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Journal

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Travelling for Planetary Imaging

Our Universe Through the Unruh Effect and Information Theory

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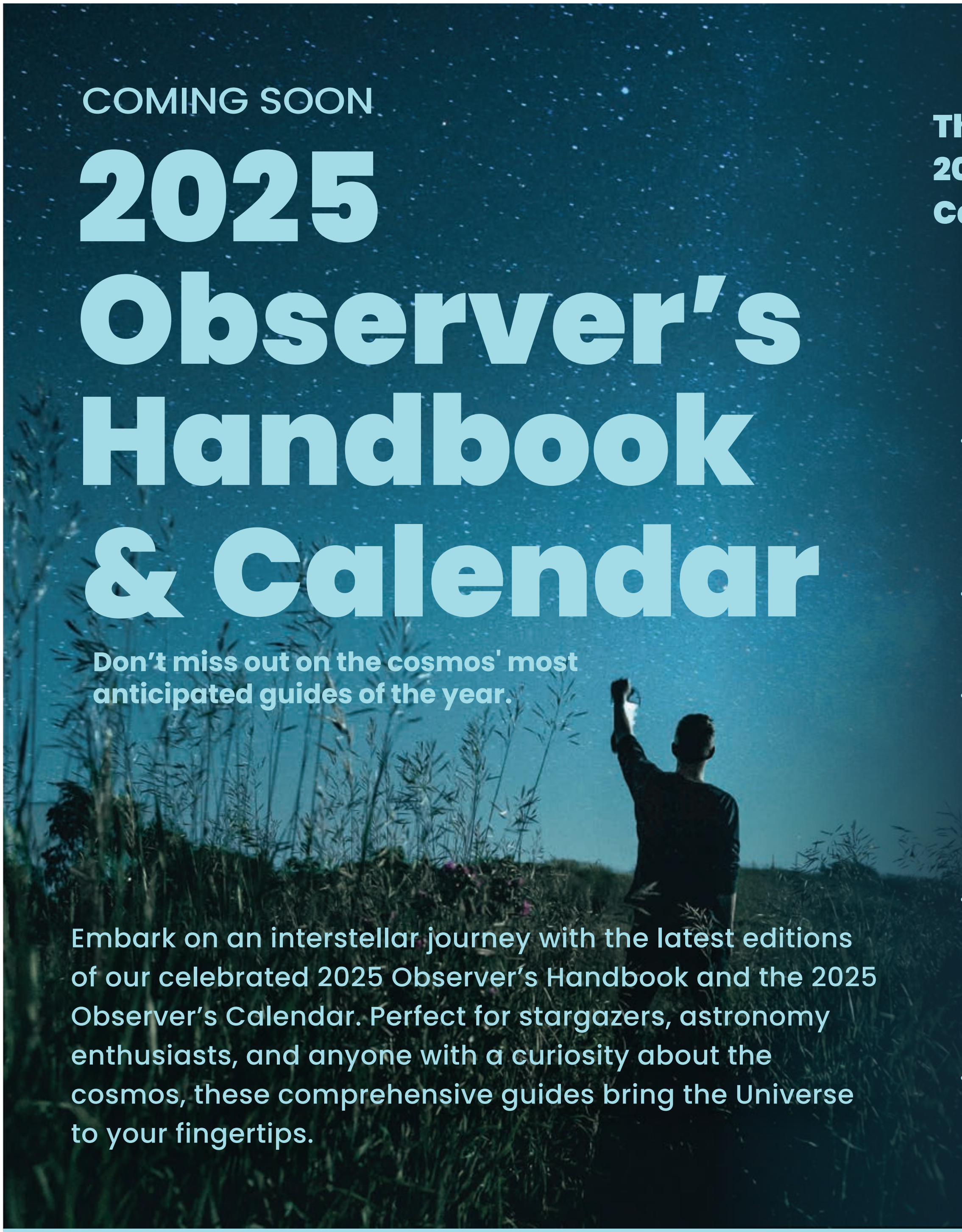

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Royal Astronomical Society of Canada
Société Royale d'Astronomie du Canada

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Great Images / Superbes images

This stunning image of Messier 16, colloquially referred to as the Pillars of Creation thanks to a Hubble Space Telescope *image taken in 1995, was taken by Kingston Centre President Malcolm Park.*

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

Looking Up and Looking Back

by Michael Watson, President
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In his professional life he was a high school mathematics teacher in Toronto. In his astronomical life he has been a teacher to all of us in Canada who share a love of the celestial world above us. His greatest service to the Canadian astronomical community, however, is undoubtedly his numerous articles and books on the history of astronomy in Canada. This year marks the 30th anniversary of the publication of the definitive and seminal history of our Society: "*Looking Up – A History of The Royal Astronomical Society of Canada*," a magnificent 300-page work written by long-time Toronto Centre member and a fixture of the national Society for decades, Peter Broughton.

Peter was born in 1940, a dozen years before I was. He graduated with a B.Sc. from the Astronomy Division of the Mathematics and Physics department of the University of Toronto in 1963 and went on to earn his M.Sc. in mathematics in 1971. Peter's professional career, spanning 34 years from 1964 to 1997, was as a high school teacher in Toronto, but his great passion—developed during his youth and later during his undergraduate years—was and still is astronomy. In a recent exchange that we had in preparation for this column, Peter recalled how he came to astronomy:

> "I don't remember looking through a telescope as a kid. My earliest recollection of anything to do with astronomy was a comment made by a friend of my parents who, one summer evening, pointed my attention to a very bright star overhead and said "That's Vega." I'd heard of Venus but not Vega so I thought maybe he was wrong or that he was trying to show off.…
>
> As a teen-ager, the public library was a favourite haunt and I was attracted to the astronomy shelf, in particular a set of maroon-coloured "Harvard books on astronomy." These were written by experts at Harvard, people like Bart Bok, Donald Menzel, Cecilia Payne, Harlow Shapley, Fred Whipple—each one dealing with their own speciality: the Milky Way, Our Sun, Stars and Clusters, Variable Stars, Galaxies, the Earth, Moon and Planets. They were amazing books written for adults but well within reach of high school students. Through them I learned how knowledge is acquired and developed. For me, that is the great adventure—one with no beginning or end and full of unexpected twists and turns.
>
> At the University of Toronto, I studied maths and physics with very limited success but found astronomy much more congenial. [This was accompanied by] summer employment observing meteors at the Meanook Observatory in

> Northern Alberta and working with data from the *Alouette* satellite in Ottawa the following year.
>
> It was during that summer in Alberta, in 1962, that the RASC held its annual GA, and it was then that I joined the Society. A few years later, Ruth Northcott (who had taught astronomy lab courses during my student years) asked if I would consider serving the RASC as librarian—the first of a long line of positions I filled in the ensuing years."

As for this last point, starting in 1962, Peter held an impressive array of positions at the national level: Librarian, Secretary, Treasurer, First and Second Vice-President, and President from 1994 to 1996. He has been awarded the Society's Service Award and Chant Medal, and in 2013 was named a Fellow of the RASC. For his contributions to the RASC, the International Astronomical Union named asteroid 16217 after him—"Peterbroughton"—in 2005.

In addition to *Looking Up*, to which I will return shortly, Peter undertook a decade of meticulous research on the life of Canada's preeminent astronomer of the early 1900s, John Stanley Plaskett, and published his definitive biography of Plaskett—*Northern Star: J.S. Plaskett*—in 2018. For this work Peter was awarded the 2023 Osterbrock Book Prize by the American Astronomical Society. RASC archivist Randall Rosenfeld had this to say about *Northern Star*: "The publication of Peter Broughton's *Northern Star: J.S. Plaskett*, is a watershed event for the history of Canadian astronomy. Plaskett, founder of the still-vital Dominion Astrophysical Observatory, was the first Canadian astrophysicist whose quality and quantity of research and professional connections ensured his ability to walk on the world stage of the discipline. Broughton's scholarship is thorough, and he presents it in an attractively readable form."

But back to *Looking Up*. As Peter explained in the preface, the motivation for his book was the centenary, in 1990, of the incorporation of what was then called "The Astronomical and Physical Society of Toronto" (it is worth noting that the Society's roots dated back to the founding in 1868 of the Toronto Astronomical Club). The RASC established a Centennial committee, of which Peter was a member. The most significant result of that committee was the creation of the *Beginner's Observing Guide*, which was a great success and continued to be printed for more than two decades.

Peter has also explained to me—or reminded me, because I was on the National Council as Second Vice-President at the time but had since forgotten the details—how Society approval for his book took place. In his own words from an exchange that he and I had recently:

> "An image came to mind of the annual meeting where I sought permission to proceed with the project. As President, I was in an awkward position since I knew some members would take the view that I was taking advantage of my position to get the Society to finance my "pet project." After laying out my proposal, including the plan that the copyright, and thus any royalties, would belong to the RASC, I excused myself from the meeting so that a free debate could proceed without any influence by me. I can picture myself sitting on the lobby and being summoned back by you after a few minutes."

I must emphasize some of his quoted words: "the plan that the copyright, and thus any royalties, would belong to the RASC." Peter's devotion to and love of the Society is shown so clearly by the fact that he never intended to make any monetary profit from *Looking Up*.

Looking Up took Peter two years to research and write, and it was published in 1994, 30 years ago. Although it has been out of print for many years, *Looking Up* is still on the RASC's website and available for all members and the public at www.rasc.ca/sites/default/files/ardocuments/LookingUp.pdf. In it, readers can learn of the origins of the RASC, the expansion of the Society beyond Toronto to all provinces of Canada, and the activities of numerous Centres in observation, astrophotography, and the bringing of our passion to the Canadian public. One of Peter's goals was to highlight the contributions of many members of the Society over the decades, both professional and amateur, to the RASC's success, and the book is peppered with notes of dozens of such members and is liberally illustrated with historical photographs of the people and activities that have made our Society what it is today.

Looking Up is a wonderful record of the history of the RASC, and well worth spending several hours with during cloudy nights. I will close by thanking Peter Broughton for all that he has done for the Royal Astronomical Society of Canada. I am so very fortunate to have known him over many years. ✶

Figure 1 — Peter Broughton.

News Notes / En manchette

Compiled by Jay Anderson

Striking insight on Mars craters!

