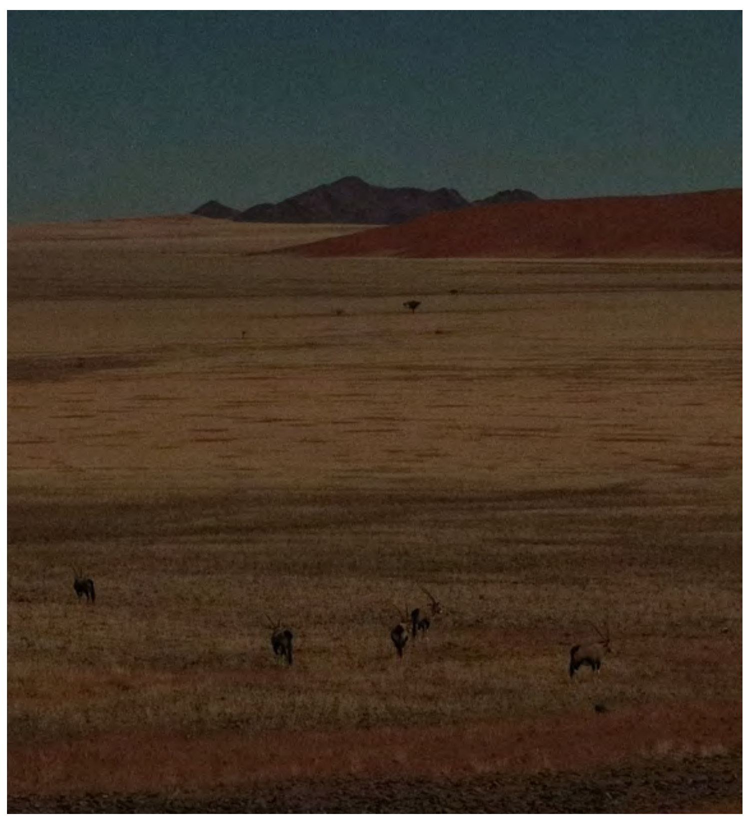


Figure 3 — Oryx by the light of the full Moon. Canon Ra, for 1 s at ISO 25600, with 70-mm at f/5.6.

Research Article / Article de Recherche

Photometric Timing and Fourier Orbital Modelling of the Eclipsing M-Dwarf Binary BX Trianguli: A Baseline for Exoplanet Monitoring

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Abstract

We present photometric timing and orbital modelling of BX Trianguli, a short-period eclipsing M-dwarf binary system. Using time-series observations from two sessions with 16-inch ground-based telescopes, we obtained high-cadence differential light curves covering the full orbital phase. Mid-eclipse times were determined with timing uncertainties of ~20–90 seconds, sufficient for eclipse timing variation (ETV) analysis. The system's light variations were modelled using a 3-harmonic Fourier series. The resulting empirical model closely reproduces observed flux variations and eclipse timing, providing a stable baseline for future ETV studies. This work supports the use of small-aperture telescopes in generating predictive models for exoplanet detection in compact binary systems.

Introduction

BX Trianguli is a short-period M-dwarf eclipsing binary system that offers an ideal testbed for photometric monitoring and modelling. M-dwarf stars are particularly compelling targets (Kopparapu, 2013; Ment & Charbonneau, 2023) for exoplanet research due to their low luminosity, small radii, and long lifespans, which are well-suited to photometric monitoring with small telescopes and are associated with a high occurrence rate of rocky planets (Kopparapu, 2013). These properties also mean that the habitable zone is much closer to the star (Kopparapu, 2013), resulting in shorter orbital periods for potentially habitable planets. This makes M-dwarfs prime candidates in the search for extraterrestrial life, as terrestrial planets in these zones are easier to detect with current instrumentation.

Characterizing such binaries is essential for understanding low-mass stellar evolution (Ribas, 2006) and supports the search for transiting exoplanets (Torres et al., 2010), particularly in compact, low-luminosity systems. This study was conducted through The Royal Astronomical Society of Canada (RASC) as part of an education outreach initiative aimed at engaging students and amateur astronomers in structured, data-driven astronomical investigations. Our objective is to present a detailed photometric analysis of BX Tri, determine key orbital parameters, and validate the model with observational data. This modelling effort was originally conceived as part of a broader initiative to search for exoplanets in M-dwarf binary systems. By creating a high-precision model of the BX Trianguli light curve and orbital dynamics, we aim to establish a predictive baseline against which future deviations—whether in timing or flux—can be measured as potential indicators of planetary companions.

Target System

BX Trianguli is a contact binary composed of two M-dwarf stars with a spectral classification of M2e D (Bowler et al., 2019). This classification reflects mid-M dwarfs exhibiting chromospheric emission features ('e') and a main-sequence luminosity class ('D'), consistent with active, low-mass stars. These characteristics suggest significant magnetic activity, which may manifest in photometric variability, as has been observed in BX Tri (Luo et al., 2019) and in other contact binaries exhibiting similar asymmetries (Zhang et al., 2014). BX Trianguli is an eclipsing binary system located in the northern sky with a period of less than 12 hours, making it

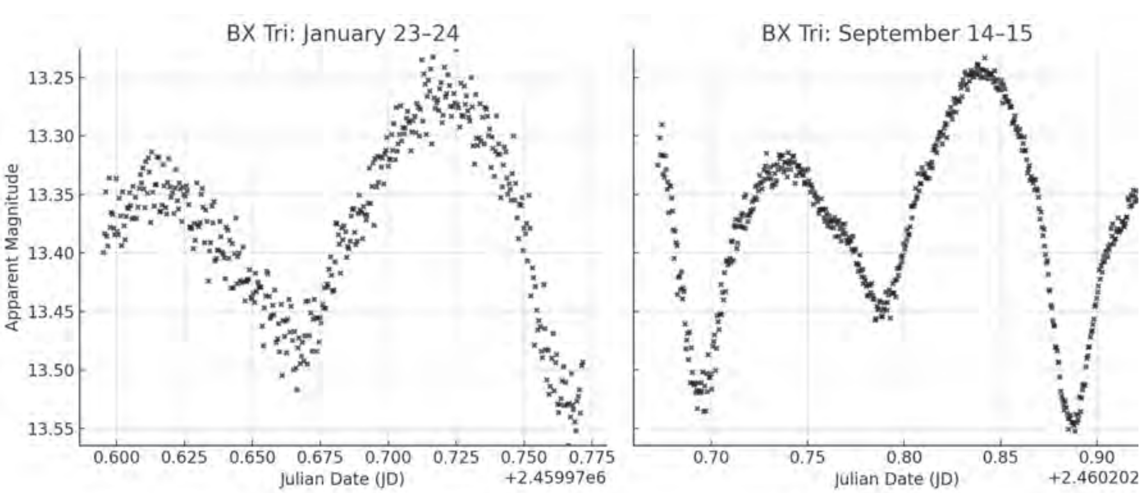

Figure 1 — Differential light curves of BX Tri from two observing sessions. (a) 2023 January 24–25: Both eclipses are captured, with slightly elevated photometric scatter. (b) 2023 September 14–15: Higher signal-to-noise yields improved precision and baseline stability.

possible to observe the full orbital period in one night from our observing locations in the western United States. Its short period makes it ideal for complete coverage within a single night of observation. The system's components are low-mass, cool stars typical of M-dwarfs, making them valuable for studies involving low-luminosity stellar evolution and potential planet-hosting characteristics. Given its relatively bright magnitude of 13.4 in the visible band, BX Tri is accessible to medium-aperture telescopes and suitable for high-cadence photometric studies.

Observational Campaign

Observation Dates and Telescopes

Observations were conducted on 2023 January 24–25, using the RASC's robotic telescope at Sierra Remote Observatories in Auberry, California. This telescope is a 16-inch Ritchey-Chrétien Optical System with an f/8.9 focal ratio, paired with a 4K × 4K SBIG STX16803 CCD camera featuring 9-micron pixels (MacDonald, 2018). The 2023 September 14–15, session employed the ATEO-1 telescope, a 16-inch f/3.75 astrograph operated by Insight Observatory and equipped with an FLI Proline 16803 CCD camera (Petrasko, 2023). Both telescopes used luminance filters for broad-band photometry.

4.2 Data Acquisition and Calibration

During the January observation, 417 30-second exposures were captured, totalling 254 minutes of continuous imaging, which covered nearly one complete orbital cycle. The September session collected 534 30-second exposures over 358 minutes, fully encompassing one orbital cycle. Calibration involved dark, flat, and bias frames obtained during or prior to each session, followed by alignment and stacking in AstroImageJ. Data reduction and photometric analysis were performed using AstroImageJ. Frame alignment and differential photometry were conducted to construct high-quality light curves. The combination of these two datasets enabled cross-validation of eclipse timings and enhanced the precision of the derived orbital parameters. Photometric measurements were extracted to construct light curves for each session. Figure 1 shows the differential light curves from both sessions, capturing the full orbital phase and both eclipse events.

Photometric Analysis

To evaluate the photometric precision and reliability of the light curves, we computed the root mean square (RMS) scatter of the out-of-eclipse measurements. The RMS scatter was approximately 0.0194 mag. in the January dataset and 0.0086 mag. in the September dataset, indicating consistent precision across both sessions. SNRs averaged around 84.6 (range: 53.2–103.1) per exposure in January and 210.0 (range: 159.3–238.3) in September, sufficient for resolving eclipse depths and timing minima with sufficient precision for eclipse-timing analysis.

Photometric aperture settings were manually optimized in AstroImageJ using curve-of-growth analysis to balance signal capture and background minimization. A circular aperture with a radius of 20 pixels, and inner and outer sky annuli of 30 and 60 pixels, respectively, was selected as it consistently maximized the signal-to-noise ratio without introducing background contamination. A total of six comparison stars were manually selected based on their photometric stability, similarity in brightness and colour to the target, and lack of detectable variability following the selection methodology outlined by Howell (1989), ensuring reliable differential photometry across all exposures.

The timing of primary and secondary minima was determined through polynomial fitting to the light-curve dips using second-order parabolic models. Timing uncertainties were estimated from the fit residuals and propagation of polynomial coefficients. In the January dataset, two minima were measured with uncertainties of ±0.00048 and ±0.00047 days (±41.5 s and ±40.4 s, respectively). For the September dataset, the uncertainties were ±0.00025, ±0.00104, and ±0.00067 days (equivalent to ±21.9 s, ±89.9 s, and ±57.9 s, respectively) across three well-defined minima. These levels of precision are well within the threshold needed for modelling orbital evolution or detecting subtle variations due to additional companions in the system. Mid-eclipse times for both primary and secondary eclipses were extracted using parabolic fits, with uncertainties calculated from fit residuals. These are summarized in Table 1.

Dataset	Eclipse	Mid-Eclipse JD	Uncertainty (days)	Uncertainty (Sec)
January 24 - 25	Primary	2459970.66525	±0.00048	±41.5
January 24 - 25	Secondary	2459970.76670	±0.00047	±40.4
September 14 - 15	Primary A	2460202.69679	±0.00025	±21.9
September 14 - 15	Secondary	2460202.78817	±0.00104	±89.9
September 14 - 15	Primary B	2460202.88850	±0.00067	±57.9

Table 1 — Mid-eclipse timings and uncertainties for BX Tri. Photometrically determined mid-eclipse timings and uncertainties for the BX Tri binary system based on January and September 2023 observations. Values were derived from second-order polynomial fits to eclipse minima. Timing precision enables future eclipse timing variation (ETV) monitoring and potential detection of orbiting companions.e

Orbital Modelling

To model the periodic light curve of BX Tri, we used a 3-harmonic Fourier series with a fixed orbital period of 0.192634 days. This model captures the overall shape of the system's brightness variations with quantitative fidelity while maintaining model simplicity and stability across different observational epochs.

We selected this modelling approach based on its empirical flexibility, ease of implementation, and consistency with the goals of our study (Rucinski, S. M., 1993). Our primary objectives were to obtain accurate mid-eclipse timings for O–C (Observed minus Calculated) analysis and to characterize the eclipse minimum flux for the purpose of exoplanet transit detection. A low-order Fourier model provides smooth, reproducible fits that are ideal for these purposes. Importantly, the use of a fixed period and limited number of harmonics helps prevent overfitting and ensures stability in eclipse timing measurements.

While physically parameterized models such as PHOEBE (Prša & Zwitter, 2005) can offer insight into the physical structure of binary systems, they often require detailed knowledge of stellar and orbital parameters and may introduce additional uncertainties or degeneracies when fit to photometry alone. For our analysis, the added complexity of a physically parameterized model was unnecessary and potentially counterproductive, given our emphasis on photometric timing accuracy and baseline flux stability.

A vertical shift of −0.002 flux units was applied to the model output to correct a consistent offset and to better align the model with the observed data. This empirical adjustment improved the visual and statistical agreement between the model and the light curve, particularly in the eclipse minima where high precision is critical.

The final model was fit independently to each dataset using least-squares optimization. Figure 2 shows the model fit to the January dataset, illustrating close alignment with observed data and capturing both primary and secondary eclipses.

The residuals were computed as the difference between the observed and modelled flux and examined for phase-dependent trends or outliers. While generally small and symmetrically distributed, moderate wave-like features remain, indicating higher-order structure not captured by the model. Residuals from the January dataset exhibit a slightly higher RMS of 0.00365 compared to 0.00297 for the September dataset. This difference is consistent with increased observational noise in the January session but does not significantly affect the model's ability to represent the system's periodic behaviour. Figure 3 shows the corresponding model fit to

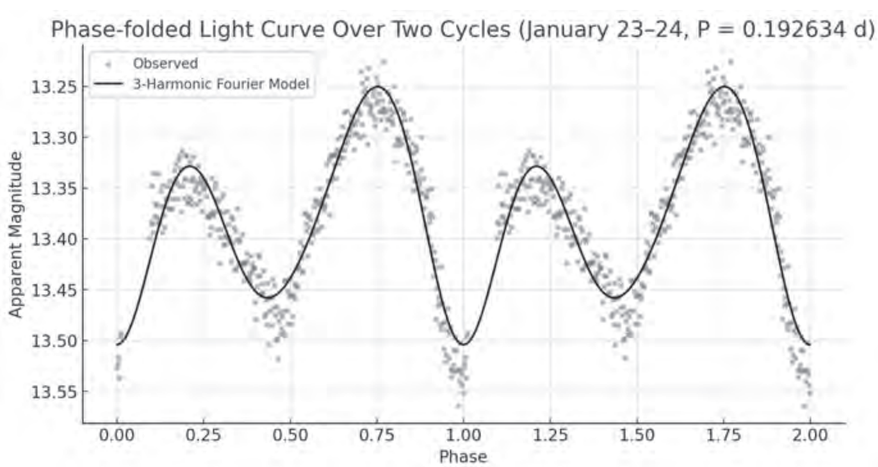

Figure 2 — Best-fit 3-harmonic Fourier model (solid line) applied to the January 2023 light curve. The model accurately reproduces eclipse timing and depth despite moderate noise levels.

