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Journal

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PROMOTING ASTRONOMY IN CANADA

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Inside this issue:

The Great North American Eclipse

Great Images

by Katelyn Beecroft

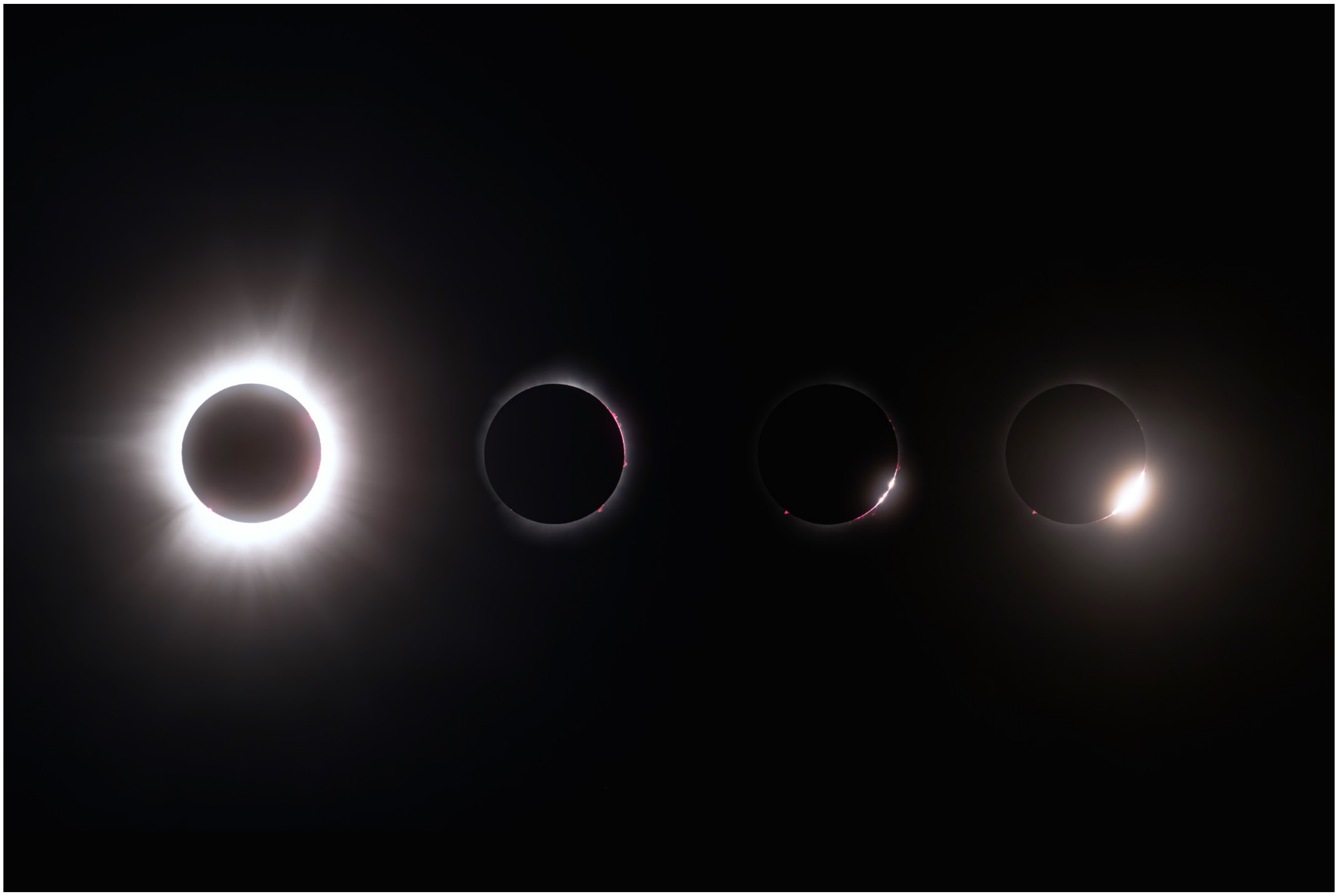

Figure 1 — Katelyn Beecroft took in the total eclipse from Port Glasgow, Ontario. In these four images, Katelyn captured the end of totality with the corona; just the chromosphere and inner corona; Baily's beads; and finally, the diamond ring. All were taken with a modified Canon Rebel T6i and a Canon 55-250 mm lens at 250 mm, ƒ/8 and ISO 100. She used a Sky-Watcher Star Adventurer 2i mount and processed the images in Photoshop.

Journal

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Société Royale d'Astronomie du Canada

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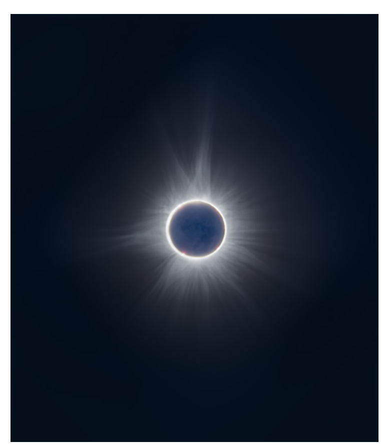

On April 8, millions of heads across Mexico, the U.S. and Canada were craned to the sky to take in a total solar eclipse. Andrea Girones took this HDR blend of several different lengths of exposures during totality from Lac Mégantic, Québec. Andrea shot this with a Sky-Watcher Evolux 62-mm refractor telescope and a Nikon D750 tracked on a Sky-Watcher GTi mount. Final image was blended in Photoshop.

Journal

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

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President's Corner

The 2024 April 8 Total Solar Eclipse

by Michael Watson, President
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Those who are lucky enough to have seen such an event often say, quite justifiably, that a total eclipse of the Sun is the most striking, awe-inspiring, and emotion-evoking natural phenomenon that one can observe.

In a 1982 paper titled "The Frequency of Total and Annular Solar Eclipses for a Given Place" published in the *Journal of the British Astronomical Association, Vol. 92, No. 3*, famed Belgian meteorologist, amateur astronomer, and specialist in mathematical astronomy, Jean Meeus, calculated that on average, a total eclipse of the Sun can be seen from any one place on Earth's surface about every 375 years (they are more frequent in the Northern Hemisphere and less frequent in the Southern Hemisphere). Dedicated skywatchers, other than those who by good fortune happen to live within the narrow path of totality of a total eclipse, therefore often have to travel great distances to see one of these events during their lifetimes. Many amateur and professional astronomers never have the privilege of seeing one. But some dedicated eclipsophiles, including many RASC members, have made it their business to travel into the path of totality dozens of times, with no small effort and at considerable expense.

Although I was clouded out of my first total eclipse in the Gaspé Peninsula in July 1972, before this year I had been lucky enough to see, under completely or at least sufficiently clear skies, nine subsequent total eclipses in Canada, Indonesia, Papua New Guinea, The Philippines, Mexico, Chile, France, and the United States, between 1979 and 2017. That's in addition to three annular or beaded annular eclipses in the U.S. and one in Gabon.

When I joined the RASC in 1970, people were already talking about both the 2017 August 21 total eclipse and the total eclipse this past April, even though they were 47 and 54 years in the future. A few days after this April's eclipse, veteran RASC Hamilton Centre member and RASCals moderator Mark Kaye wrote an eloquent, touching, lovely account of his relationship to and thoughts about this most recent eclipse in the decades after he joined the Society in 1968, which was two years before I followed him and joined the RASC at the end of high school.

Many RASC members—as well as hundreds of thousands of Canadians and Americans—were fortunate to have witnessed the first "Great American Eclipse" of August 2017, the path of which crossed the United States from Oregon to

Figure 1 — The solar corona.

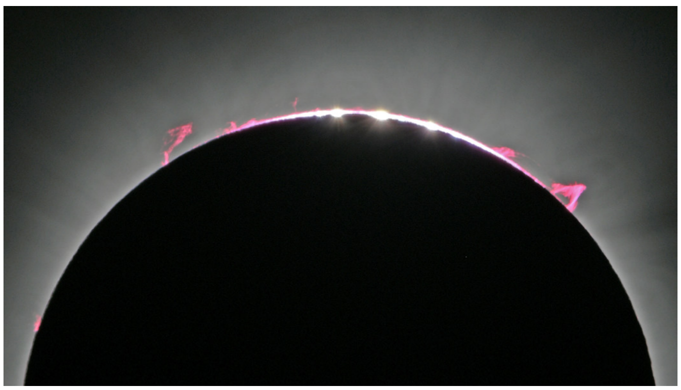

Figure 2 — Baily's Beads and prominences at the end of totality (third contact).

South Carolina, and across ten states in between. From my family's observing site in western Nebraska, this was the best total eclipse that I had seen, even though with a 2-minute, 30-second duration of totality, it was far from the longest I had witnessed (photos of the eclipse can be seen here: www.flickr.com/photos/97587627@N06/albums/72157685550332504/).

Back in August 2017, it seemed like an interminably long time to wait until the second Great American Eclipse this past April, six and a half years later. But time passes so quickly, especially as one gets older, and suddenly last autumn we were six months away from the long-anticipated event. (By the way, I prefer to refer to this most recent event as the Great *North* American Eclipse, in recognition of the fact the Moon's umbral shadow came ashore from the Pacific Ocean first in Mexico, crossed our continent, and then sped out into the Atlantic Ocean having spent 33.5 minutes crossing parts of 5 Canadian provinces.)

Earth's best known and most trusted solar eclipse weather predictor is RASC member Jay Anderson, a retired meteorologist with the Meteorological Service of Environment Canada. Jay has been producing detailed weather analyses and cloud cover forecasts for solar eclipses for three-and-half decades. Years ago he published on his Eclipsophile website his weather study for the April 8 solar eclipse. That study showed that the location on *terra firma* with the best chance of a cloud–free sky was in Mexico, 100 kilometres across the border from west Texas. The chance of a clear sky was about 50 percent in southwest Texas, and progressively decreased further north and east along the eclipse path until it reached about 30 percent in the Niagara Peninsula, and then 15–20 percent in southern Quebec, New Brunswick, Prince Edward Island, and Newfoundland.

Because of these forecasts, and the historical data behind them, many Canadian eclipse chasers—my family included—had decided years ago to make the Lone Star State our observing destination, even though the path of totality passed over or within 100 kilometres of no fewer than 14 of the RASC's 30 Centres in our home country! With all of the equipment that I would be hauling, we decided to drive to Texas from Toronto rather than to fly, as I did for the annular eclipse in October last year. But as a precaution against the very uncertain weather that was likely along the entire eclipse path in the U.S. and Canada, I picked out observing sites not only in Texas, but also in Missouri, Illinois, and Ohio on the south shore of Lake Erie, and made hotel reservations in all of those locations, in case the weather forced us to make a mad dash to a different state on the day before or even the morning of the eclipse.

In the couple of weeks before the big event, astronomers across the continent started to experience heart palpitations as North American meteorologists were predicting an immense low–pressure area, with attendant cloud, rain, and possibly tornados, over Texas and Oklahoma. And the forecasts were for this eclipse-killer weather system to persist stubbornly in place and even intensify for two or more weeks. By contrast, and against the odds, a zone of high pressure—with the likelihood of clear skies—was developing in Quebec and points east in the northeast U.S. and Canada.

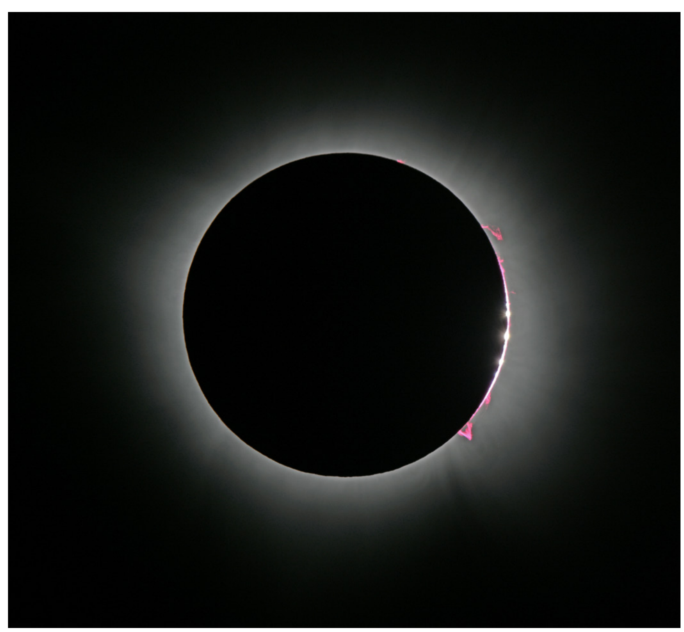

Figure 3 — Prominences at third contact.

So after years of focusing on Texas, our family decided five days before the eclipse to abandon that plan and to make a beeline instead for les Cantons de l'Est (the Eastern Townships) of La Belle Province. We managed to get what appeared to be the last remaining available hotel room in Sherbrooke—at an exorbitant price—in the vicinity of which I scouted out several potential observing sites, municipal parks, and softball fields. I was nervous enough about the predicted cloud over Ontario and the likelihood of it moving east (as weather systems tend to move in the northern temperate zone latitudes) that I looked in western Maine as well and found the little town of Jackman—population about 870, about 210 kilometres east of Sherbrooke. My wife Helen—who has now seen five total eclipses with me starting in 1988—and I made a preview drive to Jackman the day before the eclipse to check out the town, which was being touted on news media as Maine's eclipse central, to see what the potential observing sites looked like and how jammed the town was likely to be the next day.

Unfortunately, two days before, there had been a huge dump of snow in eastern Quebec and western Maine, and the backcountry roads to the border made for treacherous driving. The local parks were covered with snow, and there was mud and water everywhere. State police, U.S. Border Patrol, the Maine Forest Service, and the local Sheriff's office, Fire Department, and EMS people were all to be on–site, and at the town's request, the Canadian Pacific Kansas City Southern railroad—whose single line ran right through Jackman—had agreed not to run any trains through the town during the eclipse.

Eclipse Day was magic. When we arrived in Jackman early on Monday morning for the mid–afternoon eclipse, the town was jam–packed. Thousands of people had arrived the previous day and overnight. We saw licence plates from as far away as Texas. Everyone was in a festive mood. From talking to people in the hours preceding the eclipse, it seemed to me that a large majority of the visitors were first–time eclipse observers, who were revelling under a blue sky with no visible clouds and a temperature of 12˚C.

Everything went off beautifully. Ten minutes before the total phase, Venus to the west side of the Sun and Jupiter on the east side popped into view. The Moon's shadow sped toward us at 1.3 kilometres per second, and soon the solar corona appeared. Eclipse observers all around us erupted with "oohs, aahs," and exclamations of delight, as happens at every eclipse. I was busy with photography for the first half of the 3 minute and 27 second total phase of the eclipse, while Helen, our son, and friends who had decided at the last minute to meet up with us looked through the third telescope I had brought. The sight—with the unaided eye—of the jet-black hole in the sky surrounded by the gossamer tendrils of the solar corona is always heart–stoppingly amazing and emotional. This time was no different.

All too soon it was over as the Moon continued in its perpetual orbital motion eastward, and the Sun reappeared. At the end of totality, the town erupted in cheers—again, as always happens—and we opened our usual celebratory bottle of champagne that had been chilling in a cooler.

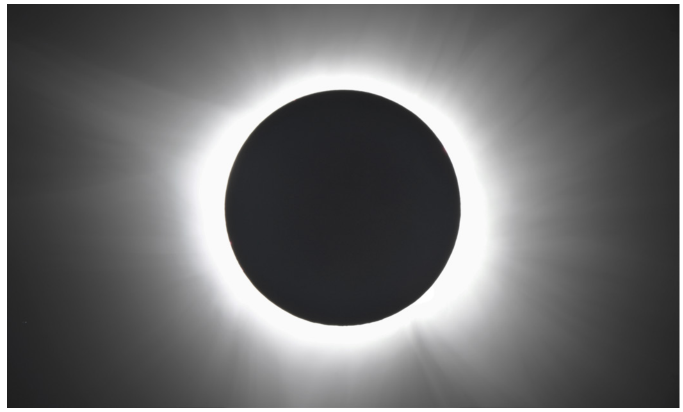

Figure 4 — The solar corona.

I know from reading many accounts of that day that RASC members were successful in seeing the solar corona at the April 8 eclipse, many for the first time and some for the dozenth time. Congratulations to everyone who managed to get into the Moon's umbral shadow under a clear sky!

Here is a small album of my photos from this very memorable eclipse: www.flickr.com/photos/97587627@N06/albums/72177720316137359, which I hope you will enjoy. ✶

Figure 5 — Michael & telescopes.

News Notes / En manchette

Compiled by Jay Anderson

Even space isn't safe from humidity

A few layers of water ice—the width of a strand of DNA—are starting to impact *Euclid*'s vision; a common issue for spacecraft in the freezing cold of space, but a potential problem for this highly sensitive mission that requires remarkable precision to investigate the nature of the dark Universe. After months of research, *Euclid* teams across Europe are now testing a newly designed procedure to de-ice the mission's optics. If successful, the operations will validate the mission teams' plan to keep *Euclid*'s optical system as ice-free as possible for the rest of its life in orbit.

Euclid is a wide-angle space telescope with a 600-megapixel camera to record visible light, a near-infrared spectrometer, and a photometer, to determine the redshift of detected galaxies. In recent months, while fine-tuning and calibrating *Euclid*'s instruments after launch and preparing for the start of the mission's first survey, science operations experts noticed a small but progressive decrease in the amount of light measured from stars observed repeatedly with the visible instrument (VIS).

Water contamination is a common problem with spacecraft: the *Hubble Space Telescope*, *Gaia*, *Cassini*, and *Rosetta*, all suffered from some sort of contamination that caused throughput losses, primarily from vapour that arises from the multi-layer insulation (MLI) that covers temperature-sensitive parts. In the freezing cold, those water molecules tend to stick to the first surface they land on—and when they land on sensitive optics, they can cause trouble.

HST's WFPC2 camera ice contamination resulted in typical flux losses of one-percent per day at short wavelengths. It was thermally decontaminated on average every 28 days between 1993 until at least 2001. The contamination rate slowly decreased by a factor of 2 during this time, and later on, WFPC2 was decontaminated every 49 days. *Gaia* required 6 decontamination cycles over 2.6 years.

"We compared the starlight coming in through the VIS instrument with the recorded brightness of the same stars at earlier times, seen by both *Euclid* and ESA's *Gaia* mission," explains Mischa Schirmer, calibration scientist for the *Euclid* consortium and one of the main designers of the new de-icing plan. "Some stars in the Universe vary in their luminosity, but the majority are stable for many millions of years. So, when our instruments detected a faint, gradual decline in photons coming in, we knew it wasn't them—it was us."

After *Euclid*'s launch, there was an "outgassing campaign" where the telescope was warmed up by onboard heaters and

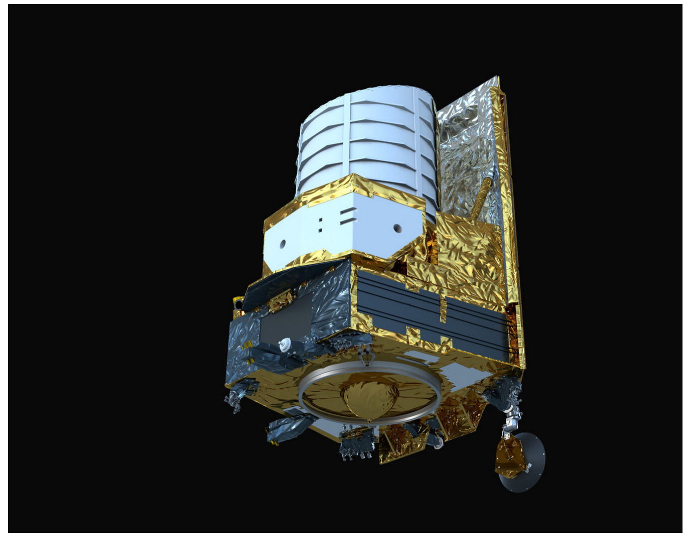

Figure 1 — Artist's impression of the Euclid spacecraft. Image: ESA.

also partially exposed to the Sun, sublimating most of the water molecules present at launch on or very near *Euclid*'s surfaces. A considerable fraction, however, has survived, by being absorbed in the multi-layer insulation, and is now being slowly released in the vacuum of space. In the case of *Euclid*, on-board heating power is insufficient for a full decontamination; partial Sun exposure of the external telescope baffle is required, implying further risks.

After a huge amount of research—including lab studies into how minuscule layers of ice on mirror surfaces scatter and reflect light—and months of calibrations in space, the team determined that several layers of water molecules are likely frozen onto mirrors in *Euclid*'s optics. Likely just a few to a few tens of nanometres thick—equivalent to the width of a strand of DNA—it's a remarkable testament to the mission's sensitivity that it is detecting such tiny amounts of ice.

While *Euclid*'s observations and science continue, teams have come up with a plan to understand where the ice is in the optical system and mitigate its impact now and in the future, if it continues to accumulate. The easiest approach would be to use the decontamination procedure developed well before launch and heat the entire spacecraft. Teams at mission control would send the commands to turn on every onboard heater for several days, slowly increasing temperatures from about −140 °C to, in some parts of the spacecraft, a "balmy" −3 °C. A full decontamination cycle for *Euclid* lasts about one month, including warm-up, cool-down, and recalibration, and only 1–2 days are spent at maximum temperature to allow the sublimates to find their way out of the spacecraft. Given a mission duration of six years, this is a very costly procedure.

Doing this would clean the optics but would also heat the entire mechanical structure of the spacecraft. As most materials heat, they expand and don't necessarily return to precisely the same state after a week-long cool-down, meaning

Figure 2 — The Perseid meteor shower of 2021. Image: Judy Anderson

a potentially subtle difference in *Euclid*'s optical alignment. This won't do for such a sensitive mission where effects can be noticed on the optics from a temperature change of just a fraction of a degree, requiring at least several weeks of fine recalibration.

"To fulfil *Euclid*'s scientific goals of making a 3-D map of the Universe by observing billions of galaxies out to 10 billion light-years, across more than a third of the sky, means we have to keep the mission incredibly stable—and that includes its temperature. Switching on the heaters in the payload module therefore needs to be done with extreme care."

Small amounts of water will continue to be released within *Euclid* over the life of the mission, so a long-term solution is needed to regularly de-ice its optics without taking up too much precious mission time. *Euclid* has six years to complete its survey.

"VIS will be measuring weak gravitational lensing—how matter in the Universe has bunched together under the influence of gravity as the Universe expands—and to understand this, the more galaxies we observe, the better," explains Reiko Nakajima, VIS instrument scientist. "De-icing should restore and preserve *Euclid*'s ability to collect light from these ancient galaxies, but it's the first time we're doing this procedure. We have very good guesses about which surface the ice is sticking to, but we won't be sure until we do it."

Despite how common this contamination issue is for spacecraft operating in cold conditions, there is surprisingly little published research about precisely how ice forms on optical mirrors and its impact on observations. Not only could *Euclid* reveal the nature of dark matter, but it could also shed light on an issue that has long plagued our roving eyes in space, peering down at Earth and out across the Universe.

Compiled with material provided by the European Space Agency

Heating and freezing main cause of dust in zodiacal light

The dust of comets fills the space between the planets, collectively called the zodiacal cloud. Severe breakdown has reduced that dust in size so much that it now scatters sunlight efficiently, causing the faint glow in the night sky known as the zodiacal light. It was long thought that high-speed collisions pulverized the comet ejecta, but now a 45-member team of researchers reports, in a paper published in the journal *Icarus*, that heat is to blame.

"Comets eject most debris as large sand-grain to pebble-sized particles, called meteoroids, that move in meteoroid streams and cause the visible meteors in our meteor showers," says Dr. Peter Jenniskens, meteor astronomer at the SETI Institute. "In contrast, the zodiacal cloud is mostly composed of particles the size of tobacco smoke that even radars have difficulty detecting as meteors.

"Meteor showers show us this loss of pebbles over time because older showers tend to contain fewer bright meteors than young showers," said Jenniskens. "We set out to investigate what is responsible."

Jenniskens leads a NASA-sponsored global network called "CAMS" that monitors the night sky for meteors with low-light video security cameras. Most co-authors on the paper are the researchers and citizen scientists who built and operated the 15 CAMS camera networks in 10 countries. "We developed software that detects meteors in videos recorded from different locations and then triangulates their trajectory in the atmosphere," said detection specialist Peter S. Gural. "Meteors arriving from the same direction each day belong to a meteor shower."

Nightly maps showing from what direction those meteors arrive at Earth are at the website: meteorshowers.seti.org. After 13 years of observations, the combined maps were recently published as a book, *Atlas of Earth's Meteor Showers*, an encyclopedia of information on each known meteor shower. In this research project the team measured the orbital element dispersions, the magnitude size distribution index, the ratio of fluffy and dense materials in the stream and their bulk densities, and the meteor light-curve shape-parameter for 487 streams.

"As part of this work, we determined the age of meteor showers from how much they had dispersed," says Stuart Pilorz of the SETI Institute, "and then examined how rapidly they were losing their large meteoroids compared to the smaller ones."

To investigate, the team examined how close those streams came to the Sun. If collisions were to blame, then the pebbles were expected to be destroyed faster directly proportionally to their proximity to the Sun. "Because there is more comet dust closer to the Sun, we had expected collisions there would pulverize the pebbles that much faster," says Jenniskens. "Instead, we found that the pebbles survived better than expected."

The research team concluded that, instead, the pebbles are destroyed proportional to the peak temperature they reach along their orbit. Thermal stresses are likely to blame for breaking up the large meteoroids near Earth and all the way to the orbit of Mercury, while deep inside the orbit of Mercury, the particles are heated so much that they fall apart from losing material.

"Here at Earth, we sometimes see that process in action when in a short time of say 10 seconds, we detect 10 or 20 meteors in part of the sky, a meteor cluster, the result of a meteoroid having fallen apart by thermal stresses just before entering Earth's atmosphere," says Jenniskens.