An international team of researchers, co-led by ETH Zurich and Imperial College London, have derived the first estimate of global meteorite impacts on Mars using seismic data. Their findings indicate between 280 to 360 meteorites strike the planet each year forming impact craters greater than 8 metres across. Géraldine Zenhäusern, ETH Zurich, who co-led the study, commented, "This rate was about five times higher than the number estimated from orbital imagery alone. Aligned with orbital imagery, our findings demonstrate that seismology is an excellent tool for measuring impact rates."

Using data from the seismometer deployed on Elysium Planitia during the NASA *InSight* Mission to Mars, researchers found that six seismic events recorded in the near proximity of the station had been previously identified as meteoric impacts—a process enabled by the recording of a specific acoustic atmospheric signal generated when meteorites enter the Martian atmosphere. Now, Zenhäusern, ETH Zurich, co-lead, Natalia Wójcicka, Imperial College London, and the research team have found that these six seismic events belong to a much larger group of marsquakes, so-called very-high-frequency (VHF) events.

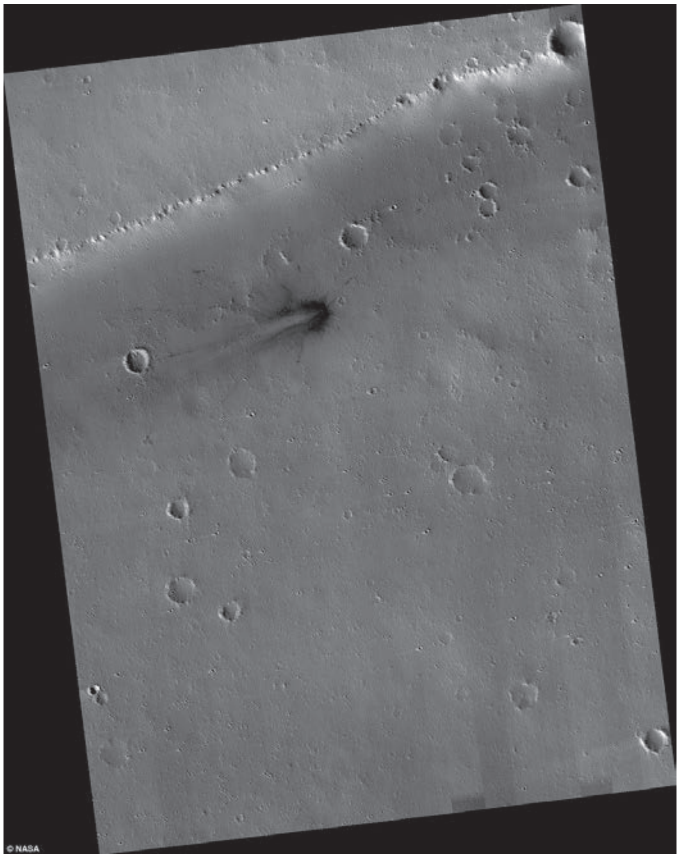

Figure 1 — A recent impact crater in Elysium Planitia discovered by the Mars Context Camera (CTX) on-board the Mars Reconnaissance Orbiter *that formed between February 2012 and June 2014. It appeared as a dark streak with multiple secondary craters that was not seen in a previous CTX image. The image shows a very distinct crater rim and ejecta that is much darker than the surrounding dust-covered terrain. The distribution of the rayed ejecta suggests that the impactor struck from the west. Image: NASA.*

The process responsible for these quakes occurs much faster than for a tectonic marsquake of similar size. Where a normal magnitude 3 quake on Mars takes several seconds, an impact-generated event of the same size takes only 0.2 seconds or less, due to the hypervelocity of the collision. The distinctive signal that these abrupt events produce was described as a "chirp" by the research team. By analyzing the total sample of marsquake spectra, a further 80 marsquakes were identified that are now thought to be caused by meteoroid strikes.

InSight was a NASA Discovery Program mission that placed a geophysical lander on the planet to study its deep interior. It addressed one of the most fundamental issues of planetary science: understanding the processes that shaped the rocky planets of the inner Solar System (including Earth) more than four billion years ago. The mission terminated in December 2022 after more than four years of collecting science data, when accumulated dust on the solar panels reduced power and eventually ended communication with the lander.

The ETH and Imperial College research quest began in December 2021 when a large, distant quake recorded by the seismometer reverberated with a broadband seismic signal throughout the planet. Remote sensing associated the quake with a 150-metre-wide crater. To confirm, the *InSight* team partnered with the *Mars Reconnaissance Orbiter* (MRO) Context Camera (CTX) to search for other fresh craters that would match the timing and location of the seismic events detected by *InSight*. The team's detective work paid off and they were lucky to find a second fresh crater over 100 metres in diameter. Smaller craters, formed when basketball-sized meteoroids strike the planet and which should be far more common, remained elusive. Now, the number of meteorite strikes has been newly estimated by the occurrence of these characteristic high-frequency quakes.

Approximately 17,000 meteorites fall to Earth each year, but unless they streak across the visible night sky, they are rarely noticed. Most meteors disintegrate as they enter Earth's atmosphere, but on Mars the atmosphere is 100 times thinner, leaving its surface exposed to smaller and more frequent meteorite strikes.

Until now, planetary scientists have relied on orbital images and models inferred from well-preserved meteorite impact craters on the Moon but extrapolating these estimates to Mars proved challenging. Scientists had to account for the stronger gravitational pull of Mars and its proximity to the asteroid belt, both of which mean that more meteorites hit the Red

Planet. On the other hand, regular sandstorms result in craters that are much less well-preserved than those on the Moon, and, therefore, not as easily detected from orbit. However, when a meteorite strikes the planet, the seismic waves of the impact travel through the crust and mantle and can be picked up by seismometers, an entirely new way of measuring Mars's impact rate.

Wójcicka explains, "We estimated crater diameters from the magnitude of all the VF-marsquakes and their distances, then used it to calculate how many craters formed around the *InSight* lander over the course of a year. We then extrapolated this data to estimate the number of impacts that happen annually on the whole surface of Mars."

Zenhäusern adds, "While new craters can best be seen on flat and dusty terrain where they really stand out, this type of terrain covers less than half of the surface of Mars. The sensitive *InSight* seismometer, however, could hear every single impact within the lander's range."

Much like the lines and wrinkles on our face, the size and density of craters from strikes reveal clues about the age of different regions of a planetary body. The fewer the visible craters, the younger the surface of that region of the planet. Venus, for example, has almost no visible craters because it is protected by a thick atmosphere and its surface is continually reworked by volcanism. The ancient surfaces of Mercury and the Moon are heavily cratered. Mars falls in between these examples, with some old and some young regions that can be distinguished by the number of craters.

New data show that an 8-metre crater happens somewhere on the surface of Mars nearly every day and a 30-metre crater occurs about once a month. Since hypervelocity impacts cause blast zones that are easily 100 times larger in diameter than the crater, knowing the exact number of impacts is important for the safety of robotic and future human missions to the Red Planet.

"This is the first paper of its kind to determine how often meteorites impact the surface of Mars from seismological data—which was a level-one mission goal of the Mars *InSight* Mission," says Domenico Giardini, Professor of Seismology and Geodynamics at ETH Zurich and co-Principal Investigator for the NASA Mars *InSight* Mission. "Such data factors into the planning for future missions to Mars."

Compiled with material provided by ETH Zurich.

New solar observations from 1609

Researchers have re-examined half-forgotten sunspot drawings by Johannes Kepler and revealed previously hidden information about the solar cycles from before the grand solar minimum.

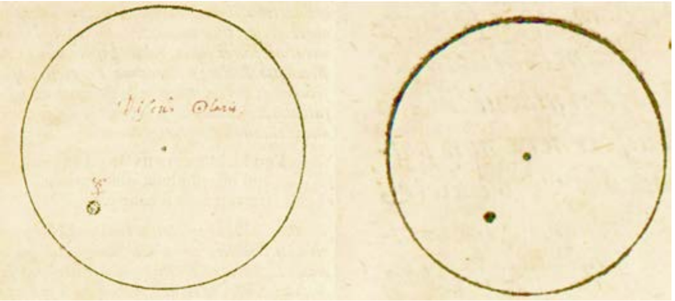

Figure 2 — Kepler's drawings of the Sun and his mistaken identification of a sunspot for Mercury (to the lower left; the other dot marks the centre of the disk).

By recreating the conditions of the great astronomer's observations and applying Spörer's law in the light of modern statistics, an international collaborative group led by Nagoya University in Japan has measured the position of Kepler's sunspot group, placing it at the tail-end of the solar cycle that came before the cycle that Thomas Harriot (1610), Christoph Scheiner (1611), Galileo Galilei (1610), and other early telescopic observers later witnessed. These telescopic observations were not new discoveries as naked-eye sunspots were observed centuries before the telescope was invented.

The research group's findings offer a key to resolving the controversy on the duration of solar cycles at the beginning of the 17th century, which are associated with the transition from regular solar cycles to the grand solar minimum, known as the Maunder Minimum (1645–1715). The Maunder Minimum was an abnormally prolonged period of low sunspot activity, which is important for telling researchers about solar activity and its effect on the Earth.

Kepler made one of the earliest datable instrumental records of solar activity in the early 17th century, before the first telescopic sunspot drawings. He used an apparatus known as a camera obscura, consisting of a small hole in a wall to project the Sun's image onto a sheet of paper, which allowed him to sketch visible features on the Sun.

In May 1607, he recorded what he mistakenly interpreted as a transit of Mercury across the Sun, later clarified to be a sunspot group sighting. Sunspots' occurrences, frequency, and latitudinal distributions are all related to the strength and the phase of the sunspot cycle.

Hisashi Hayakawa, the lead author of the study, noted, "Since this record was not a telescopic observation, it has only been discussed in the context of the history of science and had not been used for quantitative analyses for the solar cycles in the 17th century," he said. "But this is the oldest sunspot sketch ever made with an instrumental observation and a projection."

He continued, "We realized that this sunspot drawing should be able to tell us the location of the sunspot and indicate the solar-cycle phase in 1607 as long as we managed to narrow down the observation point and time and reconstruct the tilt of the heliographic coordinates—meaning the positions of features on the Sun's surface—at that point in time."

The observations were important because the 17th century was a pivotal period in the solar cycle, not only as the time when sunspot observations had just begun but also when solar activity transitioned from normal solar cycles to the Maunder Minimum.