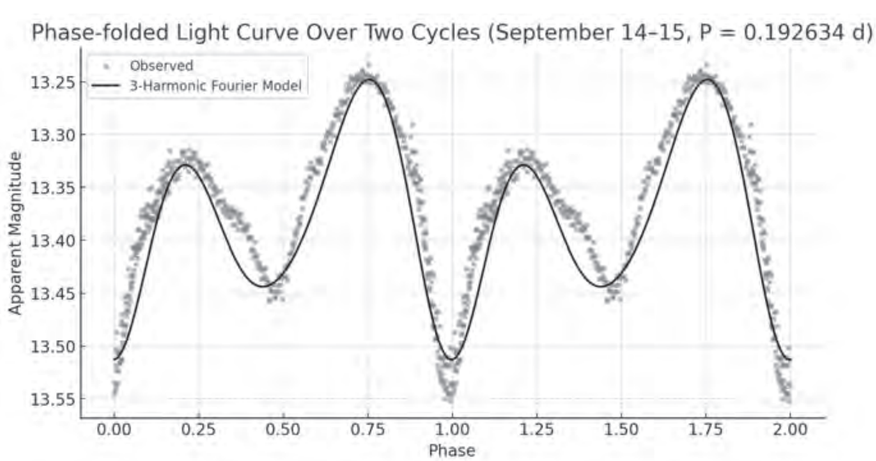

Figure 3 — Best-fit 3-harmonic Fourier model for the September 2023 light curve. The model closely tracks the observed photometry, with minimal residuals due to improved data quality.

the September dataset, which demonstrates improved noise characteristics and confirms the consistency of the Fourier model across observing sessions.

The best-fit 3-harmonic Fourier series models for the January 23–24 (m_1) and September 14–15 (m_2) datasets expressing the apparent magnitude as a function of time (Julian Date) are:

$$m_{Jan}(t) = -2.5 \times log_{10}(\; 0.14862 - 0.00016 \times cos(2\pi\varphi(t)) + 0.00645 \times sin(2\pi\varphi(t)) - 0.01182 \times cos(4\pi\varphi(t)) - 0.00320 \times sin(4\pi\varphi(t)) + 0.00208 \times cos(6\pi\varphi(t)) + 0.00160 \times sin(6\pi\varphi(t)) - 0.002) + 11.3122$$

$$\varphi_{Jan}(t) = \left(\frac{t - 2459970.66525}{0.192634}\right) mod\ 1$$

$$m_{sept}(t) = -2.5 \times log_{10}(\; 0.11284 - 0.00167 \times cos(2\pi\varphi(t)) - 0.00446 \times sin(2\pi\varphi(t)) - 0.00908 \times cos(4\pi\varphi(t)) + 0.00182 \times sin(4\pi\varphi(t)) - 0.00217 \times cos(6\pi\varphi(t)) + 0.00059 \times sin(6\pi\varphi(t)) - 0.002) + 10.9899$$

$$\varphi_{Sept}(t) = \left(\frac{t - 2460202.69679}{0.192634}\right) mod\ 1$$

These models represent the apparent magnitude as a function of time, where the orbital phase is computed using a fixed fundamental period of 0.192634 days and a published mid-eclipse reference epoch.

To complement our empirical approach, we also constructed a physically parameterized model using PHOEBE 1.0. This model incorporated fixed orbital parameters from Luo et al. (2019), who used spectroscopic radial-velocity measurements to determine the component masses, effective temperatures, and orbital period of BX Tri. These values were held fixed in our PHOEBE implementation, which was used solely to constrain the orbital geometry and surface configuration based on our photometric data. The PHOEBE model produced a light curve consistent with our observations and provided estimated values for inclination, surface potentials, and fractional radii that align with expectations for a short-period contact M-dwarf binary. Although the physical model was not used for ephemeris prediction or transit monitoring, it serves as a valuable check on the consistency and realism of our photometric interpretation. Figure 4 compares the PHOEBE model with observed data, validating eclipse timing but not reproducing the O'Connell effect.

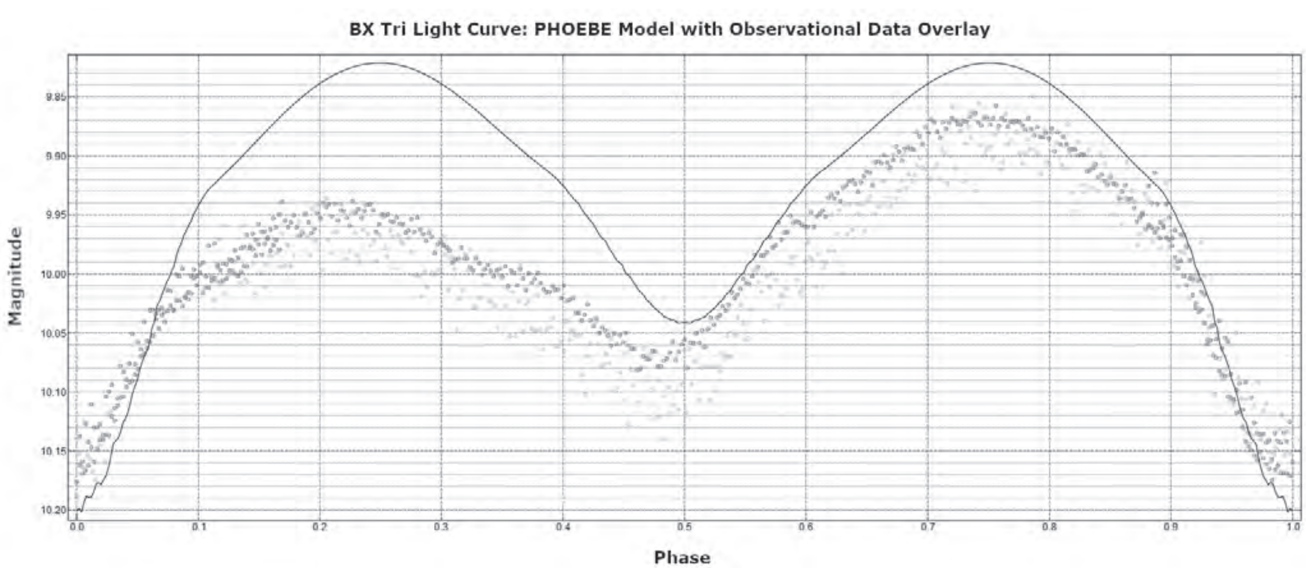

Figure 4 — Comparison between the PHOEBE-simulated light curve (solid line) and observed photometric data (gray points) for BX Tri. The model captures the overall shape of the light curve, including eclipse depths and timing, though it does not reproduce the observed asymmetry in the maxima (O'Connell effect).

While the PHOEBE model effectively reproduces the eclipse timings and general morphology of the light curve, it does not capture the observed asymmetry in the out-of-eclipse maxima—commonly referred to as the O'Connell effect (Wilsey & Beaky, 2009). This omission is intentional. Accurately modelling the O'Connell effect within PHOEBE would require introducing one or more hypothetical star spots or surface asymmetries, such as cool regions on the stellar surface, to reproduce the flux imbalance. However, in the absence of direct observational evidence, such as spectroscopic line-profile variations or spot modulation across multiple epochs, we have opted not to include speculative features in the physical model.

Furthermore, the primary purpose of incorporating the PHOEBE model in this study is not to fit all morphological light curve features, but rather to validate the timing accuracy and overall orbital geometry against a physically parameterized model. The Fourier series captures the light curve asymmetry empirically, while the PHOEBE model supports the physical plausibility of the system configuration based on established parameters. This complementary approach avoids overfitting while maintaining physical rigour.

Results

The final orbital model reproduces the light curve with low residual scatter and consistent phase alignment. This agreement supports the validity of the assumed stellar and orbital parameters and confirms the effectiveness of using photometric modelling for contact binary systems.

The observed light curve closely matches the synthetic light curve generated earlier, with key model outputs aligning well with empirical expectations for M-dwarf binaries. An orbital period of 0.192634 days was adopted from Dimitrov & Kjurkchieva (2010), whose spectroscopic and photometric analysis also established component masses and radii consistent with typical M-dwarf contact binaries. The stellar temperatures derived through the model-fitting process were also consistent with mass–temperature relationships reported in the literature (Mann et al., 2015).

Residuals were computed as the difference between the observed flux and the model prediction. While generally small and symmetrically distributed about zero, the residuals exhibit a moderate, wave-like pattern. This suggests the presence of higher-order or asymmetric features not captured by the low-order model. Nevertheless, the absence of large outliers or systematic phase-dependent deviations supports the model's effectiveness for periodic light-curve analysis. This is further illustrated in Figure 5, which shows the residuals from both datasets, highlighting differences in scatter and symmetry.

We deliberately chose not to increase the harmonic order beyond three. While additional harmonics could reduce residual structure, doing so risks introducing artificial features that may distort the timing and depth of eclipses—key observables in this study. Given our goals, the low-complexity model provides a stable modelling baseline that preserves the timing and depth accuracy of eclipse features.

The consistency of the model across two independent observing sessions, as well as its reproducibility over multiple orbital cycles, further supports this approach.

Discussion

One particularly interesting feature observed in the light curve of BX Tri was a pronounced O'Connell effect (Wilsey & Beaky, 2009), characterized by unequal maxima in the out-of-eclipse portions of the light curve. In our observations, the maximum following the primary eclipse (Max I) was brighter than that following the secondary eclipse (Max II), suggesting a positive O'Connell effect. We hypothesize that this asymmetry is due to the presence of a cool spot on the trailing hemisphere of one of the stars, likely caused by magnetic activity such as persistent star spots (Zhang, X. B., et al., 2014). While no flares were detected during our sessions, the occurrence of large flares in

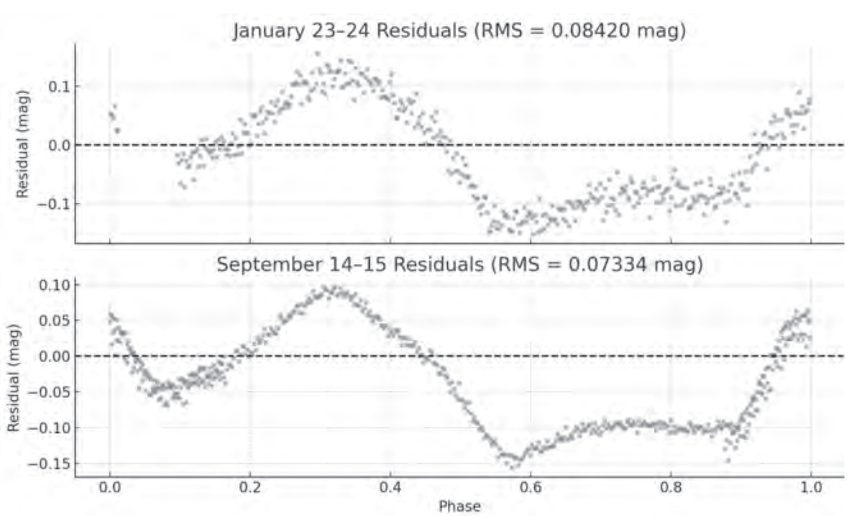

*Figure 5 — Residuals between observed and modelled flux. **(a)** January 2023 data shows modest scatter and wave-like structure. **(b)** September 2023 data exhibits reduced RMS and symmetrical distribution, indicating a more precise fit.*

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Pen & Pixel

Figure 1 — Katelyn Beecroft captured LDN 1295, known as the "Baby Giraffe" in September and October 2025. She used an Askar FRA400, 72-mm aperture, ƒ/5.6 with a ZWO ASI 2600-mm pro, gain 100, 26 MP with Antlia 4.5-nm Edge Hα and Antlia V-Series Pro filters. 197 × 300 s Antlia 4.5-nm Hα filter; 831 × 120 s Antlia V-Series Pro Luminance; 136 × 120s Antlia V-Series Pro Blue; 133 × 120s Antlia V-Series Pro Red; 137 × 120s Antlia V-Series Pro Green.