Compiled with material provided by the SETI Institute.

Oldest star in the neighbourhood

The first generation of stars transformed the Universe. Inside their cores, simple hydrogen and helium fused into a rainbow of elements. When these stars died, they exploded and sent these new elements across the Universe. The iron running in your veins and the calcium in your teeth and the sodium powering your thoughts were all born in the heart of a long-dead star.

No one has been able to find any of those first generation of stars, but scientists have announced a unique finding: a star from the second generation residing in the Large Magellanic Cloud.

"This star provides a unique window into the very early element-forming process in galaxies other than our own," said Anirudh Chiti, a University of Chicago postdoctoral fellow and first author on a paper announcing the findings. "We have built up an idea of how these stars that were chemically enriched by the first stars look like in the Milky Way, but we don't yet know if some of these signatures are unique, or if things happened similarly across other galaxies."

But no one has yet managed to directly see these first-generation stars, if any remain in the Universe. Instead, Chiti and his colleagues look for stars that formed from the ashes of that first generation.

It's hard work, because even the second generation of stars is now incredibly ancient and rare. Most stars in the Universe, including our own Sun, are the result of tens to thousands of generations, building up more and more heavy elements each time. "Maybe fewer than one in 100,000 stars in the Milky Way is one of these second-gen stars," he said. "You really are fishing needles out of haystacks."

But it's worth it to get snapshots of what the Universe looked like back in time. "In their outer layers, these stars preserve the elements near where they formed," he explained. "If you can find a very old star and get its chemical composition, you can understand what the chemical composition of the Universe was like where that star formed, billions of years ago."

For this study, Chiti and his colleagues aimed their telescopes at an unusual target: the stars that make up the Large Magellanic Cloud (LMC).

The LMC is a companion galaxy that was captured by the Milky Way's gravity just a few billion years ago. This makes

Figure 3 — The blue supergiant Rigel illuminates the Witch Head Nebula (IC 2118) in Eridanus, Image: European Southern Observatory, Robert Gendler (CC BY 4.0)

it particularly interesting because its oldest stars were formed outside the Milky Way—giving astronomers a chance to learn about whether conditions in the early Universe all looked the same, or were different in other places.

The scientists searched for evidence of these particularly ancient stars in the LMC and catalogued ten of them, first with the European Space Agency's *Gaia* satellite and then with the Magellan Telescope in Chile. The authors note that the elemental abundances of the 10 stars had iron-to-hydrogen ratios ranging from ~1/300th to ~1/12,000th that of the Sun.

The most metal-poor star immediately jumped out as an oddity. It had much, much less of the heavier elements in it than any other star yet seen in the LMC. This means it was probably formed in the wake of the first generation of stars, so it had not yet built up heavier elements over the course of repeated star births and deaths. After mapping out its elements, the scientists were surprised to see that it also had a lot less carbon than iron compared to what we see in Milky Way stars.

"That was very intriguing, and it suggests that perhaps carbon enhancement of the earliest generation, as we see in the Milky Way, was not universal," Chiti said. "We'll have to do further studies, but it suggests there are differences from place to place." Their findings also corroborated other studies that have suggested that the LMC made much fewer stars early on compared to the Milky Way.

"I think we're filling out the picture of what the early element enrichment process looked like in different environments," he said.

"This discovery suggests there should be many of these stars in the Large Magellanic Cloud if we look closely," he said. "It's really exciting to be opening up stellar archaeology of the Large Magellanic Cloud, and to be able to map out in such detail how the first stars chemically enriched the Universe in different regions."

Compiled with material provided by the University of Chicago.

Dimorphos still reeling from DART blow

When NASA's DART (Double Asteroid Redirection Test) deliberately smashed into a 170-metre-wide asteroid on 2022 September 26, it made its mark in more ways than one. The demonstration showed that a kinetic impactor could deflect a hazardous asteroid should one ever be on a collision course with Earth.

Now, a new study published in the *Planetary Science Journal* shows the impact changed not only the motion of the asteroid but also its shape.

DART's target, the asteroid Dimorphos, orbits a larger near-Earth asteroid called Didymos. Before the impact, Dimorphos had a roughly symmetrical "oblate spheroid" shape—like a squashed ball that is wider than it is tall. With a well-defined, circular orbit at a distance of about 1.189 kilometres, Dimorphos took 11 hours and 55 minutes to complete one loop around Didymos.

"When DART made an impact, things got very interesting," said Shantanu Naidu, a navigation engineer at NASA's Jet Propulsion Laboratory in Southern California, who led the study. "Dimorphos's orbit is no longer circular: Its orbital period is now 33 minutes and 15 seconds shorter. And the entire shape of the asteroid has changed, from a relatively symmetrical object to a triaxial ellipsoid—something more like an oblong watermelon."

Naidu's team used three data sources in their computer models to deduce what had happened to the asteroid after impact. The first source was aboard DART: The spacecraft captured images as it approached the asteroid and sent them back to Earth via NASA's Deep Space Network (DSN). These images provided close-up measurements of the gap between Didymos and Dimorphos while also gauging the dimensions of both asteroids just prior to impact.

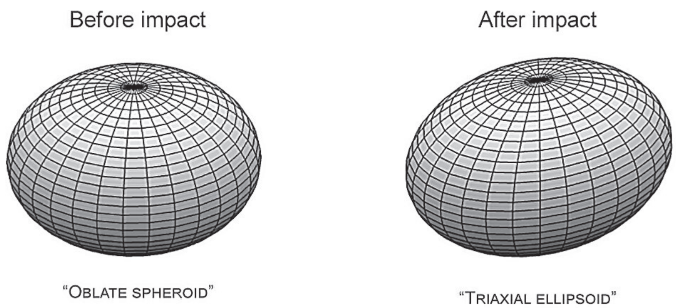

Figure 4 — This illustration shows the approximate shape change that the asteroid Dimorphos experienced after DART hit it. Before impact, left, the asteroid was shaped like a squashed ball; after impact, it took on a more elongated shape, like a watermelon. Credit: NASA/JPL-Caltech

The second data source was the Deep Space Network's Goldstone Solar System Radar, located near Barstow, California, which bounced radio waves off both asteroids to precisely measure the position and velocity of Dimorphos relative to Didymos after impact. Radar observations quickly helped NASA conclude that DART's effect on the asteroid greatly exceeded minimum expectations.

The third and most significant source of data is ground telescopes around the world that measured both asteroids' light curves. By comparing the light curves before and after impact, the researchers could learn how DART altered Dimorphos's motion.

As Dimorphos orbits, it periodically passes in front of and then behind Didymos. In these so-called mutual events, one asteroid can cast a shadow on the other or block our view from Earth. In either case, a temporary dimming—a dip in the light curve—will be recorded by telescopes.

"We used the timing of this precise series of light-curve dips to deduce the shape of the orbit, and because our models were so sensitive, we could also figure out the shape of the asteroid," said Steve Chesley, a senior research scientist at JPL and study co-author. The team found Dimorphos's orbit is now slightly elongated or eccentric.

"Before impact," Chesley continued, "the times of the events occurred regularly, showing a circular orbit. After impact, there were very slight timing differences, showing something was askew. We never expected to get this kind of accuracy." The models are so precise that they even show that Dimorphos rocks back and forth as it orbits Didymos, Naidu said.

The team's models also calculated how Dimorphos's orbital period evolved. Immediately after impact, DART reduced the average distance between the two asteroids, shortening Dimorphos's orbital period by 32 minutes and 42 seconds. Over the following weeks, the asteroid's orbital period continued to shorten as Dimorphos lost more rocky material to space, finally settling at 11 hours, 22 minutes, and 3 seconds per orbit—33 minutes and 15 seconds less time than before impact. This calculation is accurate to within 1.5 seconds, Naidu said. Dimorphos now has a mean orbital distance from Didymos of about 1,152 metres—about 37 metres closer than before impact.

"The results of this study agree with others that are being published," said Tom Statler, lead scientist for Solar System small bodies at NASA Headquarters in Washington. "Seeing separate groups analyze the data and independently come to the same conclusions is a hallmark of a solid scientific result. DART is not only showing us the pathway to an asteroid-deflection technology; it's revealing a new fundamental understanding of what asteroids are and how they behave."

These results and observations of the debris left after impact indicate that Dimorphos is a loosely packed "rubble pile" object, similar to asteroid Bennu. ESA's *Hera* mission, planned to launch in October 2024, will travel to the asteroid pair to carry out a detailed survey and confirm how DART reshaped Dimorphos. ✶

Compiled with material provided by the ESA.

Feature Article / Article de fond

Venus as seen by the Mayas

by Laura Elena Morales Guerrero

Abstract

We present here a numerical analysis of planetary and calendric cycles of planet Venus showing how Mayas could have known about Maximum Common Divisor and least common multiples concepts. Venus cycles were of capital importance for them as shown in the Dresden Codex. We will learn about Ring numbers and read several pages related to various astronomical Venus facts.

Key words: Maya astronomy, Maya arithmetic, Venus.

Introduction

Dresden Codex (DC) is one of four surviving Maya hieroglyphic books. The others are the Paris and the Madrid codices and now a fourth one, the Grolier Codex in Mexico City whose authenticity has been recently (March 2021) proven. DC was the first Maya manuscript known. It was brought to the Dresden library in Vienna by its director in 1789 and it has been there since. This Codex contains the most impressive testimony to the sophistication of Maya sky watching and is believed to be produced in the so-called post-classical era, 1200–1500 CE, and its style suggests it was made in eastern Yucatán by some 15 scribes. However, illustrations in painted ceramics also suggest that it comes from the earlier classical age of Maya civilization.

In the Dresden Codex there is evidence that Mayas had some knowledge of both the Greatest Common Divisor (GCD) and of the least common multiple (lcm) concepts among numbers. In various pages there are shown diverse correlations between the revolutions of the planets, to mention only some numerical interesting relations, whose provability can only be obtained with the procedures used to obtain those factors (GCD, lcm) for numbers. In the particular case of Venus, the crucial numbers in the Venus table of the Dresden Codex (page 24) are explained only in terms of the mentioned concepts.

To analyze the relation of Maya arithmetic with planet Venus, we define the cycles or periods of the planets that orbit around the Sun. When one deals with objects that orbit the Sun, there exist two types of **orbital periods**:

- **Sidereal period** is the time that an object takes to give a complete turn around the Sun, taking as reference point a fixed star and would be the one that would see an immobile observer not orbiting around the Sun. The sidereal orbital period of Venus is 224.701 days.
- **The synodic period** is the time an object takes to reappear in the same point of the sky with respect to the Sun when one observes the object from Earth. This period takes into account that Earth, the place from which the object is observed, also orbits the Sun. This is, hence, the time that passes between two successive conjunctions with the Sun and is the apparent orbital period. The synodic orbital period of Venus is 583.92 days.

When one considers the movement of a planet, the cycle that governs its position in sky is the denominated synodic cycle, that is, the time it takes the considered planet in acquiring the same position relative to the Sun and Earth.

Venus

Venus is the second planet of the Solar System in order of distance from the Sun and the third considering size, from the smaller to the bigger. It receives its name in honour of Venus, the Roman goddess of love. Scholars like Jesús Galindo and John Teeple, among others, evaluate the importance Venus had for the Mayas who invented for her several names: *Xux Ek* or aunt star, since they believed in given moments the light of the planet was nocuous. Also, Venus is the Great Star, *Nok Ek*, the big star; *Sastal Ek*, the brilliant star, due to its intense brightness; *Chac Ek*, the red star, because of the colour it acquires when it is near the horizon. Venus is also *Ahzab Kab Ek*, the star that awakens Earth.

Venus is associated to *Kukulcán* among Mayas. In the case of Venus, the synodic period of 584 days was divided in four parts by the Mayas: during 236 days, Venus is the morning star (*Ahzab Kab Ek*); the posterior 90 days correspond to the passage of Venus behind the Sun (superior conjunction); afterwards they count 250 days in which Venus is the evening star, followed by a brief but important period of 8 days in which Venus is found in inferior conjunction (that is, in front of the Sun) and disappears due to impossibility of reflecting Sun's light towards Earth. It is when it reappears after 8 days, during the time inferior conjunction lasts, that was believed to be highly harming to human beings causing "fear, pestilence, and destruction," depending on the day in which the reappearance was produced within the ritual calendar of 260 days. The importance Mayas gave Venus was such that the design of Caracol Temple, considered the most important astronomical observatory of the Mayas, is highly influenced by Venus's trajectory in the sky. For instance, the alignment of its base with the most northern Venus setting differs by less than a degree. The cult to Venus persisted till the time of the Aztecs as it was thought the bad influence Venus could have when reappearing after the inferior conjunction. Accordingly, to the annals of *Quauhtitlán*, the Aztecs also believed that "its penetrating rays" could cause wounds. They named Venus as *Huey Citlalín*, the big star and, in its character of morning star, associated with the Maya equivalent: *Quetzalcóatl*, the Aztec God.

In spite of some voices denying the knowledge Mayas had of the astronomical phenomenon called Transit of Venus, there is evidence that it was a fact discovered and recorded by Mayas. For instance, the date 8.2.0 9 *Ahau* (in page 24 of DC) amounts to 37,960 = 1 × 13 × 2,920 days and corresponds to the transit of Venus of year 546 CE, according to Carlos Barrera Atuesta (personal communication) in a project called "Proyecto Independiente de Investigación Sobre Ciclos Astronómicos" in Colombia.

Venus period

Mayas were capable of calculating the synodic period of Venus even within a centesimal part of the day as we will see. But it was in Mayas' obsession for cycles where a great deal of the importance of Venus resides: 5 synodic cycles of Venus correspond almost exactly to 8 years of 365 days (5 × 584 days = 8 × 365 days = 2,920 days), that is, 5 revolutions of Venus are equivalent to 8 of Earth. Perhaps they obtained those numbers by pure sky watching, but we find that the correlation between the 365 revolutions of Earth with the 584 days revolutions of Venus of is obtained from their GCD and its lcm values as follows:

584 ⁝ 2	
292 ⁝ 2	
146 ⁝ 2	365 ⁝ 5
73 ⁝ 73	73 ⁝ 73
1	1

The lcm of 365 and 584 is $2^3 \times 5 \times 73 = 2920$. The GCD is 73, so that

$$584 \times 365 = \frac{213,160}{73} = 2920.$$

This number of days is essential in page 24 of the Dresden Codex, as we will see. Mayas, at first, calculated the synodic revolution of Venus in 45 "trecenas," that is, 45 × 13 = 585 days. Posterior calculations gave 583.5 but, for practical reasons, they chose 584 days for Venus. Maya's repeated observation of this planet showed that after 61 Venus years, from which they subtracted 4 days, the total of those elapsed could be made divisible by 260 (a *Tzolkin* year). But the 365-day year continued to offer problems. It was necessary, every 5 cycles, to introduce a new modification of 8 days at the end of the 57th revolution (Teeple, 1937: p. 95). The interposed correlations certainly implied an error in the computation of the synodic period of Venus but this consisted only of 0.08 of a day in every 481 years. Inspired in Teeple's corrections, Thompson in "Maya Hieroglyphic…" (Thompson, 1959: pp. 225, 226) suggests three corrections of 4 days at the end of the 61st revolution, 4 times; one correction of 8 days at the end of the 57th revolution, and a correction of 20 days for 240 revolutions. The true correction is 19.2, an error of less than a day in 384 years.

This achievement very definitely does honour to the chronological endeavours of the Maya.

Interestingly enough, in addition, if we take the number 34,445 of column 4 (in the middle of p. 48 in DC) to be an integral multiple of Venusian revolutions—for instance, 59 revolutions—we have that the Venusian period is 583.8135. That is 34,445= 59 × 583.8135. This value we now average with the 584 that one finds in the bottom section of the same Venus pages (pp. 46–50 of DC) to find 583.90. Clearly, when this value (583.90) is compared with the modern one (583.92), it is seen the Maya were off by only 2/100 of a day—only some 30 minutes of a day in 481 years—when determining Venus's synodic period. It is common to find and reproduce a value of 0.08 in related publications, but we prove here that Mayas had a better figure of 0.02. Indeed, the Maya's astronomical achievements portray a magnificent intellectual success in an age in which Europe was subsumed in Middle Ages obscurity.

E. Förstemann identified the Venus glyph on the basis of its recurrence in the Venus Table (p. 24) of the Dresden Codex, which he discovered. He also recognized the uncommon eclipse intervals of 177 and 148 days in the lunar–Sun Eclipse Table (pp. 51–58 of DC), a topic we deal with elsewhere.

Figure 1 — Six pages of the Dresden codex (pages 55–59, 74) on eclipses (left), multiplication tables, and a flood (far right). Credit: Wikipedia

Venus and calendars

The connection with the "ritual year" of 260 days appears after a *Huehuetiliztli*, a period of 104 years (double of the calendric round of 52 years); the product 104 × 365 = 37,960 days, corresponds to 65 synodic Venusian cycles (65 × 584 =37,960) and to 146 "ritual years" (146 × 260 = 37,960). Also, 37,960 = 13 × 2920, that is 13 cycles of 2920 days.

These numbers are approximated since the Venus cycle is 583.92 days, while the year lasts 365.24 days. Mayas made elaborate tables to correct the small discrepancies among Venus's period, the year, and other cycles, see Thompson "Maya Astronomy" (Thompson, 1974: pp. 86, 87).

From what was explained before, we find that after 301 Venus cycles (5 × 61= 305, subtracting 4 = 301) of 584 days (301 × 584 = 175,784 days) Mayas had subtracted a total of 24 days (analogously to our form of adding a day every four years) after 6 periods of 301 days, and with only this correlation, they could predict Venus's position within an error of only 2 hours in 481 years (175,565 days). The knowledge of this last correction by the Mayas is without doubt one of the most outstanding discoveries of ancient astronomy.

Page 24 presents predictions of Venus's phases over an interval of approximately 104 years. Also, in pages 46–50 of the Dresden Codex we find information about Venus phases. In the next section, we will be reading several pages' contents to have an idea of how long they observed and registered the planet in those pages and then compare with Morley's findings.

The contents of pages 46, 47, 48, 49, 50. will be analyzed here to find Venus characteristic periods of appearance and be able to compute for how long Mayas observed and registered Venus movements in those 5 pages together with findings for Venus cycles in page 24 of the Dresden Codex.

Page 46, damaged below, in middle part one reads, first in Maya notation and next in ours:

11.16 = 11 × 20 + 16 × 1 = 236
16.6 = 16 × 20 + 6 × 1 = 326
1.10.16 = 1 × 360 + 10 × 20 + 16 × 1 = 576
1.11.4=1 × 360+11 × 20+4 × 1=584, a Venus period
The sum of these four is: 1,722, almost 3 Venus years of 583–584 days.

Page 47, damaged below, in middle part, for each of four columns:

2.5.0 = 2 × 360 + 5 × 20 = 820
2.9.10= 2 × 360 + 9 × 20 + 10 = 910
3.4.0 = 3 × 360 + 4 × 20 = 1,160.
3.4.8 = 3 × 360 + 4 × 20 + 8 =1,168; dividing by 584 = 2, double Venus period
The sum of the four columns is: 4058, almost 7 Venus years of 583–584 days.

Numbers shown in middle part of page 48, from left to right and from top to bottom:

3.16.3 = 1403	4.2.14 = 1494	4.15.4.17 = 34,297	4.15.12.5 = 34,445
About 2.4 Venus years of 584	About 2.6 Venus years of 584 days	Almost 59 Venus years of 583 days	59 Venus years of 583 days

The total of those days is: 71,639 and this amounts to almost 123 Venus years of 583–584 days. In a weighted average of the above (that is, 5Vy of 584d against 118Vy of 583d some 24 more times of 583d for each of 584d) the predominant value for Venus's revolution is only slightly over 583 days (583.04).

Figure 2 — Three pages of the five consecutive ones dedicated to study Venus., pages 48, 49, and 50 (Códice de Dresde, 2019). Credit Margarita Juárez Nájera.

Page 48, above:
11.10 = 11 × 20 + 10 = 230
4.10 = 4 × 20 + 10 = 90
12.10 = 12 × 20 + 10 = 250
8 = 8

Adding the columns, the total of days amounts to 578. Numbers here correspond to:

Inferior left column 230 (235?) days, Morning Star
Next column: 90 days, superior conjunction
Third column: 250 days, Evening Star
Fourth and last 8 days: inferior conjunction
The total of 578 days (for a possible error, 583) means probably a bar (5 days) in the Codex is missing in the inferior left column, a copyist's error.

On page 49, a detail above, the relevant information referring to Venus reads:

There, in its lower numerical part in red, one reads, from top to bottom and from left to right:

11.11=11 × 20 + 11 × 1 = 231
4.10 = 4 × 20 + 10 = 90
12.10 = 12 × 20 + 10 × 1=250
0.8 = 8 days

Adding columns, the total of those days is 579.

So, we have in the inferior left column 231 days for a Morning Star.
Next column: 90 days, superior conjunction
Third column: 250 days, Evening Star
Fourth and last: 8 days, inferior conjunction
The 579 total days is almost a Venus period.

Same p. 49 up, middle:
For each column one has, also in our numbers:

5.9.8 = 5 × 360 + 9 × 20 + 8 × 1 = 1988
5.13.18 = 5 × 360 + 13 × 20 + 18 × 1 = 2078
6.8.8 = 6 × 360 + 8 × 20 + 8 × 1 = 2328
6.8.16 = 6 × 360 + 8 × 20 + 16 × 1 = 2336

We find in this last fourth column the number: 6.8.16, that is = 2336 days or 4 Venus periods of 584 days each.

Adding the four of them up gives: 8,730; almost 15 Venus years of 583–584 days.

For the middle part of page 50, one finds:
7.2.12 = 7 × 360 + 2 × 20 + 12 × 1 = 2572
7.7.2 = 7 × 360 + 7 × 20 + 2 × 1 = 2662
8.1.12 = 8 × 360 + 1 × 20 + 12 × 1 = 2,912
8.2.0 = 8 × 360 + 2 × 20 = 2,920; dividing by 584 = 5.

We find in fourth column the number 8.2.0 = 2,920 days, that is, 5 Venus periods of 584 days each, a crucial number in page 24 of DC. Adding them up: 11,066, almost 19 Venus years of 583–584 days.

For the bottom part of page 50 one has:
11.16 = 11 × 20 + 16 × 1 = 236
4.10 = 4 × 20 + 10 = 90
12.10 = 12 × 20 + 10 × 1 = 250
0.8 = 8 days

On page 50, we read in the bottom of the first column, 11.16 = 11 × 20 + 16 × 1 = 236. That is, a difference of five days in the Morning Star period with that of p. 49. Summing up those days gives a total value of 584 days for the Venusian cycle, a Venus period.

We guessed that in the bottom damaged parts of pages 46 and 47 there are similar patterns as in the following 48, 49, and 50 pages since they both finish with the same 8 days as the others and in the other columns numbers look the same except perhaps for a day, a bar (5 days) or so in the first column. That could amount to two extra Venus periods of 583 or 584 days each. Also taking into consideration the ones in the middle of p. 48, gives a total of about 170 Venus years of 583–584 days. This means the table in those 5 pages records the passage of about 98,961 days, equivalent to about 271 solar, common years.

The information found in those pages reinforces the conviction that the Maya's Venus period is to be a little less than the accepted value of 584. It inclines more to a higher value of 583. The official value of a Venus period is 583.92 and this value is now to be compared with a high Maya value of 583 rather than with the sharp and higher 584. The result of the comparison undoubtedly shows the discrepancy is certainly less than the traditional 0.08 of a day.

The reality in the Codex shown here, step by step, is different from what Morley talks about in "An Introduction…" (Morley, 1915: 32)

He says about those five DC pages:

> *The most striking proof of the astronomical character of the codices is to be seen in pages 46–50 of the Dresden Manuscript. Here, to begin with, a period of 2,920 days is represented, which exactly contains five Venus years of 584 days each (one on each page) as well as eight solar years of 365 days each. Each of the Venus years is divided into four parts, respectively, 236, 90, 250, and 8 days. The first and third of these constitute the periods when Venus was the morning and the evening star, respectively, and the second and fourth, the periods of invisibility after each of these manifestations. This Venus-solar period of 2,920 days was taken as the basis from which the number 37, 960 was formed. This contains 13 Venus-solar periods, 65 Venus years, 104 solar years, and 146 tonalamatls, or sacred years of 260 days each. Finally, the last number (37, 960) with all the subdivisions above given was thrice repeated, so that these five pages of the manuscript record the passage of 113,880 days, or 312 solar years.*

However, we found, as written in our paper, that in those 5 pages there are recorded the passage of about 100,000 days equivalent to about 271 solar common years, different from what Morley says: 312 solar years. Even more, the mentioned number 37,960 is present not here, as he says, but in page 24 of the same codex, together with the 13 multiples of it. We study this in our next section on page 24.

Other Numbers

A Maya "Ring number" is 1.7.11 and it can be found on page 58 of Dresden Codex.

There is also another number named "distance number" so called because it was used together with the ring number to calculate previous dates in the Long Counts of the days, as we will see.

A Study of Page 24

In what follows we will do an interpretation of something of the very much expressed in page 24 of the Dresden Codex, which is an example of sophistication in astronomical notation. There is a lot to be discovered there yet. An analysis of this page is an overall research subject. We will limit ourselves to point out several facts related to numbers and their factors.

Page 24 consists of calculations in the Long Count of the days, a table of multiples related to Venus cycles and a series of four numbers which, according to Thompson, were probably used to correct the shift of the table with time. However, for that series of four numbers we have another interpretation to be shown in the appendix that has nothing to do with corrections in time.