It is not fully understood how the pattern of solar activity shifted from regular cycles to the grand minimum, other than that the transition was gradual. One of the previous tree-ring-based reconstructions claimed a sequence consisting of an extremely short solar cycle (≈ 5 years) and an extremely long solar cycle (≈ 16 years), associating these anomalous solar-cycle durations with a precursor of the transition from regular solar cycles to the grand solar minimum.

"If true, this would indeed be interesting. However, another tree-ring-based reconstruction indicated a sequence of solar cycles with normal durations," said Nagoya University's Hisashi Hayakawa. "Then, which reconstruction should we trust? It is extremely important to check these reconstructions with independent—preferably observational—records."

Kepler's sunspot record is a key observational reference. By analyzing Kepler's records and comparing them with contemporaneous data and modern statistics, the researchers made several important discoveries:

First, after "deprojecting" Kepler's sunspot drawings and compensating for the solar position angle, they were able to determine that the sunspot group was at a low heliographic latitude. This suggests that the famous schematic drawing of the solar image that Kepler diagrammed in his book is not consistent with Kepler's original text and the two camera obscura images, which show the sunspot in the upper-left portion of the solar disk.

Second, by applying Spörer's law and the knowledge gained from modern sunspot statistics, they identified the sunspot group as being probably located in the tail-end of solar cycle 13 rather than the beginning of solar cycle 14.

Third, their findings contrast with later telescopic observations, which show sunspots at higher latitudes. "This shows a typical transition from the preceding solar cycle to the following cycle, in accordance with Spörer's law," Thomas Teague, an observer for the WDC SILSO [World Data Center Sunspot Index and Long-term Solar Observations] and a member of the team, said, referring to the German astronomer Gustav Spörer who described a migration of sunspots from higher to lower latitudes during a solar cycle.

Fourth, this finding allows the authors to approximate the transition between the previous solar cycle (14) and the next solar cycle (13) between 1607 and 1610, narrowing down the possible dates when it occurred. On this basis, Kepler's records suggested a regular duration for solar cycle 13, challenging alternative reconstructions that propose an extremely long cycle during this period.

"Kepler's legacy extends beyond his observational prowess; it informs ongoing debates about the transition from regular solar cycles to the Maunder Minimum, a period of extremely reduced solar activity and anomalous hemispheric asymmetry between 1645 and 1715," Hayakawa explained.

"By situating Kepler's findings within broader solar activity reconstructions, scientists gain crucial context for interpreting changes in solar behaviour in this pivotal period.

"Here, we add to that by showing that Kepler's sunspot records predate the existing telescopic sunspot records from 1610 by several years. His sunspot sketches serve as a testament to his scientific acumen and perseverance in the face of technological constraints."

Compiled with material provided by Nagoya University

Gaia springs a leak

Launched in December 2013, the European Space Agency (ESA)'s *Gaia* spacecraft is on a mission to map the locations and motions of more than a billion stars in the Milky Way with extreme precision.

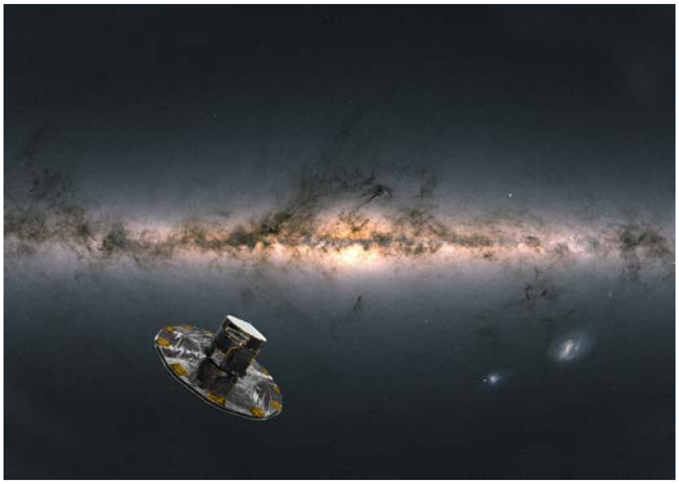

Figure 3 — Artist's impression of ESA's Gaia *satellite observing the Milky Way. The background image of the sky is compiled from data from more than 1.8 billion stars. It shows the total brightness and colour of stars observed by* Gaia *released as part of* Gaia*'s Early Data Release 3 (*Gaia *EDR3) in December 2020. Image: Spacecraft: ESA/ATG medialab; Milky Way: ESA/*Gaia*/DPAC. Acknowledgement: A. Moitinho.*

But it's not easy being a satellite: space is a dangerous place. In recent months, hyper-velocity space dust and the strongest solar storm in 20 years have threatened *Gaia*'s ability to carry out the precise measurements for which it is famous.

In April, a tiny particle smaller than a grain of sand struck *Gaia* at high speed. Known as a micrometeoroid, millions of these particles burn up in Earth's atmosphere every day.

But *Gaia* is located 1.5 million km from Earth at the second Sun-Earth Lagrange point (L2). Out there, far from our planet's protective atmosphere, *Gaia* is often struck by particles like this. Impacts are expected, and the spacecraft was designed to withstand them. This object, however, struck *Gaia* at a very high speed and at just the wrong angle, damaging the spacecraft's protective cover. The impact created a little gap that allowed stray sunlight—around one billionth of the intensity of direct sunlight felt on Earth—to occasionally disrupt *Gaia*'s very sensitive sensors.

Gaia's engineers were in the middle of dealing with this issue when they were faced with another problem.

The spacecraft's billion-pixel camera relies on a series of 106 charge-coupled devices (CCDs) to convert light into electrical signals. Last May, the electronics controlling one of these CCDs failed—*Gaia*'s first CCD issue in more than 10 years in space. Each sensor has a different role, and the affected sensor was vital for *Gaia*'s ability to confirm the detection of stars. Without this sensor to validate its observations, *Gaia* began to register thousands of false detections.

The root cause for the electronics failure is not entirely clear. *Gaia* was designed to operate for up to six years but has now survived almost twice as long under the harsh conditions of space.

Around the time of failure, *Gaia* was hit by the same violent burst of energetic particles from the Sun that triggered spectacular auroral light shows around the world. The spacecraft was built to withstand radiation, but during the current period of high solar activity, it is being pushed to its limits.

It is possible that the storm was the final straw for this piece of the spacecraft's aging hardware.

The *Gaia* teams at ESA's European Space Operations Centre, the European Space Research and Technology Centre and European Space Astronomy Centre, together with experts from the spacecraft's manufacturer, Airbus Defense and Space, and the payload experts of the Data Processing and Analysis Consortium, have worked together closely over the past few months to investigate, analyze and, ultimately, solve these problems.

"*Gaia* typically sends over 25 gigabytes of data to Earth every day, but this amount would be much, much higher if the spacecraft's onboard software didn't eliminate false star detections first."

"Both recent incidents disrupted this process. As a result, the spacecraft began generating a huge number of false detections that overwhelmed our systems," explains Edmund Serpell, *Gaia* spacecraft operations engineer at ESOC.

"We cannot physically repair the spacecraft from 1.5 million km away. However, by carefully modifying the threshold at which *Gaia*'s software identifies a faint point of light as a star, we have been able to dramatically reduce the number of false detections generated by both the stray light and the CCD issues."

Thanks to the hard work and efficient collaboration of all the teams involved, *Gaia* was recently returned to routine operations. During the down time, engineers made use of the opportunity to refocus the optics of *Gaia*'s twin telescopes for the final time. As a result, *Gaia* is now producing some of the best quality data that it ever has.

Compiled with material provided by ESA.

Star Trek gets a foothold in reality

Imagine a spaceship driven not by engines, but by compressing the spacetime in front of it. That's the realm of science fiction, right? Well, not entirely. Physicists have been exploring the theoretical possibility of "warp drives" for decades, and a new study published in the *Open Journal of Astrophysics* takes things a step further—simulating the gravitational waves such a drive might emit if it broke down.

Figure 4 — AI impression of a warp bubble collapse created using pixlr.com.

Warp drives are staples of science fiction, and in principle could propel spaceships faster than the speed of light. Unfortunately, there are many problems with constructing them in practice, such as the requirement for an exotic type of matter with negative energy.

Other issues with the warp drive metric include the potential to use it to create closed time-like curves that violate causality and, from a more practical perspective, the difficulties for those in the ship in actually controlling and deactivating the bubble.

This new research is the result of a collaboration between specialists in gravitational physics at Queen Mary University of London, the University of Potsdam, the Max Planck Institute (MPI) for Gravitational Physics in Potsdam, and Cardiff University. While it doesn't claim to have cracked the warp-drive code, it explores the theoretical consequences of a warp drive "containment failure" using numerical simulations.

Dr. Katy Clough of Queen Mary University of London, the first author of the study, explains, "Even though warp drives are purely theoretical, they have a well-defined description in Einstein's theory of general relativity, and so numerical simulations allow us to explore the impact they might have on spacetime in the form of gravitational waves."

Co-author Dr. Sebastian Khan, from Cardiff University's School of Physics and Astronomy, adds, "Miguel Alcubierre created the first warp drive solution during his Ph.D. at Cardiff University in 1994, and subsequently worked at the MPI in Potsdam. So it's only natural that we carry on the tradition of warp drive research in the era of gravitational-wave astronomy."

In the words of the authors, "The principle idea behind a warp drive is that instead of exceeding the speed of light directly in a local reference frame, which would violate Lorentz invariance, a "warp bubble" could traverse distances faster than the speed of light (as measured by some distant observer) by contracting spacetime in front of it and expanding spacetime behind it."

The results are fascinating. The collapsing warp drive generates a distinct burst of gravitational waves, a ripple in spacetime that could be detectable by gravitational wave detectors that normally target black hole and neutron star mergers. Unlike the chirps from merging astrophysical objects, this signal would be a short, high-frequency burst, and so current detectors wouldn't pick it up.

However, future higher-frequency instruments might, and although no such instruments have yet been funded, the technology to build them exists. This raises the possibility of using these signals to search for evidence of warp drive technology, even if we can't build it ourselves.

Dr. Khan cautions, "In our study, the initial shape of the spacetime is the warp bubble described by Alcubierre. While we were able to demonstrate that an observable signal could in principle be found by future detectors, given the speculative nature of the work, this isn't sufficient to drive instrument development."

The study also delves into the energy dynamics of the collapsing warp drive. The process emits a wave of negative energy matter, followed by alternating positive and negative waves. This complex dance results in a net increase in the overall energy of the system, and in principle could provide another signature of the collapse if the outgoing waves interacted with normal matter.