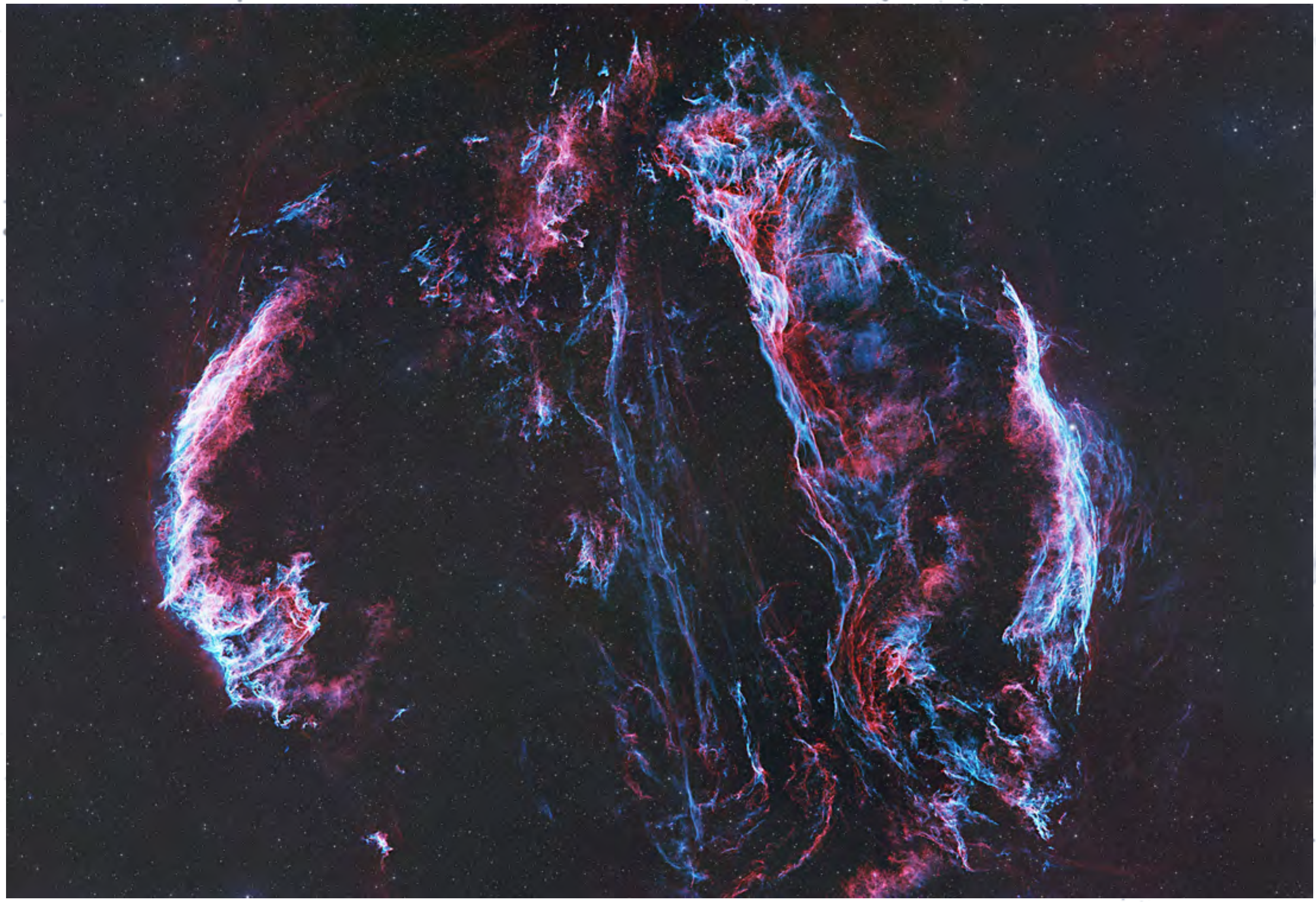

Figure 2 – This beautiful image of the Cygnus Loop was taken by Liala Halawa. She used an AM3 mount, Redcat 71, ASI air mini, ASI 2600MC-P, ASI 120-mm guide camera, ZWO 30F4 mini scope and Askar D1 (narrowband) filter. It consisted of 174 frames at 180 s and 118 frames at 240 s, totalling 16.5 hrs. Taken on several nights in October 2025.

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What's Up in the Sky?

February/March 2026

Compiled by James Edgar

February Skies

The Moon is full on February 1 and also just over 1 degree north of the Beehive Cluster (M44). Regulus, the bright star in Leo, The Lion, is occulted on the 4th for most of North America. For viewers outside the occultation zone, the star will be within half a degree of the full Moon. Spica, the bright star in Virgo, The Maiden, will be 1.8 degrees north of the waning gibbous Moon on the 7th. This occurs very early in the morning, with moonrise shortly after 1:30. The Moon is at last quarter on the 9th–look for it in the daytime sky until around noon. Apogee occurs with the Moon at its farthest distance from Earth, on February 10, at a distance of 404,576 km. That same day, Antares is occulted in the Southern Hemisphere; a close 0.7-degree separation in the north. For those seeking a challenge, Pluto is occulted by the crescent Moon for most of North America on the 15th. This occurs just before sunrise, so much planning is required just to identify the tiny object in the days ahead and then track the Moon's progress in the morning twilight–in eastern North America, it rises just before the occultation; for central and western regions, the occultation is half over at moonrise. A true challenge! The Moon is new on the 17th, which also generates an annular solar eclipse for the extreme Southern Hemisphere. On the 19th, Saturn and the thin crescent Moon descend together in the western twilight, separated by 5 degrees. The Moon passes by or through the Pleiades (M45) on a regular basis. This month, the 1st-quarter Moon is among those Seven Sisters on the 23rd; also at perigee on that day, closest to Earth in its orbit at 370,135 km. The Moon is 4 degrees north of Jupiter on the 27th. At month-end, the Beehive Cluster gets another visit by the nearly full Moon.

Mercury presents a brief apparition for northern viewers from the 7th until the 22nd–always elusive in the western evening twilight.

Venus is too close to the Sun to be seen until mid-month. Then it begins a lengthy session as the Evening Star, dancing with Mercury rising then falling in its speedy orbit. The thin crescent Moon passes by on the 17th/18th.

Mars is too close to the Sun to be seen.

Jupiter has been retrograding in the southeast, becoming visible among the stars of Gemini at sunset. It appears to be moving westward against the background stars, a phenomenon that puzzled ancient astronomers. They imagined the Earth to be the centre of the Universe, not realizing that Earth and all the other planets orbit the Sun. Retrograde motion is a result of Earth orbiting faster than the outer planets, so they appear to move backward. Take advantage of the giant planet being visible all through the night–it's an excellent time to track the Galilean moons as they orbit Jupiter. Two of the moons cast their shadows on Jupiter's cloud tops on the 12th. Jupiter is 4 degrees south of the Moon on the 27th.

Saturn rises during the day, presenting a cream coloured dot for a couple of hours after sunset. Neptune is about 1 degree north of the ringed planet on the 15th. Saturn becomes lost in the Sun's glare by the end of the month.

Uranus has been retrograding among the stars of Taurus, The Bull, but becomes stationary on the 4th. The blue-green planet crosses the sky during the day, appearing after sunset in the south.

Neptune and Saturn remain together among the stars of Pisces, The Fish. See Saturn above.

The zodiacal light is visible in northern latitudes in the west after evening twilight for the first two weeks of February.

February's western sky shows Venus, just barely visible above the horizon, with Mercury a little farther north. Saturn, in Pisces, glows a creamy yellow, while high up, blue-green Uranus is in Taurus. Image courtesy of Starry Night Pro Plus 8

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The Sky February/March 2026

Compiled by Nicole Jiang, Toronto Centre

Celestial Calendar (bold=impressive or rare)

February 2026

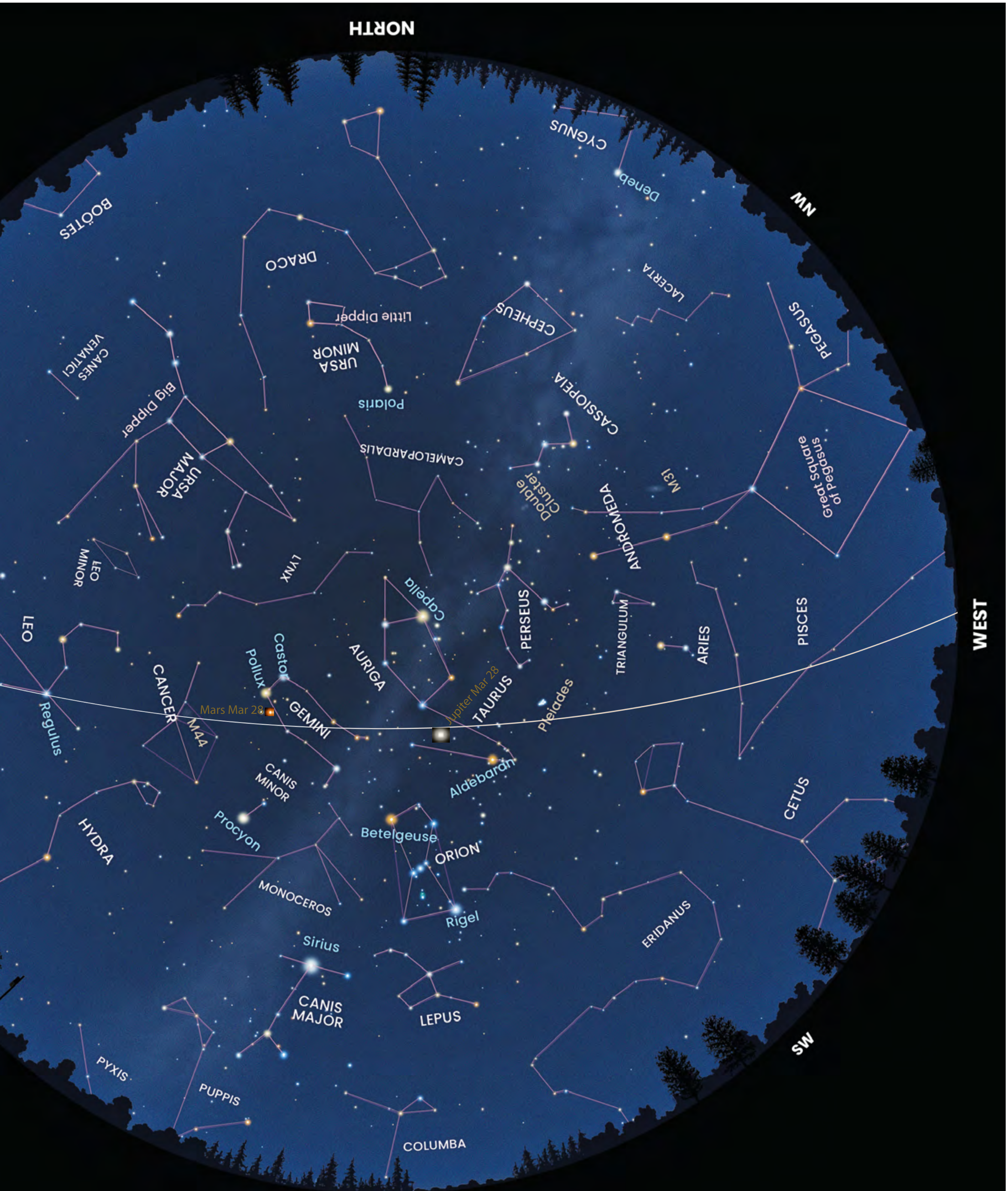
Feb. 1 Moon 1.2° N of Beehive (M44)
Feb. 1 full Moon at 5:09 p.m. EST
Feb. 3 Zodiacal light visible in west after evening twilight
Feb. 3 Regulus 0.4° south of Moon, occultation
Feb. 7 Spica 1.8° north of waning gibbous Moon
Feb. 9 Moon at last quarter
Feb. 10 Moon at apogee (404,576 km)
Feb. 11 Antares 0.7° north of waning crescent Moon
Feb. 12 Double shadows on Jupiter
Feb. 17 new Moon (lunation 1276)
Feb. 18 Mercury 0.1° north of one-day-old Moon
Feb. 19 Mercury greatest elongation east (18°)
Feb. 20 Saturn 5° south of thin crescent Moon
Feb. 24 Moon in Pleiades (M45)
Feb. 24 Moon at first quarter
Feb. 24 Moon at perigee (370,135 km)
Feb. 27 Jupiter 4° south of waxing gibbous Moon
Feb. 28 Moon 1.3° north of Beehive (M44)

March 2026

Mar. 2 Regulus 0.4° south of full Moon
Mar. 3 full Moon at 6:38 a.m. EST
Mar. 3 Total Lunar Eclipse begins at 6:38 a.m. EST
Mar. 5 Zodiacal light visible in west after evening twilight
Mar. 5 Double shadows on Jupiter
Mar. 6 Spica 1.9° north of thin crescent Moon
Mar. 8 Daylight Saving Time begins
Mar. 10 Antares 0.7° north of waning gibbous Moon
Mar. 10 Moon at apogee (404,384 km)
Mar. 11 Moon at last quarter
Mar. 12 Double shadows on Jupiter
Mar. 19 new Moon (lunation 1277)
Mar. 20 Venus 5° south of new Moon
Mar. 20 Spring Equinox
Mar. 22 Moon at perigee (366,857 km)
Mar. 23 Moon in Pleiades (M45)
Mar. 25 Moon at first quarter
Mar. 26 Jupiter 4° south of first-quarter Moon
Mar. 28 Moon 1.2° north of Beehive (M44)
Mar. 29 Regulus 0.4° south of waxing crescent Moon

Planets at a Glance

	DATE	MAGNITUDE	DIAMETER (″)	CONSTELLATION	VISABILITY
Mercury	Feb. 1	—	5.0	Capricorn	—
	Mar. 1	—	9.5	Pisces	—
Venus	Feb. 1	—	9.8	Capricorn	—
	Mar. 1	−3.9	10.1	Aquarius	Evening
Mars	Feb. 1	—	3.9	Capricorn	—
	Mar. 1	—	4.0	Aquarius	—
Jupiter	Feb. 1	−2.6	45.7	Gemini	Evening
	Mar. 1	−2.4	42.8	Gemini	Evening
Saturn	Feb. 1	1.0	16.4	Pisces	Evening
	Mar. 1	1.0	16.0	Pisces	Evening
Uranus	Feb. 1	5.7	3.7	Taurus	Evening
	Mar. 1	5.8	3.6	Taurus	Evening
Neptune	Feb. 1	7.8	2.2	Pisces	Evening
	Mar. 1	7.8	2.2	Pisces	Evening


NORTH
NW
WEST
SW
CYGNUS
Deneb
BOÖTES
DRACO
LACERTA
PEGASUS
Little Dipper
URSA MINOR
CEPHEUS
CANES VENATICI
Big Dipper
Polaris
CASSIOPEIA
URSA MAJOR
CAMELOPARDALIS
Great Square of Pegasus
M31
Double Cluster
ANDROMEDA
LEO MINOR
LYNX
Capella
PERSEUS
TRIANGULUM
ARIES
PISCES
LEO
Castor
Pollux
AURIGA
CANCER
Mars Mar 28
GEMINI
Jupiter Mar 28
TAURUS
Pleiades
Regulus
M44
CANIS MINOR
Aldebaran
CETUS
HYDRA
Procyon
Betelgeuse
ORION
MONOCEROS
Rigel
ERIDANUS
Sirius
CANIS MAJOR
LEPUS
PYXIS
PUPPIS
COLUMBA

Continued from page 17

March Skies

The Moon occults Regulus (twice) and Antares this month, but not for North America. Nonetheless, Regulus is a mere 0.4 degrees south on the opening days of March. The Moon is full on the 3rd, which is also at total lunar eclipse (of course–it's 14 days following the solar eclipse in February). The Moon passes completely through Earth's shadow during the eclipse, so expect to see a deep orange or brown Moon. On the 6th, Spica is 1.9 degrees north of the waning gibbous Moon. The 10th sees Antares 0.7 degrees north of our satellite, the same day it reaches apogee of 404,384 km. The 17th has Mercury 2 degrees north of the thin sliver of the waning Moon–an early morning event in the eastern twilight. The Moon is new on the 18th. The thin sliver of the 1.5-day-old Moon is 5 degrees north of Venus in the western evening sky on March 20, which happens to be the vernal equinox. On the 22nd, the Moon reaches perigee of 366,857 km, right up close to the Pleiades and Uranus. The 26th finds Jupiter 4 degrees south of first-quarter Luna; the 27th sees it among the stars of the Beehive Cluster (M44). Once again, Regulus is occulted on the 29th, but only for a small region of northeastern Canada.