Summarizing the information of the preceding pages in a single table we have:

p.46	p.47		p.48	p.49	p.50
11.16 = 11 × 20 + 16 × 1 = 236 16.6 = 16 × 20 + 6 × 1 = 326 1.10.16 = 1 × 360 + 10 × 20 + 16 × 1 = 576. The sum of the three is: 1 138. Almost 2 Venus years of 583-584 days. 1.11.4 = 1 × 360 + 11 × 20 + 4 = 584, a Venus period	2.5.0 = 2 × 360 + 5 × 20 = 820 2.9.10 = 2 × 360 + 9 × 20 + 10 = 910 3.4.0 = 3 × 360 + 4 × 20 = 1160. The sum of the three is: 2 890. Almost 5 Venus years of 583–584 days. 3.4.8 = 3 × 360 + 4 × 20 + 8 = 1168/584 = 2, a double Venus period	Middle Part	3.16.3 = 1 403 About 2.4 Venus years of 584 days 4.2.14 = 1 494 About 2.5 Venus years of 584 days 4.15.4.17 = 34,297 Almost 59 Venus years of 583 days 4.15.12.5 = 34,445 59 Venus years of 583 days Total is: 71,639 days Almost 123 Venus years of 583-584 days.	5 × 360 + 9 × 20 + 8 × 1 = 1988 5 × 360 + 13 × 20 + 18 = 2078 6 × 360 + 8 × 20 + 8 × 1 = 2 328 Adding them: 6 394; almost 11 Venus years of 583-584 days. 6 × 360 + 8 × 20 + 16 × 1 = 2336/584 = 4 That is, 4 Venus periods of 584 days each.	7 × 360 + 2 × 20 + 12 = 2572 7 × 360 +7 × 20 + 2 = 2662 8 × 360 + 1 × 20 + 12 = 2912 Adding them: 8146; almost 14 Venus years of 583-584 days 8 x 360 + 2 x 20 = 2 920/584 = 5 That is, 5 Venus periods of 584 days each.
Information illegible	Information illegible	Bottom Morning Star Superior conjunction Evening Star Inferior conjunction Adding	11.10 = 11 × 20 + 10 = 230 days Missing bar 5 days error 4.10 = 4 × 20 + 10 = 90 days 12.10 = 12 × 20 + 0 = 250 days 0.8 = 8 days 578 total days	11.15 = 11 × 20 + 15 = 235 days 4.10 = 4 × 20 + 10 = 90 days 12.10 = 12 × 20 + 10 × 1 = 250 days 0.8 = 8 days 583 total days	11.16, = 11 × 20 + 16 × 1 = 236 days 4.10 = 4 × 20 + 10 = 90 days 12.10 = 12 × 20 + 10 × 1 = 250 days 0.8 = 8 days 584 total days

Figure 4 — Summary of information in pages 46 to 50

Page 24 of the Dresden Codex is also called Venus table; there one finds two dates in the Long Count of the days (9.9.16.0.0 and 9.9.9.16.0) that offer information of the moment in which this table could have been used. Aside from this, the number 6.2.0, given it is surrounded by a circle, is called ring number. Usually, one of the numbers is added to a base date in the previous Long Count to give a further coming date. In this case, the intention was to add the ring number to a date previous to 0.0.0.0.0 4 *Ahau* 8 *Cumhú* so as to reach a date that points to the actual time. Starting with the numbers of the first left column, below the glyphs, one reads, from top to bottom, the ring number 6 *tun* 2 *uinal* 0 *kin* 4 *Ahau* 8 *Cumhú*, that is 2 200 days 4 *Ahau* 8 *Cumhú*. (The 4 of Ahau and the 8 of *Cumhú* are not visible in FAMSI web copies)

Next column reads 9.9.16.0.0 1 *Ahau* 18 *Kayab*, that is, 9 *baktún* 9 *katún*, 16 *tun*, 0 *uinal*, 0 *kin* 1 *Ahau* 18 *Kayab*. This number is called distance number and amounts to 1,366,560 days 1 *Ahau* 18 *Kayab*.

In the third, column one finds a date from the Long Count 9.9.9.16.0 1 *Ahau* 18 *Zip* equivalent to 1,364,360 days 1 *Ahau* 18 *Zip*.

Below the so-called distance number and also of the date of the Long Count there are the positions of the Calendric Round 1 *Ahau* 18 *Kayab y* 1 *Ahau* 18 *Zip*, respectively. Below the ring number there is the initial date for the Maya époque of the moment 4 *Ahau* 8 *Cumhú* (see Table 1a).

The ring number subtracted from the initial date of the Maya age 13-0-0-0-0, 4 *Ahau* 8 *Cumhú*, will reach the ring base number 12.19.13.18.0, 1 *Ahau* 18 *Kayab*, of the previous age.

The distance number 9.9.16.0.0 added to 12.19.13.18.0 must reach the number in the Long Count; one arrives at (9.9.9.16.0) + (13.0.0.0.0) 1 *Ahau* 18 *Kayab*, and not to (9.9.9.16.0), which is the apparent starting date of the table. (Note that 1,364,360 + 2200= 1,366,560).

The date: 9.9.9.16.0, 1 *Ahau* 18 *Kayab*, corresponds to February 7, BCE year 623 in the Julian calendar. Date 0.0.0.0.0. 4 *Ahau* 8 *Cumhú* is equivalent to August 11, BCE year 3114. (Thompson correlation of 1950).

Ring number	Distance number	Date in the Long Count
6.2.0 *4 Ahau 8 Cumhú*	9.9.16.0.0 1 *Ahau* 18 *Kayab*	9.9.9.16.0 1 *Ahau* 18 *Zip*
6 tun 2 uinal 0 kin = 2200 days	*9 baktún 9 katún 16 tun 0 uinal 0 kin* = 1,366,560 days	*9 baktún 9 katún 9 tun 16 uinal 0 kin* = 1,364,360 days

Table 1a - Left low part of page 24 of Dresden Codex

In the right-upper side of the page, severe damage makes it impossible to do the direct reading of the numbers, nonetheless we have proposed four columns to complete the information. Those numbers are shown on Table 1b. The four columns are to be read from top to bottom starting in the superior line in which one reads 1 *Ahau*, below the illegible numbers. Each one of the four entrances are dates 1 *Ahau* that must have been a canonical requisite for the appearance of Venus relative to the calendric round. The first number is 1.5.14.4.0 1 *Ahau*, that is, 185 120 days 1 *Ahau*. The next number going down is 35,040 days 6 *Ahau*. Follows number equivalent to 23,360 days 13 *Ahau*, to end that column with the number: 11,620 days 7 *Ahau*. At this point we make clear that we have added 3 dots over the black bar for a total of 11,680 and not 11,620 as is written. This correction is made with the purpose of continuing the evident pattern of multiples of 2920 generated when reading from right to left, a pattern that continues to superior levels.

The column that follows to the right reads: 9.11.7.0 1 *Ahau* that is, 68,900 days. Next number is 4.9.4.0 11 *Ahau*, equal to 32,120 days. Following is 2.16.14.0 5 *Ahau*, equal to 20,440 days. Continues with number 1.4.6.0 12 *Ahau* equivalent to 8,760 days. In the third column one has: 4.12.8.0 1 *Ahau*u, equal to 33,280 days. Continuing next is 4.1.2.0 3 *Ahau*, or, 29,200 days. Follows date 2.8.12.0 10 *Ahau*, or 17,520 days. The next is 16.4.0 4 *Ahau*, or 5840 days. The fourth (and last column) can be read directly from Table 1b (next page).

In the right base of the table page, one reads, from right to left and going up, the progression of multiples of the Venus period of 2920 days (a crucial number being the basis of page 24. Arithmetically speaking the number, 2920, comes from the least common multiple (lcm) and Greatest Common Divisor (GCD) between Venus and Earth revolution periods) until 12º multiple.

Note number 37,960 = 13 × 2 920, is equivalent to 13 cycles of 2 920 days, equivalent to 5 Venus periods This 13º multiple is shown in the first line of Table 1b, in the reconstructed numbers, and is double the Calendric Round and is as well the lcm of 365, the *Haab-Uayeb* days or common or *vague* year, the Venusian period of 584 days and the *Tzolkin* of 260 days (37,960 = 13 × 2920 and 2920 × 468 = 1,366,560 = 37,960 × 36) as shown next:

	584 ⋮ 2	260 ⋮ 2
	292 ⋮ 2	130 ⋮ 2
365 ⋮ 5	146 ⋮ 2	65 ⋮ 5
73 ⋮ 73	73 ⋮ 73	13 ⋮ 13
1 ⋮	1	1

The lcm is $2^3 \times 5 \times 13 \times 73 = 18{,}980 \times 2 = 37{,}960$. This double Calendric Round is then used as a multiple to generate the last terms of the page.

As Venus cycle is of 584 days and *Tzolkin* calendar has 260 days, their relation is 146 × 260 = 65 × 584 = 37,960 days or 5.5.8.0. Then one could expect that Venus presence would be repeated in a given date of the calendric round after that period. This interval turns out to be the 104 *vague years* or two complete calendric rounds.

Aveni (2005) has pointed out that 65 real Venus revolutions, each one with an average of 583.92 days, are closer to 37,955 days than the 37,960 in the table. This means that after two calendric, rounds a phase shift of 5 days that was surely known and corrected by Mayas, was not a matter of worries in the short but in the long term.

Page 24 actually starts in 151,840 days that is equivalent to 5 multiples of 52 times the solar Venus period and to the product of the *Tzolkin* and Venus (5 × 52 × 584 = 260 × 584 = 151,840) and to four double calendric rounds of (4 × 37,960 = 151,840). Morley (1938) noticed that line of four runs in the table. There is agreement between our findings shown in our Tables 1a and 1b and his, even more a possible numerological reason to include those 151,840 days is that they are equivalent also to 1 *baktún* 1 *katún* 1 *tun* 1 *tzolkin* 1 *uinal* 0 *kin*. (=144,000 + 7,200 + 360 + 260 + 20). You can find page 24 of the Dresden Codex http://www.bibliotecapleyades.net/ciencia/dresden/dresdencodex04.htm.

The "super–number" 9.9.16.0.0 (1,366,560 days; February 7, BCE year 623) has the property of being divisible by a large amount of numbers in the Maya calendar. This number would represent the installation date of the table even when Lounsbury (1983) maintains that the date is 10.5.6.4 (20th November BCE year 934).

Conclusions

The evidence left in Dresden Codex shows Mayas had a remarkable interest in the motion of the Sun, Moon and the planets, among them, particularly in Venus. In this Codex, they record years of astronomical observation that show us the magnificent system they developed and dominated through thousands of years permitting nowadays to recognize their advanced knowledge in the field of measuring time. The Venus trajectory and movements were observed with such a precision that the position of the planet in the sky could be predicted

Illegible 151 840 (4 × 13 × 2920)	Illegible 113 880 (3 × 13 × 2920)	Illegible 75 920 (2 × 13 × 2920)	Illegible 37 960 (1 × 13 × 2920)
Proposed: 1.1.1.14.0 1 *Ahau* 1 *baktún* 1 *katún* 1 *tun* 14 *uinal* 0 *kin* = 151,840	Proposed: 15.16.6.0 1 *Ahau* 15 *katún* 16 *tun* 6 *uinal* 0 *kin* = 113,880	Proposed: 10.10.16.0 1 *Ahau* 10 *katún* 10 *tun* 16 *uinal* 0 *kin* = 75,920	Proposed: 5.5.8.0 1 *Ahau* 5 *katún* 4 *tun* 8 *uinal* 0 *kin* = 37,960
.-.-.-.-	.-.-.-.-	.-.-.-.-	.-.-.-.-
1.5.14.4.0 1 *Ahau* 1 *baktún* 5 *katún* 14 *tun* 4 *uinal* 0 *kin* = 185,120 days	9.11.7.0 1 *Ahau* 9 *katún* 11 *tun* 7 *uinal* 0 *kin* = 68,900 days	4.12.8.0 1 *Ahau* 4 *katún* 12 *tun* 8 *uinal* 0 *kin* = 33,280 days	1.5.5.0 1 *Ahau* 1 *katún* 5 *tun* 5 *uinal* 0 *kin*= 9100 days
.-.-.-.-	.-.-.-.-	.-.-.-.-	.-.-.-.-
4.17.6.0 6 *Ahau* 4 *katún* 17 *tun* 6 *uinal* 0 *kin* = 35 040 days (12 × 2920)	4.9.4.0 11 *Ahau* 4 *katún* 9 *tun* 5 *uinal* 0 *kin* = 32 120 days (11 × 2920)	4.1.2.0 3 *Ahau* 4 *katún* 1 *tun* 2 *uinal* 0 *kin* = 29 200 days (10 × 2920)	3.13.0.0 8 *Ahau* 3 *katún* 13 *tun* 0 *uinal* 0 *kin* = 26 280 days (9 × 2920)
3.4.16.0 13 *Ahau* 3 *katún* 4 *tun* 16 *uinal* 0 *kin* = 23 360 days (8 × 2920)	2.16.14.0 5 *Ahau* 2 *katún* 16 *tun* 14 *uinal* 0 *kin* = 20,440 days (7 X 2920)	2.8.12.0 10 *Ahau* 2 *katún* 8 *tun* 12 *uinal* 0 *kin* = 17,520 days (6 × 2920)	2.0.10.0 2 *Ahau* 2 *katún* 0 *tun* 10 *uinal* 0 *kin* = 14,600 days (5 × 2920)
1.12.(5+3).0 7 *Ahau* 1 *katún* 12 *tun* 8 *uinal* 0 *kin* = 11,680 days (4 × 2920)	1.4.6.0 12 *Ahau* 1 *katún* 4 *tun* 6 *uinal* 0 *kin* = 8760 days (3 × 2920)	16.4.0 4 *Ahau* 16 *tún* 4 *uinal* 0 *kin* = 5840 days (2 × 2920)	8.2.0 9 *Ahau* 8 *tun* 2 *uinal* 0 *kin* = 2920 days (1 × 2920)

Table 1b - Right side of page 24 of Dresden Codex

within a centesimal part of the day in a period of 481 years. The error between real and tabulated times of the position of Venus would be off by just two hours in about 500 years. The crucial numbers in the Venus table of Dresden Codex (page 24) are explained only in terms of the GCD and lcm concepts of numbers, among another mathematical concepts, seems a knowledge Mayas had. ✶

Appendix

In page 24 of Dresden Codex one finds a row of four so-called Peculiar Numbers here we give our interpretation:

1.5.14.4.0 = 185,120	9.11.7.0 = 68,900	4.12.8.0 = 33,280	1.5.5.0 = 9100
Our Interpretation:			
= (780×237) +260 = 260×712	= (780×100)–9100 = 260×300–9100	= (780×43)–260 = 260×128	= 7×13×100

Fig. 7 Detail of page 24 of DC showing the peculiar numbers

We gave in this table an interpretation of the "peculiar numbers" in terms of Martian years (780 days) and the *Tzolkin* calendar (260 days). In addition, we find some relations among them:

From left to right, subtracting

- The first and second: 185,120-68,900 = 116,220 = 149 Mars rev = 447 *Tzolkins*
- The second and third: 68,900-33,280 = 35,620 = 137 *Tzolkins* = 548x65
- The third and last: 33,280-9,100 = 24,180 = 31 Mars rev= 93 *Tzolkin*

Besides, these three numbers (116,220; 35,620; 24,180) are each divisible by 52.

The first and third: 185,120- 33,280 = 151,840 = 584 *Tzolkins* = 260 Venus periods. Here we have a happy coincidence: Venus period is 584 days and *Tzolkin* cycle is 260 days. See also that 151,840/2920 (base number in page 24) = 52.

- The first and last: 185,120-9100 = 176,020 = 677 *Tzolkins* Also 176,020 /52 = 3385.
- The second and last: 68,900-9100 = 59,800 = 230 *Tzolkins* Also 59,800/52 = 1150.

Note: The number 52 is the number of panels in the Maya Pyramid; it's the fourth multiple of 13 (4 × 13) in the multiples of 13 tables in Dresden Codex and the number of years in a calendric cycle and Mesoamerican century.

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Dresden Codex in Förstemann and Kingsborough versions. When Codex was found it was in a poor condition so Europeans assigned a page numbering that, later, was proved to be wrong. The numbering was conserved almost the same, however, the order of the pages inside the Codex was probably 1–24, 46–74 and 25–45. We find Dresden Codex in FAMSI page: www.famsi.org/mayawriting/codices/dresden.html. Förstemann and Kingsborough versions differ slightly in page numbering. Pages Kingsborough 1, 2, are the Förstemann's 44, 45. Pages F1 and F2 are K44 and K45. From page 3 to 43, have the same numeration. From page 46 to the last page, 74, numbers coincide. The Dresden Codex, as it appears in the Lord Kingsborough was prepared with the cooperation and courtesy of the Jay Kislak Foundation, Miami Lakes, Florida. Arthur Dunkelman, Director. Although the artist Agostino Aglio followed the original codex with great precision, there are subtle differences in the rendering of some of the glyphs and figures.

Dresden Codex, see also: www.famsi.org/mayawriting/codices/pdf/grolier_kerr.pdf

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The August 2024 *Journal* deadline for submissions is 2024 June 1.

See the published schedule at rasc.ca/sites/default/files/jrascschedule2024.pdf

The Noctilucent Cloud Observing Program of Michael Noble

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"Mike Noble—a faraway voice at a dark site—the guy who was already set up when you arrived—a faithful admirer of the aurora and noctilucent clouds." — Sherrilyn Jahrig

Abstract

This paper considers observational results of noctilucent clouds (NLC) performed by Michael Noble, who was an outstanding amateur observer. One of his special efforts was driving outside Edmonton to avoid weather clouds, hence obtaining clear skies to get more probability of observing NLC. It is demonstrated that this technique can greatly increase the number of NLC-active nights. Doubling the number of sites used or quadrupling the area between all sites can increase seasonal NLC-active night totals by half.

Introduction

Noctilucent clouds (NLC) occur not in space but at the top of Earth's mesosphere, 80-km high. Hence, they are not a true astronomical phenomenon, yet they nonetheless delight many observers from May through August in the Northern Hemisphere with their filigree opalescent patterns against the backdrop of the twilight sky. If the display of NLC is broad enough and at great elevation angle at the observer's location, it can fill over half the sky and be bright enough to cast shadows, a memorable sight.

Since they first appeared in Europe in 1885, and not in North America until 1933, observers have been monitoring their spring and summer skies to catch NLC. The attendant data from several observers can construct a picture of what the phenomenon did regionally for that season. Results from various networks dating back to the 1960s, when global monitoring began in earnest, have shown that the seasonal totals from any one site have trended upward, but only slightly and not with statistical significance (Dalin et al., 2020, Pertsev et al., 2014).

As with many citizen science pursuits, success goes hand in hand with time devoted to the project. We in Edmonton have been blessed with a classical example. Michael Noble (Fig. 1), who died in October 2022 at the age of 68, was a longtime member of the Edmonton Centre. He was a tireless volunteer at the observing deck at Telus World of Science Edmonton, as remembered by fellow member Sharilyn Jahrig and others

Figure 1 — Michael Noble in 2017, holding one of his own photographs of the extensive NLC display of 2016 July 13–14. Photo by Mark Zalcik.

at a tribute to Mike (RASC Edmonton, 2022). Among his fields of expertise were telescopic and photographic equipment and the observation of comets and the aurora. He was also an avid meteorite hunter. Recently retired in 2014, Mike found a new passion: NLC. Not content with observing the clouds solely from home, Mike quickly found that driving outside the city to avoid weather clouds can result in more nights with NLC each season by placing oneself under clear enough skies to catch the mesospheric clouds. A noctilucent tour de force, Mike hit the highways through the entire three-month season.

Results and Discussion

A sole observer monitoring from a single site can tally up to 20 NLC-active nights per season (Zalcik et al., 2021). When a few observers check the sky independently within a certain area, let's say, in the environs of a city, the total will be slightly greater as one or more observers will detect displays on nights when other observers did not. Such an example is from 2023, when three NLC observers in northern Scotland sent their sightings to the reporting website NLCNET (www.nlcnet.co.uk).

Figure 2 — Photo of bright NLC display as seen from north of Sullivan Lake, Alberta, on 2018 July 2–3, at 0320 MDT (0920 UT). Mike Noble drove some 200 km to evade weather clouds in order to witness this display. Photo by Mike Noble.

A 150-square-km triangle formed by James Fraser from Alness, Sandra Brantingham in Glenbarry, and Alan Tough in Elgin, stretches along the 57th parallel. In concert the 3 tallied 13 NLC-active nights in 2023. Of the three, Fraser had the greatest number of NLC-active nights at nine. Brantingham had eight, four of which Fraser did not see; Fraser had five, which Brantingham did not see. Tough had five active nights, all corroborated by at least one of the other observers.

For any one site or one area lies a "true number" of NLC-active nights for that season. Factors such as weather conditions, viewing angle, faintness of the displays, and overall ability for the group to detect and recognize a display, will influence this number. Latitude is also a factor. The farther south the observer or observer group, the fewer the number of active nights as one gets farther away from the southernmost reaches of the NLC formation zone in the 60s of latitude. The Aeronomy of Ice in the Mesosphere (AIM) satellite has showed that globally, the average NLC start and end dates are May 22 and August 26, respectively, yielding a 97-night season (Dr. Cora Randall, pers. com). Empirically, the most NLC-active nights in North America were during the 2020-2022 seasons as determined by the NLC CAN AM surveillance network, with over 70 per season (yearly summaries of network observations can be found at https://www.researchgate.net/profile/M-Zalcik/research).

Hence, the disparity between a good NLC season's total by an individual (20 nights) and the global total (more than 90) is great. How does an observer bridge this gap? Mike Noble's observations showed that increasing one's geographical coverage by being mobile can do just that. He tallied 350 NLC-active nights over the 9-season period, an average of nearly 39 nights per season. Over the 9 years, there were only a dozen displays that Mike missed. His most prolific season was 2018, with 49 active nights, including a run of 25 consecutive nights from June 22–23 to July 16–17.

The most obvious advantage of mobility is catching NLC at a far-flung site when a large mass of tropospheric cloud covers a wide area around an observer's home base. One way is to launch a simple drone-quadcopter up to four kilometres in altitude, thus observing NLC above a tropospheric cloud base. However, this technique requires knowledge of launching and controlling a drone flight as well as getting permission from aviation authorities to launch a drone. Another way to see NLC on such nights is to travel beyond the fringes of the cloud mass, or to find a void within it. Complicating such a venture is the fact that if the NLC are distant, they will be only a few degrees above the horizon, so a nearly tropospheric cloud-free northern horizon is essential to see them. Zalcik et al. (2014) highlighted the situation by showing the relationship between different levels of tropospheric cloud and the ability to detect NLC. When driving southward to avoid a large cloudy area, just reaching the edge of the cloud mass is not sufficient. Usually, one has to travel much further south so that the weather cloud mass has receded all the way to the northern horizon above which NLC hover only a few degrees.

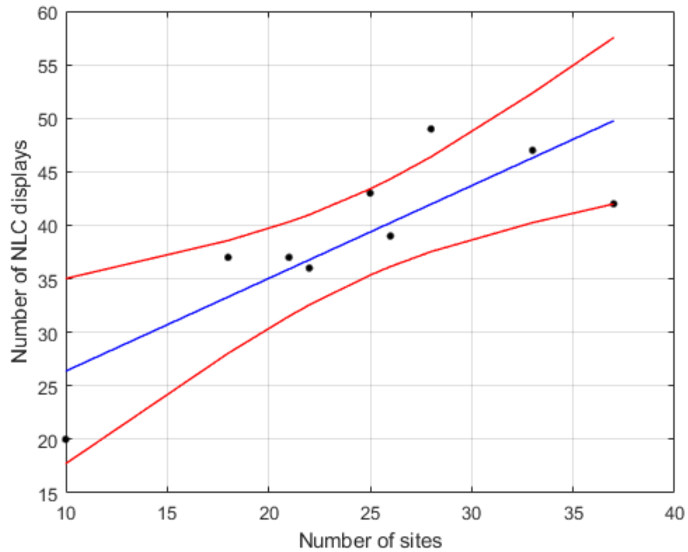

Figure 3 — Number of observing sites used by Mike Noble during each season in his 2014–2022 NLC observing campaign versus number of NLC-active nights (the black dots). The blue line is a linear regression line estimated using the least-squares method. The red curves are 95 percent confidence interval of the regression line.

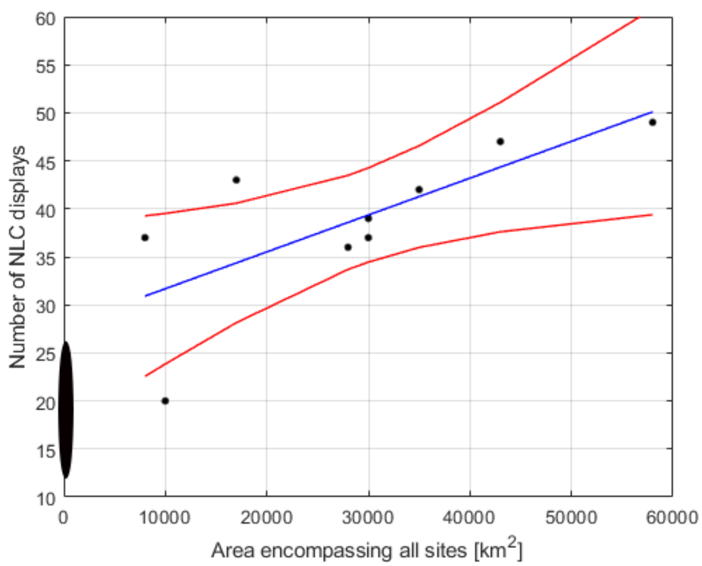

Figure 4 — Area encompassing all of Mike Noble's sites during each season versus number of NLC-active sites (the black dots). The blue line is a linear regression line estimated using the least-squares method. The red curves are 95 percent confidence interval of the regression line. The ellipse along the y-axis denotes the range of NLC-active nights, 12–26, in the same study period by Mark Zalcik, who used only 3 sites in the Edmonton area.