This research pushes the boundaries of our understanding of exotic spacetimes and gravitational waves. Professor Tim Dietrich comments, "For me, the most important aspect of the study is the novelty of accurately modeling the dynamics of negative energy spacetimes, and the possibility of extending the techniques to physical situations that can help us better understand the evolution and origin of our Universe, or the avoidance of singularities at the centre of black holes."

Dr. Clough adds, "It's a reminder that theoretical ideas can push us to explore the Universe in new ways. Even though we are skeptical about the likelihood of seeing anything, I do think it is sufficiently interesting to be worth looking at." ✶

Composed with material provided by Queen Mary University of London.

Feature Article /
Article de fond

Travelling for Planetary Imaging

by Mike Karakas, Winnipeg Centre
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I think it would be fair to say that I am not the only Canadian who yearns to image planets from a more ideal, southern location. And if you enjoy planetary imaging, I'm sure you already know why.

Ever notice that the best amateur planetary images often come from southern locations and are usually near an ocean? And the closer to the equator, the better. As an avid planetary imager, those geographic factors have not escaped me.

High-resolution planetary imaging and living in Canada aren't exactly synonymous with each other primarily for two reasons. First, planets follow the ecliptic and are lower in the sky from our latitude. And the lower they are, the more susceptible they are to atmospheric turbulence, so the seeing is compromised. Secondly, the geographic and topographic conditions necessary for excellent seeing don't exist here on a *consistent* basis. The only good news is that we are far from alone. Many locations worldwide don't have those ideal conditions either.

Here's another reason to consider travel. The ideal time to image superior planets (planets outside Earth's orbit) is when they are a month or so on either side of their opposition date. This is occurring later each year and will be for years to come. For example, Jupiter reaches opposition in early December this year, and Mars reaches opposition in January 2025. Please take my word for it: imaging in January or February isn't fun from where I live in Winnipeg.

After a dedicated 7+ year campaign of imaging the planets for pro-am collaboration, I was not entirely pleased with the results. Sure, good results did come occasionally, but not exceptional ones. Was I missing something in my workflow? Or perhaps, was it because I never experienced truly excellent seeing conditions yet? I have had good seeing on my best nights, but my results didn't reflect what I've seen others accomplish. How do you know superb conditions if you haven't witnessed 10/10 seeing before, with image results to back it up? I needed to find that out firsthand.

Now, approaching my retirement years, I set a plan in motion to make this happen. Travelling for planetary imaging takes time to plan. Even the thought of packing all that sensitive gear for airline travel is daunting. Add to that the difficult choice of where to go. But if I could combine travelling to a southern location to escape the winter temperatures *and* to image planets in ideal conditions—now that's my idea of a perfect vacation!

Figure 1 – Imaging Jupiter. Notice telescope position with Jupiter well placed at zenith.

Figure 2 – Final setup with wind tarps in place. Tripod was set low, to keep the telescope below the top of the tarps.

Deciding where to go

A well-chosen southern location provides the ideal requirements that "ticks all the right boxes" for the planetary imager. First, the planets are much higher in elevation—some near zenith. And the higher the planet appears, the less atmosphere there is to affect image quality.

Second, the seeing conditions are better on a scale that must be experienced. When air moves over the ocean uninterrupted for long distances, it becomes very stable. The trade winds in the southern Caribbean flow consistently from one direction, from the east. More importantly, these winds travel in that same direction through most, if not all, atmospheric layers. This consistent laminar airflow creates excellent seeing conditions.

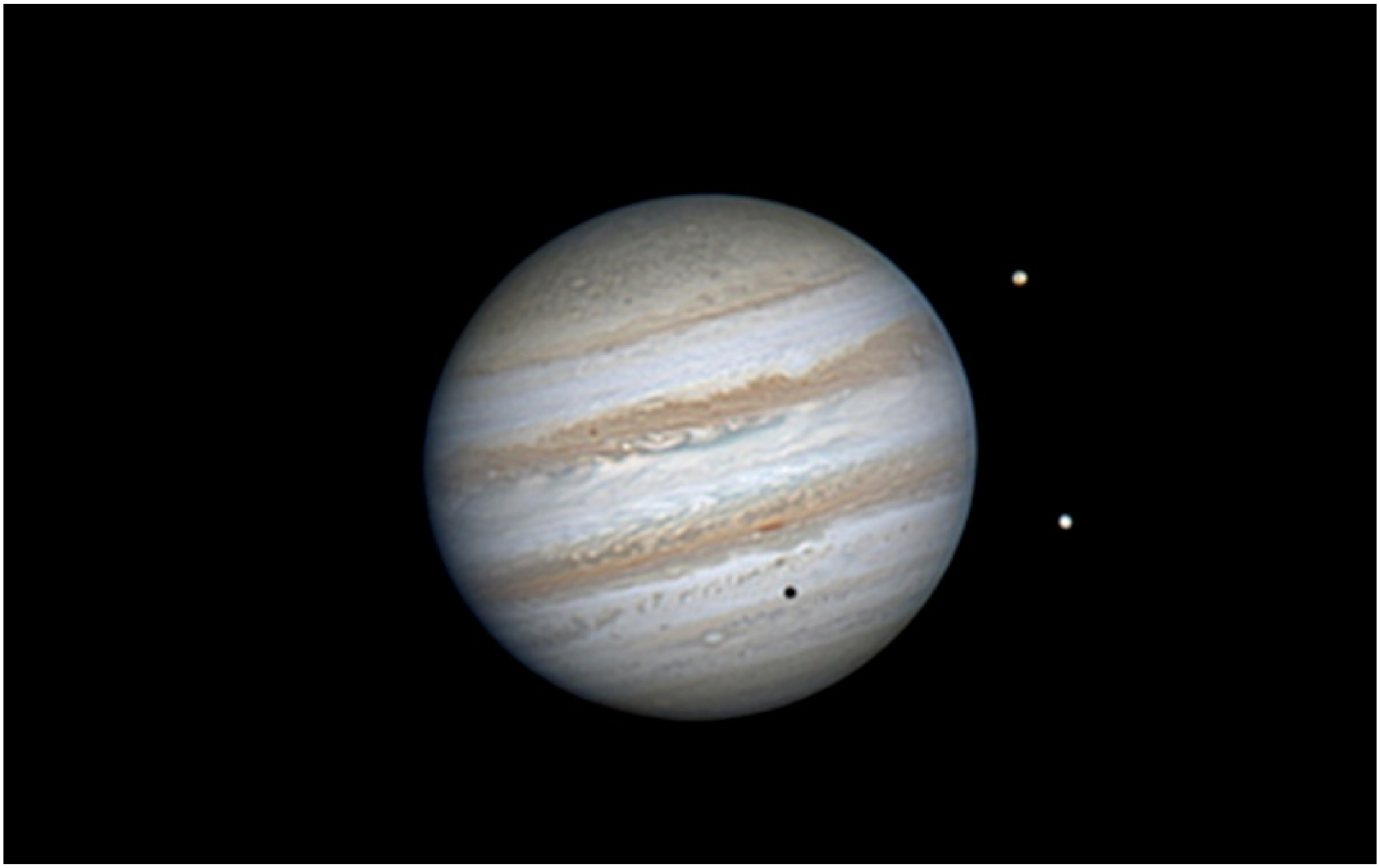

Figure 3 – First night of imaging from Curaçao. Io is at the top right and Europa below with its shadow cast on the planet.

Damian Peach, arguably the world's best-known planetary imager, has long championed travelling to the Caribbean (Barbados, to be exact) to take advantage of these specific conditions. His extraordinary work is a testament to how good those conditions can be. Thanks to him, I steered my choice to one of the Caribbean islands instead of exploring elsewhere. My wife, Tami, and I enjoyed our previous (non-astronomical) Caribbean vacations, so it was easy to get her support.

Just west of Barbados and off the northern coast of Venezuela are the ABC islands of the Netherlands: Aruba, Curaçao, and Bonaire. Curaçao is the largest island among them and is known for having excellent seeing conditions. Based on its geographic location and topography, it stood out as being the best choice among the three islands to investigate.

A nice bonus is that both Barbados and the ABC islands are south of "Hurricane Alley," adding peace of mind knowing that a hurricane is unlikely from either location. Therefore, I narrowed down my destination to either Barbados or Curaçao.

Some may wonder, why not shortlist Florida? Florida is a closer destination and a direct flight from most major cities in Canada so it's a logical choice. After all, some of the best planetary images have come from the Sunshine State. A long-time friend, retired meteorologist Jay Anderson, cautioned me about the subtropical jet stream. When present, this jet stream cuts across the southern U.S. and into Florida, and it can persist for weeks. Your imaging success would unquestionably be compromised if you timed your vacation then. In fact, that jet stream lasted for most of December last year, *exactly* when I planned to be imaging.

After much thought, we decided on Curaçao (pronounced as kur-uh-sau). In addition, the other benefits of Curaçao (a developed infrastructure, safe drinking water, driving on the right side of the road, outstanding beaches, etc.), made it the better choice for us.

I rented a vacation home on the island's east side with an ocean view, to best take advantage of the easterly trade winds and the favourable land topography. At only 27 metres above sea level, it maximized the potential for excellent seeing conditions.

Our property owner was very supportive when I explained the purpose of our trip and he answered all my questions—knowing where the exterior power outlets were and the voltage was of great help. He even provided drone footage of his property!