Mercury has been hiding in front of the Sun, but gradually emerges in the eastern morning twilight, becoming brighter as it moves away from the Sun's glare. This apparition favours Southern Hemisphere observers.

Venus climbs up the ecliptic as the Evening Star, a welcome beacon throughout the next six months. The brightest planet snuggles up close to Saturn and Neptune on the 7th. A challenge presents itself on the 19th, when the razor-thin crescent Moon passes by.

Mars is too close to the Sun for viewing until late in the month.

Jupiter is well placed for viewing all month, becoming visible high above Orion, remaining among the stars of Gemini. Double shadows show up on the giant planet's cloud tops on the 5th. Retrograde motion ceases on the 11th, when Jupiter briefly stands still and begins prograde motion eastward. The waxing gibbous Moon glides by on the 26th.

Saturn will be a tough observation, but finding Venus in the west can be a guide on the 7th and 8th. After that, the ringed planet is too close to the Sun for viewing.

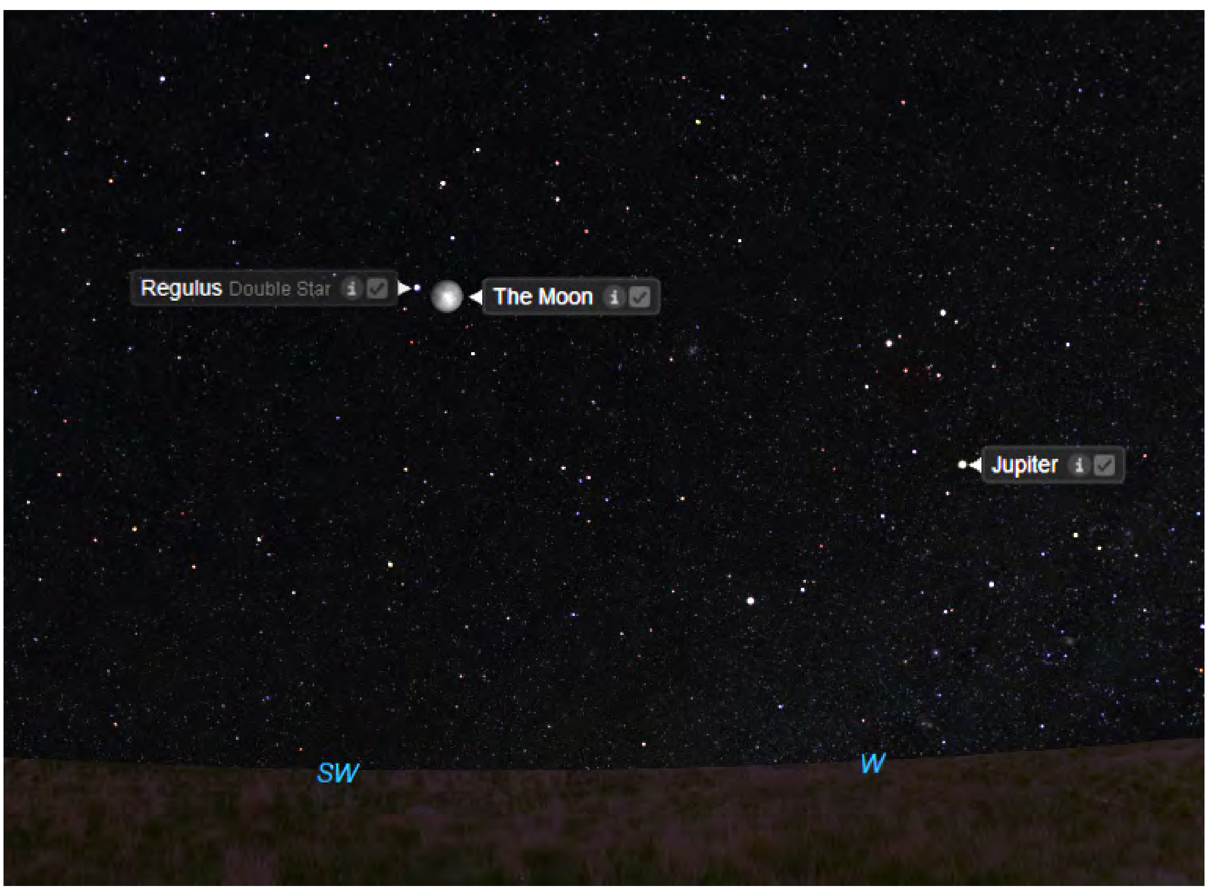
Uranus remains high above the horizon in Taurus, The Bull. The waxing crescent Moon joins the scene on the 22nd.

Neptune is still in Pisces, where it will remain all year. Saturn nearby is an easier find, but they both descend into the Sun's glare by mid-month.

Daylight Saving Time begins on March 8.

The zodiacal light is visible in northern latitudes in the west after evening twilight for the first two weeks.

The vernal equinox is on March 20, marking the beginning of spring.



March finds the Moon up close to Regulus, the bright star in Leo, The Lion, with Jupiter among the stars of Gemini. Image courtesy of Starry Night Pro Plus 8

Continued from page 16

Figure 3 – The thick, dusty tendrils of LDN 1228 reach across space in this fantastic image from Stefan Jackson. He used a Stellarvue 105 on an AZ-EQ6 mount with a ZWO 2600 camera. 150 each RGB at 120 s; 350 L at 60 s. Processed in PixInsight.

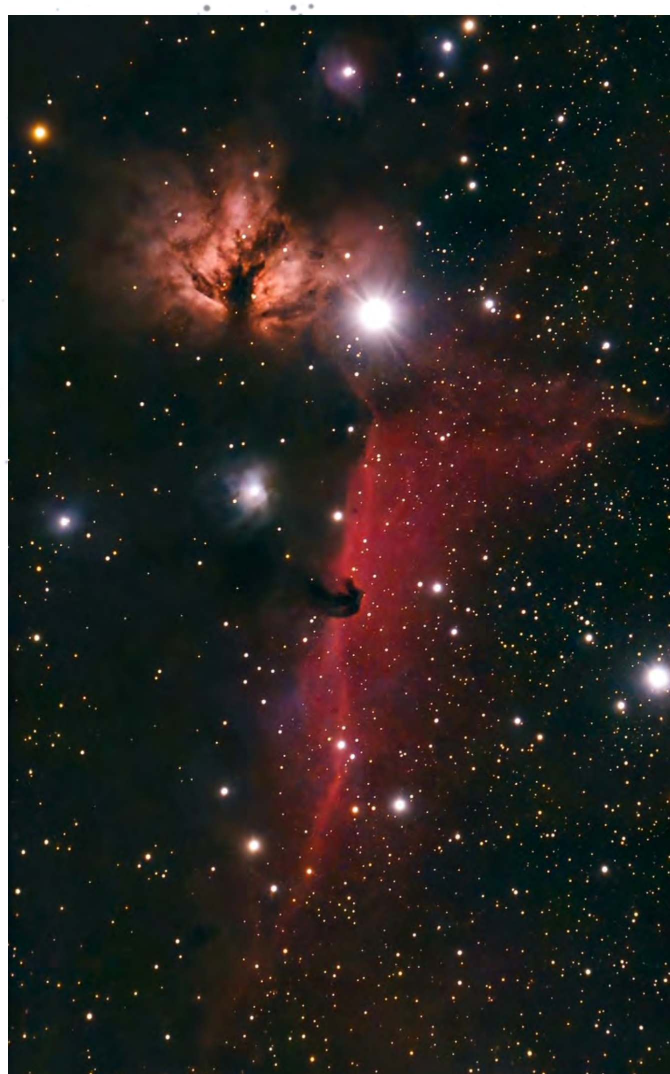


Figure 4 – This is a first for Journal *images: Tim Yaworski used a Seestar 30 to capture the Flame and Horsehead nebulae. He used it in EQ mode, 270 × 10s subs under a Bortle 4 sky east of Saskatoon. Edited on an iPhone 14Pro with Photoshop Express. It's amazing what these new telescopes are able to capture under even the most light-polluted skies.*

Continued from page 15

past studies supports the idea that the system is magnetically active (Luo et al., 2019; Wang et al., 2024).

These results yield a well-constrained orbital model for BX Tri based on medium-aperture ground-based observations. The high precision of the eclipse timings and the successful fit of the orbital model confirm the system's suitability for future exoplanet transit monitoring. In addition to characterizing BX Tri, the Fourier-based model enables predictive monitoring. Future photometric campaigns can use this model as a benchmark to identify anomalies. For example, transit-like dips or eclipse-timing variations (ETVs) may provide indirect evidence of orbiting planets within the system, supporting broader exoplanet detection goals. The project demonstrates the scientific utility of coordinated small-aperture telescope observations and underscores the potential for student-led research under the RASC framework.

Conclusion

Using photometric data from the RASC robotic telescope and Insight Observatory's ATEO-1, we modelled the periodic behaviour of the BX Tri binary system. Although not physically parameterized, this empirical model provides a smooth and stable representation of the system's light curve, enabling precise eclipse timing and minimum flux analysis. It offers a framework for O–C eclipse-timing variation studies and supports the identification of subtle photometric deviations that could indicate transiting exoplanets.

While the model does not constrain stellar structure, its consistency across independent observing sessions underscores its utility as a predictive tool. This work contributes to the empirical modelling of short-period binaries and establishes a reproducible baseline for high-precision photometric monitoring in support of exoplanet detection efforts.

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We gratefully acknowledge Jenna Hinds and Samantha Jewitt of the RASC for their invaluable support and assistance with data collection and analysis throughout this research. We also thank the broader RASC membership for their generous support and mentorship, which made this study possible. We thank Michael Petrasko and Muir Evenden for their contributions to data collection and analysis, as well as their financial support that enabled this research.

We respectfully acknowledge the Indigenous peoples of the lands on which this research was conducted. From traditional knowledge that shaped early understandings of the cosmos to ongoing contributions in contemporary astronomy, their insights continue to enrich the field. In particular, we recognize the Haudenosaunee, Anishinabewaki, and Attiwonderonk peoples of Waterloo, Ontario; the Nyyhmy (Western Mono/Manache) peoples of Auberry, California; and the Nuwuvi (Southern Paiute) peoples of Beryl, Utah. We honour their connection to these lands and thank them for the opportunity to conduct research on their territories, even in the absence of formal permission. ✶

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Mostly Variable Stars

It Ain't Aliens

by Hilding Neilson
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"No, Professor Loeb, it is not aliens." This is becoming a common and well-worn statement in the academic astronomy community; at least this is the more polite version that can be written here. If I'm honest, I probably should be a little grateful to Professor Loeb since I've done a number of media interviews to talk about "Harvard Astronomer claims something is alien ship/probe/etc." and how the something actually does not have to be alien and is really interesting all on its own.

For a number of years, the claims of aliens have been coming forth, like for the first detected interstellar asteroid, 'Oumuamua. Bialy & Loeb (2018) suggested that 'Oumuamua could be (the claims are always couched with coulds and maybes) an artificial solar sail that was launched toward our Solar System based on the anomalous acceleration of the asteroid by solar radiation. Loeb (2018) wrote in *Scientific American* about six strange facts about this asteroid to further consider the alien origin hypothesis, such that these asteroids should be statistically far too rare for us to have discovered it in 2017 and more. I'm not sure how the discovery of the first object is a statistical problem, but whatever. In a broad overview of the asteroid, the 'Oumuamua ISSI Team et al. (2019) discussed the many, many potential natural causes of the asteroid's peculiarities and shut down the "hypothesis" based on 'Oumuamua is not flat enough, its light curve varies too much to be consistent with something powered by solar radiation and its albedo (ability to reflect) is too small to build up the pressure needed for a solar sail.

It is one thing for an academic to write in a professional article that something could be alien in origin, and Loeb is not the first to do so. One of the more famous discoveries by Kepler is Tabby's Star or KIC 842852 (Boyajian, T. 2014). This star is found in the *Kepler Space Telescope* field but was rejected as a host star to an exoplanet because its dips in light were not periodic and not the same depth like you would expect for a regular exoplanet. Wright et al. (2016) suggested that these light curves could be caused by a "Dyson Swarm," that is a swarm of artificial structures. This is akin to the traditional Dyson sphere, just in pieces (Dyson 1960). The difference between this claim and what we have been witnessing in the past few years is that the Wright et al. team weren't forceful with the alien hypothesis.