During an NLC season, Mike would have a small number of "go-to" sites close to Edmonton that had reasonably dark skies and a flat northern horizon. But the majority of Mike's sites fanned out in all directions, typically 50-100km from the city, indicating that the sky on many nights was too cloudy at the go-to sites, and some additional driving was necessary. On some nights Mike would have to use multiple sites to find holes in tropospheric cloud decks or drive ahead of an eastward-moving cloudy area. Some sites were over 100 km away; the farthest ones were Olds in 2018, 200 km south of Edmonton, and Sullivan Lake, 200 km to the southeast (Fig. 2), visited in 2018 and 2020. Regarding the 2018 visitations, the aforementioned 25-night streak hung in the balance; the sightings at both sites helped keep the streak alive!

Mike would keep us all apprised in real time by posting during the night on our Edmonton RASC Astro chat. The tropospheric cloud interference on some nights was truly challenging. During the first season of Mike's campaign, on 2014 July 4–5, Mike described a night of site-hopping:

I drove northeast of the city in hopes of staying ahead of the oncoming cloud and storms. I got to a point 10km west-southwest of Boyle and had a nice location. Unfortunately, the cloud was fast moving toward the northeast and forced me further to the north at 11:20 p.m. I got to Grasslands and called it quits driving because the cloud got

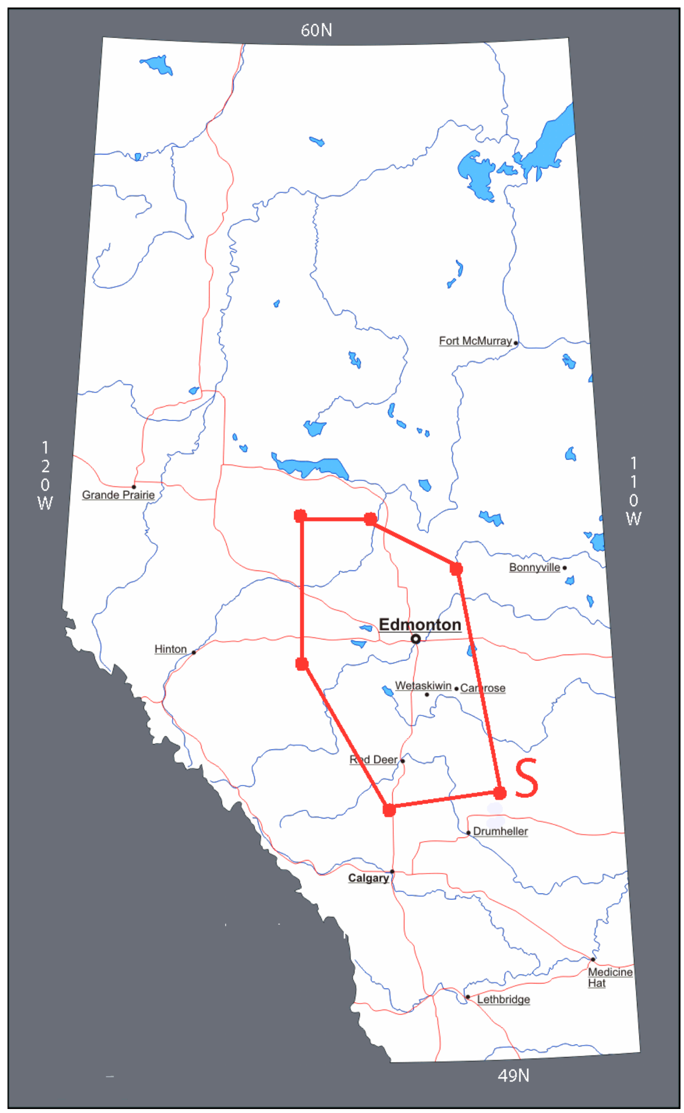

Figure 5 — Map of Alberta showing polygon formed by outermost of Mike Noble's NLC observing sites during the 2018 season. The letter "S" denotes Sullivan Lake.

there before me. I had about 5-8 degrees visible along the horizon at 11:45, but no NLC were visible or imaged. By 12:15 a.m., only 4 degrees of northern sky along the horizon was still relatively clear, but no NLC were visible. I started home at 12:30 a.m. and got home at 2:20 a.m. The rainstorms had lots of lightning and downpours that reduced my speed down to 20-30 km/h under the speed limit. The downpours were extremely heavy for about 10-15 minutes as I drove south of Gibbons back to the city.

To see whether or not the total number of Mike's sites in a season had a correlation with the total of his active nights, we composed a graph (Fig. 3). We then drew a polygon on a map of Alberta showing the farthest sites for each season and calculated the area within the polygon. The area for each of the nine seasons of observing and the corresponding active-night total is plotted in Figure 4. Both regression lines (blue) are 95 percent statistically significant and have a clearly positive trend. Figure 3 shows that doubling sites from 15 to 30 increased NLC-active night totals from 30 to nearly 45; Figure 4 shows that the same result can be achieved by quadrupling the area between sites from 10,000 to 45,000 square kilometres. Mike's most prolific year for NLC travel was 2018, with the resulting polygon having an area of 58,000 square kilometres (Fig. 5). Recall that the 2018 season was also Mike's record for NLC-active nights, a total of 49. The graphs do not take into consideration year-to-year variations in NLC activity. During this survey period there was heightened NLC activity in the 2018–2022 seasons, perhaps as a result of increased volcanic activity in 2015–2016 (Dalin et al., 2023).

Mobility alone was not responsible for Mike's NLC observing success. Other factors would include his extensive experience at identifying NLC, and the ideal site conditions he secured at his selected sites. The fact that Mike would set up at dusk and stay all night on-site meant that he monitored the night's entire NLC-observing window, which from Edmonton is around 2300-0400 local time at peak season in late June/early July. Using digital cameras to discover the first vestiges of NLC, and to follow the faintest displays during the night, augmented Mike's totals; the faintest displays would have been very difficult to pick out with the naked eye, certainly from within the city of Edmonton. In the aforementioned study by Zalcik et al. (2021), it was determined that Mike's NLC brightness rating (on a scale of 1-3, 1=faint, 2=moderate, 3=bright) at the start of a display was a "1" 91 percent of the time. In comparison, staff at weather stations and airports through the 1960s and 1970s more often unequivocally identified NLC only when they were at a brightness of 2 or even 3. Dedicated fixed NLC cameras, either belonging to organized networks (Dalin et al., 2006) or individuals, have had great success. The record for such a camera is 39 active nights in 2021 by the camera at Vidiskes, Lithuania.

How Mike Noble's use of multiple sites each season can be an analogue for multiple observers within a similar area is open to question. Many of Mike's sites were only visited once. Multiple-observer monitoring, on the other hand, usually involves participants checking the local sky several times during any one NLC season. Large, bright displays, however, tend to bring more one-off reports.

Conclusions

The prolific NLC observing program of Michael Noble showed that driving to obtain clear skies during the NLC season can greatly increase the number of NLC-active nights obtained. Doubling the number of sites used or quadrupling the area between all sites can increase seasonal NLC-active night totals by half. ✶

Acknowledgements

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Figure 1 — Allendria Brunjes' Sun shots were taken simply with a Nikon D5200 at 200mm, in risky fashion by putting old SkyNews solar viewers in front of the glass. Very little photo editing (I just had to dim the Sun shot a bit!).

Figure 2 — Trying to find clear skies in the path of totality in Ontario was difficult, but Shakeel Anwar managed to see the eclipse from the Niagara Region through the clouds. He used a Radian 75-mm f/5.4 Petzval refractor on a ZWO AM5 mount and shot with a Canon T3i camera. The image of the prominences was taken with a shutter speed of 1/15 at ISO 100.

Continues on page 123

What's Up in the Sky?

June/July 2024

Compiled by James Edgar and Scott Young

Solar System

Mercury is barely visible in the dawn sky at the beginning of the month, passing only 7 arcminutes from Jupiter on the morning of the 4th. The innermost planet then passes behind the Sun in mid-June, re-emerging into the evening sky late in the month.

Venus passes directly behind the Sun on June 4 (although this occultation won't be observed except by Sun-watching satellites). It passes into the evening sky but remains very low and difficult to observe.

Mars is low in the morning sky in June, its disk only 5 arcseconds across at the beginning of its 2024–25 observing season. The waning crescent Moon is nearby on the mornings of the 2nd and 3rd.

Jupiter emerges into the morning twilight this month, low in the east-northeast in the hour before sunrise. It is only 7 arcminutes away from Mercury on the morning of the 4th.

Saturn is low in the morning sky. The rings are very close to edge-on this year, which makes Saturn appear fainter than usual in other years. However, there are a series of events where Saturn's moons transit either the rings or the planet itself, which will be interesting and challenging observations throughout the year. See the Sky Calendar for specific events visible from Canadian longitudes.

Uranus has moved into the morning sky, but is still too close to the Sun to be easily visible this month.

Neptune is in the morning sky below the circlet that marks one tail of Pisces, the Fish.

Dwarf planet **Ceres** is near the handle of the "teapot" asterism in Sagittarius, easily visible in binoculars at magnitude 8 and brightening to near magnitude 7 by month's end. Dwarf planet **Pluto** remains near magnitude 14.5 and is invisible without at least a 20-cm telescope. Finder charts for both dwarf planets are available in the *2024 Observer's Handbook*.

Comet C/2023 A3 (Tsuchinshan-ATLAS) is in the evening sky, a 10th-magnitude spot among the stars of Virgo. It brightens to perhaps 8th magnitude by the end of the month, a preview of its potential bright apparition in the fall when it could reach 1st magnitude.

Sky Calendar for June 2024

Tue Jun 4: Mercury in conjunction with Jupiter this evening, a separation of 7 arcminutes but only 12 degrees from the Sun. Meanwhile, Venus passes directly behind the Sun today.

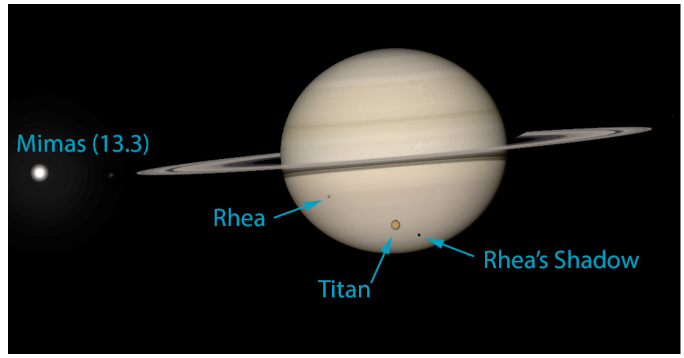


Figure 1 — Titan and Rhea transit Saturn's southern hemisphere on June 14. The view here is shown at 11:00 UTC. [Image: S. Young/ Stellarium]"

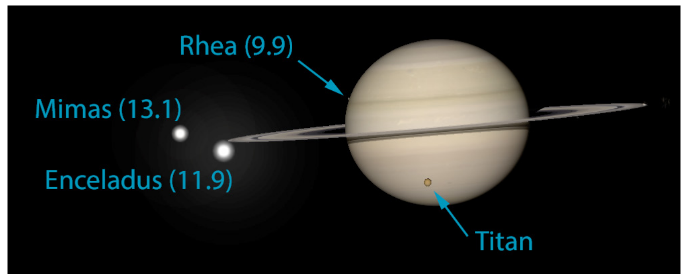


Figure 2 — Titan in transit on June 30. This event is at least partially visible in a dark sky from most of Canada. [Image: S. Young/ Stellarium]

Thu Jun 6: New Moon

Thu Jun 13-Fri Jun 14: First-quarter Moon

Fri Jun 14: Saturn's two brightest moons,Titan and Rhea, will transit the ringed planet's southern hemisphere simultaneously on the morning of June 14th. Best views will be from British Columbia and so best seen from western Canada (and points farther south). Titan begins its transit about 8:48 UTC; Titan transits were seen both visually and with high-resolution imaging during the last ring-plane crossing in 2009. Rhea's shadow joins it beginning about 9:05 UTC, while Rhea itself ingresses about 10:22 UTC. Will Rhea be visible with today's modern imaging techniques, at only a quarter arcsecond across? What about its higher contrast and elongated shadow? Let's find out!

Thu Jun 20: Summer Solstice occurs at 20:51 UTC today. This marks the Sun's highest point, and the midpoint of the perpetual twilight that many Canadian cities experience. After today, sunset will get earlier and darker skies are not far away.

Fri Jun 21: Full Moon

Thu Jun 27: Saturn is to the left of the nearly last-quarter Moon in the east this morning.

Continues on page 122

The Sky June/July

Compiled by James Edgar with cartography by Glenn LeDrew

Celestial Calendar

(bold=impressive or rare)

Jun. 1 Neptune 0.02° northwest of waning crescent Moon

Jun. 2 Moon at perigee (368,102 km)

Jun. 2 Mars 2° southeast of waning crescent Moon

Jun. 6 new Moon at 8:38 a.m. EDT (lunation 1255)

Jun. 14 Moon at first quarter

Jun. 14 Moon at apogee (404,076 km)

Jun. 16 Spica 1.2° south of waxing gibbous Moon

Jun. 20 summer solstice at 4:51 p.m. EDT

Jun. 21 full Moon at 9:08 p.m. EDT

Jun. 23 Ceres occulted by Moon at 1:00 a.m. EDT

Jun. 27 Moon at perigee (369,286 km)

Jun. 28 Moon at last quarter

Jul. 1 Mars 4° south of waning crescent Moon

Jul. 2 Uranus 4° south of waning crescent Moon

Jul. 2 Moon 0.3° south of Pleiades (M45)

Jul. 5 Earth at aphelion (152,099,968 km)

Jul. 5 new Moon at 6:57 p.m. EDT (lunation 1256)

Jul. 7 Mercury in Beehive (M44)

Jul. 7 Mercury 3° south of thin crescent Moon

Jul. 12 Moon at apogee (404,362 km)

Jul. 13 Moon at first quarter

Jul. 13 Spica occulted by Moon at 11:00 p.m. EDT

Jul. 15 Mars 0.6° S of Uranus

Jul. 16 double shadows on Jupiter

Jul. 21 full Moon at 6:17 EDT

Jul. 22 Mercury greatest elongation east (GEE) (27°)

Jul. 23 double shadows on Jupiter

Jul. 24 double shadows and transits on Jupiter

Jul. 24 Moon at perigee (364,917 km)

Jul. 27 Moon at last quarter

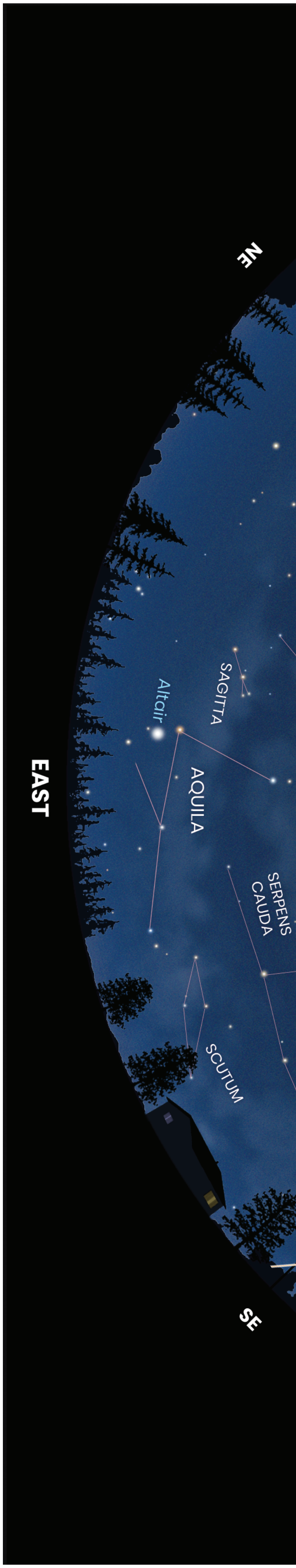
Jul. 28 S. d-Aquariid meteors peak

Jul. 29 Uranus 4° south of waning crescent Moon

Jul. 30 Mars 5° south of waning crescent Moon

Planets at a Glance

	DATE	MAGNITUDE	DIAMETER (″)	CONSTELLATION	VISIBILITY
Mercury	Jun. 1		5.6	Taurus	—
	Jul. 1	–0.6	5.7	Cancer	Evening
Venus	Jun. 1	—	9.6	Taurus	—
	Jul. 1	—	9.7	Gemini	—
Mars	Jun. 1	1.1	5.0	Pisces	Morning
	Jul. 1	1.0	5.4	Aires	Morning
Jupiter	Jun. 1	—	32.8	Taurus	—
	Jul. 1	–2.0	33.6	Taurus	Dawn
Saturn	Jun. 1	1.1	17.0	Aquarius	Morning
	Jul. 1	1.0	17.9	Aquarius	Morning
Uranus	Jun. 1	—	3.4	Taurus	—
	Jul. 1	5.8	3.4	Taurus	Morning
Neptune	Jun. 1	7.9	2.2	Pisces	Morning
	Jul. 1	7.9	2.3	Pisces	Morning




NORTH
PERSEUS
Double Cluster
CASSIOPEIA
LACERTA
Capella
AURIGA
NW
CAMELOPARDALIS
CEPHEUS
Deneb
Northern Cross
Polaris
URSA MINOR
LYNX
Castor
GEMINI
Little Dipper
CYGNUS
VULPECULA
DRACO
Pollux
Vega
LYRA
URSA MAJOR
M44
Big Dipper
HERCULES
CANCER
WEST
CANES VENATICI
LEO MINOR
Regulus
BOÖTES
LEO
CORONA BOREALIS
COMA BERENICES
Arcturus
SERPENS CAPUT
OPHIUCHUS
HYDRA
VIRGO
Spica
CORVUS
CRATER
LIBRA
SCORPIUS
Antares
SW
LUPUS
CENTAURUS
SOUTH

Continued from page 119

Fri Jun 28: Last-quarter Moon

Sun Jun 30: Titan transits the southern hemisphere of Saturn from 7:37 to 12:23 UTC. Although better from western sites, most of Canada will have a chance to see at least part of this event with Saturn reasonably high above the horizon.

July 2024

Solar System

Mercury is visible in the evening sky this month, although the low angle of Mercury's orbit with the horizon in Canada makes this a poor apparition. For Southern Hemisphere observers, this is the best view of Mercury for 2024.

Venus is very low in the western sky after sunset throughout July, probably unobservable early in the month but glimpsed just above the horizon by month's end. What is the first day you can spot it with the unaided eye?

Mars is rising earlier in the morning sky, finally visible in a dark sky free from the horizon's haze by month's end. Forms a compact triangle with Jupiter and the bright star Aldebaran for the last week of the month.

Jupiter disappears into the evening twilight early in the month as it swings behind the Sun. It is in conjunction with the Sun on May 18, and basically invisible all month.

Saturn becomes visible later in the month, rising about 3 a.m. local time but hugging the southeast horizon at dawn.

Uranus is in conjunction with the Sun on May 13 and thus invisible, while **Neptune** has reappeared in the predawn sky.

Dwarf planet **Pluto** reaches opposition on July 23 at 6h UTC, becoming visible all night. At magnitude 14.4 it will take a decent-sized telescope to track down even at its best.

Comet C/2023 A3 (Tsuchinshan-ATLAS) disappears into evening twilight for a while as it loops around the Sun over the summer. Watch for its return in the morning sky in fall.

Sky Calendar for July 2024

Mon Jul 1: The waning crescent Moon is about 4 degrees above Mars in the morning sky.

Fri Jul 5: The dwarf planet Ceres is at opposition in Sagittarius, shining at magnitude 7.4 against the southern Milky Way. It's also new Moon.

Sat Jul 13: The first-quarter Moon will occult the bright star Spica in Virgo. Visible from Québec west but in bright twilight or daylight from Manitoba west. See the *2024 Observer's Handbook* occultation tables beginning on page 165 for details for your location.

Mon Jul 15: The dwarf planet Ceres passes a half-degree north of the globular cluster M54. Meanwhile, the planets Mars and Uranus are only a half-degree apart in the morning sky as well.

Tue Jul 16: Titan transits the southern hemisphere of Saturn beginning about 6:19 UTC, a roughly five-hour event visible (at least partially) across the country.

Sun Jul 21: Full Moon

Wed Jul 24: Titan is occulted by Saturn beginning at 5:08 UTC, a 20-minute event best observed from eastern and central Canada. About three and a half hours later, central and western Canada can watch Titan emerge from behind Saturn's disk.

Fri Jul 26: Mars and Jupiter form a right triangle with the red star Aldebaran in the Hyades. Nearby are the Pleiades, and the faint planet Uranus is also in the area.

Sat Jul 27-Sun Jul 28: Last-quarter Moon, and the peak of the south Delta Aquariid meteor shower.

Mon Jul 29: The waning crescent Moon, Mars, Aldebaran, and Jupiter form a jagged line in the eastern sky before dawn.

Tue Jul 30: The waning crescent Moon, Mars, and Jupiter are at their closest this month, hanging above the Hyades.

Wed Jul 31: The waning crescent Moon, Jupiter, and Aldebaran are in a crooked line, with Mars above.

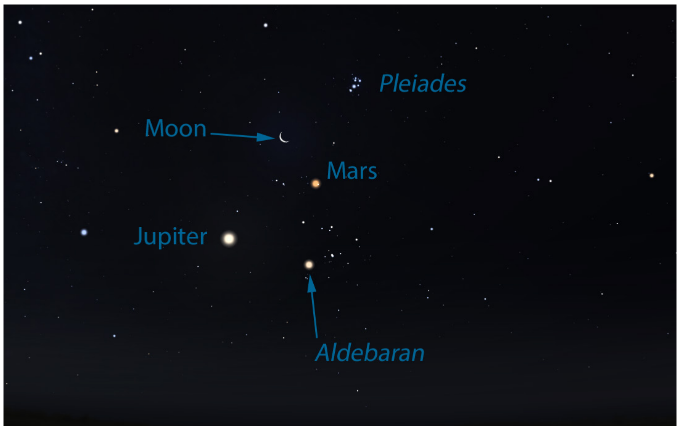


Figure 1 — Jupiter, Mars, and the Moon gather in Taurus near the bright stars Aldebaran in late July. The most compact view occurs on July 30 (shown here), but the view is striking on the mornings before and after as well. [Image: S. Young/Stellarium]

Continued from page 118

Figure 3 — Steve Leonard chased the eclipse to Magog, Québec, and managed to capture a stellar view of the Sun's corona. He used an Astro-Tech AT115EDT 4.5″ triplet refractor at f/5.6, on an EQ6-R mount, as well as a Sharpcap, an ASI 1600MMPro camera, and an Astrodon G filter. The final image was processed in PixInsight.

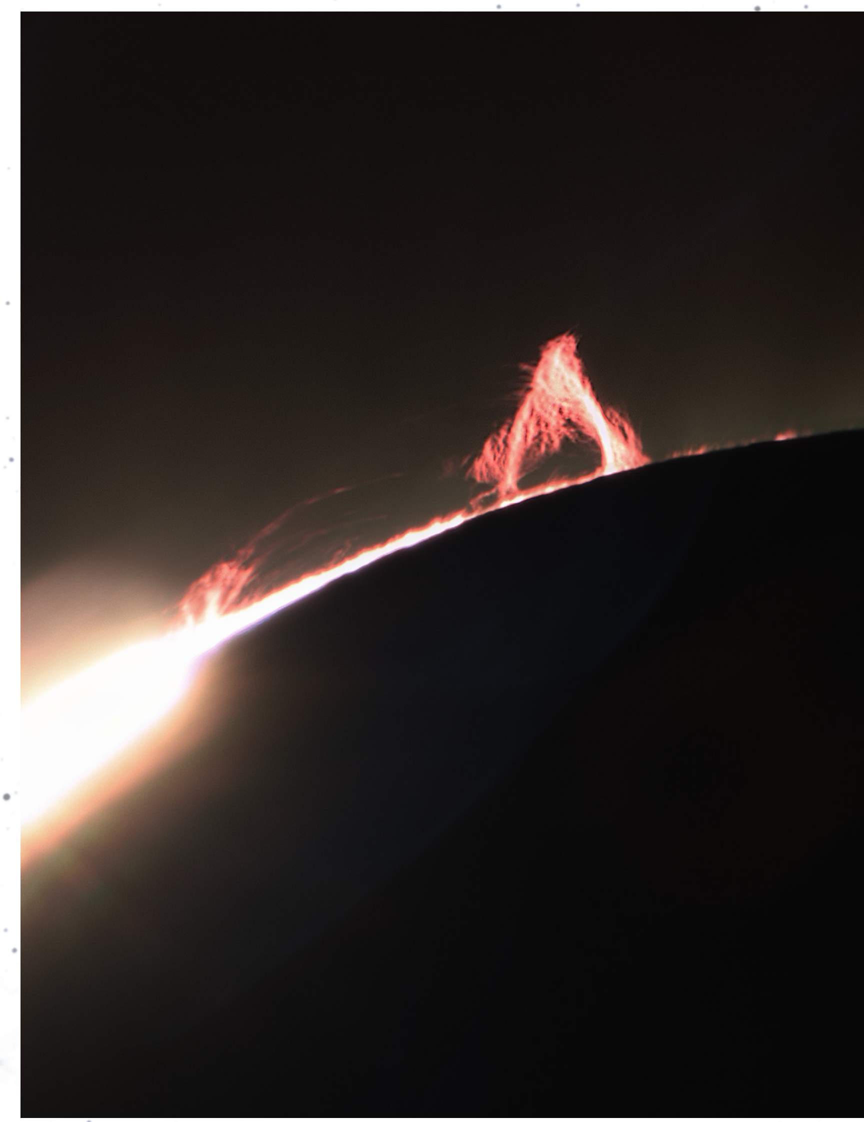


Figure 4 — This spectacular image shows two solar prominences during April's total solar eclipse. Taras Rabarskyi took this from Parc de la Gorge de Coaticook, Québec, using an 8″ Meade SCT on a Celestron AVX mount with a TouCam IMX178-based camera as a roughly 7-second-long video, frames of 3096 x 2080 were aligned later in PIPP, stacked and processed in Registax with final touches done in Photoshop.