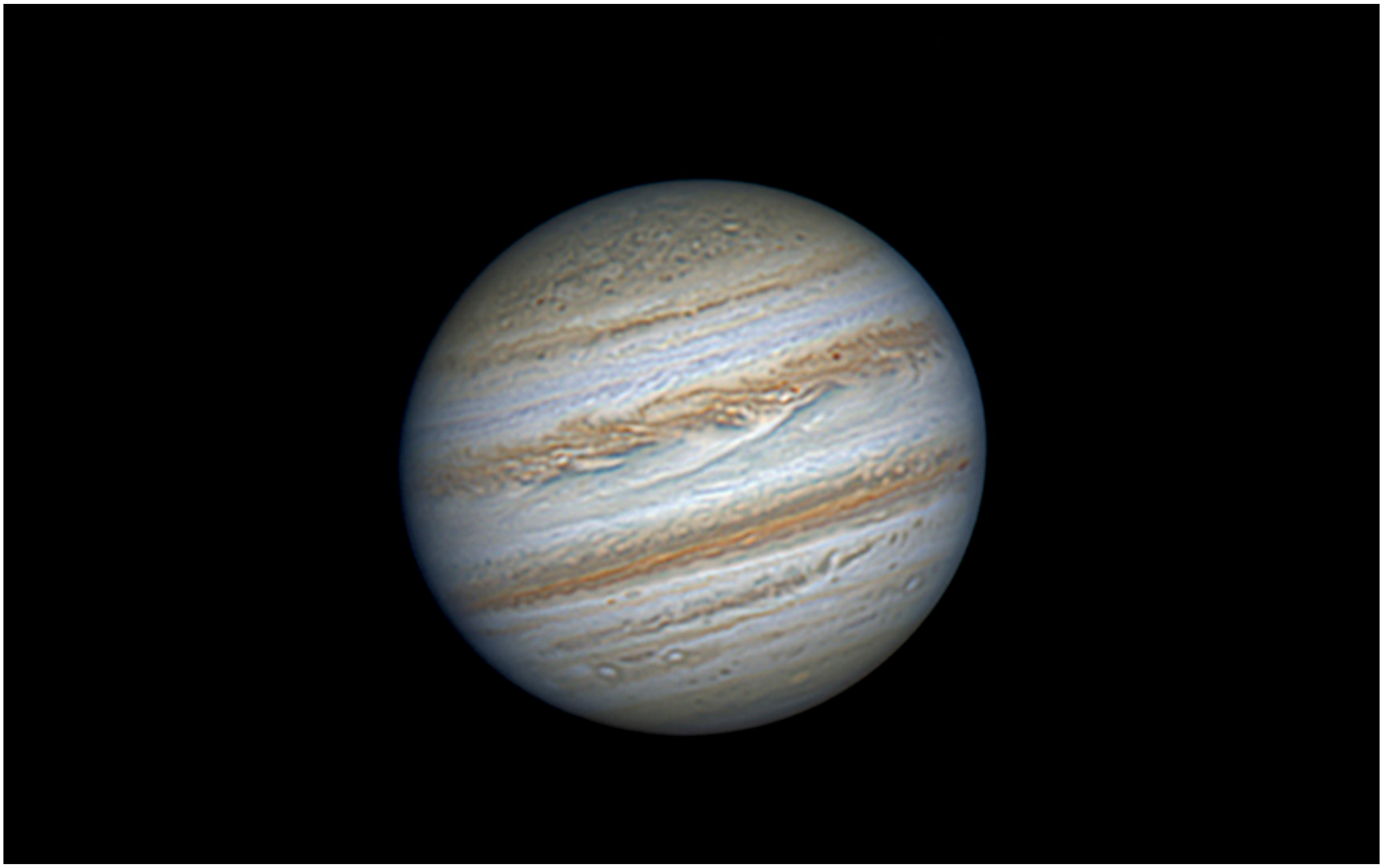

Figure 4 – This Jupiter image, taken on Dec. 9th, 2023, was captured in superb seeing conditions. Based on the minutiae of fine detail resolved, the author believes that his C9.25 was performing at its optical limits of resolving power.

Figure 5 – Saturn image with Rhea (upper left), and Dione at lower right. Tethys and its shadow are in transit.

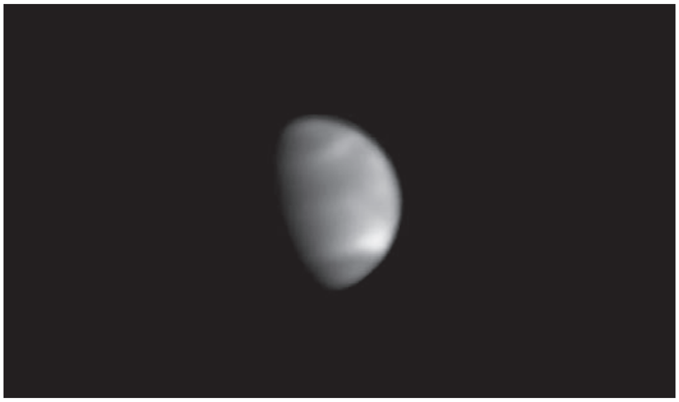

Figure 6 – Venus in UV light

Another advantage of choosing Curaçao is connecting with local planetary imager, Eric Sussenbach. After following his work for years, Eric's superb planetary images convinced me that excellent seeing conditions were more the norm than the exception.

Equipment Choice

The choice of equipment became a balancing act between my imaging goals, airline baggage allowances and what I was willing to lug through the airports. Hard decisions had to be made. But before getting into my equipment selection*, I must state that I have not received any financial compensation, nor have I an invested interest in the companies mentioned. The selections were the result of my own research and particular requirements.*

To get sufficient resolution of the planetary detail I wanted to capture requires aperture. In my case, the choice came down to either my Celestron C9.25 or my C11, as I considered each manageable and airline-transportable. Given this was my first trip taking gear of this size by air, I decided to play it safe and picked the lighter C9.25.

Of course, the scope needed an exceptionally durable case able to withstand the rigours of air travel (I surprised Tami one day when she saw my 210 lbs. frame jumping on the case to check its crush strength). As the case would exceed airline checked baggage size requirements, it would be checked in as oversized luggage but not too large or heavy to be considered as cargo.

Next came the choice of mount. Before planning this trip, I did not have a suitable mount that would fit in a suitcase and still meet airline baggage restrictions. Coincidently, harmonic drive mounts were introduced around that time and offered a solution I never thought possible.

After considerable research, I chose the ZWO AM5. It has the capacity to support either scope (should I take the C11 on a future trip) while also small enough to fit in my carry-on suitcase. Now, that's impressive! I also purchased the ASI AIR, which was used to accurately polar align the AM5 using its plate-solving programming, as Polaris is too low in the sky to be visible (Curaçao is only at 12 degrees North).

The choice of tripod wasn't an easy one. It must have excellent rigidity and payload capacity while still being able to collapse and fit within a standard 28″ suitcase. Part of the challenge of taking advantage of the consistent trade winds is to deal with the vibration caused by those winds. And those winds are relentless! The only tripod meeting that criterion was the Avalon T-Pod 110.

Because the mount's RA shaft had to be set to 12 degrees to polar align, the clearance between the tripod and mount became an important consideration from such a southern location. A pier extension combined with a smaller diameter counterweight was needed to ensure the counterweight did not strike the tripod when slewing.

When it was all said and done, decisions on where to go, where to stay, which gear to take, and where to source the appropriate hard-sided case took the better part of a year.

Travelling from Winnipeg to Curaçao took two flights and an overnight stay. I checked all my gear for damage when we arrived at our first layover and then upon arrival in Curaçao. Everything was in perfect condition at each stage of the journey. It's hard to put the feeling of relief into words, but euphoria comes close! It would have spelled disaster for my imaging plans if anything had been damaged.

Finally, Time to Image

The day following our arrival, it was time to prepare for imaging. The scope's location was important – it needed to have the correct orientation for the planets I wanted to image, plus be exposed to the east. Fortunately for me, the easterly trade winds served a dual purpose of providing excellent seeing while keeping the mosquitoes at bay.

Did I mention that those trade winds were relentless? Knowing they would be, I had brought a 6′×8′ tarp to string between the fence posts at the back of the property. After the first night, it was clear that one tarp was not enough as a windbreak. A quick trip to a local hardware store solved that problem, and a second tarp was added the following day.

Another by-product of the trade wind is fast-moving clouds. These cause minor annoyances, as they typically leave as soon as they arrive. Because I use a colour video camera, I just had to pause the video capture until the clouds passed. Those using a monochrome camera might find capturing data from separate RGB sequences more challenging.

Rain showers also occur with little warning. Surprised by the first shower, I quickly held a lawn chair cushion over the scope as rain pelted down. Fortunately, showers blow in and out fairly quickly, too.

Finally, with my setup done, it was time to start imaging. I noticed that stars at the 45-to-50-degree elevation twinkled rapidly, which every planetary imager knows signifies poor seeing conditions. I thought the night would be a bust but decided to try to image Jupiter anyway since it rose to near zenith. I carefully collimated the scope on a star near Jupiter. The view was very steady, which made accurate collimation a straightforward process. I did not expect to see this drastic of a seeing improvement.

I then moved the hand controller to centre Jupiter. The view was very stable, hardly a waver in my laptop's live view. The dark festoons jumped out clearly from the brighter equatorial zone. Europa and Io were perfect disks. Europa's shadow was a clearly defined black bullet hole cast on the planet's cloud top. It was the best seeing conditions I have seen. After taking that first video, I immediately stacked it in AutoStakkert! 4 to see the results. Over 98% of the frames were above the 50% quality line. I was stunned. Never have I seen that level of quality before.

Then I opened Registax, moved only one wavelet slider and WOW. It was the best Jupiter image I had ever taken, and it was using a humble C9.25 with minimal processing. I can still remember that moment of awe.

I imaged 9 out of 11 nights with seeing conditions ranging from good to excellent. Only one evening had poor-to-average seeing conditions (but being spoiled, I didn't bother imaging that night). In total, four planets were imaged during our stay in Curaçao: Jupiter, Saturn, Uranus, and Venus. Each image represented a personal best compared to the images I took in Canada—regardless of aperture.

Final Thoughts

The main driving force behind this trip was to find out if my imaging techniques and workflow would still be valid from a location with excellent seeing conditions. I could do a side-by-side comparison (factoring in the aperture differences) with others, including Eric, who was imaging on those same nights with his C14. Any flaw would undoubtedly show.

Figure 7 – Mike Karakas (author) on left, Brett Ruiz, and Eric Sussenbach at far right.

I breathed a sigh of relief when the results confirmed that, with the fundamentals done correctly (cool-down, collimation, and focus), excellent data could be captured when the seeing allows. I had finally witnessed perfect seeing conditions and achieved the image quality I had hoped for.

This trip's unexpected but most pleasant benefit was connecting with local amateur astronomers Eric Sussenbach and Brett Ruiz. We became good friends and freely shared our experiences, imaging workflows, and processing techniques—all to take our images to a higher level, so they represented our best efforts for pro-am collaboration. After all, better images result in better data for the planetary science community to do their work. It's a gratifying experience to do this alongside a network of dedicated and talented imagers worldwide for that common goal.