This forcefulness came to light during a discussion in early 2021 via Zoom where Professor Loeb rudely confronts one of the long-standing leaders in the search for extraterrestrial intelligence (SETI), Dr. Jill Tarter (https://www.forbes.com/sites/startswithabang/2021/02/16/watch-harvard-astronomer-mansplains-seti-to-the-legend-who-inspired-carl-sagans-contact/). In the discussion, Dr. Tarter breaks down all of the reasons that many astrophysicists noted that 'Oumuamua is a natural asteroid and why that is pretty awesome on its own. In response, Professor Loeb starts complaining that SETI is underfunded and that people get ridiculed for the mere suggestion of technological origins or signatures. He even claimed that people are "bullied" for it. He then continued speaking over Dr. Tarter by claiming that disagreeing with him means not being robust as a scientist, i.e. we have to understand *every* possible idea no matter how unlikely. Further he claimed rejecting alien origin ideas as being equivalent to rejecting science because of religion. It's weird; I don't get that one myself. A third time he speaks over Dr. Tarter, that there is an "acidic culture that suppresses innovation in the current culture of science." and that SETI is being blocked from funding and exploration. Professor Loeb continued belittling Dr Tartar and the so-called culture of science. As noted in the article, Professor Loeb did offer a type of apology.

Is there a motivation for this? It's part of the culture of the academy and it's about power and influence and, yes, money. As my colleague Seven Rasmussen (2021) wrote the blogging site *Medium* about how this professor came to go to graduate school and how this professor's work is all about being the centre of attention. When a Harvard professor says "aliens," people are very likely to pay attention and it sells books and clicks and more.

This "everything is aliens" rhetoric continues with the interstellar comet 3I/ATLAS that is a really interesting celestial object. It is only the third interstellar visitor that astronomers have discovered but is the first one discovered before it reached perihelion, its closest approach to the Sun. Being a comet, this is exciting because we might observe the comet lose mass and see both tails that comets tend to have. Of course, 3I/ATLAS has to be weird relative to comets from our Solar System. For instance, most comets will have two tails: one pointing away from the comet along the direction of motion and one pointing away from the comet along the direction from the Sun. 3I/ATLAS has the first one but, instead of the second, has an anti-tail. The anti-tail is in front of the comet and seems to be composed of dust.

Since 3I/ATLAS is weird, Professor Loeb is focused on the many ways that this might be an alien probe and writes prolifically about this and other things on Medium (https://avi-loeb.medium.com/), about one essay per day. I confess I'm a little jealous of the rate of production. The Harvard professor has produced many calculations of how the interstellar comet should behave and cites these calculations as tests to see

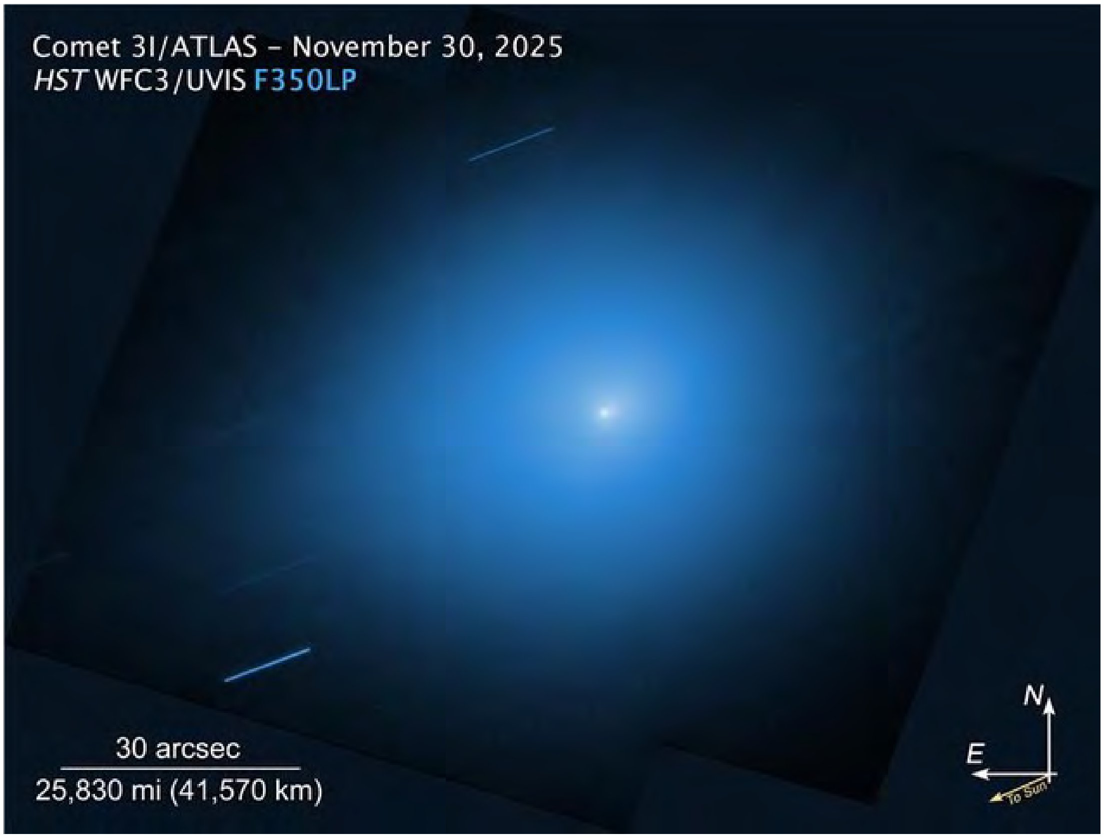

*Figure 1 — Image of 3I/ATLAS observed on 2025 November 30, with the Wide Field Camera 3 on the **Hubble Space Telescope** (Image Credit: NASA).*

whether it is a natural comet or artificial probe. He is routinely chastised on social media for his calculations being wrong because he is not trained as a planetary scientist and doesn't understand a lot of the nuances. But that is irrelevant; he has the audience and they do not understand so he gets to keep his influence. SETI researcher, Professor Jason Wright from the University of Pennsylvania has frequently blogged in response to Professor Loeb's claims noting some of the bad science that is being done (https://sites.psu.edu/astrowright/).

In the end, this might seem like bickering, but it creates issues. The comet 3I/ATLAS is awesome all on its own without having to be framed as a potential alien probe. This unnecessary frame detracts from the great research being done by other groups exploring the gas depletion and variability of the comet. As we discover more interstellar visitors, we will learn more about comets and asteroids in general, as well as how planetary systems form and evolve. It is not necessary to evoke aliens like the story of the boy who cried wolf to garner attention. I think it is even more silly to push that 3I/ATLAS or any other interstellar asteroid or comet are aliens because this has been a science fiction trope for decades, whether it is in Kim Stanley Robinson's Mars trilogy or *Star Trek: The Original Series* or *Star Trek: The Next Generation*. Hey, if we could send a probe to land on 3I/ATLAS in a sample-return mission and the sample was a flute then that would be world changing, but most likely it would be dust and ice–that is weird because it had spent billions of years in interstellar space. What would be more interesting is if we can move past the dated science fiction references for SETI and think about life on other worlds through non-anthropocentric means or, at least, non-Eurocentric/non-Western lenses. This would allow scientists to consider novel and different ideas for the search for life instead of being stuck in old *Star Trek* episodes. ✶

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Keep Calm and Orbit On

Megaproblems from Megaconstellations

By Samantha Lawler, Regina Centre
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In 2019, I moved to rural farmland outside Regina, Saskatchewan. It's the first time in my life I've lived in a place where I can see the Milky Way from my back door. Every clear night, I am grateful for my Bortle[1] 4 skies. I also have easy access to Bortle 2 skies less than an hour's drive away.

Coincidentally, the first batch of *Starlink* satellites also launched in 2019. This means that I have had a front row seat to watching our night sky transition from an occasional, rare, naked-eye visible satellite, to the crawling, sprawling superhighway that it's now become. With less than 80 percent of people in North America able to see the Milky Way from their home[2], odds are you may not have even noticed this transition.

Of course, I should acknowledge that you, dear readers, are a very biased sample of North America. Even if you live in a light-polluted city, you are very likely to have regularly trekked out to a fairly dark site with your telescope, binoculars, or astrophotography equipment. And that means you have been right there with me, watching the night sky change.

That transition marks the beginning of the megaconstellation era, easily visible in Figure 1 as the 2019 "hockey stick" uptick in the orange "Payloads" line. Megaconstellations are groups of hundreds to tens of thousands of satellites that have an extremely rapid launch and replacement cycle, more like the wasteful planned obsolescence of consumer electronics than traditional expensive satellites with decades-long service. SpaceX's *Starlink* is the first of these megaconstellations, but there are many companies planning to use the same disposability model now starting to launch their own.

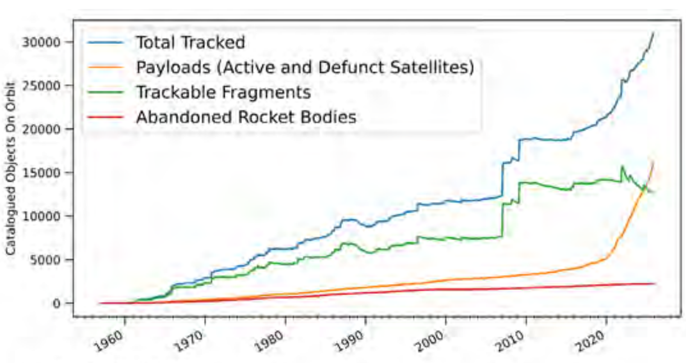

Figure 1 — The number of objects in orbit over time. This includes active and defunct satellites (orange line), trackable fragments (debris larger than approximately 10cm; green line), abandoned rocket bodies (red line), and the sum total of those three components (blue line). Figure credit: Aaron Boley/Outer Space Institute.

Astronomers loudly complained as the first *Starlink* satellites launched and were observed to be far brighter than anyone expected. *Starlink* did make some attempts to make them darker, and even publicly declared their promise to get below magnitude 7[3], which is a typical naked-eye visibility limit. But they quietly removed this promise from their website and continued to make their *Starlink* satellites larger and spending more time at lower altitudes. So, their engineering to make the satellites darker has been almost completely cancelled out and the newest *Starlinks* are about as bright as the originals[4].

The fact that *Starlinks* started launching right when I got access to dark skies from my home for the first time felt like a personal affront. And I wanted to know how bad it might get. So, like a good scientist, I recruited a couple of collaborators (Aaron Boley at UBC and Hanno Rein at University of Toronto), helped write some code[5] to simulate reflected sunlight from satellites, and wrote a research paper.

Much to my annoyance, our simulations revealed that the orbits being chosen by satellite operators (dominated by *Starlink*) would cause light pollution from satellites to have the worst effects over latitudes near 50° north and south[6], right where I (and a large fraction of Canadians) live. Figure 2 shows one of our simulations.

As a scientist, I generally do my best to publish scientific predictions that will continue to match observations going forward into the future. But in this case, I was truly hoping to be wrong. Maybe all these companies won't launch as many satellites as they said they will? Maybe they will actually

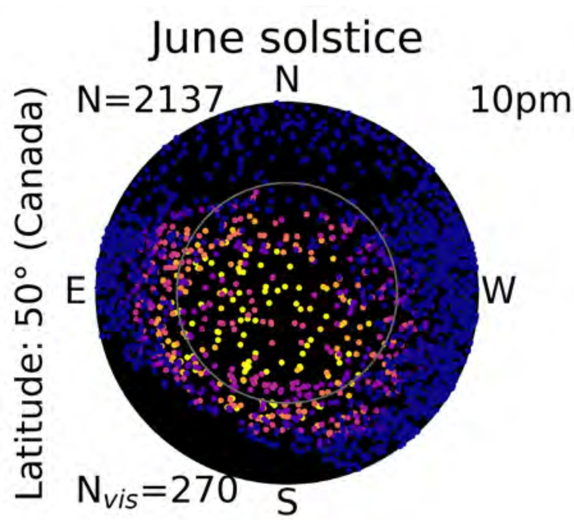

Figure 2 — An all-sky plot showing the positions and brightnesses of 65,000 planned megaconstellation satellites at 10 p.m. on the summer solstice from 50° north latitude. N is the number of sunlit satellites above the horizon, and N_{vis} is the number of naked-eye visible satellites; yellow shows the brightest satellites and blue shows the faintest. Figure based on Lawler et al. (2022).

improve their engineering practices to make them as dark as *Starlink* originally promised? Maybe they will change their orbits?

But instead, I've watched as more and more bright satellites crawl across my sky. There is a near-continuous line of them that happens to crawl from west to east right across the North Star from my latitude. This line appears there because of the 53° orbital inclination chosen by *Starlink* for one of its highly populated orbital shells. I could see this dense band of satellites in the simulations we ran in our 2022 paper, and now I can see it in the night sky with my own eyeballs, from my home, every clear night.

As of this writing in late November 2025, there are 9,103 *Starlink* satellites in orbit, out of a planned 42,000[7], and *Starlink* has recently filed for 15,000 additional direct-to-cell satellites beyond this[8]. The 15,000 direct-to-cell *Starlinks* are much larger, and planning for much lower orbits, so they will be far, far brighter than the *Starlinks* up there now.

So far, 1,398 *Starlinks* have already reached the end of their 5-year operational lifetime and burned up in Earth's atmosphere, with at least one of them impacting the ground in Saskatchewan in 2024[9].

Many have been observed re-entering across huge swaths of the world, including Canada[10]. (Discussing the pollution and ground casualty risk from these reentries is a whole other article. Well, multiple articles. And maybe even a book, too.)

The International Astronomical Union has official recommendations for satellite brightness[11] to cause as few disruptions to both research astronomy and casual stargazing. U.S.-based megaconstellation operators are required to have coordination agreements with the U.S. National Science Foundation, showing how the satellite companies are working to disrupt astronomy research as little as possible, and how astronomy researchers are working around the problems caused by megaconstellations. These agreements are secret, and non-binding, which I personally find very frustrating, but it's better than nothing. It's an imperfect compromise in a tricky situation, as the megaconstellation companies can stop listening to astronomers and do anything they want at any point.

Likely the most powerful tool in the fight to save the night sky from satellite light pollution is consumer pressure. Don't buy your internet access from *Starlink*, or any other megaconstellation. But as a rural dweller myself, I fully understand that there really aren't many good options for internet access in rural Canada. If *Starlink* is your only option, tell them that you want them to make their satellites darker, use fewer satellites to provide service, and use smaller satellites. They are more likely to listen to you as a paying customer than me as a complaining astronomer.