Skyward

In the Shadow of the Moon

by David Levy, Kingston & Montréal Centre

This is a story, not a report on observations.

On April 8, a total eclipse of the Sun tracked across Mexico, the United States, and Canada. Most of the United States enjoyed clear weather, and most of Canada did, too.

We were in Texas. We did not have clear weather.

Admittedly, we knew we might be in for bad luck a week out. But when my friends David and Pam Rossetter came by Friday morning at 5:45 a.m., we knew we would be in for quite an adventure. We arrived at the home in which we planned to stay early Friday evening. Dena McClung, former president of the Denver Astronomical Society, was an important part of our group. It appeared that the house had been vacant for months or years. Although we decided to grin, bear it, and make do, by the next afternoon Scott Roberts, our host, had put us up in a wonderful hotel.

The afternoon before the eclipse, a new report predicted clearing during the eclipse. We were heartened, but that prediction was wrong.

Eclipse day dawned cloudy with drizzle. We arrived at the Explore Scientific site near Leakey, Texas. We did see the Sun for a few seconds now and then. The eclipse began right on time—to the second, even though it may first have been predicted by astrologers in ancient Greece. I remembered how happy Dad was when the 1963 eclipse began the same way. We did get several brief views of the incoming partial. But as the Moon advanced inexorably, the clouds thickened. And as totality neared, it became pretty obvious we would miss the total phase.

About 10 minutes before the total phase began, someone in our group asked me to share a poem at the start of totality. The one I had in mind was Ross's speech after Macbeth murders King Duncan:

> *By th' clock 'tis day,*
>
> *And yet dark night strangles the travelling lamp.*
>
> *Is 't night's predominance, or the day's shame*
>
> *That darkness does the face of Earth entomb*
>
> *When living light should kiss it?*

Figure 1: The total eclipse from Montréal, Canada. You can spot Venus in between the telephone wires. Credit: Joyce Stein and Dr. Lawrence Stein.

Short and sweet, and so Shakespeare. But two minutes before the onset of the total eclipse, I thought of Wendee's favourite poem, The closing lines of "The Song of Honour" by Ralph Hodgson. I suddenly missed Wendee more than I can write. During the 2017 eclipse, my wife opined that she hoped still to be alive to see this one. I understood that this eclipse I would have to appreciate for both of us. The idea of her not being here, at this moment, hit me like a clap of thunder.

The sky was darkening fast; the temperature was falling like a stone. It grew much colder. And still the sky grew darker. It was past noon, and it was night. We were silent.

It was the moment of total eclipse.

I stood and faced the group. I said:

> "I stood and stared; the sky was lit,
>
> The sky was stars all over it,
>
> I stood, I knew not why,
>
> Without a wish, without a will,
>
> I stood upon that silent hill
>
> And stared into the sky until
>
> My eyes were blind with stars, and still
>
> I stared into the sky."

Figure 2 — The author's image of the total eclipse as seen from Leakey, Texas.

The group listened with rapt attention. When I was done, there were smiles and some applause. We would not see a total eclipse but we had a poem. Then there was silence.

Twenty seconds passed.

And then, the Sun appeared in total eclipse. Just like that.

I could not believe it. For about half a minute—for 30, maybe 45 seconds—we swathed Sun's corona, the centrepiece of a total eclipse of the Sun. I did not notice the big prominence at the bottom of the Sun, but I did not care. The Sun's corona, circular because this was near the maximum of the sunspot cycle, smiled at us. (At other parts of the cycle the corona would be more oval.) It was the most dramatic thing I have ever seen.

After that unforgettable, precious, sight, clouds came in again. We did get to glimpse the corona on and off a few times after that. I noticed the sky starting to brighten as the end of totality approached. Suddenly it was over.

Only it wasn't.

For one delicious moment the Sun's photosphere appeared. The Sun was shining through valleys at the edge, or the limb, of the Moon. It was a magnificent, stunning view of Baily's beads. First described by Francis Baily after he observed them during the eclipse of 1836 May 15, the effect bears his name. However, the first person to describe this effect was actually Edmond Halley (of comet fame) who recorded them 121 years earlier during the total eclipse of 1715 May 15. What we saw was splendid. And then we got to see a large portion of the ending partial phase. Clouds again obscured the very end of the eclipse.

I sat in my chair, alone. I thought of Wendee. I missed her so much. I could not stop crying. Scott Roberts sat with me and put his hand on my shoulder. Even as I write these words, I am not quite over it.

This eclipse, by far the most dramatic I ever saw, was my 12th total eclipse, and the 101st eclipse I have seen since 1959 October 2. ✶

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

Astronomical Art & Artifact

Colours of Saturn — Browning, Elvins, and the Resolution of a Mystery in the "Astronomical And Physical Society Toronto" Album

R.A. Rosenfeld, FRASC, National Member
(r.rosenfeld@rasc.ca)

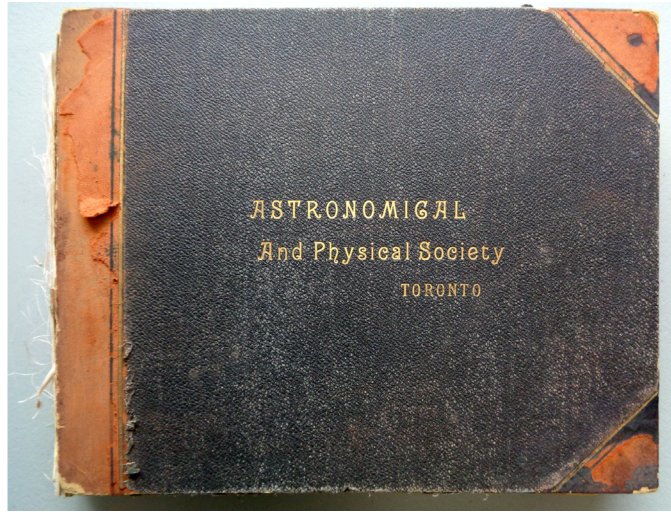


Figure 1 — Front cover of The Toronto Astronomical and Physical Society Album (1892–), the gift of member Charles Sparling. This album contains the majority of the surviving early observational art produced by members in the 19th century. (The binding structure has seen better days). Reproduced courtesy of the RASC Archives.

Abstract

Uncovers the identity of one of the RASC's oldest images of Saturn, and discusses who might have produced it, and why.

A suitable place for astronomical art

On 1892 October 18, Andrew Elvins (1823–1918), one of the Society's original founders, announced at a regular meeting of The Astronomical and Physical Society of Toronto (as the RASC then was), that fellow member Charles P. Sparling (1851–1934) had

> "...presented to the Society a large and handsomely bound album, suitably inscribed, and intended to receive the astronomical drawings, plates and views belonging to the Society. Mr. Elvins said he had inserted various plates and sketches and would be glad to receive others to be thus preserved. Mr. Sparling was heartily thanked for his timely and valuable donation." (Lumsden 1892).

Sparling worked for an established Toronto firm, Rowsell & Hutchinson, that specialized in bookselling and publishing. He was well-placed to commission such a gift.

The album survives to this day in the RASC Archives (Figure 1), and it is valued now as the largest repository of early observational art (astrosketches) by members. Some of its contents may go back to the earliest days of the Toronto Astronomical Club in 1868 (specifically, sketches by Elvins of the phases of Venus; www.rasc.ca/venus-phases-1868).

Pasted in its leaves are watercolours of Saturn, one of which has presented something of a mystery, until now.

Images of Saturn

The drawings of Saturn are the largest planetary images in the album. One is in *grisaille* (a sort of grayscale) and is identified as the work of Allan F. Miller (1851–1947), copied "from Trouvelot," that is, Étienne Léopold Trouvelot (1827–1895), who can be numbered among the most talented of 19th-century observational artists (Broughton 1994, 137; Rosenfeld & Sheehan, 2011). The Trouvelot model that served for Miller's drawing appears to be the lithograph of Saturn from the celebrated set of lithographs published by Charles Scribner's Sons (Trouvelot 1882), although its tonal range is closer to the unpublished Trouvelot pastel of Saturn from 1874 (Bibliothèque de l'Observatoire de Paris, Inv.T2).

The distance between Trouvelot's skills and Miller's is all too evident in the latter's copy. The copy (www.rasc.ca/saturn-sketch), while not a dire image, can hardly be considered either a particularly skilled, or striking copy. The spoke phenomena Trouvelot subtly depicts become exaggerated hard-edged scallops of distorted proportion in Miller's version of the original. And Miller both creates features that are not present in the original, and omits others that are. He introduces short radial lines in Rings B and C, and transforms the equatorial zone into a feature as dark as a belt enclosing it within sharply defined, wide, pie-crust borders, while omitting most of the disk belts from the French-American artist's original. Besides these inaccuracies, in general appearance Miller's copy lacks the assurance, and subtlety of something from Trouvelot's hand.

Had Miller labelled his copy as "after" Trouvelot, some departure from the original could be accommodated by the preposition, but, as it bears the label "from Trouvelot," his chosen preposition carries the expectation that his copy is a faithful one. That it isn't may be more a result of the limitations of Miller's mastery of watercolour rather than anything else. His intention was doubtless to produce as accurate a copy of Trouvelot's image as he could manage.

The other large watercolour of Saturn in the TAPST Album (Figure 2) is drawn to approximately the same scale as Miller's copy of Trouvelot's Saturn. Unlike the *grisaille* of the Miller copy, this image is executed in colour, using white, yellow, red, brown, grey, and black pigments. In general aspect the drawing doesn't seem any more assured than Miller's Trouvelot copy. And, bearing neither signature, attribution, nor any indication of its source, it's circumstances of creation were something of a mystery. Is it an original late-19th-century observational drawing by one of the Society's members? Or is it, like Miller's version of Trouvelot's image(s), a copy of someone else's work? And if the latter, who made the copy, and when? And why were hand-produced copies of printed observational drawings made by people who were not the original observers long after the advent of print?

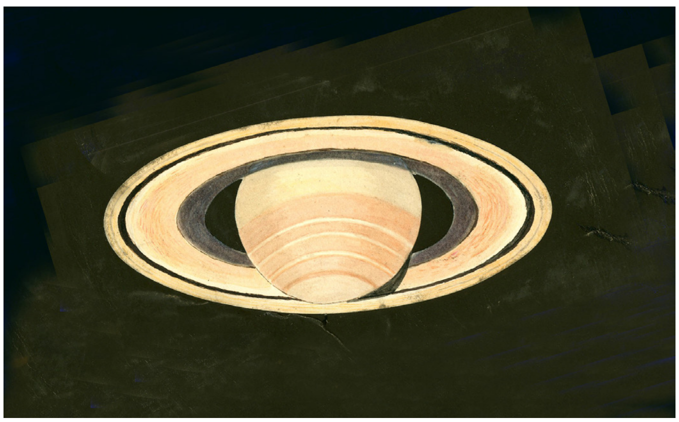


Figure 2 — Copy in watercolour of the drawing of Saturn by John Browning, London, 1868 May 14. This image was produced in Toronto sometime between 1868–ca. 1900, possibly by Andrew Elvins, or Allan F. Miller, or one of their colleagues. It is preserved in the TAPST Album. It has been rotated 180 degrees to present the same orientation as the model it was copied from (see Figure 3). Reproduced courtesy of the RASC Archives.

A chance finding of the source image

The author has more than once made a discovery during the casual perusal of source material, and so it was in the case of the second image of Saturn in the TAPST Album. When idly turning the pages of some early copies of *The Student and Intellectual Observer of Science, Literature and Art* (1868–1871)—one of the seeming endless number of fairly high-level Victorian periodicals for people interested in scientific communication and self-improvement—the model for the Toronto image rose off the printed page to meet the image of its progeny in the mind's eye.[1] The original is by John Browning (1830/1831–1925), FRAS, a very good Victorian observational artist, who enjoyed a significant name as one of the leading professional instrument makers in London (Anon. 1930; Meliconi 2020). It appeared in 1869 in the second volume of the periodical (Figure 3), interestingly enough during the first year of the existence of the Toronto astronomical society. Browning was certainly known by reputation and through correspondence to some of the members of The Astronomical and Physical Society of Toronto (Rosenfeld 2022). The question about the status of the second watercolour of the ringed planet was answered; it wasn't an observational drawing originating in a Toronto eyepiece. What of the other questions?

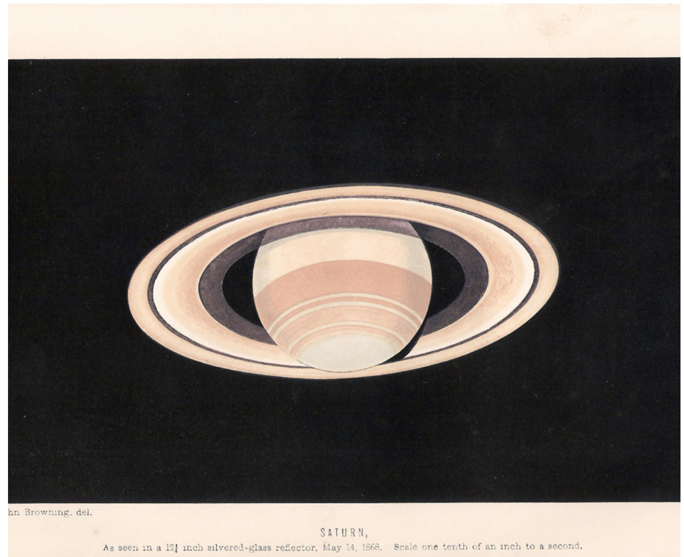


Figure 3 — Lithograph of John Browning's observation of Saturn, London, 1868 May 14, as seen in a Newtonian reflector with a 12.5-inch primary mirror, published in The Student and Intellectual Observer of Science, Literature and Art in 1869. Reproduced courtesy of the Specula Astronomica Minima.

The existence of direct textual evidence that Browning's image was known to Andrew Elvins in the year of its publication, as revealed in his letter to the editor of *The Student and Intellectual Observer*, might be suggestive when formulating answers to the remaining questions:

> "Sir, - The always-welcome Student has just arrived. You have given your astronomical readers a rich treat in this number. Mr. Browning's beautiful view of Saturn, with its accompanying paper, is worth very much to us, who have seldom a chance to look through a telescope of more than three inches;" (Elvins 1869, 467).

The use of the plural here could indicate that Browning's image was known to Elvins' colleagues in The Astronomical and Physical Society of Toronto as well. It raises the possibility that the Toronto copy of Browning's image was done within the year of its publication, early on in the Toronto group's existence. And it offers some reason to believe that Elvins may have been the artist of the copy. There isn't yet enough evidence to elevate any of these to certainties; the copy could have been made by Miller, or some other member of the Society, and it could have been made in the 1890s, or even a little later. None of these possibilities can be ruled out.

The copy is no more faithful to its original than is Miller's to Trouvelot's. The Toronto copyist has made the C ring more opaque, and thinner than in the original. He has rendered the belts indistinguishable in colour and intensity, unlike in Browning's drawing, and reversed the colours along the border of the belt nearest the foot of the drawing, as well as ignored the quite marked differences in thickness of the belts.

Finally, why would people who were not the original observers produce hand-drawn copies of printed observational drawings long after the advent of print? There are several reasons that can be advanced. In the Victorian period, the advice was often given to amateur still-life, portrait, and landscape painters that they could become better artists through copying the works of masters. The learning experience came from trying to see as they saw, and draw as they drew. New techniques could be acquired, and those already possessed could be made better through the process (Jackson 2022, 15–71). Some professional artists did this throughout their careers (by way of analogy, remember that the more one observes the better one observes, in a process that cumulatively continues throughout one's astronomical life). There is no reason the advice to copy the work of masters wouldn't have applied to astronomical artists as well.

Another reason to make copies is to have copies, that is, for a locale to have an image at all. In an age before cell-phone cameras, ready access to photocopiers, and the easy multiplication of digital copies upon publication, published copies could be difficult to come by. Just because something was in print didn't mean it was accessible. Sometimes the only way to procure a copy of an image in order to have it on hand when needed was to make a hand-produced copy, or pay someone else to draw or paint a copy. Handmade copies are resources that can perform various educative functions. A hand-drawn copy of a published observational image could have served for display at a meeting of 19th-century astronomers, and served the same purpose as a digital image at a meeting today. It could be a source for data, and discussion of the phenomena illustrated.

Appendix

The colours of saturn
by john browning, f.r.a.s.[2]

In Mr. Proctor's admirable monograph, "Saturn and its system," the colours of the planet are thus referred to:—"No object in the heavens presents so beautiful an appearance as Saturn, viewed with an instrument of adequate power. The golden disc, faintly striped with silver-tinted belts; the circling rings, with their various shades of brilliancy and colour; and the perfect symmetry of the system as it sweeps across the dark background of the field of view, combine to form a picture as charming as it is sublime and impressive." [3]

Yet this glowing description will give a very inadequate idea of the wondrous display of colour exhibited by the planet, when it is viewed with great optical power, and under a highly favourable condition of our atmosphere.

With a telescope of only two inches aperture, Saturn may be seen of a golden yellow, provided a tolerably high power be used, but it is only when an instrument of very large aperture is employed that the great variety of colours of the various parts becomes apparent.[4]

In this case, also, to obtain the contrast of the colours in their greatest intensity, a proportionally high power, say sixty to every inch of aperture, must be used; owing to unsteady air, such a power cannot always be applied with advantage even to a three-inch telescope, and the nights that so high a power can be satisfactorily employed, with an aperture exceeding ten inches, are few indeed.

The colours of Mars are best seen when the air is somewhat misty, and this is generally the case with Saturn.[5] Occasionally, however, the colours may be well seen on a clear night, and misty nights will occur on which little colour is perceptible.

The cause of this has not yet been fully elucidated, though, perhaps, the arrest of the blue rays of light by a misty atmosphere may be considered sufficient explanation.[6]

The following notes, of recent colour observations, were written at the telescope:—

"May 9th, 1868. Midnight. Observed Saturn with $12^{1/4}$ inch. Air very steady, at intervals. Power 100, no perceptible colour. Power 200 to 450 [*note*: this is just ca. 16 to 37 per inch of aperture]; ring, lemon yellow; globe, light cinnamon, with [p. 241|p. 242] darker belts, scarcely same colour; Ball's division,[7] purple-chocolate; crape ring,[8] same colour; pole of the planet, *bright azure blue*."[9]

"May 14th. Definition very fine, much better than on the 9th. Took a set of measurements of the planet. Colours not nearly so vivid as on the 9th. Air misty, the N. pole of the globe *neutral grey* and *darker* than any other part of the globe, excepting the broad reddish-brown belt immediately N. of the equatorial bright belt. No part of the globe pure white.["]

The coloured drawing, now so faithfully reproduced [Figure 3], represents the planet as seen on the foregoing night, with a 12-inch silvered-glass mirror,[10] using a power of 500 [42 per inch of aperture].

With such a power, the whole ring system produces the impression that it consists of fine lines.[11] Slight inequalities may, sometimes, be detected in the belts of the globe; more generally they appear quite regular, like the rim of a wheel in rapid motion. In this particular, the globe of Saturn presents a marked contrast to that of Jupiter, to which, in many other respects, it bears a strong resemblance. Like Jupiter the globe is greatly flattened at the poles; is surrounded by a cloudy envelope;[12] has a permanent bright belt, about one-seventh of its diameter, encircling it at the equator;[13] add to these points of comparison, that the dark belts of each planet near the equator are of a chocolate-red tint, while the poles are blue. Here the resemblance ceases. The red belts of Jupiter are dark and rugged, those of Saturn are faint and smooth. Though this uniformity detracts somewhat from the interest with which the belts are examined, it adds greatly to the unique beauty of the planet.

In the drawing from which the engraving is copied, the following colours were used to represent the parts indicated—

The rings, yellow-ochre, shaded with the same, and sepia.[14] The globe, yellow-ochre, and brown madder,[15] orange and purple, shaded with sepia. The crape ring, purple-madder and sepia.[16] The great division in the rings,[17] sepia. The pole and the narrow belts,[18] situated near to it on the globe, pale cobalt-blue.[19] These tints are the nearest I could find to represent those seen on the planet, but there is a muddiness about all terrestrial colours when compared with the colours of the objects seen in the skies. These colours could not be represented in their brilliancy and purity, unless we could dip our pencil in a rainbow, and transfer the prismatic tints to our paper.[20]

Hearing that I was engaged on this subject, Mr. Huggins very kindly sent me the following interesting notes, concerning his own [p. 242|p. 243] observations.[21] Coming from such an authority, I am sure I need not apologise for reproducing these notes here. Mr. Huggins says:—"Though I can see the colours of Saturn fairly well with powers of 500 or 600, yet I find that a power of at least 900 necessary to bring out the contrast of the colours in the fullest manner [this would be 112.5 per inch of aperture on Huggins' 8-inch Alvan Clarke-Thomas Cooke refractor!]. Probably reflection, by a solar eyepiece, would answer with a lower power.[22] Inexperienced observers must be warned that, in consequence of the small altitudes of Saturn [above the horizon in England], there are prismatic colours seen on it, produced by our atmosphere. From this cause red is seen along the upper-edge of the planet, in an inverting telescope, and a strong blue at the lower or north edge of the ring, and at the pole. Some years ago, I considered the crape ring to be of the colour of watchspring [Figure 4], lately I have considered it rather more of a greyish blue." Regarding this, I may remark that Mr. With[23] informs me that he sees the crape ring of a purplish hue, and Mr. De la Rue makes it a light purplish-chocolate. The colour will, however, vary greatly with the state of our atmosphere. When we have much mist in the air, the colour will incline towards red, when the air is clear, the colour will become a purer blue.

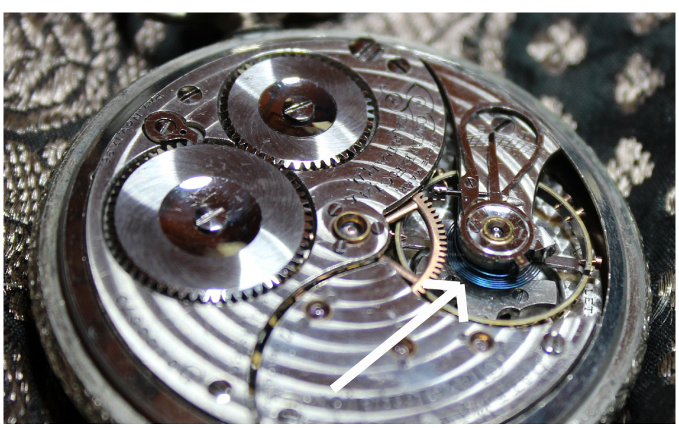


Figure 4 — Photograph of a late 19th-century railway chronometer movement by American Waltham; the arrow points to the blued-steel watch spring, to illustrate the colour William Huggins cited. Reproduced courtesy of the Specula Astronomica Minima.

Unlike Mars, of which the oceans, seas, inlets, bays, continents, and islands, have been named, and charts and globes constructed, nothing is known of the physical conformation of the surface of Saturn.[24] The spectroscope, that powerful instrument of modern research, affords us no information.[25] In the absence of actual knowledge, conjecture may be permissible. The researches of mathematicians lead to the conclusion that the rings of the planet consist of a countless multitude of minute satellites.[26] These small bodies, probably, resemble the planet Mars, in colour, and the different tints on the various

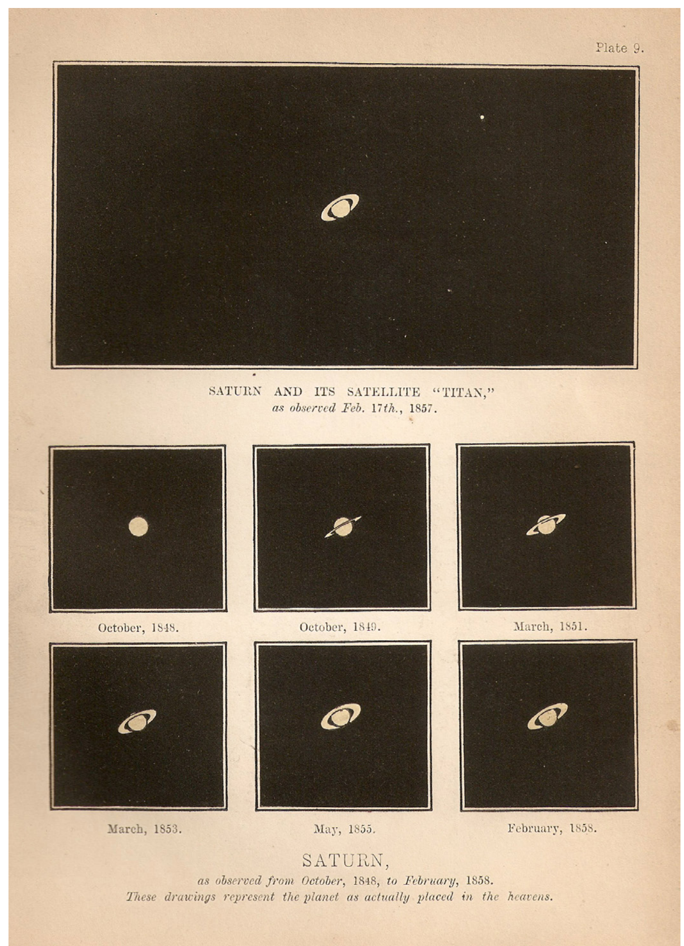


Figure 5 — Lithograph of drawings of Saturn by Mary Ward as seen in her achromatic refractor with a 2-inch objective lens, published in 1859. Reproduced courtesy of the Specula Astronomica Minima.

portions of the rings may be due to an unequal distribution of the satellites in different zones. Their colours may be further modified by the presence of an atmosphere, and that the rings have an atmosphere is, I think, pretty certain, from the appearance they present, when their edges are turned towards us, nebulous appendages, like clouds, having, when they were in this position, been seen upon them.[27]

The surface of the globe of Saturn may have a soil of a colour resembling our Bagshot Sand,[28] or New Red Sandstone,[29] this would certainly be greatly modified by cloud-belts, which exist principally at the equator, but extend to the poles.[30] The poles may consist of masses of ice.[31] It is very difficult to account for their strong blue colour upon this hypothesis. Yet the same difficulty would be experienced in the case of Mars, whose poles appear light blue or [p. 243|p. 244] light green to many observers, and the existence of ice on these poles may be almost considered as proved.[32]

The uniformity of the red belts would seem to indicate that the whole of the surface over which they extend must possess the same character. If, as I have supposed, the colour is due to the soil, the seas must be confined to the poles of the planet.[33]

Acknowledgements

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Endnotes

1 On this literature, see Lightman 2007, and Dawson et al. 2020.

2 Browning 1869.

3 Richard Anthony Proctor (1837–1888), FRAS, one of the most successful Victorian popularizers of astronomy, who also accomplished some fundamental work on the rotation of Mars, planetary and celestial cartography, and stellar distribution; North 1981; Baum 2017. Three of his relatives rose to prominence in the Society after his death. The quote is from Proctor 1865, 76.