With the logistics tackled, Tami and I plan to return to Curaçao in early 2025 to capture the next Mars opposition with our friends Eric and Brett. But this time, it will be with a C11. ✶

Pro-am organizations to submit images:

Association of Lunar and Planetary Observers (ALPO): alpo-astronomy.org

ALPO – Japan: alpo-j.sakura.ne.jp/indexE.htm

Mike Karakas is an amateur planetary imager and a member of the Winnipeg Centre. Committed to citizen-science initiatives, he regularly contributes images to pro-am organizations such as ALPO, ALPO-Japan, PVOL, and the BAA.

Our Universe Through the Unruh Effect and Information Theory

by Mark Schweitzer, RASC Calgary PARSEC Group
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Abstract

This article explores the implications of bridging quantum mechanics and general relativity when the Unruh effect is observed by a particle moving at escape velocity in a gravitational field. A quantum model is developed where the Unruh effect can produce a graviton particle which when added to the Universe would increase the information content of the Universe horizon by one bit of energy as per the holographic principle. A strange particle, s = 95 MeV/c^2, can produce a graviton via the Unruh effect in its gravitational field at a distance of its particle wavelength from its center of mass. If the smallest unit of information is one bit, the strange particle would be the smallest detector possible in our Universe, limiting the vacuum energy density to 10^{-9} J/m^3. Observers at the strange particle wavelength would observe a Rindler horizon at $R_H = 2\phi R = 10^{26} m$ and would perceive the ratio of matter as $\frac{1}{2\phi} = 0.309$ of the Universe energy. A wavefunction can be used to represent membranes composed of wave packets of strange particle energy and these membranes made up of any quantized number of strange particles can be used to determine the limits of size and structure of mass-energy composition within our Universe along with providing a mechanism for the expansion of the Universe itself. The luminosity of stars, quasars, and galaxies can be predicted by this model. It is theorized that the Universe contains Q quanta of time, Q^3 bits of information, and can be modeled with Q^2 strange particles. Finally, the Unruh effect from a group of Q particles will always stretch space by a strange particle wavelength and produce a new strange particle pair for each quantum of time, equivalent to the strong interaction.

Quantized Unruh Effect

This article expands on the idea of the quantum mechanical Unruh effect felt by observers escaping gravitational fields as a starting point into bridging these the two incompatible theories of quantum mechanics and general relativity. The size of the Universe along with its information content can be estimated from its event horizon described by its Schwarzschild radius $R = \frac{2GU}{c^2} = 10^{26}\ m$ as a function of its mass, $U = 10^{53} kg$. One bit of information corresponds to four Planck areas $4lp^2 = \frac{4\hbar G}{c^3} = (\frac{2Gp}{c^2})^2$ found on a bounding surface as per the Holographic Principle,[1,2] where p is the Planck mass, $\hbar$ is the Planck constant, G is the gravitational constant, and c is the speed of light. The total Universe information becomes: $I_U = \frac{(\frac{2GU}{c^2})^2}{4\ l_p^2} = 10^{123}$.

The smallest quantized amount of energy in the Universe is the energy needed to change the information of the Universe horizon by one bit of information. In this paper, this smallest quantum of energy is referred to as a graviton particle, Γ, whose particle wavelength would be the size of the Universe event horizon and when its energy is added to the Universe it increases the event horizon by one bit of information or $4lp^2$.

A uniformly accelerated observer gains an average energy due to quantum effects of the vacuum via the Unruh effect, $E = Tk_B = \frac{\hbar a}{2\pi c}$.[3] Observers moving at escape velocity in a gravitational field would experience this Unruh effect since they are uniformly accelerating and the predicted Hawking radiation near an event horizon of a black hole is: $E = T_H k_B = \frac{\hbar c^3}{8\pi GM}$.[4] The Unruh effect at the event horizon of the Universe would produce the energy needed per observer to produce a graviton: $E_\Gamma = \frac{\hbar c^3}{8\pi GU} = \Gamma c^2$. If the mass of the Universe is $U = 10^{53} kg$, then the graviton mass would be $\Gamma = \frac{p}{Q^{\frac{3}{2}}} = 10^{-69} kg$. No process in the Universe can produce energy smaller than a graviton if we assume that information is quantized. Thus, a quantum information theory where the Universe increases in information must be based on interactions that can produce a graviton. Figure 1 below shows the predictions made in this paper using the Unruh effect and information compared to the luminosities of the entire mass range of stars, galaxies, Seyfert galaxy cores, and quasars. The luminosity on the y-axis in figure 1 is measured in mass equivalence per strange particle time ($t_s = \frac{\hbar}{sc^2} = 10^{-23} s$) for comparison to the mass on the x-axis. There is a strong correlation between this paper's predicted minimum information content generated by a mass of particles (E_{min} trendline) and the luminosities of main sequence and brown dwarf stars (yellow dots). The total Unruh effect trendline (E_T) shows the predicted energy added to the Universe for each quantum of time as a function of mass: $E_T = \frac{M}{s} \Gamma c^2$, where $M = ns$, where n is the number of strange particles and s is the strange particle mass and it can be seen that this trendline provides the limit to luminosities in our Universe with measured quasar values getting close to this limit. Furthermore, it can be seen that the maximum stellar mass limit is realized when the E_T and E_{min} trendlines intersect at a stellar of mass of around $10^{32} kg$.

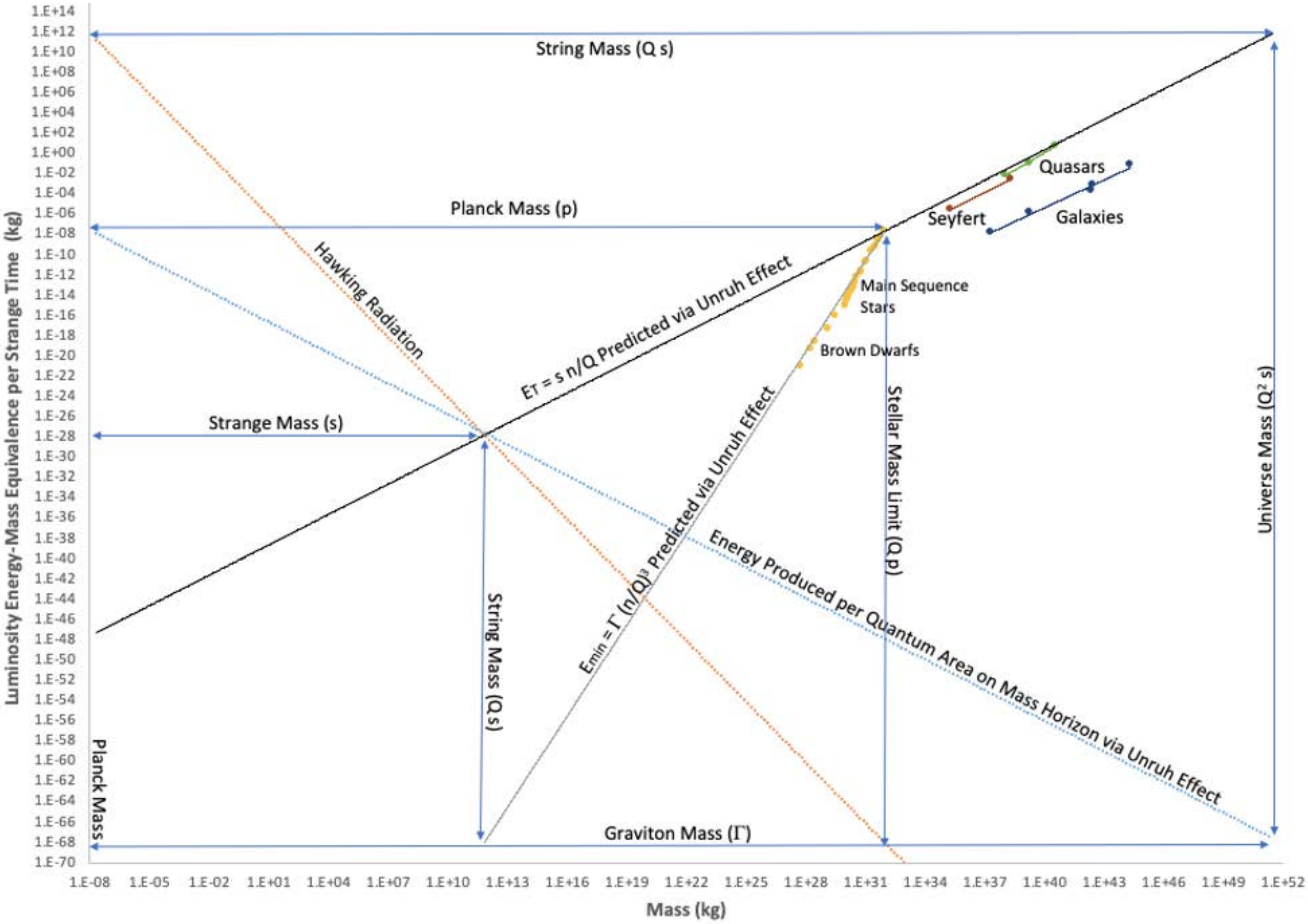

Figure 1 — Predicted luminosity via the Unruh Effect compared to measured cosmological luminosity.

A graviton could also be produced via the Unruh effect of a particle escaping its gravitation field at the boundary defined by the particle's wavelength around its center of mass producing a graviton: $\Gamma c^2 = \frac{\hbar a}{2\pi c} = \frac{\hbar}{2\pi c} \frac{Gs}{(\lambda_s)^2}$ where, $\lambda_s = \frac{\hbar}{sc}$, when $s = \frac{p}{\sqrt{Q}} = \sqrt{\frac{\hbar c}{QG}} = 10^{-28} kg$ or 95 MeV/c^2. This mass is similar to a strange quark mass and so I refer to this particle as a strange particle. The strange particle loses a graviton energy equivalence of mass and increases its particle wavelength horizon by four Planck areas or one bit of information. It also experiences a change in gravitational potential energy equivalent to a graviton energy. Quantum mechanics predicts a vacuum energy density of $10^{113} \frac{J}{m^3}$ but this is around 10^{123} orders of magnitude larger than the precise measurement of $5.3566\ x\ 10^{-10}\,\frac{J}{m^3}$ by the Planck group.[7] This discrepancy is resolved if we think of the Universe interacting in bits of information via strange particles, making the smallest measurable vacuum energy density: $\rho = \frac{\Gamma c^2}{(\frac{\hbar}{sc})^3} = 10^{-10}\,\frac{J}{m^3}$.