Talk to your government representatives, at all levels of government, about funding rural broadband internet access. I live 10 km from the nearest town, and I am connected to an electric line, I could be connected to a wired phone line if I chose, and I could even be connected to a natural gas line if I wanted. But I do not have any options for hardwired broadband internet. I do have access to a cell-tower-based internet provider, but if I lived a little farther from the city of Regina, I might not even have that.

I know RASC Centres all across Canada have regular, volunteer-run public observing nights, and many of you reading this are deeply involved in making sure those events happen. Thank you, that is such important work—keep doing it! Showing the beauty of the night sky to the general public is vital—show people how it's changing, and what they will be missing in the future as megaconstellation satellites get bigger, brighter, and more numerous.

The night sky is not lost, but it is rapidly changing, and we need to keep reminding everyone how it used to be, and what it could look like in the future with strong international regulation. ✶

Endnotes

1 A Bortle Scale interactive demonstration: https://academo.org/demos/bortle-scale/
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John Percy's Universe

The Royal Canadian Institute (for Science)

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Figure 1 — The official crest of the RCIS, designed by Sir Sandford Fleming in 1850, together with the new logo (right). The original crest reflects the interests of its three founders—surveying, civil engineering, and architecture. The juxtaposition helps to show us just how far the Institute has progressed in 175 years. Source: the RCIS.

From time to time in this column, I highlight an organization that has been meaningful to me and/or astronomy and/or Canada. This month it's the Royal Canadian Institute (or, as it rebranded itself in 2017, the Royal Canadian Institute for Science, or RCIS, or RCIScience). Here, I shall refer to it as RCIS, or the Institute.

In the mid-19th century, Toronto was growing like a weed. In 1837, it had been promoted from "Town of York" to "City of Toronto." Its population was 31,775 in 1851. It was developing into a major centre for transportation, banking, and commerce—and education.

In 1827, the University of Toronto received its royal charter, though it was not fully established until mid-century. In 1831, the Toronto Mechanics Institute was founded to provide education opportunities for the general public—mechanics, for instance. And on 1849 June 20, Sandford Fleming, Kivas Tully, and Hamilton Hartley Killaly met to form the Canadian Institute. (Fleming is the best-known of these founders, as a result of his role in the building of the trans-Canada railway, and his successful promotion of the concept of Standard Time. He was later knighted in 1897, and there's a college named after him in Peterborough.)

Initially, the Institute was intended to provide a discussion forum for surveyors, engineers, and architects, like the three founders. The official crest of the RCIS (Figure 1), designed by Fleming in 1850 reflects this. By 1851, the Institute was granted a royal charter for "the encouragement and general advancement of the physical sciences, arts, and manufactures"—a much broader mandate. It is Canada's oldest scientific society.

Members and others met to give, listen to, and discuss papers on a wide range of scientific topics, and were keen to disseminate them more broadly. The opportunities for doing so in Canada were limited. So, almost immediately, the Institute began to publish a journal to communicate and promote science in Canada: the *Canadian Journal* (1852–78), then the *Proceedings* (1879–90) and then the *Transactions* (1890–1969). These were exchanged for publications from up to 485 similar organizations, producing an Institute library of 34,000 volumes. By 1911, this was one of the largest of its kind in Canada. In 1948, the collection was purchased by the University of Toronto Library, so that it could be preserved and made more accessible. I remember the concept of "building a library through exchanges" from my time as RASC National Librarian in 1965–68. That's how the RASC amassed much of its collection at that time.

The Institute also accumulated a museum of archaeological and ethnographic items, which, after 1911, was transferred to the new Royal Ontario Museum. It would be interesting to find out more about these items, to see whether they would conform to present-day policies about such collections.

In 1913, the Institute began holding public lectures on the University of Toronto Campus. That's where I and my girlfriend (now my wife) first encountered the Institute, when we were undergraduates at the University of Toronto in the 1960s. These free Saturday evening lectures attracted crowds of up to 1,500 in Convocation Hall, to hear from speakers such as Jacques Cousteau and J. Tuzo Wilson. There were lectures on astronomy, usually co-sponsored by the RASC. Lectures tended to be formal; many RCIS council members came dressed in formal attire.

From 1963–70, the Institute offered a summer science program for 35 exceptionally talented high school students from across Canada. One year, I had the pleasure of presenting astronomy to this group at Lakefield College School in Peterborough, and at least two of them ended up in astronomy at the University of Toronto. I recently discovered a webpage for alumni of this program!

In 1982, the Institute established the Sandford Fleming Medal, awarded to a Canadian who has made significant contributions to the public understanding of science in Canada. I was honoured to receive it in 1997. In 2015, the Sir William Edmond Logan Award was created to recognize similar contributions by a Canadian organization. The RASC would be an excellent candidate!

In the 1980s, I joined the Institute's council and became president in 1985–86. By that time, the Institute was becoming more modern and less formal, thanks especially to the work of my predecessors George Luste, Alan Emery, and Graham Mudge. One of our projects was a radio series on scientific topics, to spread science beyond the lecture hall. A Youth Science Academy sprang up, led by Veronika Huta, a University of Toronto student. The Institute had traditionally focused on outreach to adults (though I can personally vouch for its interest and relevance to undergraduates). Veronika became RCIS president in 1996–97, shortly after receiving her B.Sc. Would there be such leadership opportunities for young people in your RASC Centre or other organization?

A decade or two ago, the Institute really began to blossom. The range of programs and partners increased. Programs were no longer confined to campus, but reached out to communities, including underserved ones. The RCIS went to meet people where they were at! Programs included presentations on a diverse array of topics, field trips, a wide variety of nature walks and activities, and events focused on the relationship of science to other aspects of our everyday lives—food and drink, for instance. And there were even science-themed variety shows, something like the University of Toronto's *Astronomy on Tap*. The goal was to spread science "culture" by engaging the public in new and diverse ways.

Institute resources were no longer a massive library and museum with very limited access, but a range of free online resources: a blog, newsletter, magazine; and an impressive collection of digital and Indigenous STEM resources, among other things. Their offerings also included courses, workshops (with up to 150 participants), networking on effective outreach strategies, and an annual conference on STEM communication (the next is 2026 February 19–20). In these ways, the Institute has been able to share their expertise and experience with like-minded organizations and people. The RASC is one such organization that has partnered with the RCIS in its new form, and I urge us to continue and expand such partnership.

During the pandemic, the RCIS went on-line and, although there was not the possibility of person-to-person contacts, their virtual audience could now reach across Canada and beyond. They have used the pandemic to make even better use of virtual programming. We should thank the RCIS council, currently chaired by Jock Fleming, a direct descendant of founder Sir Sandford Fleming.

In 2016, the RCIS received a national award from the Natural Sciences and Engineering Research Council of Canada (NSERC) for excellence in science promotion. (The RASC won a similar award from NSERC in 2003—the Michael Smith Award—named after one of Canada's Nobel Laureates). The award citation notes that "in the last three years alone, RCIS has hosted 115 events featuring over 300 scientists and reaching more than two million people, both in-person and online."

Much of the RCIS's success is due to its small but very capable staff—Executive Director Carrie Boyce and Programs Manager Celia Du—both of whom have training and experience in science outreach and communication, and a passion for doing it. We often forget that effective outreach demands just as much knowledge and skill as formal education—which requires a year or two in teacher's college. (Likewise, it's strange that beginning university professors are expected to have many years of training and experience in research, but little or none in teaching!)

I urge the RASC, its Centres and members, other *JRASC* readers, professional astronomers, and everyone else who does science outreach to check the RCIS website: www.rciscience.ca for lots of inspiration and ideas to improve the quality and diversity of their own outreach programs. The Institute still has a lot to teach us—even 175 years after its birth.

Acknowledgement

I thank Carrie Boyce for providing timely information, and for her excellent work as RCIS Executive Director. ✶

John Percy FRASC is a still-active Professor Emeritus in Astronomy & Astrophysics at the University of Toronto. He is a former President (1978–80) and Honorary President (2013–17) of the RASC.

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

Dish on the Cosmos

Into the Unknown

by Pamela Freeman
(pamela.freeman@ucalgary.ca)

It is incredible how much we understand about the Universe. Yes, there is quite a lot still unknown, but over time humans have done pretty well learning about the cosmos from our little rocky planet. In the modern era, our understanding is evolving quickly and studies that were once pipe dreams are becoming reality.

There is an entire era of the early Universe that astronomers have not observed—the time in between the Cosmic Microwave Background (CMB) and the earliest galaxies the JWST has found. This consists of the Dark Ages, Cosmic Dawn, and Epoch of Reionization. Now, researchers are going to the ends of the Earth, and further, in attempts to observe the cosmic signals from this unknown time.

Mapping our Early Universe

The CMB, our current probe of the early Universe, is a relic of the Era of Recombination about 380,000 years after the Big Bang. At this time, the Universe had cooled enough for electrons and protons to form neutral atoms, and radiation became free to travel the Universe, unimpeded. This radiation is now seen in long wavelength observations, at a cool temperature of 2.7 K. Our next probes, thanks to telescopes like the JWST, are some of the first galaxies from just a few hundred million years after the Big Bang.

In between these phenomena, however, is an unobserved age. After the Era of Recombination, the ordinary matter in the Universe was mainly neutral hydrogen (denoted as HI) gas. These so-called Dark Ages contained no source of visible light. Gradually, with time, denser regions of this gas formed the first stars and galaxies, igniting what is known as the Cosmic Dawn.

Luckily for astronomers, neutral hydrogen emits a signal. An atom of neutral hydrogen is made of one proton and one electron, each of which has a "spin"[1] to it. These spins are quantized, meaning they have defined values they can take. When the spins are anti-aligned, the hydrogen atom is in its lowest energy, and preferred, state. If the atom gains energy, say through a collision with another particle or by absorbing radiation, the spins can become aligned. To return to the lowest energy state, this extra bundle of energy needs to be released. This happens in a spontaneous emission of radiation whose frequency is related to the amount of energy released. As these energy levels have specific values, the energy difference is constant and thus so is the frequency. It is conveniently seen in the radio band, visible from the ground, at 1420 MHz or 21 cm. While it takes about 10 million years for one atom to spontaneously emit, there is, to put it scientifically, just so, so much neutral hydrogen in the Universe that from our vantage point it could appear as a faint signal.

For distant objects, the signal is not quite at 1420 MHz. The expansion of the Universe stretches the radiation to longer wavelengths in a process known as redshift. The longer in wavelength or lower in frequency we observe the spectral line of neutral hydrogen, the further back in time we're seeing.

Radiation from the Dark Ages has a wavelength that has been stretched by a factor of over 30, shifting the frequency down to several or tens of MHz. For the Cosmic Dawn, the signals are stretched by a factor of 10–30, appearing in the frequency range of 45–130 MHz. There is no strict definition of this era in redshift, however, and this roughly encompasses when astronomers expect to find the processes related to the formation of the first stars and galaxies.

In relation to the pervasive background radiation of the CMB, HI signals can appear absorbing or emitting this light, leaving a fingerprint in the radio emission (Figure 1). The shape of this fingerprint contains a wealth of information about the evolution of this gas—about the gas density and temperature, the formation of structure, the different heating sources, and, based on frequency, when it all happened. Smoothing over the complicated physics that underlies these models, the rough shape of the HI signal over time is as follows.

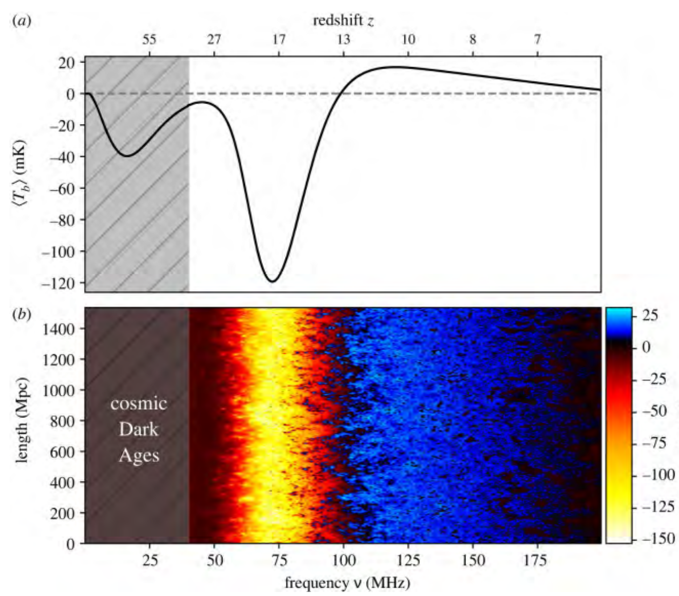

Figure 1 — A simulation of the HI signal across time and frequency. This model shows a changing signal over the different eras of the early Universe: the Dark Ages, Cosmic Dawn, and Epoch of Reionization. Credit: Fialkov et al. (2024)

In the Dark Ages, the CMB was not as cool as it is today, but rather at a toasty 3000 K (i.e. the radiation was as if a blackbody was emitting at 3000 K). The neutral hydrogen gas, at this time, is cooler than the CMB. The HI signal is connected to the gas temperature either by collisions between particles or by radiation. This temperature difference results in the redshifted HI signal being seen in absorption, being seen as a dip below the background CMB. As the Universe expands, the efficiency of these collisions is lowered, and the absorption feature disappears.

As the first stars turn on, at the Cosmic Dawn, the radiation from these stars takes over the role that collisions played and links the HI line to the gas temperature. Again, the neutral gas is cooler than the CMB, resulting in an absorption dip in this signal, however, it is predicted to be stronger than during the Dark Ages. In the model of Figure 1, the deepest part of the signal occurs around a redshift of 18.

As the first stars evolve and die, they form X-ray sources, which heat the surrounding gas. There's a sharp ascent in the HI signal as the temperature difference between the gas and CMB decreases. Depending on the strength of heating, this could be to near or over the strength of the CMB signal. Eventually, in the Epoch of Reionization, UV light from the first stars ionizes and dissipates the gas surrounding them. As the gas is ionized, the signal disappears, marking the end of this area of research of neutral hydrogen cosmology. This Epoch of Reionization concluded when the Universe was just over 1 billion years old.