4 A refractor with a two-inch object glass was a common size for a modest telescope in amateur circles. Ward 1859 is an observing guide designed for such an instrument, and her representation of Saturn bears out Browning's description of a "golden yellow" Saturn offered by that aperture (Figure 5). At the time there was no hard and fast definition of the diameter which was considered "large," or "very large;" Rosenfeld 2022, 179, 182–184. What is clear from the context is that Browning considered his 12.25-inch (sometimes referred to as 12-inch) silver on glass reflector as a "very large" telescope.

5 While I have not found references specifically to misty nights proving the best for the detection of colour on Mars, or Saturn, there are sufficient reports since the later 18th century of those nights offering views of superior definition; Flammarion 2015, 50, 58–59, 143, 224.

6 Browning speculates that blue wavelengths are supressed by terrestrial mist. His brevity doesn't reveal whether he understands it as due to a scattering effect. It is noteworthy that discussions in the scientific literature leading to our present models of the scattering of light date from this period; Tyndall 1869; Strutt 1899, 87–110 (originally published 1871).

7 "Ball's division" is an alternative name for Cassini's division, the principal division in the ring system. An instance of astronomical nationalism, it enjoyed some currency from the 1820s to the 1880s in England when it was thought that there was proof to attribute the discovery to an Englishman, rather than to the founder of the Cassini dynasty. It is to the credit of some British astronomers—W.T. Lynn (1835–1911), John Couch Adams (1819–1892), and Captain William Noble (1828–1904)—that they investigated and dispelled the nationalist myth (which, given their otherwise nationalist inclinations, speaks well of them); Lynn 1882; Adams 1883; Noble 1897; Alexander 1962, 115.

8 Also known as the Crepe ring, in current nomenclature this is ring C, the inner crepe ring; Benton 2005, 12, 25–26. "Crape," also spelled "crepe," was used in the 17th–19th centuries to denote "a thin transparent gauze-like fabric;" OED.

9 The term now generally refers to a "bright blue," or "the blue of the sky on a cloudless day;" Paterson 2003, 32. This is for all intents and purposes identical with the definition in a 19th-century source: "Azure Blue.—A beautiful light blue, very bright and delicate, used for painting a certain class of skies, such as a cloudless summer sky as seen in Italy or Spain;" Gardner 1887, 318. The temporal stability of the terms used by Browning is fortunate, for interpreting colour vocabulary in older sources can often be quite challenging given shifts in meaning, differences in perception, and personal preferences in the use of terms.

10 Browning was a leading maker of reflectors, with the relatively new technology of glass specula with silver coatings; Browning 1867. He often used mirrors by George H. With of Hereford (1827–1904).

11 It is unclear here which ring features correspond to the "lines." Browning is most likely referring to concentric divisions discerned in the rings, by comparison with contemporary usage; Proctor 1865, 55, 107. He is unlikely to be referring to the spokes virtuosically observed by Stephen James O'Meara in the 1970s, and perhaps seen by a few previous observers; Alexander 1962, 255–257; Bryan 2007; Sheehan 2019, 126–129; Carbary et al. 2019, 106–107.

12 It appears from what Browning writes further on that he favours a model of Saturn with a "terrestrial" globe, surrounded by a "terrestrial" or "areographic" atmosphere.

13 One assumes that he means either the North Equatorial Belt (NEB), or its southern equivalent (SEB)—if it is indeed a belt he intends. The equatorial zones are brighter if one equates bright with light.

14 "N[oun] ochre, ocher—An ancient mineral pigment containing clay and silica used in producing paint to create colours ranging from red to yellow to brown;" Paterson 2003, 276. For the Victorian meaning: "YELLOW OCHRE. A sunny, but somewhat opaque, yellow earth, suitable, in thin washes, for the warm tones of clouds...;" Green n.d., 33. "Shading" derives from "Shade.—The dark portion of a picture; the thickness or relief given to a letter when painted upon a flat surface; degree or gradation of light or color;" Gardner 1887, 345. "c sepia—Reddish dark brown originally prepared from ink of the cuttlefish;" Paterson 2003, 354, and "A valuable animal brown, useful for cool grays…;" Green n.d., 38. Green (1823–1899), as well as being one of the 19th century's outstanding professional watercolourists, was also one of the greatest observational astronomical artists of all time; McKim 2004.

15 "MADDER BROWN. A rich and very transparent vegetable brown, reddish in its tendency, gummy in its consistency...It is suitable for any rich browns...; Green n.d., 38.

16 "**Choc'olate Brown** (L. *chocolati'nus*), n. A rich dark reddish brown color, like the exterior glazed surface of a cake of chocolate. (Purple madder + sepia.)...**Clar'et Brown** (L. *vina'ceo-brunn'eus*), n. A rich dark brownish purple, much like the pigment called "Purple-madder." Nearly the same as "maroon," but more purple. (Purple-madder.);" Ridgeway 1886, 70.

17 The Cassini division.

18 Presumably the North Temperate Belt (NTB), North North Temperate Belt (NNTB), South Temperate Belt (STB), and South South Temperate Belt (SSTB).

19 "COBALT. A bright mineral blue, partly opaque, and one of the most valuable water-colours; it enters into combination with every tone where either gray or atmosphere is required...;" Green n.d., 36.

20 "Pencil" was an alternative term for a small brush—these were produced in various standard sizes and shapes; Gardner 1887, 267–273.

21 Sir William Huggins (1824-1910), one of the pioneers in the use of spectroscopy in astrophysics, started out in astronomy as planetary observer; Becker 2011, 34–45.

22 At this time, "reflection, by a solar eyepiece" would most probably refer to what we now know as the Herschel wedge; Chambers 1868, 707.

23 Warren De la Rue (1815–1889), one of the pioneers of astrophotography who made superb reflectors for his own use, and designed a successful photoheliograph. Earlier in his astronomical career he produced a celebrated and much reproduced drawing of Saturn; Williams 1981; Hirshfeld 2017.

24 Many then thought that the observable albedo features on Mars were in the main a clear indication of its topography; Proctor 1870, 84–109; 1872, 105–123; Sheehan & Bell 2021, 94–97.

25 William Huggins and his collaborator, William Allen Miller, attempted to observe the spectrum of Saturn several times during the years 1862–1864, but the results did not reveal much at this stage of the art; Huggins & Miller 1864, 423.

26 Uppermost in Browning's mind would be James Clerk Maxwell's Adams Prize Essay of 1856, "On the Stability of the Motion of Saturn's Rings;" Maxwell 1983.

27 Proctor 1865, 59, 66, 107, 236, discuses the supposed "atmosphere" of the rings, and attributes the first observation to be given that interpretation to William Herschel.

28 BGS Bagshot Formation.

29 BGS New Red Sandstone.

30 This reads as if Browning interprets the observable features of Saturn as revealing a version of a "terrestrial"-type topography. Proctor 1865, 158, disagrees.

31 This theory is absent from Proctor 1865.

32 Or so they thought at the time; Proctor 1870, 104–105.

33 This also follows from reading the appearance of Saturn's features in the eyepiece according to an "Earth"-like model.

Dish on the Cosmos

Scintillating Topics

by Erik Rosolowsky, University of Alberta (rosolowsky@ualberta.ca)

Gamma rays lie at the opposite end of the electromagnetic spectrum from the radio waves that are usually featured in this column. Gamma rays are the highest-energy form of light, where each single photon has billions of times more energy than a typical radio photon. Gamma rays are so named as one of the first types of nuclear radiation detected: alpha, beta, and gamma particles. Alpha and beta particles were discovered to be regular matter: helium nuclei and electrons respectively, but gamma particles were light. Like radio astronomy, gamma rays have their own subfield in astronomy, focusing on the highest-energy phenomena in the Universe. One of the latest mysteries in gamma-ray astronomy is the study of the gamma-ray "excess" toward the centre of the Milky Way Galaxy. The excess means that there are more gamma rays coming from that part of the galaxy than we can explain using well-understood physics. However, this mystery in the gamma rays also connects directly with radio astronomy, requiring knowledge from both ends of the electromagnetic spectrum.

We know that there are extra gamma rays coming from the galactic centre because gamma rays are always just the tip of a physics iceberg. Everything that emits gamma rays also has light or other signals coming from other parts of the spectrum. For example, one of the main sources of gamma rays is from high-energy particles striking hydrogen gas clouds. We can trace out the hydrogen gas clouds and the presence of these high-energy particles using radio astronomy, so we can predict how many gamma rays we should see. Another source of gamma rays is pulsars, which are spinning neutron stars that beam out pulses of light that we detect as "blips" of radio emission in our telescopes. The excess emission in gamma rays does not appear to be connected to a source that we know about, but we have some ideas.

The most exotic and exciting idea is that the excess emission is from the annihilation of dark-matter particles through physics that we do not yet understand. Some of the particle models for dark matter suggest that the individual particles of dark matter and anti-dark matter can occasionally collide and annihilate each other becoming gamma rays that we can detect. Since dark matter should be concentrated by gravitational attraction toward the centre of the galaxy, we might see an excess of gamma rays there. Such a detection would be a landmark discovery: we have been searching for decades into clues on the nature of dark matter but have had few breakthroughs.

While the dark-matter explanation would be exciting, the competing idea is that the gamma rays are also coming from pulsars, but this would require more pulsars than we are currently detecting in the galactic centre. It is entirely plausible that we are not counting correctly, and the likely reason is from ionized hydrogen plasma that lies along the line of sight from here to the galactic centre. When a sharp pulse of radio radiation from a pulsar passes through a cloud of plasma, the pulse ends up spreading out. A useful analogy comes in what happens after dropping a stone into a still pool of water, leading to a spreading pulse of waves moving out from the point of impact. As the waves get farther from the centre, the height of the waves drops because the energy spreads out. However, a careful observer will also note that the thickness of the waves spreads out and the waves start to blend together. This spreading of the individual wave fronts is called dispersion, and the plasma in interstellar space acts to disperse the pulses that are passing through it.

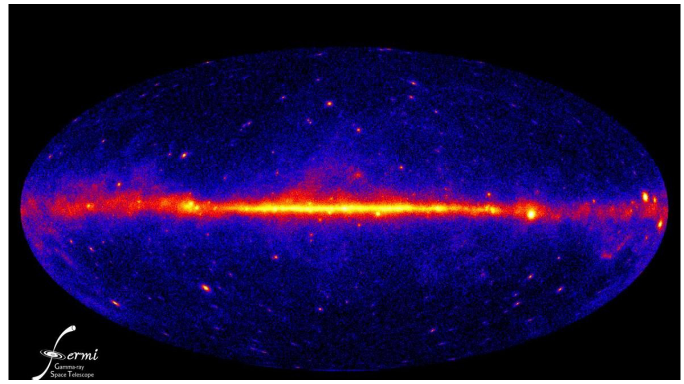

Figure 1 — Gamma-ray map of the Milky Way made by the Fermi Gamma-ray Space Telescope. *The plane of the galaxy is shown across the centre of the image with the galactic centre in the middle.*

Plasma means that the electrons and protons of hydrogen and other elements are not bound together into atoms. Instead, plasmas have the individual subatomic particles moving freely around. When the atoms are separated out in a plasma, the electrically charged protons and electrons become far more sensitive to electric fields and hence to electromagnetic radiation moving through the plasma. The oscillating electric field in the light wave pushes the charged protons and electrons in opposite directions. However, the electrons and protons are also electrically attracted to each other, so this attraction pulls the particles back together. The net effect of this push-pull is that the light wave appears to slow down as it moves through the plasma and this slowing affects short-wavelength light more compared to longer-wavelength light, where the push-pull is gentler.

Dispersion has a close cousin called scintillation that happens because the plasma is not completely uniform. Instead, the plasma is being blown around and stirred by gas flows in the galaxy, the passage of supernova shocks, and the twisting and untangling of magnetic fields. Much like atmospheric seeing in the optical, the dispersion and scintillation causes twinkling of the stars and galaxies that we can observe in the radio. Between scintillation and dispersion, the radio pulses from fainter pulsars in the galactic centre get blurred out and become difficult to see with current radio observatories. One of the big promises of the upcoming Square Kilometre Array observatory will be that it is sufficiently sensitive to detect the dispersed pulses and identify whether there are enough pulsars in the galactic centre to explain the gamma-ray excess.

Dispersion and scintillation may seem like bad news for radio astronomy. After all, we tend to appreciate the nights when the atmospheric seeing is the best. However, dispersion provides an important tool for understanding the geography of the galaxy and understanding signals from distant galaxies. Using the signals from pulsars that we have detected, we can use the wavelength dependence of the dispersion measure to determine how much plasma lies between Earth and the pulsar. By mapping out several pulsars throughout the Milky Way, we have built up a map of the nearly invisible gas in the galaxy. Indeed, one of the key pieces of evidence that fast radio bursts originated from beyond the Milky Way came from how much the pulses were dispersed. They were spread out too much to have originated from anywhere nearby. The extra dispersion also tells us about the amount of plasma found in intergalactic space. Such information is nearly impossible to come by any other way, yet most of the actual matter in the Universe is found in the tenuous plasma in the vast spaces between galaxies.

Radio astronomers rarely write exciting press releases about dispersion and scintillation, but they play a major role in observations. With a deeper understanding of dispersion and more careful observations, we will soon be able to answer open questions about dark matter and map out the invisible matter in the Universe.

More information about the gamma ray excess and pulsars: arxiv.org/abs/1507.05616 ✶

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Blast from the Past!

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The Variability in Light of *Mira Ceti* and on the Temperature of Sun-Spots

By I.J. Kavanagh

[This article first appeared in the Journal *in 1908, Vol. 2, p. 32.]*

It is refreshing to be assured that on the Sun, it is not equally hot all the time and everywhere. That on the Sun there are regions relatively cool, if not absolutely balmy, is the conclusion of Father Cortie, S.J., F.R.A.S., of Stonyhurst, in the Astrophysical Journal of September, 1907. He shows that if we may ascribe to temperature, as we do, the observed differences in stellar spectra, it should be easy to admit the existence of a lower temperature in sun-spots as compared with that of the photosphere; and this all the more easily if the argument be founded on the influence of the same substance on the stellar and sunspot spectra.

The well named Mira Ceti is a variable which has received long and richly rewarded attention at Stonyhurst Observatory. Its spectrum, which contains a series of dark bands due to titanium oxide, puts it under Secchi's III. Type. The existence of such flutings in spectra is attributed to the presence of compound bodies. Adequate increase of temperature would split these up, with the consequent production of line spectra; intermediate temperatures would produce intermediate spectra, with more or less condensation into line appearance. As, however, such dissociation occurs at different temperatures for different bodies, one cannot argue from the appearance of flutings to conditions of temperature, unless it be in the case of the spectrum of the same substance.

In the variations in Mira's brilliancy the spectrograph reveals a steady sharpening of the heads of the flutings and a shortening of the winged extensions, with the rise in the scale of visibility.

Comparing the splendid series of spectrograms, five of the maxima of 1907 and 1906, (the latter being the brighter by one magnitude), these spectrograms, taken by Father Sidgreaves under absolutely identical conditions as to the plates and instruments employed, exhibit in the spectrum of the more brilliant maximum of 1906, a more marked tendency towards the line spectrum of dissociation temperatures than in that of 1907. Now as these very titanium oxide bands have been observed in the spectrum of sun-spots, especially at periods near and at maximum spot activity, we may, in all consistency, conclude that at these points of the solar surface the heat does not reach as elsewhere the temperature of total, dissociation, and that, therefore, the temperature of sun-spots is lower than that of the solar photosphere. Some of the useful references given by Father Cortie are here inserted:—

Astrophysical Journal, 25, 17, 1907,

Monthly Notices, 67, 482, 1907, *58*, 844, 1898,

JOURNAL of the R.A.S. of Canada, Mr. J. S. Plaskett, I, 56, 1907.

[Rev. Father I.J. Kavanagh, S.J., professor of mathematics and science in Loyola College, Montréal, was an early member of the Society.] ✶

CFHT Chronicles

Faint Galaxies and Unusual Stars

by Mary Beth Laychak, Director of Strategic Communications, Canada-France-Hawaii Telescope (mary@cfht.hawaii.edu)

CFHT celebrates its 45th anniversary this year. Over the course of the rest of the year, I will use this column to highlight what we are currently doing, historic accomplishments, and our plans for the coming years. CFHT remains one of the most scientifically productive facilities on Earth. Two of the many reasons are highlighted in today's column: large programs with multifaceted science applications and exquisite instrumentation.

The Darkest Galaxy? Discovery of the faintest Milky Way satellite (author's note: this section liberally uses a jointly written news release by the author, Principal Investigator, and public information officers at several institutions).

Galaxies are generally thought of as majestic collections of billions of stars, often arranged on a swirling disk teeming with spiral patterns. Galaxies can also span a wide range of masses; the most massive ones contain hundreds of billions of stars, while at the other end, galaxies as faint as a few thousand stars are known. A recent discovery using the Canada-France-Hawai'i Telescope (CFHT) and W. M. Keck Observatory on Maunakea, and the Pan-STARRS Telescope on Haleakalā, is now challenging astronomers' understanding of galaxy size.

An international team of scientists reports in *The Astrophysical Journal* the discovery of an ancient group of stars orbiting the Milky Way. This newly discovered satellite, known as Ursa Major 3/UNIONS 1 (UMa3/U1) consists of only 60 bright stars spread over a volume just 10 light–years across. This is minute compared to the Milky Way, which contains over 10 billion stars and measures 100,000 light-years across. In comparison, UMa3/U1 is a feeble over-density of ancient stars and the faintest satellite of the Milky Way known to date.

The team obtained the data as part of the Ultraviolet Near-Infrared Optical Northern Survey (UNIONS) at CFHT. I wrote at length about UNIONS in an article last year after the launch of the *Euclid* mission. In short, the UNIONS project is an ambitious imaging survey of the northern sky in the optical and near–infrared conducted by three Hawai'i-based telescopes since 2017: CFHT, Japan's Subaru Telescope on Maunakea, and the University of Hawai'i Institute for Astronomy (IfA) Pan-STARRS telescope on Haleakalā, Maui. Subaru observations add far-red and green, Pan-STARRS adds red, and CFHT adds blue. The discovery of UMa3/U1 used UNIONS images from CFHT and Pan-STARRS along with spectra from the W. M. Keck Observatory.

"Being able to detect such a tiny system, with only about 60 stars, speaks for the quality of the UNIONS dataset," explains Simon Smith, a graduate student at the University of Victoria

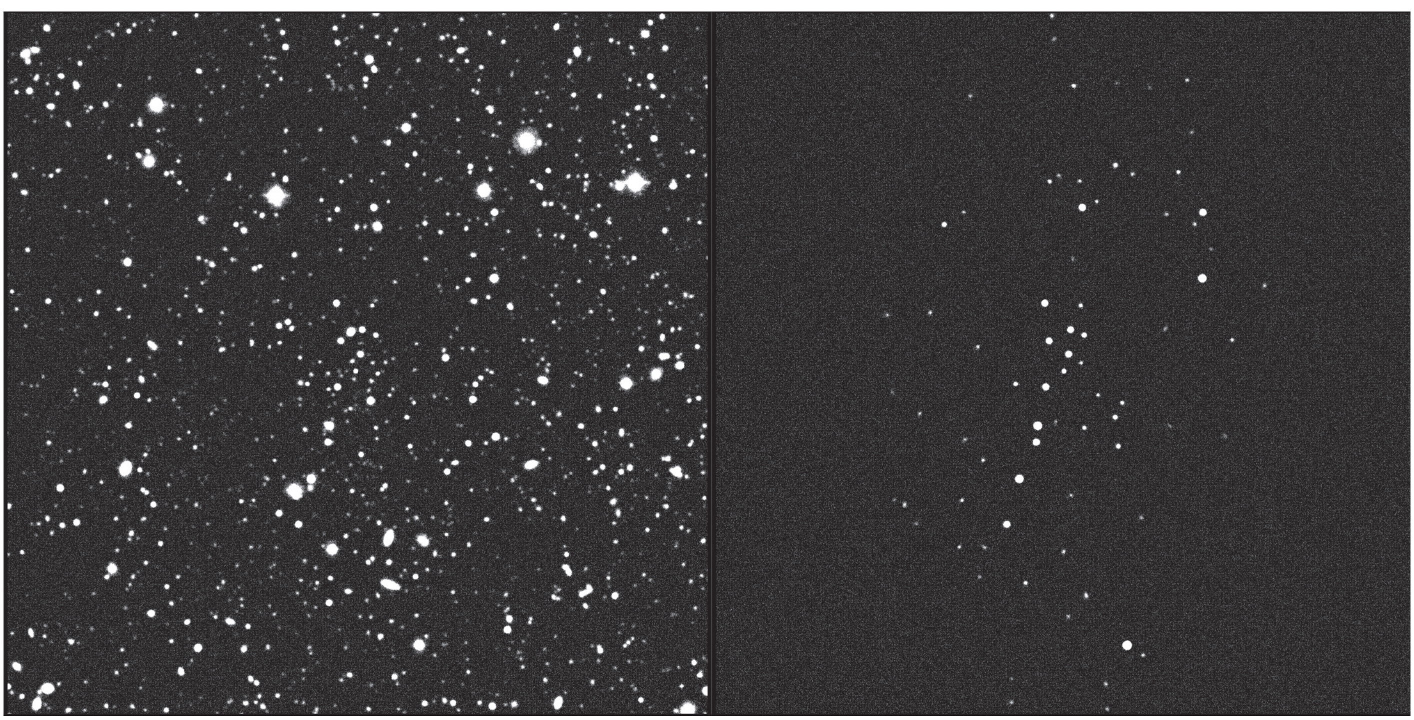


Figure 1 — Hidden in the deep-sky image (left) is a truly miniscule group of stars (right) bound together by their own gravity and possibly dark matter orbiting the Milky Way. Credit CFHT/S. Gwyn (right)/S. Smith (left).

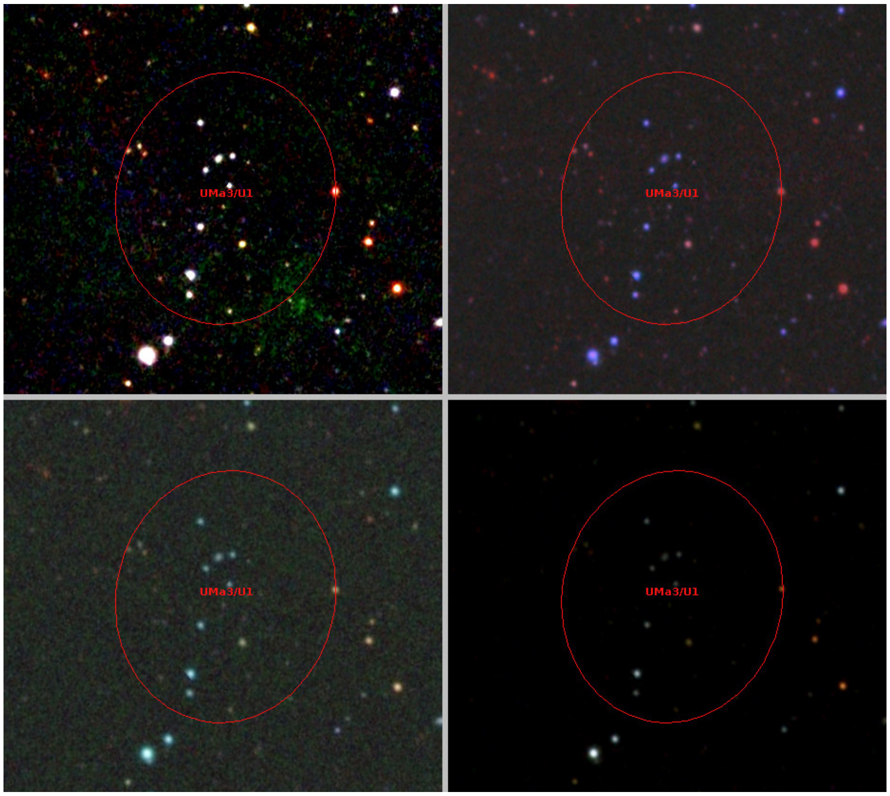


Figure 2 — View of the galaxy UMa3/U1 in several astronomical surveys: PanSTARRS DR1 (top left), DESI Legacy survey (top right), DECaLS DR5 (bottom left), and SDSS9 (bottom right). The red ellipse corresponds to the claimed size in the original paper. Credit: Observatorie astronomique de Strasbourg team.

and lead author of the discovery paper. UMa3/U1 consists of stars that are more than 10 billion years old, twice the age of the Sun and roughly two-thirds the age of the Universe.