Furthermore, the Rindler horizon observed by an observer accelerating at the strange particle horizon is $R_H = \frac{c^2}{a} = \frac{c^2(\lambda_s)^2}{Gs} = I_s\lambda_s = 10^{26}m$, which is the horizon of the Universe, and $I_s = \frac{(\frac{2\hbar}{sc})^2}{4\,l_p^2} = Q = 10^{41}$ is the information that could be described by the area on the strange particle wavelength horizon. This Rindler horizon is 10^{26} m for all observers experiencing this graviton producing Unruh effect regardless of whether they are located on a membrane enclosing the Universe or anywhere throughout the Universe because they have the same proper acceleration $a = \frac{Gs}{(\lambda_s)^2}$.

Any empty region of space bounded by a strange particle membrane (wavefunction with a standing wave pattern of energy wave packets with strange particle deBroglie wavelengths), will produce a graviton per strange particle on the membrane as Unruh energy $E_{Unruh} = \Gamma c^2 = \frac{\hbar}{2\pi c}\frac{Gn^2s}{(n\lambda_s)^2}$ from gravitational field effects at these strange membrane boundaries produced by any group of n^2 strange particles. These bounded regions of space will always have a volume radius of n strange particles wavelengths, a surface area of n^2 strange areas, a mass of n^2 strange masses, a volume of n^3 strange volumes, and every quantum strange volume increases in surface area by $4lp^2$ or one bit of information per quantum of time.

Strange particles only found on a bounding strange membrane is just one possible particle distribution pattern for where those particles could be found within the volume of space in question. At the other extreme, these particles could all be found clumped into a black hole, but would most likely be found near the central tendency between these extremes. Whatever the distribution around the center of mass, the Unruh energy per strange area on the maximum horizon of radius, $n\lambda_s$, is always a graviton. A group of n strange particles produces n bits of information per quantum of time regardless of their location.

I use the symbol Q to represent the approximate value 10^{41} and as such the Universe would contain Q^2 strange particles, Q^3 bits of information, and if time is quantized, then there has been Q quanta of time events in our Universe. As an example, let's look at the information produced from a group of Q strange particles (10^{12} kg) anywhere in the Universe. As shown in figure 1, if all Q particles were found on a strange membrane, along with the rest of the mass and strange particles in the Universe enclosing the Universe event horizon, then the Universe would gain $E_Q = \frac{Q\hbar c^3}{8\pi GU} = Q\Gamma c^2 = sc^2$ amount of Unruh energy associated with these Q particles and increase in information content by Q bits of information. If these same Q particles created a black hole, then the Schwarzschild radius would be $R_Q = \frac{2G}{Qsc^2} = \frac{\hbar}{sc}$, and the Unruh energy produced at the event horizon of this black hole, which has dimensions of a strange particle wavelength, would be $E_Q = \frac{\hbar c^3}{8\pi GQs} = Q\Gamma c^2 = sc^2$. This amount of energy added to any region of the Universe would also increase the Universe event horizon by Q Planck areas and thus Q bits of information. But the information added to the $Qs = 10^{12}kg$ mass black hole itself would only be one bit of information because adding $E_Q = sc^2$ amount of energy to this Qs black hole only increases its event horizon by four Planck areas and by one bit of information. These Q number of strange particles found as a strange membrane enclosing its empty volume of radius, $\sqrt{Q}\lambda_s = \frac{\sqrt{Q}\hbar}{sc} = 10^5m$, would also give the same Unruh energy: $Q\Gamma c^2 = sc^2 = \frac{\hbar}{2\pi c}\frac{GQ^2s}{(\sqrt{Q}\lambda_s)^2}$.

I refer to a collection of Q particles as a string of particles and each strange particle has Q bits of information (one bit for each quantum of time that has elapsed in the Universe) for a total of Q^2 bits of information per string. It is important to note that strange particles would have started the size of a Planck particle at the first quantum of time in the Universe and for each quantum of time that elapses the strange particle wavelength area increases by $4lp^2$ and as such its particle mass decreases. Each time quanta results in each of the Q particles in a string to increase by one unit of information and the cumulative expansion of the entire string amounts to an increase of Q units of information or $4Qlp^2$ in particle area. Since $s = \frac{p}{\sqrt{Q}}$ then this increase in string area of $4Qlp^2 = (\frac{2\hbar}{sc})^2$ is equivalent to an increase in a strange particle wavelength area. If an increase in one unit of information is equivalent to adding a graviton particle to the Universe, then the growth of these Q additional units of information to the string would be equivalent to adding Q graviton particles to the Universe which is equivalent to adding a strange mass, $Q\Gamma = \frac{p}{\sqrt{Q}} = s$. This is equivalent to quark pair production when the energy put into separating two strange quarks by a strange quark length produces another strange quark pair, but instead of this phenomenon being attributed to the strong interaction, the quark pair production is produced by the Unruh effect in gravitational fields. I believe this is why the gravitational force is perceived as being $Q = 10^{41}$ times weaker than the strong force. This theory describes how the Universe grows from a Planck particle (p = 2.18x10^{-8} kg), with one bit of information and grows to the current size $I_U = \frac{(\frac{2GQ^2p}{c^2\sqrt{Q}})^2}{4\,l_p^2} = Q^3$.

Information

Figure 2 shows a tiny universe after 4 quanta of time with a total information of $Q^3 = 4^3 = 64$ units of information, $Q^2 = 16$ particles, each particle with Q = 4 units of information, and there are Q = 4 strings of Q = 4 particles each. The blue box represents the first quantum of time, the green boxes accumulate in the second quanta, the yellow boxes in the third and the orange boxes in the fourth time quanta. Each arrowed line in figure 1 represents communication between a particle and a unique string for one unit of information per arrowhead. The information that is needed to describe a region can be found by adding one unit of information for each arrowhead associated with arrowed lines that don't leave the bounded region in question.

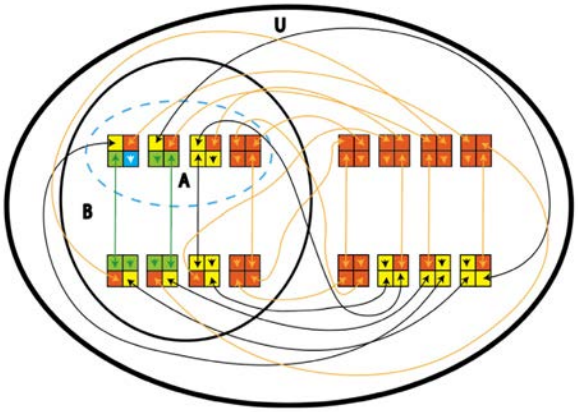

Figure 2 — Communication between particles and strings in a Q_4 Universe.

Region A, enclosed by the blue dashed oval, would have 4 units of information corresponding to its 4 particles each communicating one unit of information with their parent string (short line with one arrowhead). The total information in that Universe is 64 but the sum total of information found internally in the 4 separate string regions like region A is only 16. This is because increasing the region of space being measured involves encompassing more communication lines between particles on one string with those on another.

If you were to measure the information in region B (solid oval encompassing two strings) then you would find that there are 16 arrowheads associated with communication lines that do not leave the region for a total of 16 units of information. Do the same process by creating an event horizon (region U) around all 4 strings and none of the communication lines leave this tiny Universe for the total of $Q^3 = 4^3 = 64$ units of information.

Since one unit of information is communicated through one unit of area in information space, then the surface area needed to describe the 4 internal units of information in region A would be the size of a particle having an area of 4 units of information. Region B would need 16 units of information to describe its internal information so it would require 4 particles to cover the surface area enclosing the 2 strings of particles (8 particles total). Do the same for region U and you would need an area of 64 units of information which is all 16 of the information particles in this Universe.

Figure 3 represents the surface area needed to cover region A in figure 2. There are only 4 units of information communicated fully inside the interior of that region so there has to be a surface area of 4 units of information (one particle) covering region A. The one surface particle that could cover region A would receive one unit of information communicating with it from its parent string in the interior (arrow from left) and it would also receive 3 units of information (3 arrows from the right) communicating with it from all of the strings located outside of region A. Region B in figure 2 would need 4 particles to enclose the volume containing the 8 eight particles (2 strings) because there are 16 units of internal information. The 4 particles covering the surface area of region B would observe 8 units of information coming from the interior and a further 8 units of information coming from exterior strings. Extending out to the entire Universe, region U, then all 16 particles would need to be on the surface to describe the 64 units of information in the Universe and all 64 units of information would be received on the surface from the interior.

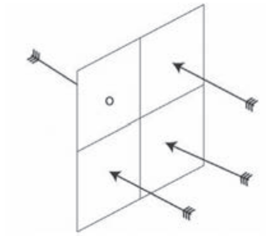

Figure 3 — Communication

Information communicating from strings in an interior region to an encompassing bounding area, as shown with figure 3, is equal to the total power emitted from that region when one graviton of energy is associated with each bit of information (arrow) and this luminosity is realized as the Emin trendline in figure 1 that can be used to predict stellar luminosity. This minimum information as described above resulting from communication from interior strings can also be found from $I_{min} = (\frac{n}{Q})^3$ the cubed number of strings consisting of Q strange particles found in the region that contains *n* strange particles. The average information that is needed to describe the internal particles in a region is the geometric mean (central tendency) of information content between the minimum information in that region $I_{min} = (\frac{n}{Q})^3$ and the maximum information $I_{max} = nQ$ associated with all of the particles in that region (inclusive of information with communication outside of the region) $I_{ave} = \sqrt{(I_{min})(I_{max})} = \frac{n^2}{Q}$. Since there are $n = Q^2$ strange particles in our Universe, then the minimum Universe information $I_{min} = (\frac{Q^2}{Q})^3 = Q^3$ is the same as the maximum information $I_{max} = Q^2 Q = Q^3$. Or at the other extreme, the average information needed to describe a region that contains only one string of particles is the information $I_s = Q$ associated with a strange particle: $I_{min} = 1 = (\frac{Q}{Q})^3$ and $I_{max} = Q^2$ so $I_{ave} = \sqrt{Q^2} = Q$. It is found that calculating average information using this method for *n* strange particles produces the same information as the Bekenstein bound found by Bekenstein, Hawking, and Susskind that is contained on the event horizon of a black hole with the mass of *n* strange particles.