To test the underlying processes going into these models, scientists need observations to compare to. One promising way they perform observations is to take a sky-averaged or global measurement of the HI signal, to determine the shape of this spectral fingerprint through the intensity and frequency of it. So far, there is only one reported detection of the Cosmic Dawn signal by the Experiment to Detect the Global EoR (Epoch of Reionization) Signature (Bowman et al. 2018) in Australia—a detection that has not been replicated and was much stronger than expected. There are currently several experiments in progress or in development looking for the global signal to add to this data point.

Going to the ends of the Earth

Two leading researchers in this field are at McGill University in the observational cosmology research group: Dr. H. Cynthia Chiang and Dr. Jonathan Sievers. They are developing experiments at the McGill Arctic Research Station (MARS), a small and established station at 79º latitude on Axel Heiberg Island, Nunavut.

This work builds on experiments Dr. Chiang and Dr. Sievers led or were a part of while at the University of KwaZulu-Natal in South Africa. There, they developed cosmology experiments on a remote island about halfway to Antarctica that they learned about through an in-flight magazine. This place, Marion Island, is salty, boggy, mountainous, and windy, and was already set up with a research base. Both Marion Island and Axel Heiberg Island are advantageous for HI cosmology experiments as they are extremely remote. Experiments like these are highly sensitive to radio frequency interference (RFI) as they are averaging a very faint signal over the sky and are doing so over frequencies that FM radio uses.

In 2017, the Probing Radio Intensity at high-Z from Marion (PRI^{Z}M; Philip et al. 2019) experiment started. It was to study the cosmic dawn using two antennae, one at 70 MHz and one at 100 MHz. By using two different frequencies, the team hopes to be able to identify any instrumental effects and to be able to compare between them for any possible sky signal detected.

In 2018, the next experiment began, called the Array of Long Baseline Antennas for Taking Radio Observations from the Sub-antarctic/Seventy-ninth parallel (ALBATROS; Chiang et al. 2020). This array was scattered across the island to take interferometric observations at frequencies lower than 30 MHz. Interferometry allows for higher resolution, which might not be assumed to be important for sky-averaged HI studies. They're using it not to measure the Dark Ages signal, but to measure the strong foreground emission from the Milky Way in order to subtract it from future experiments.

In 2023, these were packed up—PRI^{Z}M for good, and to take ALBATROS to MARS. Currently, the eight ALBATROS antennas are being set up on MARS. MARS has its own unique challenges when it comes to research. There is no winter population here, so the instruments need to be autonomous. This is of high importance as during the Arctic winter there is less solar activity and better viewing conditions through the ionosphere.

ALBATROS won't be the only experiment under the excellent Arctic skies. Dr. Chiang and Dr. Sievers are both team members of the Mapper of the IGM (intergalactic medium) Temperature (MIST; Monsalve et al. 2024) experiment, which aims to cover all three eras—the Dark Ages, Cosmic Dawn, and Epoch of Reionization. Currently, they've built two instruments to observe between 25 and 105 MHz, each with a single antenna.

Instruments like MIST have one more important consideration: the ground. Radio waves can move through soil and be reflected, potentially forming distortions in the data entering the antenna. The conductivity of a soil is variable and hard to measure, which makes it tricky to understand and remove its effects from the data. Cosmologists around the world approach this problem with many creative approaches, for example using a metal ground plane under the antenna, hanging the antenna from a canyon, or floating it on a deep lake. For MIST, they

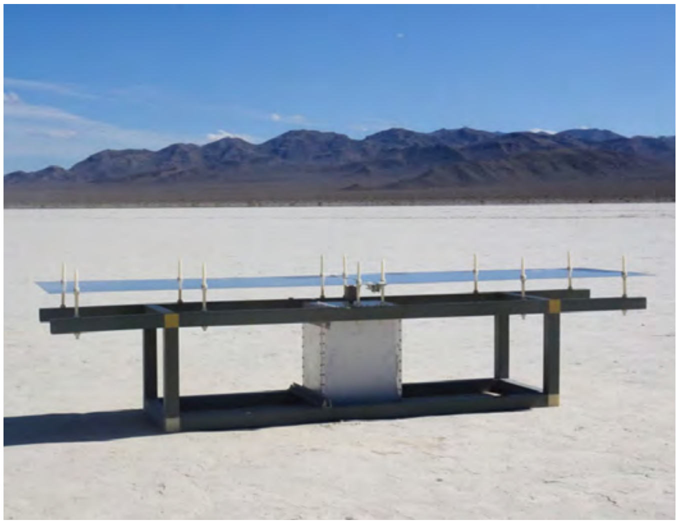

Figure 2 — A Mapper of the IGM Temperature experiment instrument at the testing site in Nevada, USA. Credit: MIST team/Monsalve et al. (2024).

are going to characterize the ground and incorporate it into their measurements.

The MIST antennae have so far been tested at MARS and at sites in the southwest USA, taking advantage of sites with different ground properties below and skies above in order to gain confidence in the instrument's performance. One of the goals of MARS, in developing these experiments, is to use it as a "space analogue" site, where they can characterize these instruments for future space missions of the same design.

Shooting for the Moon

It's often said as a pipe dream for there to be a radio telescope on the Moon. One astrophysicist, Jack Burns of the University of Colorado Boulder, told *Scientific American* recently, "if I were to design an ideal place to do low-frequency radio astronomy, I would have to build the [M]oon."

All the benefits of remote polar sites still leave something to be desired. The Earth's ionosphere, primarily, is in the way of low-frequency observations. At frequencies below about 300 MHz, the ionized matter distorts or scatters radio waves passing through it. This is increasingly disruptive toward lower frequencies, and at frequencies below about 10 MHz, the ionosphere completely reflects radio waves back into space. Researchers can aim to observe when there is a lower level of ionization and thus better observing conditions—during times of less solar activity and during the winter at high Arctic latitudes.

The Moon, high above the ionosphere, completely removes this problem. It pushes the lower boundary of possible radio astronomy observations. The lower boundary becomes closer to 2 MHz, around which ionized particles in interstellar space can block extragalactic radio signals.

On the far side of the Moon, in particular, no Earth-based RFI can be seen. Here, the Moon goes through a cycle of 14 days of sunlight followed by 14 days of darkness. During the lunar night, any radio signals from the Sun are also blocked. It is, aside from the galactic foreground, quite a pristine place to view billions of years back in time. These advantages of having no atmosphere come at a cost—there are temperature swings from –175 ˚C to 120 ˚C and there is no protection from cosmic radiation. There are strict design requirements to launch and land a self-sufficient instrument that needs an external instrument to communicate with Earth.

There have been two notable attempts to place a radio antenna on the Moon. In 2019, China's Chang'e-4 made the first successful soft landing on the far side of the Moon. It was accompanied and connected to Earth by Queqiao, a relay satellite stationed about 65,000 km past the Moon. Both instruments were carrying radio antennae with the goal of performing low-frequency radio observations, and neither of them have been able to successfully carry out said observations. On Chang'e-4, the observations have been limited by self-imposed RFI. On Queqiao, the antennas did not deploy properly.

Fast forward to 2024, and the aerospace company Intuitive Machines attempted the first commercial landing on the Moon with its Odysseus lander. On Odysseus was the Radio wave Observation at the Lunar Surface of the photoElectron Sheath (ROLSES) instrument to measure the radio environment on the Moon. It would measure all the cosmic and Earth-based signals in order to characterize the Moon's surface for future science missions. Since I'm not sharing these results, you may guess or know what will come next. Shortly after landing, Odysseus tipped over. A short period of data was collected by ROLSES, a soft start to the era of Moon-based radio astronomy.

These experiments demonstrate the difficulties and the capabilities of humans to perform radio astronomy on the Moon. The next great attempt is scheduled for 2026 through a collaboration of NASA and the U.S. Department of Energy. They are developing a pathfinder 21-cm experiment called the Lunar Surface Electromagnetics Experiment-Night (LuSEE-Night; Bale et al. 2023; Figure 3). It is primarily a test to see if the design can withstand the environment of the far side of the Moon. For this, it will be solar powered with a rechargeable battery (that takes up almost half its total mass) in order to survive and collect data during the long polar night. It contains a heat pump and radiator to distribute heat, maintaining a reasonable operating temperature any day. LuSEE-Night's science goal is to detect the Dark Ages signal by simultaneously observing frequencies between 0.5 and 50 MHz. It uses two pairs of 6-metre antennae to gather a sky-averaged signal of this era. As the signal is expected to be the same in all directions, the antennae have a rotating mechanism to tune

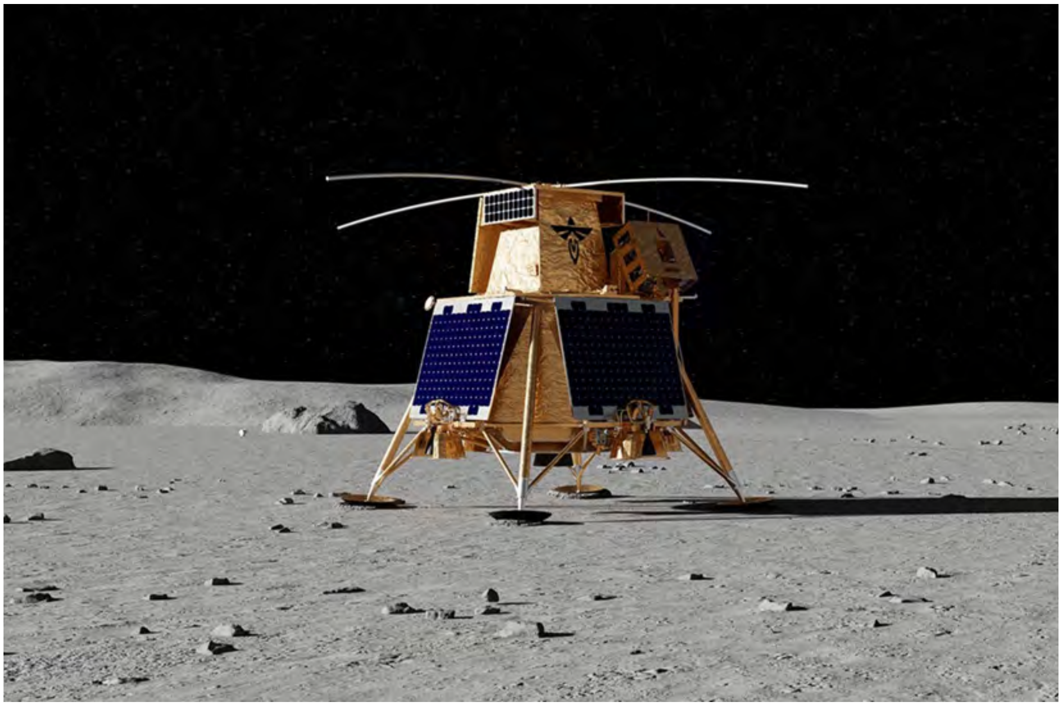

Figure 3 — An illustration of the Blue Ghost 2 lander set for the Moon in 2026. It will carry LuSEE-Night, a collection of antennas to detect faint neutral hydrogen signals from the early Universe. Credit: Firefly Aerospace.

out anything that changes in the sky above. With the collective protections from other signals, LuSEE-Night is well designed to see the faint signals it is looking for.

The successful deployment of LuSEE-Night will also direct future experiments on the Moon. There are loftier goals for what a radio antenna on the Moon may look like. For example, the Lunar Crater Radio Telescope (LCRT; Bandyopadhyay et al. 2021) is proposed to be a 1-km-wide dish built in an even larger crater on the Moon's far side. It is currently in development under NASA's Innovative Advanced Concepts program—it is not officially a go, but is on its way to being so. The idea is for robotic rovers to deliver and construct the dish of thin wire mesh, using the crater as a support for the structure. The main building would be done by a pair of rovers acting like rock climbers with one as an anchor and one descending into the crater.

As with LuSEE-Night, the development of any other experiment grapples with maintaining a lightweight, durable instrument that can withstand the intense lunar day and frigid lunar night. In addition, as the far side of the Moon potentially becomes populated with scientific endeavours, dealing with additional sources of radio noise may become pertinent. It will be an important, long-term consideration.

A recent study published about the composition of the Moon used samples from Apollo missions that had been, with foresight, preserved for decades. NASA, at the time, understood that laboratory technology would only improve and that future generations would be able to obtain better results. This is a laudable action done for the good of scientific knowledge. Our technology in radio astronomy is also catching up to the dreams people had decades ago, and luckily the Universe remains relatively static for us to observe over time. These experiments, now leveraging modern technology to put instruments in new environments, to study an unknown time in the Universe, is a clear story of how science is a long-term investment. We don't know what we might find in the future, or when we might find it. We can, though, chart a path to allow us to go into the unknown. ✶

Endnotes

1 As a good meme puts it: 'imagine a ball that's rotating, except it's not a ball and it's not rotating.'

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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.

Alfred, Lord Tennyson — *Eleanore*

by David Levy, Kingston & Montréal Centres

As tho' a star, in inmost heaven set,
Ev'n while we gaze on it,
Should slowly round his orb, and slowly grow
To a full face, there like a sun remain
Fix'd--then as slowly fade again,
And draw itself to what it was before;
So full, so deep, so slow, …

Alfred, Lord Tennyson—*Eleanore,* circa 1830

This article begins with an excerpt from *Eleanore,* one of the early poems written by Alfred Tennyson. It is one of the finest pieces of verse I have ever encountered. The poem tells a story about a youthful Eleanore, who falls in love. But at a point in the final third part of this poem, he turns his tale into a sermon about variable stars. How could young Tennyson possibly know anything about stars that change in brightness? The American Association of Variable Star Observers, better known by its famous acronym AAVSO, would not be founded for 81 years after this poem was written, in 1911.

Young Tennyson was almost certainly familiar with the work of Friedrich Wilhelm Argelander, who today is accredited with launching the study of variable stars. It is probably that familiarity that led the young poet to insert his little lecture on variable stars.