"It is either the faintest ancient star cluster known to date, or the faintest and closest known dwarf galaxy ever discovered," says Smith.

The latter scenario is the most exciting. The key difference between the two scenarios hinges on astronomers' ability to determine the presence of dark matter in or around UMa3/U1. Unlike normal matter, dark matter appears not to emit or interact with light or electromagnetic fields. Rather, astronomers infer the presence of dark matter due to its gravitational effects on observable matter.

The presence of faint, ancient, dark matter-dominated satellites is a cornerstone prediction of Lambda Cold Dark Matter (LCDM), the leading theory for the origin of structure in the Universe. LCDM predicts that galaxies like the Milky Way have absorbed, a process known as accretion, hundreds of satellites during their formation and assembly.

Confirming the presence of dark matter in UMa3/U1 is therefore critical for determining its origin. Direct confirmation requires stellar spectra of exquisite quality taken over time, which are not yet available. But the presence of dark matter is highly likely, according to a companion study by a group of scientists from Carnegie Mellon University (CMU), the University of Victoria (UVic), and the National Research Council of Canada's Herzberg Astronomy and Astrophysics Research Centre.

This is because UMa3/U1's orbit takes it through the inner regions of the Milky Way, where gravitational "tidal" forces are strongest. Without the gravity of large amounts of dark matter to bind the object together, UMa3/U1 would not be able to survive in its current orbit for even a small fraction of its estimated lifetime.

"Estimating the dark matter content of a dwarf galaxy requires accurate and repeated measurements of its stellar velocities. Remarkably, the spectroscopic measurements obtained with the Keck II telescope are tentatively consistent with those predicted by LCDM. Without dark matter it is not obvious how UMa3/U1 could have been able to survive unscathed for billions of years," says Raphael Errani, a postdoctoral researcher at CMU, and lead author of the theoretical study.

Further observations of UMa3/U1 will shed light on the object's true identity.

"The discovery of UMa3/U1 exemplifies the power of the UNIONS survey," says Todd Burdullis, QSO specialist at CFHT. "UNIONS observations began at CFHT in 2017. The CFHT observations combined with the total integrated data set from Pan-STARRS and observations from the Subaru Telescope create an incredibly deep data set which facilitates the discovery of the faintest of objects."

Lithium-Rich Cepheid

All stars create energy in their cores through the process of fusing hydrogen into helium. As stars age, their hydrogen is depleted, and the star's characteristics change. Some stars, known as Cepheid Variable stars, evolve into stars that regularly pulse, resulting in a variable brightness over a period of several hours to several days. The predictable nature of these variations leads to Cepheids playing an important role in astronomy in several ways: determining distances in the Universe, understanding the evolution of stars, and mapping different elements across the galaxy. Recently an international team of astronomers, led by Dr. Pierre Martin at the University of Hawai'i at Hilo, announced the discovery of a Cepheid, V470 Cas, with a very unusual composition. Its spectra reveal a very high lithium abundance, making V470 Cas one of eight Cepheids out of thousands in the Milky Way Galaxy that contain high amounts of lithium.

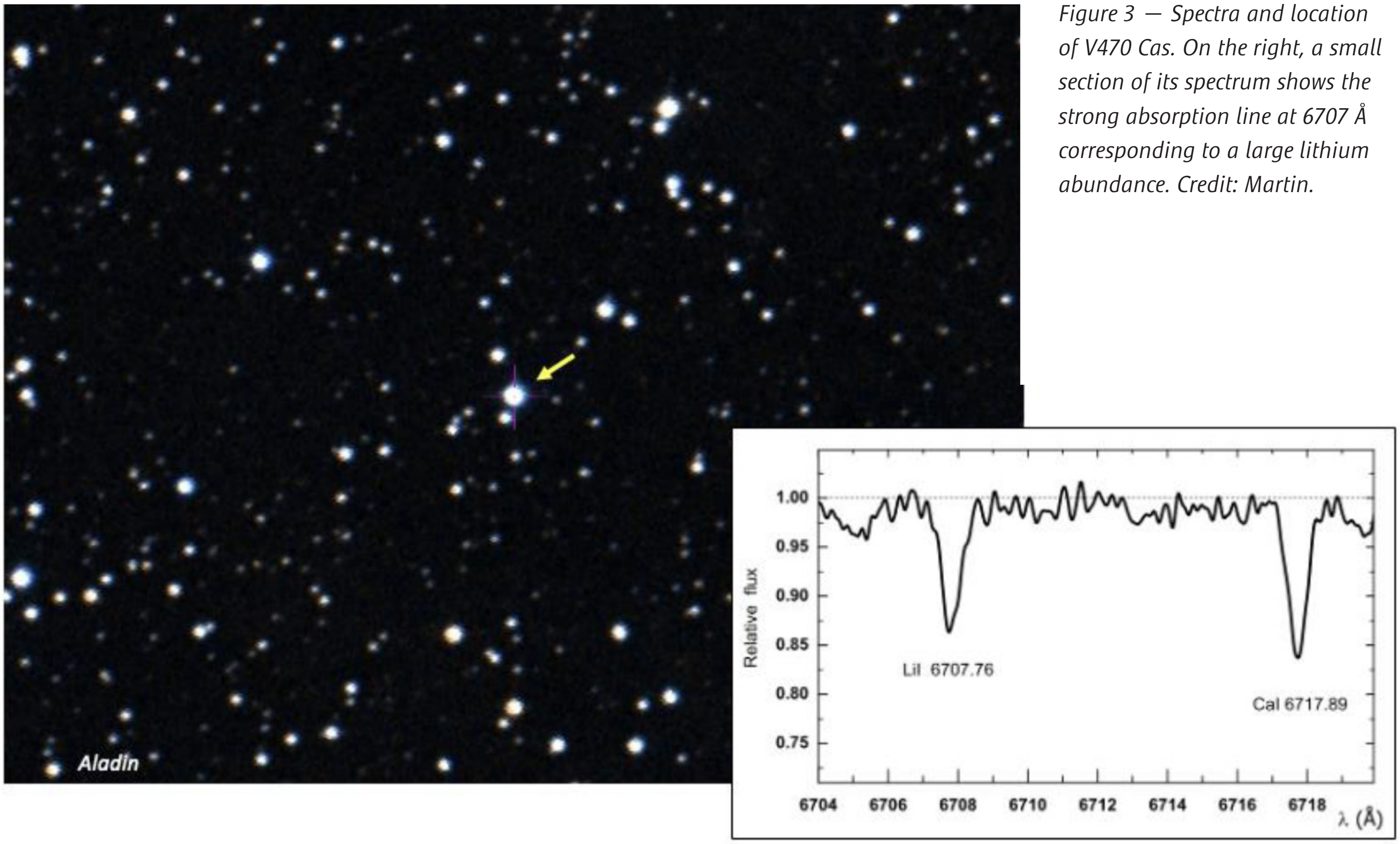


Figure 3 — Spectra and location of V470 Cas. On the right, a small section of its spectrum shows the strong absorption line at 6707 Å corresponding to a large lithium abundance. Credit: Martin.

Over the course of two decades, the team observed a large number of Cepheids distributed across the Milky Way disk, obtaining high-quality spectra and then using models of their atmospheres to accurately determine their chemical composition. During a recent survey conducted with the spectrograph ESPaDOnS at CFHT, the team detected the high lithium abundances of V470 Cas.

Like all Cepheids, V470 Cas is a large star, four times the mass of the Sun, which has evolved away from the main sequence, where stars spend the majority of their lifetime fusing hydrogen into helium. As large stars evolve off the main sequence, some enter what astronomers refer to as the Instability Strip of stellar evolution, which includes Cepheids. For stars in the Instability Strip, the hydrogen is only burning in a shell structure around an inert core made of helium. The result is the characteristic, regular pulsations of a Cepheid star.

Unlike most Cepheids, the spectra of V470 Cas indicates the presence of lithium in the star. When such a massive star transitions into a pulsating Cepheid, the interior of the star also changes, and a series of large-scale mixing events, known as dredge-up episodes occur. Elements near the surface of the star are then brought into deeper zones in the star, where it is much hotter.

Astronomers cannot observe the deeper zones of a star, so they generate computer models to simulate the conditions and resulting impact on the star's composition from dredge-up episodes. All our models predict that lithium, the third lightest element in the Universe, is rapidly destroyed in those hot zones. Spectra in almost all Cepheids show that these models are correct: lithium has disappeared in all those stars with only eight exceptions, including V470 Cas, which contains the third-highest Cepheid lithium abundance measured.

Models indicate Cepheids with lithium in their spectra are just entering the Instability Strip; they are possibly pulsating prior to the first dredge-up event. However, statistically, if this hypothesis is correct, astronomers should observe many more than the eight known young lithium-rich Cepheids. This discovery of lithium in V470 Cas suggests that there is something we do not fully understand yet in the evolution of these stars.

For those interested in trying to observe V470 Cas at home: It is a 12th-magnitude Cepheid star with a period of 21 hours located in the constellation of Cassiopeia. The spectral line of lithium observed is at 670.7nm. Depending on the size of your telescope and weather conditions, the magnitude may push the limits of what's observable at home. If anyone gets a good picture or observation, let me know.✶

Mary Beth Laychak has loved astronomy and space since following the missions of Star Trek's Enterprise. *She is the Canada-France-Hawaii Telescope Director of Strategic Communications; the CFHT is located on the summit of Maunakea on the Big Island of Hawaii.*

John Percy's Universe

North Star

by John R. Percy, FRASC
(john.percy@utoronto.ca)

North star. No, not Polaris. Rather, my colleague Professor Laurie Rousseau-Nepton, co-writer, co-director, narrator, and star (pun intended) of the award-winning 2023 National Film Board of Canada documentary *North Star/Etoile du Nord.*[1]

It is not often that a documentary is made about a Canadian astronomer. This one calls to mind the also-award-winning 1961 NFBC documentary *Universe*, which followed astronomer Donald MacRae through a night of observing with the 1.88m (74") telescope at the David Dunlap Observatory (DDO). As a tour guide at DDO in the 1960s, I showed this half-hour film dozens of times to schoolchildren and the public. As a documentary, it was well ahead of its time. And it's still available for viewing for free.[2] But *North Star* is longer, broader, deeper—and in glowing colour! The location and cinematography are both spectacular and inspiring.

As the first Indigenous woman in Canada to receive a Ph.D. in astronomy/astrophysics, Laurie Rousseau-Nepton[3] is special. She is a unique and effective role model for young women, for Indigenous people—especially for Indigenous youth—and for under-represented people in general. At the same time, as a result of her extensive public outreach and communication activities, she has an opportunity to show the relationship between Indigenous knowledge, culture, and spirituality, and the "Western" scientific knowledge that she and her astronomer colleagues create. This is a key priority for science curricula in Canadian schools today. Fortunately, Laurie is an exceptional communicator, in both French and English, and she devotes a significant fraction of her time to outreach and communication activities. *North Star* is the pinnacle of her work—so far.

Important as this work is, Laurie is first and foremost a first-rate scientist, as reflected by her degrees, publications, grants, and other measures. After award-winning doctoral studies at Université Laval, using a state-of-the-art imaging spectrometer at Mont Mégantic Observatory, she was quickly hired as a Resident Astronomer at the prestigious Canada-France-Hawaii Telescope (CFHT), where she led (and continues to lead) the SIGNALS project—Star Formation, Ionized Gas, and Nebular Abundances Legacy Survey—with more than 60 international collaborators. SIGNALS uses observations from an instrument called SITELLE, an optical imaging Fourier transform spectrometer. The goal

Figure 1 — Professor Laurie Rousseau-Nepton (right) and intern Justine Giroux at the Canada-France-Hawaii Telescope, where she was a Resident Astronomer, before becoming a faculty member in Astronomy and Astrophysics at the University of Toronto. Source: National Film Board of Canada.

of this highly competitive "Large CFHT Program" is to get new, statistically significant and systematic clues about star formation in various environments, with high spatial resolution. As principal investigator on this project, she ensured that at least half of her collaborators came from various minority groups, including women. She was and is a key resource for astronomers around the world, as reflected by her numerous collaborations, papers, and invited lectures. She now holds a highly competitive assistant professorship in my department. As of March 2024, Laurie has 54 research publications on ADS—the Astrophysics Data Service—listed in her c.v.[4]

North Star, launched 2023 August 21, is an inspiring five-part short documentary series targeted at teachers and high school students (but accessible and engaging to people of all ages) to learn about the Universe while challenging stereotypes about science, scientists, and science career paths. It promotes the participation of young women, and of Indigenous youth in the sciences, and showcases the multifaceted nature of science today, with its discoveries, excitement, interest, applications, and relevance to communities and cultures. *North Star* also humanizes astronomy and astronomers—specifically Laurie— by tracing her childhood, school days, career and, most recently, motherhood. This is possible because of her exceptional ability as a narrator and interviewee.

North Star is also an excellent astronomy documentary, showing the scientific problems that astronomers address, and how they use observatories, telescopes, and instruments to solve them. *North Star* is available in English or French and is free of charge for streaming.[1] So, it is widely accessible. To quote from the *North Star* website: "Drawing on a worldview rooted in a love of nature, as well as her talents as a science communicator, Laurie shares her passion for the study of celestial objects. Ranging from Ashuapmushuan to Wendake, Hawaii and Mont-Mégantic, Laurie's inspiring journey will leave viewers starry-eyed." As of February 2024, *North Star* has already won five awards at three international film festivals:

Silbersalz in Germany (Best Short Science Series), New Zealand Web Fest (Best Show—Factual Series, Best Editing, Best Cinematography), and Raw Science Film Festival in the U.S. (Best Professional Documentary Series).

North Star is an excellent educational resource, partly because of the nature and importance of its content, and the personality of its star, but also because of the very effective Teacher's Guide that accompanies it. Laurie served as Advisor for this guide. It was written in large part by award-winning education specialist Julie Bolduc-Duval, Director of *Discover the Universe (DU),* Canada's national bilingual astronomy program for teachers.[5] DU also hosts an excellent resource on Canadian Indigenous astronomy—*astrodigenous.ca. North Star*'s educational potential reaches across Canada and beyond, including to Indigenous communities. Please pass on the link to DU, *astrodigenous*, and *North Star* to your teacher friends!

Laurie's outreach in connection with *North Star* is done against a rich and relevant background of other outreach and communication.[6] She did about 40 public presentations, radio and TV interviews, podcasts, and newspaper and magazine interviews during 2021 and 2022—during the pandemic! While doing weekly presentations to schoolchildren in Hawaii, she also did about 60 virtual talks to school classes in Canada through *Connected North*[7], a non–profit organization whose mission is to bring education to remote and/or isolated communities. It deserves our appreciation and support. These school class visits were as close to face-to-face as possible, especially during a pandemic. Her impact on young people and Indigenous communities is substantial; she has already received significant recognitions from the Canadian Space Agency, and Université Laval, and has been nominated for Québec's Mammouth Prize.

She did a flurry of over a dozen major interviews, on radio and TV, at the time of the release of *North Star* in August 2023. Most of the media interviews would be available across Canada—on CTV National News, for instance. Many of her presentations and communications—including *North Star* itself—would also be available and relevant to other countries such as Australia, New Zealand, and the U.S., which have significant Indigenous populations.

Laurie is continuing her outreach, arising from and based on the same themes as in *North Star*. For example, she was an invited speaker to the Quebec Science Teachers Association in October 2023 (a very high-impact audience of 500+), and at *Indspire*, a high-profile non-profit that invests in the education of Indigenous people. She was the "star" presenter at a 2023 November 10, *Astronomy on Tap* event in Toronto, sponsored by the Dunlap Institute, with an audience of 450+. In early 2024, she was the star of "The Gateway," a winter installation highlighting the northern lights, at Toronto's Bentway, a public space under the Gardiner Expressway.[8] Her past outreach has included information about the role of eclipses in Indigenous knowledge and culture, and this intensified as the April 2024 solar eclipse approached.

Laurie Rousseau-Nepton is someone to watch—the latest in Canada's remarkable series of astronomy communicators, from Clarence Chant to Helen Sawyer Hogg to Terence Dickinson, among others. Remember that name!

Latest News: Laurie Rousseau-Nepton is the 2024 recipient of the Canadian Astronomical Society's Qilak Award for excellent and impactful astronomy outreach activities.

Acknowledgements

I thank Professor Carmelle Robert, Université Laval, for information about Laurie's research. ✶

Endnotes

1 North Star: www.nfb.ca/series/north-star

2 The Film *Universe*: nfb.ca/film/universe

3 Laurie Rousseau-Nepton: laurie-rousseau-nepton-03.webself.net/accueil

4 Her publications: laurie-rousseau-nepton-03.webself.net/publications

5 Discover the Universe: discovertheuniverse.ca

6 Her outreach: laurie-rousseau-nepton-03-webself.net/research

7 Connected North: connectednorth.org/en

8 "The Gateway" at The Bentway: thebentway.ca/event/northern-lights-astronomy

John Percy FRASC is Professor Emeritus, Astronomy & Astrophysics, and Science Education, University of Toronto, an Associate Member of the University's Dunlap Institute, and a former President (1978–80) and Honorary President (2013–17) of the RASC.

2024 Award Nominations

Compiled by James Edgar

Simon Newcomb Award Nomination 2024—Dr. Chris Gainor, Victoria Centre

Dr. Chris Gainor FRASC Ph.D. has long been a supporter and close follower of the Canadian and international space programs. As a historian, he has written several books and articles about various aspects of the exploration of space.

His first book was *Arrows to the Moon: Avro's Engineers and the Space Race*. This book is a thorough look at how Canadian engineers supported the Apollo manned lunar landing program. In 1959, when the Avro Arrow program was cancelled, NASA hired over 30 Avro Arrow engineers and moved them to Virginia. They ultimately worked on the Mercury, Gemini, and Apollo programs.

Chris has written several important articles on the history of space exploration. He is currently the Editor of *QUEST: The History of Spaceflight Quarterly*. This excellent publication features in-depth articles on the history of the space program.

The fact that NASA hired Dr. Gainor to write a book about the history of the *Hubble Space Telescope—Not Yet Imagined: A Study of Hubble Space Telescope Operations*—clearly demonstrates that Chris has the respect of a space historian.

In addition, he has written numerous other books:

Canada in Space: The People & Stories Behind Canada's Role in the Exploration of Space (2006)

Who killed the Avro Arrow? (2007)

To a Distant Day: The Rocket Pioneers (2008)

The Bomb and America's Missile Age (2018)

From the RASC *Journal*:

Amateur Astronomers and the *Hubble Space Telescope* (2021)

Apollo Geological Training in Canada, 1970–1972 (2022)

The Apollo 11 Astronauts Visit Canada (2022)

Canadian Visits of Early Spacefarers (2022)

The Canadian Astronomy Data Centre: Canadian Astronomy and the Beginnings of Big Data (2023)

For all of the above, and especially for the book *Not Yet Imagined*, we believe Dr. Chris Gainor is most deserving of the Simon Newcomb Award 2024.

Nominated by: J. Randy Attwood, FRASC

James Edgar, FRASC

Tony Schellinck, Halifax Centre—nomination for RASC Qilak Award 2024

The undersigned hereby submit the following citation to support presenting the RASC Qilak Award to Douglas Anthony (Tony) Schellinck, member of the RASC Halifax Centre, in recognition for his long-standing, diverse, and innovative astronomy outreach activities in Nova Scotia.

Tony Schellinck's education and outreach work is utterly unique and unlike anything else done in Canada. It is remarkably creative, delivered with energy, passion, and humour. Its variety, depth, breadth, scope, and success are astonishing. It meets peoples' interest and curiosity "where they live." Tony engages peoples' hearts and minds at their level, and enables people to engage with the Universe immediately, joyously, and personally. Tony brings the Universe to people at ground level—his audiences are expertly and efficiently guided to a key understanding, that the stars, as Helen Sawyer Hogg always said, really do belong to everyone!

Tony joined the RASC Halifax Centre in 2006 and rapidly became an active member. He earned the following observing certificates: Explore the Universe (2017), Explore the Moon—Telescope (2020), Messier (2016), Finest NGC (2020); and all three astroimaging certificates: Wide-Field (2017), Deep-Sky (2017), and Solar System (2017). This strong background in observing and imaging the sky, combined with his natural teaching ability (retired professor) allowed Tony to translate his love of astronomy into a series of outreach initiatives to engage others, especially beginners. During that time, he also edited the Centre newsletter, *Nova Notes* (2015–17) and served on the Centre Board of Directors (most years 2015–present).

To cite the instances of Tony's outreach activities event-by-event would take too long to relate. The evidence below is aggregated by topic, but to give a temporal sense of Tony's activity, here in his own words is a report to the Centre representing a single year (2016):

On a personal note, I have been quite busy with outreach this year. I have put on nine shows at the Halifax Planetarium, six SCANS classes, two Liverpool Astor Theatre flat-screen planetarium shows with Wayne Mansfield and two similar shows at the Margaret Hennigar Public Library in Bridgewater with Jerry Deveau. I set up my binoculars table for three nights at Keji DSW and two nights at Nova East. I mounted the play The Star Trek Universe: Where Empires Exist *at the Halifax Central Library on the 50th anniversary of Star Trek, and then again at CaperCon in Sydney. There was also a Breakfast Morning segment associated with these plays. I was guest speaker at a Sunday Assembly held at the Halifax Central Library. Other observing nights—four with SCANS students, Smileys Provincial Park (post Nova East), Privateer Days in Liverpool. I manned the table at HalCon for Sunday afternoon. Perhaps one of the more unusual nights was working with professional photographers from Quebec who were using Keji as a backdrop for a cover photo of a Subaru in the foreground and the Milky Way in the background. All told I gave 36 outreach presentations/shows/sessions this year with audiences ranging from 3 to 85 each time. Many of these shows required days of preparing and coordination to put on. When you add on the number of days required to put out Nova Notes and tend to RASC council matters, not to mention the nights I go out to my observatory in Port Mouton, you begin to get an idea why my spouse is starting to kindly suggest I may be spending too much time on astronomy.*

On to the evidence…

Disclaimer: *The following evidence was mined from email chat lists and* Nova Notes *newsletter accounts and may be incomplete and/or contain minor errors of detail. Tony was not consulted in the preparation of this nomination, but we did use information from his 2018* JRASC *article. We also consulted his wife, Heather (in confidence), to confirm some details.*

Innovative Outreach Initiatives

Tony has created several innovative activities for astronomy outreach. These were outlined in his article "RASC Outreach: Endless Opportunities for Creative Engagement with Novice Observers," published in JRASC February 2018 (pages 18–21).

Binocular Table—10 to 25 individuals borrow binoculars from a table set up in a dark-sky observing location and are coached by the session leader on how to use the binoculars. Then they try to locate easy-to-find objects on their own. The leader might help guide them to more difficult targets with a strong narrow light beam pointed into the sky. Sessions last about 30-45 minutes and can be repeated. The idea came to Tony when he discovered that he could find 60 of the 110 Messier objects with binoculars. The Binocular Table has been deployed more than 20 times at outreach events.

Telescope Plaza—similar to the above, but with a smaller number of 6″ or 8″ Dobsonian telescopes, with 1–3 people sharing a telescope (introduced in 2019).

Ace Amateur Astronomer—participants (especially youngsters) engage in a Binocular Table activity with a 20-object guide sheet appropriate to the month. If they find at least 5 listed objects, they are issued an Ace Amateur Astronomer certificate on the spot. A description is posted on the RASC website and was presented at the 2022 online RASC General Assembly. Tony has issued up to 40 AAA certificates in one night.

Flat-Screen Planetarium—basically a night-sky tour with a twist: fish-eye astrophotos are projected onto a flat screen and participants sit well back from the screen while the presenter points out stars and constellations. With coaching, from the presenter, they look for asterisms, star clusters, nebulae, and galaxies in the projection using supplied binoculars. Photos of various scales are used, ending up with closeups. Weather permitting, these shows are followed by outdoor observing sessions (introduced in 2016).

Star Trek Play—In 2015, Tony created, wrote, produced, and acted in the live-action and multi-screen play The Night Sky According to Star Trek—Where Empires Exist. In this play, several characters from the TV series described how to find constellations and deep sky objects on the way to their various empires. The play was presented at Hal-Con, the sci-fi and comic convention in Halifax, Caper-Con in Sydney, and finally at the Central Library in Halifax (2016), on the occasion of the 50th anniversary of the original Star Trek television series. The play grew out of the earlier presentations *The Secrets of the Universe as Revealed by Star Trek (2012)*, *Everything We Knew About Astronomy We Learned from Star Trek*, *Where in the Sky is the Klingon Empire,* and *The Night Sky According to Star Trek (2015).*

Halifax Planetarium Shows (2013–2020)

Tony became one of the several presenters at the planetarium at Dalhousie University and introduced several innovations. With the addition of a data projector, he projects his own images of deep-sky objects onto the dome. He also instructs the audience on how to use binoculars. After the show (if clear), he leads a brief observing session outside with participants, looking for the objects highlighted in the show. In the 8-year interval 2013—2020, Tony presented 48 planetarium shows to 1024 adults and 118 children (over 8 years). The planetarium closed when COVID-19 struck and has not yet re-opened for public shows. Show themes include *Love is in the Stars* (Valentine's Day), *Journey to the Centre of the Galaxy*, *Begin to Observe*, *The Klingon Empire*, and *Using Binoculars and Telescopes*.

Flat-Screen Planetarium Shows in Theatres and Lecture Halls (2016–present):

The flat-screen planetarium shows have been presented at a wealth of venues. The inaugural show was *A Practical Guide to Observing the Night Sky*—Astor Theatre (Liverpool, 2016), and became the core of his SCANS multi-week courses (see below). Other one-night screenings were presented in Shelburne and Yarmouth (2017).