Some of Tennyson's early poetry, published in the early 1830s, was reviewed in the journal *Quarterly Review*: It went badly:

"We pass by two – what shall we call them? – tales, or odes, or sketches, entitled "Mariana in the South" and "Eleanore", of which we fear we could make no intelligible extract, so curiously are they run together into one dreamy tissue— to a little novel in rhyme, called "The Miller's Daughter". Miller's daughters, poor things, have been so generally betrayed by their sweethearts, that it is refreshing to find that Mr Tennyson has united himself to his miller's daughter in lawful wedlock, and the poem is a history of his courtship and wedding."

Apparently, Tennyson was sensitive to this sarcastic and negative criticism, and he was so affected and hurt by this review that he stopped publishing for almost a decade. His colleagues and friends feared that he had given up writing, and possibly his life, but, as he later told his son Hallam, he was busy revising his older poems, and "in silence, obscurity, and solitude he perfected his art."

Figure 1 — This picture shows several telescopes at the Adirondack Astronomy Retreat. Some of the telescopes are quite small, the size of the telescope that Tennyson owned and used regularly as he was an accomplished amateur astronomer. Credit: David Levy

I believe that the 1830's review was grossly unfair. It was mean. I suspect that these reviewers were using poetry they didn't like to demonstrate how brilliant they were. These reviewers are all long forgotten; I know of nobody who has not heard of Tennyson. I know of many people, besides me, who are just as sensitive to criticism as he was. (By the way, partly as a result of this, I am not an objective reviewer. I think that if someone has the guts to write for publication, she or he deserves every possible encouragement.)

When I recited this extract to my friend Jean Mueller, a well-known discoverer of 15 comets and 107 supernovae during the 29 years she worked at Palomar Observatory, she noticed the variable star connection the minute I read it to her. She agrees: "Was there a specific variable star that he might have had in mind?" These lines teach their readers about variable stars, stars that change in brightness. Such a star does "slowly grow/To a full face" (its maximum brightness) and then "fade again,/And draw itself to what it was before" (its minimum).

I have been an active observer of variable stars for many decades. As Leslie Peltier wrote on page 69 in his autobiography *Starlight Nights*, "A variable star was a completely new experience; it was not just something that was THERE, it was something that was HAPPENING!"

On the evening of 1975 August 30, my interest in variable stars entered a new high when I independently discovered Nova Cygni, a 1.6-magnitude exploding star, and then three years later a second Nova Cygni. Variable stars are magical to me, but this little poem from Tennyson is the first one I have found that directly addresses the observation of stars that regularly change in brightness.

In a way, I wish I had known Tennyson. But I am glad I do not, because that would mean that I am at least 175 years old. But I do know the famous and highly regarded astrophysicist Jonathan Tennyson, Alfred's great, great grandson, and we have been friends since I met him at University College London a number of years ago. The Tennyson family is warm and friendly, and I think the poet from long ago would have enjoyed that, and that an appreciation for science still runs in his family. Alfred, Lord Tennyson had the ability to take a scientific fact, that some stars vary in brightness, and turn it into a verse that etches itself forever into our hearts. ✶

David H. Levy is arguably one of the most enthusiastic and famous amateur astronomers of our time. Although he has never taken a class in astronomy, he has written almost 40 books, has written for three astronomy magazines, and has appeared on television programs featured on the Discovery *and* Science *channels. Among David's accomplishments are 23 comet discoveries, the most famous being Shoemaker-Levy 9 that collided with Jupiter in 1994, a few hundred shared asteroid discoveries, an Emmy for the documentary* Three Minutes to Impact, *five honorary doctorates in science, and a Ph.D. that combines astronomy and English Literature. Currently, he is the editor of the web magazine* Sky's Up!, *has a monthly column, "Skyward," in the local* Vail Voice *paper and in other publications. David continues to hunt for comets and asteroids, and he lectures worldwide. David was President of the National Sharing the Sky Foundation, which tries to inspire people young and old to enjoy the night sky.*

Blast from the Past!

Compiled by James Edgar
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[Note: This article appeared in the first issue of the *Journal* in February 1907.]

Notes from the Dominion Observatory.

Astrophysics:—The new spectrograph is now in regular use and gives star spectra of fine quality for measurement. It is very convenient in operation and the guiding mechanism works to perfection. It has been tried both with single prism and the train of three prisms, and the exposure-time required in each case, considering linear dispersion, compares very favorably with the old instrument. This is probably in part due to the more accurate guiding possible, and also to the better proportion of the optical parts, and the transparency of the single material camera lens. As previously mentioned in these Notes, this objective gives an exceedingly flat field when used with a single prism, extending over the whole range of visible spectrum and to as far in the ultra-violet as the prism will transmit. Evidently therefore the whole star spectrum which can be obtained in a single exposure can be accurately measured, a decided advantage in early type stars with few lines. The same objective with three prisms does not, however, give so good a field, although still of greater extent than that given by the regular cemented triplet.

The outside temperature box constructed of aluminum and lined with felt is kept at constant temperature by a pair of electric contact thermometers which respond to changes of temperature of 0.1 °C. Thus, the inside of the prism box and consequently to a still greater extent the glass of the prisms, must remain at almost absolutely constant temperature.

Flexure, which was the source of much trouble in the old instrument, is entirely overcome in the new spectrograph so far as exposures of two hours' duration are concerned. Moreover the careful arrangement and adjustment of the comparison light, and the accurate means of focusing the camera employed, together with the removal of the two previously mentioned sources of error, should ensure complete freedom from systematic displacements of the lines, and give trustworthy results. Only two or three plates have as yet been measured but they entirely substantiate the above remarks.

All the spectra obtained of the spectroscopic binary *t* Orionis, which was under observation here last winter have been reduced, and the results applied to a determination of the elements of the orbit. Owing, however, to the very diffuse nature of the lines and to the fact that on most of the plates only two lines are measurable, the measures are probably subject to a considerable correction, and in consequence there has been some difficulty in obtaining a satisfactory curve. The orbit has an eccentricity of about 0.75, which is the greatest yet determined for any spectroscopic binary. It is not probable that the elements can be determined very exactly, and it seems advisable to wait for further observations to fill gaps in the present curve before completing the work. The period determined here, with which the early observations of Frost and Adams accord, is 29.12 days.

Mr. N. B. McLean, B.A., Fellow in Mathematics at the University of Toronto, has recently joined the staff, and is engaged in measuring and reducing star spectra. It is hoped, thereby, to keep the measuring nearly up to the observing, its necessity especially in binary star work, having been repeatedly shown.

J. S. P.

The Seismograph:—Since the last notes the principal movement recorded by the Bosch photographic seismograph is the Mexican earthquake of Sunday, April 14th, last. From the seismogram it appears that the earth was in a state of unrest for hours previous to the rupture. Of the latter the preliminary tremors arrived at $6^h\ 15^m\ 6^s$, G.M.T., April 15. The second group arrived at $6^h\ 19^m\ 50^s$, G.M.T., for the E-W pendulum. Similarly for the N-S pendulum, preliminary tremors, $6^h1\ 4^m$ 56^s, G.M.T., second group, $6^h\ 19^m\ 34^s$, G.M.T., from which the approximate distance of 3700 km. to the epicentre follows, agreeing well with the actual distance to the epicentral area in the state of Guerrero. The maximum amplitude 15 mm. was about one quarter of that for the San Francisco one. The quakes continued for over an hour and a half.

As a seismic disturbance it was far more severe than the one of Kingston in January last. The Mexican earthquake was reported to the local press by the Observatory as a severe and destructive one, although at the time the despatches from Mexico City were unaware of its intensity.

An attempt is being made here to establish the relationship between the change of the zero position of the horizontal pendulum of the seismograph with the change of the daily barometric gradients as taken from the daily Weather Charts; that is, the investigation seeks to determine whether the theoretical tilting of the pier towards the area of "high barometer" is shown by a deflection of the pendulums.

It is intended to carry on magnetic and gravity work during the present season over a considerable area of Canada to form part of a systematic scheme for the Dominion. For the former a fibre declinometer, dip circle and magnetometer will be used, and for the latter the half-seconds pendulum swung in an airchamber under constant pressure.

The newer science seismology has shown a relationship between it and terrestrial magnetism and gravity, and their proper correlation is one of the interesting problems awaiting solution.

O. K.

Time Service:—In conformity with the decision to replace the key as an instrument for the observation of transits, by the travelling wire micrometer, the last of the portable transit instruments belonging to the Observatory is having a micrometer attached. The attachment is now being made in the Observatory workshop, and, while in the main similar to the others which are in use here, it will embody several alterations and improvements suggested by experience. While progress in the making of such an instrument is necessarily slow, it is hoped to have it completed in a couple of months, in addition to some minor repairs to the instrument.

On account of the dismantling of the instrument for this purpose, as well as from some other causes connected with the exigencies of routine work, the research work in connection with transit observations has been practically discontinued for the present, but it will be resumed at the earliest opportunity. A more detailed description of the problem at issue than has yet appeared, will be given in the next number of the JOURNAL,

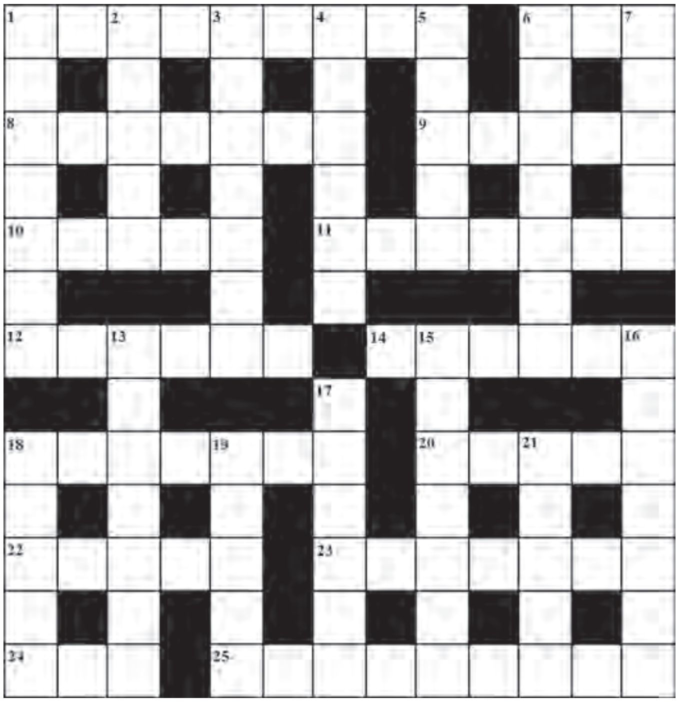
Mr. D. B. Nugent, B.A., late demonstrator in Physics in the University of Toronto, has recently been appointed to the Time Service staff, and his assistance will no doubt have a marked influence in increasing facilities for work in this and other directions.

R. M. S.

[Note: J.S.P. is John Stanley Plaskett, Astrophysics and Solar Research; O.K. is Otto Klotz, Geophysics; R.M.S. is Robert Meldrum Stewart, Meridian Work and Time Services] ✶

Astrocryptic

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



ACROSS

1. Screen lot repurposed for selling astronomy gear (9)
6. A little energy found within (3)
8. Over time nerve cell has no charge (7)
9. Sky & Tel chief started as a lunar goddess (5)
10. How one handles Saturn's rings (5)
11. First lunar sketcher echoed a cheer to civil unrest (7)
12. Meteor burst imaged at unoccupied observatory (6)
14. Cosmologist encountered earthquake after May 1 (6)
18. Boat races somehow a target for imagers (7)
20. Flashy stars return with soap from Paris (5)
22. Exist with Twister Sister on an asteroid (5)
23. Supernova lass wants a telescope. Try Khan, maybe. (7)
24. Briefly, Eros or Apophis is exemplary (1,1,1)
24. Poetic collimators of secondary importance (4,5)

DOWN

1. One seen twice in the south, several times beyond Jupiter (7)
2. Half a 60s tune about Danjon or Lacaille (5)
3. Creature oddly present around Ophiuchus (7)
4. Chiron resolved following a mirror test (6)
5. Plumb line points to a broken drain (5)
6. Star I chased around and between bears (7)
7. Star evolved from anti-G forces (5)
13. A magnet can reveal a primary or secondary colour (7)
15. Aluminum and nickel mostly take part of the belt (7)
16. Solar events to start your day (7)
17. Fairy queen takes storied boat to the Great Square (6)
18. New observatory heard to be in ruin (5)
19. Type of drive sometimes used to get one on the road (5)
21. Maiden voyage I recently got on at first (5)

Answers to previous puzzle

Across: **1** QUAOAR (QUA+oar); **4** HAUMEA (phon); **9** ARROW (2 def); **10** WHIPPLE (whi(pp)le); **11** KELLNER (Kell(N)er); **12** TRAIL (t+r+a+i+l)); **13** EDWIN (anag); **15** PISCIDS (2 def); **17** ALGEBRA (phon); **19** ALPHA (2 def); **21** IDEAL (2 def); **22** ELECTRA (elect+RA); **23** HUNTER (2 def); **24** PLUSES (anag)

Down: **1** QUARK (quirk, a=i); **2** AIRGLOW anag+ow); **3** ASWAN (2 def); **5** ARIETIS (2 def); **6** MOPRA (anag); **7** ASELLUS (asses); **8** DWARF PLANET (dwarf+plane+T); **13** EDASICH (anag); **14** NEBULAE (anag); **16** IAPETUS (anag); **18** GREEN (anag); **19** ABELL (anag); **20** ALANS (hid)

Great Images

By Mark Germani

Mark Germani imaged the Dumbbell Nebula using an Astro-Tech AT92 with a ZWO ASI585MC camera on an iOptron CEM26 mount. He used Optolong L-eXtreme 2" and Optolong L-Pro 2" filters with a ZWO ASIAIR Mini and a ZWO EAF. Processing was done in Photoshop, Aries Productions Astro Pixel Processor (APP), and PixInsight.

Journal

Debra Ceravolo imaged Comet A6 Lemmon on 2025 October 29 from Anarchist Mountain in southern British Columbia, using a 16-inch Boller & Chivens telescope at f/18. Camera used was a Canon R6 for 30 seconds × 10 stacked images.