Kejimkujik Dark Sky Preserve (2010-present)

Tony has been a volunteer presenter at 13 of 14 annual Dark-Sky Weekends (DSW) held at Kejimkujik, either as a lecturer, telescope operator, binocular table leader, or telescope plaza operator. His 2011 keynote lecture was *From Here to There, a Personal Journey from Earth to the Farthest Reaches of Space*. His Port Mouton home is close enough to Keji that he has managed to represent RASC Halifax there for several individual outreach events, such as The Dark as Keji beer launch (2017), assisting with photo and video shoots relating to the night sky (2016), and presenting to visitor groups (2013, 2019, 2022). Tony was part of the RASC team that negotiated the first Partnering Agreement for a DSP between Parks Canada and a RASC Centre, and represented dark-sky issues at a Kejimkujik Management Plan Meeting (2019). In recent years, Tony actively assisted in organizing the DSW. Currently, he is Co-Chair of the RASC Halifax DSP Committee and the principal contact with Kejimkujik.

Nova East Star Party

Tony has been a participant in the Nova East star party since he joined RASC. He brought his various outreach activities to the event annually, such as the Binocular Table, the Telescope Plaza, and the Ace Amateur Astronomer. He has also presented talks, such as *Observing the Night Sky with Binoculars* (2016) and *Observing in Nova Scotia—How to Beat the Weather Gods* (2018).

Seniors College Association of Nova Scotia (SCANS) (2016–present)

SCANS is a volunteer run, non-profit organization for members aged 50 and over where instructors teach non-credit academic courses in return for an honorarium. Tony's SCANS courses began in 2016 at the Astor Theatre in Liverpool. The first 6-week course with 37 senior students was *A Practical Guide to Observing the Night Sky Using Binoculars*, in effect an expanded version of the Flat-Screen Planetarium shows. In this course he covered observing through the four seasons, lunar observing, and basic sketching. The course included 3 nighttime viewing sessions. A second course was *Seeing Is Believing—How the Telescope Changed Who We Are and What We Know* (2020). Tony presented SCANS courses in Liverpool (2016), Mahone Bay (2017), Chester (2018), Dartmouth (2018), Truro (2018), Halifax (2020), Dartmouth (2020), and by Zoom (2020)—8 times in all.

Instructional Videos

In 2020 Tony produced 7 instructional videos on observing and telescopes, which have earned 1300+ views on the RASC Halifax YouTube Channel (see www.youtube.com/c/RASCHalifax)

- How to use Binoculars to Observe the Night Skies (2020)
- A Virtual Field Trip to Observe the November Night Sky
- International Observe the Moon Night, Sept. 26, 2020. How to Observe the Moon
- So You Want to Buy a Telescope: Episode 1—Tripods
- So You Want to Buy a Telescope: Episode 2—The Role of a Mount in a Telescope System
- So You Want to Buy a Telescope: Episode 3—Basic Telescopes
- So You Want to By a Telescope: Episode 4—Advanced telescopes and recommendations

Miscellaneous Outreach Presentations (incomplete)

- International Observe the Moon Night (Halifax, 2010)
- *Explore the Universe* at Halifax Central Library (2013) and Bridgewater Library (2013),
- Sidewalk observing (Citadel Hill, Halifax, 2013)
- Star Trek play (Nocturne, Halifax, 2015)
- Impromptu presentation (Smileys Provincial Park, 2016)
- *Astronomy on the Cheap* (Sunday Assembly, Halifax, 2016)
- Observing sessions (White Point Beach Resort, 2017, 2018)
- Senior Physicians Group (Halifax, 2017)
- Observing session (Keji Seaside Adjunct, 2017),
- Thrive Youth Group (2018)/Chowder & Chat (Lunenburg, 2019)
- Impromptu presentation (Joshua Tree National Park, 2019)
- Conference and exhibition booth shifts (multiple years at Hal-Con, RV Show, Saltscapes).

RASC Education and Public Outreach (EPO) Committee (2020–present)

From the Chair of the EPO Committee: "Tony has worked on one of our main projects, the RASC Novice Observing Program with Lucas Kuhn, Francesco Ambrogi, and the late Linda Pulliah. He has been a great supporter of using naked eye and binoculars for observing and we support and promote his Ace Amateur Astronomer program. He has helped unwaveringly when we needed something edited or reviewed, works quietly but efficiently, and gets things done. I hope he stays with us as we need his calm demeanour and thoughtfulness on our committee."

The concept of the novice observing program (still in beta test) is to have a downloadable observing program with sufficient detail so that a non-RASC leader could coach novice observers (of all ages). The observing program is designed to be completed in one evening.

Outreach to Underserved Communities

In the past, RASC Halifax Centre outreach activities have largely served the population of Halifax Regional Municipality and have under-served rural Nova Scotian communities. As a part-time resident of Port Mouton on the South Shore (2-hour drive from Halifax), Tony is in a good central location to visit other South Shore communities and beyond. Tony takes his talks and courses on multiple occasions to the communities of Chester, Mahone Bay, Lunenburg, Kingsburg, Bridgewater, Liverpool, Barrington, Shelburne, and Yarmouth (1.5 hours from Port Mouton).

Final Words

The Board of the Halifax Centre enthusiastically support this nomination of Tony Schellinck for the Qilak Award, in recognition and celebration of his national-award-worthy achievements in astronomy education and outreach. We believe the evidence shared above more than qualifies Tony Schellinck for the RASC Qilak Award. We'll let Tony summarize in his own words (from his JRASC article):

People have a real hunger to learn about what is in the sky and to have the experience of finding deep-sky objects themselves. I have the ability to help them fulfill this need. Outreach provides me with satisfaction, learning, challenges, opportunities for fulfillment, and a way to give back to the communities in which I live.

Nominated by Dave Chapman, FRASC

Warren Finlay, Edmonton Centre: Chant Medal

Warren Finlay's wide-ranging, unique, and impressive achievements in astronomy over the past 25 years firmly place him among the most accomplished amateur astronomers in Canada. In 2023, he completed observing the Herschel 2500 list—approximately 2500 objects, a feat that took him 22 years. In total, he has observed more than 3300 NGC objects, in addition to more than 500 supernovae, comets, and other deep-sky objects. In 2022, he created the "Brightest 2500 Northern NGC" list. He is the inventor of the astronomy bimarathon which involves the twin tasks of observing 110 deep-sky objects and running a regular marathon (42.195 km) between sunset and sunrise in a single night. He is the only person known to have completed a bimarathon. In 2016, he completed a Messier bimarathon by star hopping with a 10″ Dobsonian and binoculars. In 2018, he repeated that difficult feat in Australia but instead with all southern deep-sky objects. He is the inventor of the Herschel marathon, which requires observing 110 Herschel objects in a single night. He completed his Herschel marathon by observing a selection of the dimmest Herschel 2500 objects on 2023 March 16/17. Details of his observations have been shared with other RASC members.

Warren is the author of the book *Concise Catalog of Deep Sky Objects: Astrophysical Information for 550 Galaxies, Clusters, and Nebulae* (Springer). Now in its 2nd edition, the book has sold more than 5000 copies. From 2006 to 2008 he co-authored with Dr. Douglas Hube the bimonthly *Deep Sky Contemplations* column in the RASC *Journal*.

In 2004, he founded the Northern Prairie Star Party, a popular annual amateur astronomy gathering in Alberta. He was its Director until 2009 and has been a member of its organizing committee ever since. He is also the visionary behind the Black Nugget Lake Observatory, conceived by him nearly 20 years ago. Over the past seven years, he managed the team that built the 14-foot domed observatory, a visitor's centre, and a 32-inch diameter Unyk-Drew Telescope (UDT) that saw first light in 2023. The UDT is one of the largest telescopes at a dark site in Canada that is available for public viewing.

Warren is also an award-winning astrophotographer, having received the *SkyNews* Grand Prize Annual Astrophoto Award (2004) and Best Tripod-Mounted Unguided Photo (2021): as well as Honorable Mention in *Canadian Geographic*'s Skyward Photo Contest (2014). His nightscape photos have been selected for inclusion in the annual RASC *Observer's Calendar*.

Warren was a recipient of the RASC's Simon Newcomb Award (2006) and the RASC Edmonton Centre's President's Award (2019), Observer of the Year Award (2020 and 2016), Franklin Loehde Project of the Year Award (2003, 2005, and 2016), Bryce Hartwell Memorial Award for Excellence in Astroimaging (2014), and the George Moore's Memorial Award for Excellence in Public Education (2007). It would be difficult to imagine a more deserving recipient of the RASC Chant Medal.

Nominated by: Douglas P. Hube, Alister Ling

Fellowship Award, Robyn Foret, Calgary Centre

Robyn Foret first made a significant mark in the Calgary Centre in 2000 by becoming a key volunteer at the weekly Friday night public stargazing sessions held on the observing deck at the Science Centre. In 2003, he took on the role of volunteer coordinator for the observing deck and morphed it into volunteer coordinator for all public outreach events, a role he continues to this day. Robyn signed on in 2001 as one of the "instructors" of the Youth Group.

Robyn was not only the overall coordinator and host for Calgary-hosted RASC General Assembly 2018 Planning Committee, but he also hosted organizing meetings at his work office and arranged for the famous Calgary Stampede Pancake Breakfast Team to provide a true "western" welcome for delegates.

Robyn worked to get an Alberta Government gaming license to participate in the public casinos run by provincial not-for-profit organizations. Each casino has allowed the Calgary Centre to earn thousands of dollars for honoraria for public speakers, purchasing equipment for public outreach and, most significantly, for a new public observatory within the City of Calgary. Robyn has done almost all the legwork to win support from the City, choose a location, hire a team to design the building, and lobby the provincial government and donors to bring this project forward.

Robyn has been awarded the Calgary Centre's President Award for meritorious service twice, in 2011 and 2017. He also garnered a RASC National Service Award in 2019. Robyn has been the President of the Calgary Centre twice, in 2014–2016 and in the current term (2023–2025). He has served in other roles on the Calgary Centre executive.

At the National level, Robyn Served as Chair of the Education and Public Outreach Committee before joining the Board of Directors in 2014. In eight years on the Board, he served on various committees and as 1st and 2nd Vice-President before serving as National President in 2020 to 2022. During those two years, the Society faced numerous challenges arising from the COVID-19 pandemic, including staff changes and the need to move the National Office. During that time, Robyn took on the job of managing production of the RASC's *Night Sky Almanac*, a role he continues to the present day.

Nominated by: Roland Deschesne, Dr. Chris Gainor

Service Award, Charles Ennis, Sunrise Coast Centre

Charles Ennis joined the RASC in August 2013 and by 2021 had become the National President, so hisenergy and interest in promoting astronomy are well known. However, the Sunshine Coast Centre ishereby submitting an application for Charles to receive a Service Award for his outstandingcontribution to our local club alone.

He was elected to our executive in November 2013 as the Media coordinator and within months had expanded our online presence, our local advertising, and our involvement in outreach astronomy events.

He quickly assumed the heavy responsibility for booking speakers—the highlight of our monthly meetings—and in the process generated a prodigious volume of emails, contacts, reports, and applications for financial assistance from the National Speakers Program. Soon our club was at the top of the RASC in the use of that program.

The following December, Charles was elected president of the club, hosted the monthly meeting, and continued his role in promoting the club and soliciting speakers. We were in the middle of designing and building an observatory and Charles interviewed amateur astronomers from across the country and around the world for their insights and perspectives on building a small observatory. He presented the results to the club and later wrote the handbook on small observatories for the RASC.

When the club completed the observatory, it became obvious that the leading user of the telescope was Charles, and he often invited a troop of neighbours and acquaintances to join him. That pattern has continued since restarting the public use of the observatory post-COVID. He wrote a complete manual for the observatory and mentored others to become "Qualified Operators."

A few members of the club started a local television program called "Night Lights"—13 half-hour episodes per year. The first season was in 2010. Charles soon joined the effort, became the host and has continued as the mainstay up to the present—many years worth of effort.

Charles also extended the reach of our club overseas, arranging for shipping one of our telescopes to a student in Uganda.

When Charles joined the National Board he had to resign as President of the Sunshine Coast Centre and so returned to being one of several elected Members-at-Large. However, he continued to seek out speakers until his duties at the National level became overwhelming.

In the fall of 2022, he successfully applied for a federal grant to make our observatory more accessible to seniors and in this way to allow them to pass on their expertise and enthusiasm to the next generation. This June he solicited bids on the project and negotiated with and supervised the winning contractor. The project is now essentially complete.

Charles has been the indispensable promoter of club programs since his arrival in 2013 and the club owes him a debt of gratitude for his outstanding efforts. He richly deserves a Service Award.

Bruce Fryer

President, Sunshine Coast Centre

Service Award: James MacWilliam, Sunshine Coast Centre

The Sunshine Coast Centre nominates its member James MacWilliam for a Service Award. James has been associated with our astronomy Centre since January 1989 when we were the Sunshine Coast Astronomy Club: At that time, he was secretary for the club. James was one of the people that showed up in June 2004 to reorganize the club under Bill Clark. James was a regular presenter at club meetings and regular attendee at star parties and observing events with his telescope. James has always been very generous with his scope, showing visitors the skies, very enthusiastic about involving every passerby in viewing the skies and mentoring newcomers. In November 2004 he took charge of the club's brand-new website and, in the spring of 2008, he created a website to display astrophotography by club members: Again, he used his passion to get other people involved. This website lasted until 2018 when it was replaced by our current Wordpress website. James went on to be a regular contributor to our new Facebook page and many of the images on our new website are his. He doesn't just bring a telescope to the observatory. He brings his guitar and entertains us all while we are viewing the skies. It is that atmosphere that brings people back over and over. He's constantly acquiring new equipment and sharing what he's learned about it with the membership and the public.

James was one of the members involved in bringing the club into the RASC as a Centre in 2008. James created a full-colour *Observing Newsletter* for the Centre in 2010. In February 2010, James founded our Astro Café event, which has taken place on the third Friday of every month ever since except for a brief period during the pandemic lockdown. In November 2010, he became a Director at Large for the Centre. By July 2011, he was the Astro Café Coordinator, Imaging Group Webmaster, and Observing Coordinator. In August 2011, he became part of the committee planning our Centre's observatory. James has not been in formal leadership for a while now, but his informal leadership continues to the present day.

Nominated by: Bruce Fryer, Charles Ennis

June MacDonald for RASC Service Award

June MacDonald joined the RASC New Brunswick Centre in October 2002 and she is in her tenth year as Centre President. She has been the heart of RASC NB during this period and the crazy glue that held us together during the pandemic years, taming her contrary computer long enough to conduct meetings via Zoom and to keep members informed of Centre and Society business. Of particular note, June was the driving force behind the dedicated committee that resulted in the Centre becoming incorporated and obtaining charitable status. During many of these years she was also the Centre Representative on the RASC National Council.

Prior to her consecutive years of presidency June was Centre Secretary for six years, 2nd V-P for two years, and a prominent member of the Organizing Committee for the 2010 RASC General Assembly in Fredericton. She chaired the 2024 Eclipse Committee for the Centre, which included communicating with communities within the zone of totality, working with libraries to schedule information sessions, obtaining eclipse glasses, and organizing the purchase and distribution of eclipse apparel highlighted with a unique New Brunswick design by member Ted Dunphy. In addition, she was a member of the RASC 2024 Eclipse Committee.

Throughout the years June has been a frequent and jovial speaker at meetings, a contributor to the Centre newsletter, and a supporter of outreach events either through observing or working in the background to ensure they run smoothly. It is with great pride that we nominate June MacDonald as a recipient of the RASC Service Award.

Nominated by: Curt Nason, Emma MacPhee

Service Award, Heather Laird, Calgary Centre

Heather Laird is a long-serving member of the Calgary Centre who has been engaged in Centre and Society leadership since joining in May of 2013. Heather joined Calgary Council that year and attended her first General Assembly in Victoria in 2014 as one of the Centre's National Advisory Council members. In 2015, she was elected as a Director of the RASC and held that position into 2020. During that time she also became a founding member of the Inclusivity and Diversity Committee.

For the Society's 150th celebration at the 2018 General Assembly, Heather was a presenter on the topic of women in Astronomy as part of the "A Shared Sky: the RASC at 150" initiative. Her research and findings are anticipated to be printed in that published celebration of the Society's first 150 years, highlighting the role of women scientists in our journey.

Presently, Heather is the 2nd Vice-President of the Calgary Centre and Chair of the Centre's Social Committee, ensuring that all members, new and old, have opportunity to connect outside of the volunteer activities and formal Centre events as part of a welcoming, inclusive, and diverse Centre. She is also a critical part of the Centre's Marketing initiatives, managing all things Social Media, ensuring consistent messaging and advertising of Centre events of interest to the public.

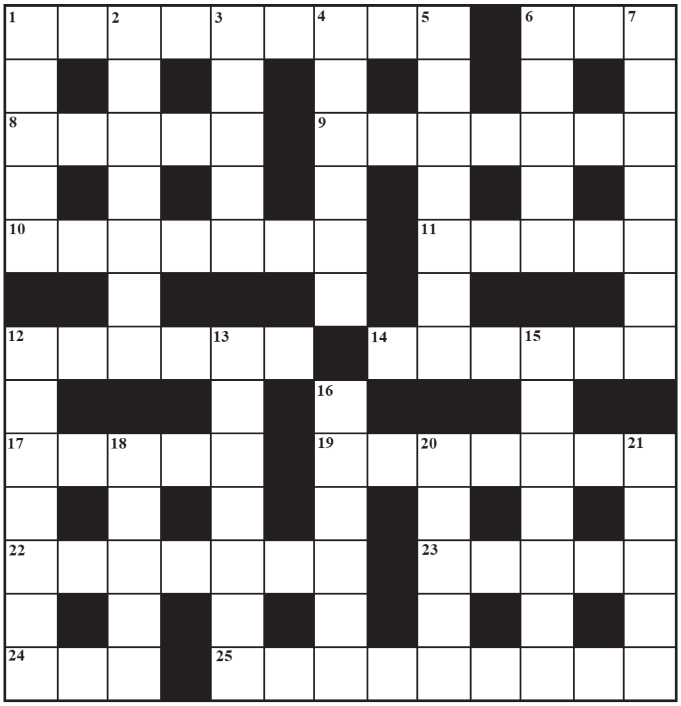
At the Centre meetings, you will find Heather and other volunteers greeting the public, showing off our publications and merchandise, and constantly informing and educating the public of the opportunities and endeavours that the RASC offers and supports.

Always enthusiastic and demonstrably committed to the Society, we are honoured to nominate Ms. Laird for this Award.

Nominated by: Robyn Foret, Craig Levine

Astrocryptic

by Curt Nason



ACROSS

1. April 8 eclipse of a vain person's eclipse (9)
6. CASCA oddly forms a related agency (3)
8. Planetary need stood in a bar (5)
9. Confusing clue in back of the Sun? Yes, centrally. (7)
10. Manual part of a GoTo mount (7)
11. Diana took a spin around Neptune (5)
12. Lost comet foretold Luthor decapitating Tell (6)
14. Stellar players at a base in Houston (6)
17. Calendar based on M45 from azimuth, etc. (5)
19. Mobil sign of gas between gym class and us (7)
22. Definitive factor of stellar magnitude (7)
23. Half of The Beatles toured around Jupiter (5)
24. Jack in a car crash (3)
25. Gold star turns backache down under (9)

DOWN

1. Our heartbroken home (5)
2. Babe follows tailless horse at a node (7)
3. Aboriginal depiction within dust clouds (5)
4. A small angular distance (6)
5. Back to the buffet for a measure of planetary width (7)
6. Einstein initially put in 151 notches of a sculptor's tool (5)
7. Astrophysical teams debate perigee and apogee (7)
12. In a tizzy, Hera let Galileo cover a telescope with it (7)
13. The French oddly cater to a lizard (7)
15. Charter of stellar evolution would audibly take stock (7)
16. Astronomy Picture of the Day is of a southern bird (6)
18. Painter Édouard turned out an X-ray telescope (5)
20. Like the Sun, but strange without northeast winds (1,4)
21. He-Man's sister makes (103) Hera's rotation (3-2)

Answers to previous puzzle

Across: **1** PHOENIX (anag+Nix); **5** RUPES (anag); **8** X-RAYS (2 def); **9** RICHARD (2 def); **10** SPINDLE (spin+anag); **11** BENNU (rev hid); **12** COYOTE (coy+rev+E); **14** THEORY (2 def); **17** LIBRA (anag-el); **19** INTEGER (anag); **22** MENKENT (an(k)ag); **23** JANUS (2 def); **24** ARIES (Ar(I)es)' **25** RETICLE (2 def)

Down: **1** PYXIS (2 def); **2** OPACITY (capacity–Ca+O); **3** NOSED (anag); **4** XERXES (rev); **5** RUCHBAH (H(anag) ur); **6** PRAWN (2 def); **7** SUDBURY (sud+ruby(anag)); **12** COLUMBA (col+u+MBA); **13** TRACERS (anag); **15** ORGANIC (organ+IC); **16** PICTOR (Pict+or); **18** BONDI (hid); **20** TEJAT (rev+at); **21** ROSSE (anag)

The Royal Astronomical Society of Canada

Vision

To be Canada's premier organization of amateur and professional astronomers, promoting astronomy to all.

Mission

To enhance understanding of and inspire curiosity about the Universe, through public outreach, education, and support for astronomical research.

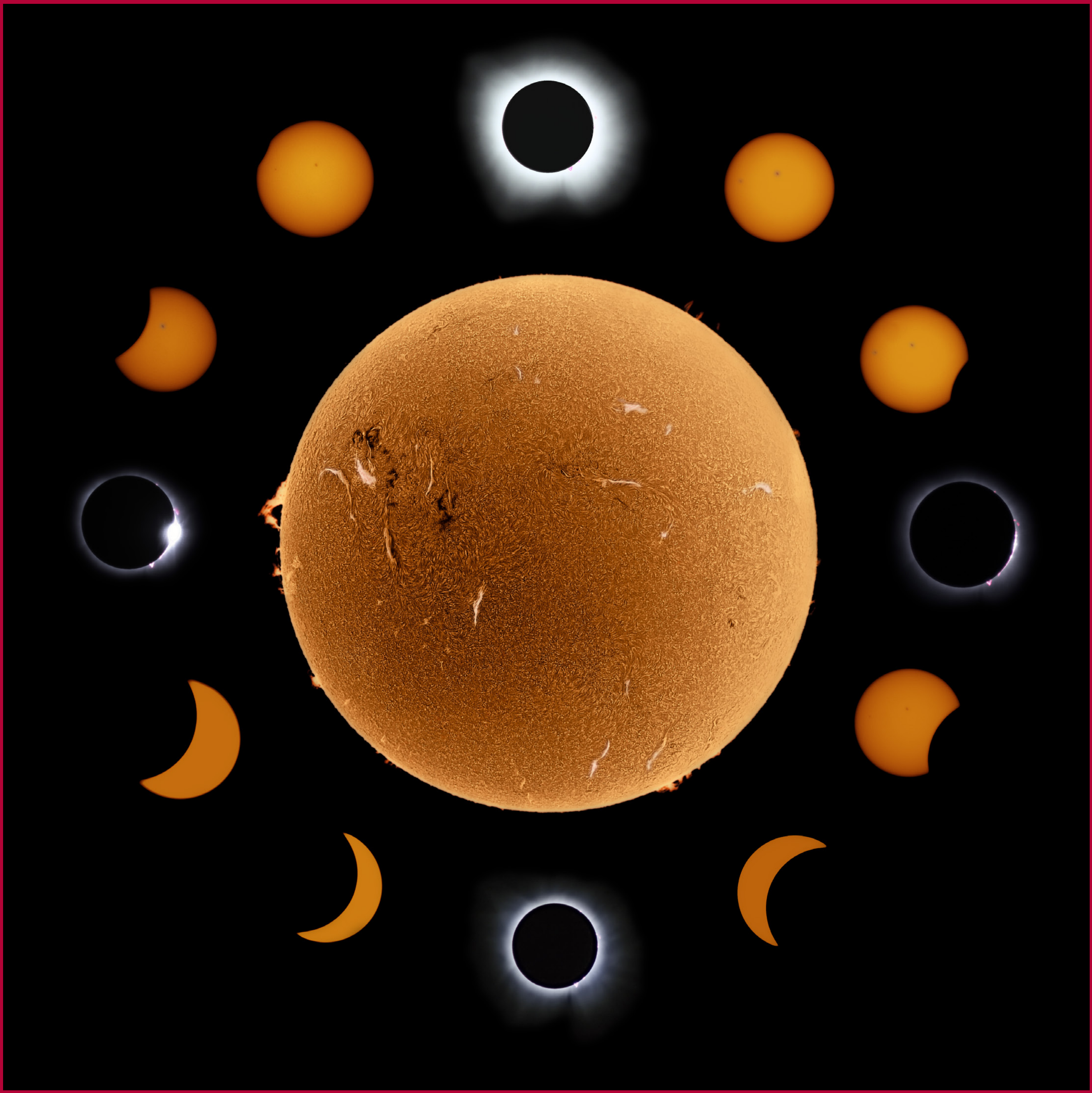
Values

- Sharing knowledge and experience
- Collaboration and fellowship
- Enrichment of our community through diversity
- Discovery through the scientific method

Great Images

by Chris Vogel

Chris Vogel battled the clouds but managed to take this stunning image of the total solar eclipse from Dunnville, Ontario. He used a Nikon D850 with a Nikkor 300 mm at ƒ/2.8 on a tripod, unguided and with no filter. Final image was lightly processed in Photoshop.



Journal

Shelley and Stefan Jackson chased the eclipse to Sutton, Québec, and were fortunate to have clear skies. Shelley put together this collage of images showing the eclipse as well as the Sun in Hα. All images were all taken with a Canon T5 rebel, with white-light filter made of Baader solar film, on a Sky-Watcher Star Adventurer tracker. The exposure times varied from 1/4000 second to 1/250 second at ISO 2000.