The minimum information in a region containing *n* strange particles $I_{min} = (\frac{n}{Q})^3$ would be communicated to particles outside the region each quantum of time as energy emission. One unit of information is equivalent to a graviton energy so emission becomes: $E_{min} = \Gamma c^2 I_{min}$ as seen in figure 1. When a graviton of energy is added to the Universe per strange particle for each quantum of time, the amount of energy that could be emitted from a group of strange particles per quantum of time can be known.

The stellar luminosity, E_{min} and E_T trendlines converge on a Planck energy per quantum of time being produced when $E_{min} = E_T$ and $n^2 = Q^3$, resulting in a maximum stellar mass of $M = Q^{\frac{3}{2}}s = 10^{32} kg$ before becoming a black hole. This is also the largest mass that a star can have both theorized and observed.[5] This amount of $Q^{3/2}$ strange particles is also the only number of strange particles that when each particle is placed adjacent to the next, they occupy the exact volume enclosed by a black hole event horizon created by the mass of $Q^{3/2}$ strange particles. Put another way, if $Q^{3/2}$ strange particles were to form a strange star where the strange particles pack side by side in the volume, then the surface area of the star would be a layer of Q strange particles (which is one string of particles) and these particles would be at the limit at which light could possibly escape the surface. Using the strange quark star of $Q^{3/2}$

strange particles (10^{32} kg) we can see that all this mass could be found between the limits of its Schwarzschild radius of 10^4 m and membrane of strange particles stretched over a horizon of 10^{15} m radius. But the central tendency would give us a higher likelihood of finding this amount of mass distributed within a volume enclosed by the geometric mean of these extremes of about a radius of 10^9 m to 10^{10} m (the observed radius of stars). The maximum volume enclosed by a strange membrane of $Q^{3/2}$ strange particles has a radius of 10^{15} m which is the average distance between stars in a galaxy and allows us to understand the probability of matter distribution in the Universe.

Expansion of the Universe

If the Universe is expanding in time then the total system time between components is, $t_T = t_0(\gamma + 1)$ where $t_0 = \frac{ct}{v}$ and $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ is minimum when, $v = \frac{c}{\sqrt{\phi}} = 0.786c$ where , $\phi = \frac{1+\sqrt{5}}{2}$ and, $\gamma = \phi$.

If the Universe horizon is increasing by $\Delta R = \frac{2GQ^2\Gamma}{c^2}$ for every time $t_s = \frac{\hbar}{sc^2} = \frac{\sqrt{Q\hbar cG}}{c^3} = 10^{-23}s$ due to the Unruh effect, then a bounding membrane of strange particles would be moving outwards at escape velocity and the positive kinetic energy of the membrane would need to be equivalent to the negative gravitational potential energy experienced by the horizon membrane for a net total energy of the Universe being zero for all quanta of time, $E_T = E_k + E_p = 0$.

Using the general relativistic solution for the gravitational potential energy $E_p = \frac{-Uc^2}{\sqrt{1-\frac{R}{\gamma R}}}$ of a particle a distance γR from the event horizon R and a zero total energy, $E_T = E_k + E_p = \frac{Uc^2}{\sqrt{1-\frac{v^2}{c^2}}} + \frac{-Uc^2}{\sqrt{1-\frac{R}{\gamma R}}} = 0$, then the solution for the escape velocity, $v = \frac{c}{\sqrt{\phi}} = 0.786c$ is found to be the same as needed for minimum system time. The Rindler horizon seen by the Universe horizon would be the same as by a strange particle $R_H = 10^{26}m = \frac{c^2}{a} = 2\phi R$ since proper acceleration at ϕR is $a = \frac{1}{\sqrt{1-\frac{R}{\phi R}}}\frac{GU}{(\phi R)^2} = \frac{c^2}{2\phi R}$. As a result, matter, M, may only be perceived as making up $\frac{M}{U} = \frac{1}{2\phi} = 0.309$ of the Universe.[7,8]

This expanding Universe caused by information communicated between particles as described in this article via the Unruh effect provides predictions for the vacuum energy density, maximum stellar luminosities and quasar luminosities, stellar mass limit, how the gravitational force and strong force can be viewed as two different perceived phenomena of the same interaction, and why there is an arrow to time. ✶

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Figure 1 – Frank Sowa imaged the Fighting Dragons (LBN 552 and LDN 1228) in Cepheus from his home in Port Franks, Ontario. He used an 80-mm Esprit and ASI071 MC at 410 mm for a total of 60 × 240-second frames with no filters.

Figure 2 – Messier 13 is an amazing globular cluster found in Hercules. Ed Mizzi captured this cluster of roughly 100,000 stars from his observatory in Waterdown, Ontario, under Bortle 7 skies. He used a Sky-Watcher Esprit 100-mm APO, *ƒ*/5.5 on a Sky-Watcher EQ6-R Pro mount with a ZWO AS183 Mono camera. The final image is RGB 15 × 3 minutes and luminance of 30 × 2 minutes for a total integration of roughly 3.35 hours. Image processed in PixInsight.

Continues on page 213

What's Up in the Sky?

October/November 2024

Compiled by James Edgar

October Skies

The Moon begins the month at new phase, also involved in an annular solar eclipse. The only land in position to see the eclipse is extreme southern Chile and Argentina, otherwise, the event is over the South Pacific. Eclipsophiles may charter a boat to get under the Moon's shadow. Annular eclipses become more and more frequent as the Moon slowly moves away from Earth. Mark your calendars–in 50,000 years, there will be no more total solar eclipses. On the 5th, Venus is 3 degrees north of the waxing gibbous Moon. Two days later, on the 7th, Antares is 0.2 degrees north of the Moon, an occultation in the Southern Hemisphere. By the 14th, the waxing gibbous Moon nearly catches up to Saturn, only 0.1 degrees away in the early morning; this is an occultation for Southern Hemisphere viewers. A day later, also in the south, Neptune is occulted; only 0.6 degrees away for the north. The Moon is at perigee on the 16th (357,174 km) and full on the 17th–the largest of 2024, and generating large tides in coastal waters. On the 19th, Uranus is 4 degrees south, and the Pleiades are even closer at 0.2 degrees south. Jupiter is 6 degrees south of the waning gibbous Moon on the 21st. On the 23rd, Pollux is 1.7 degrees north of the Moon, while Mars is 4 degrees south. The bright star in Virgo, Spica, is 0.5 degrees south of the Moon on the 31st.

Mercury comes out from behind the Sun toward the end of the month, but is a very difficult observation because the angle of the ecliptic is almost horizontal–the planet sets about the same time as the Sun does.

Venus is bright in the western evening sky, but also hampered by the shallow ecliptic. The Moon is nearby, but a very thin crescent on the 5th.

Mars is high in the morning sky, as the ecliptic favours early risers. The Red Planet is among the stars of Gemini, The Twins, for most of the month, a little southwest of Pollux and Castor. An observer should be able to notice Mars getting brighter and larger with the passing weeks, as it appears to gradually near Earth; closest approach is in early 2025.

Jupiter seems to stop moving eastward on the October 9, beginning retrograde motion thereafter for about four months. The planet rises shortly after sundown and remains high in the sky all night, giving the best opportunity for viewing.

Saturn is up at sundown, crossing the sky all through the night among the stars of Aquarius–another great viewing time for the Ringed Planet. The Moon glides by on the 14th, getting up close to the gas giant–only 0.1 degrees away.

Uranus rises in early evening near the Pleiades, crossing the sky all night. This would be a good time to catch the blue-green planet without using optical aid. The waning gibbous Moon passes by on the 18th. Uranus is roughly 3 light-hours away–about 3 billion km.

Neptune is in Pisces, The Fish. The planet is tiny, even in a telescope, given its great distance from us, over 30 astronomical units away. That's 30 times our distance from the Sun–Neptune is roughly 4.5 billion km away–its reflected light takes a little over 4 hours to reach us!

The zodiacal light is visible before eastern morning twilight for the first two weeks of October.

The Orionid meteors peak on October 21.

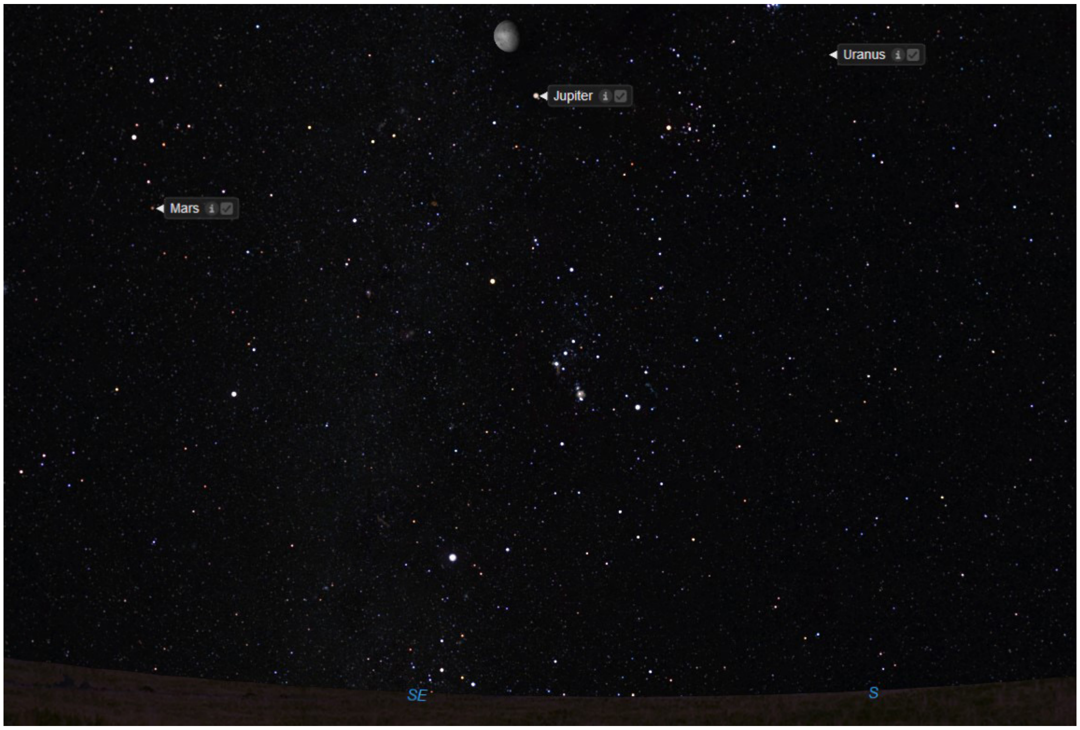


Figure 1 — October: In the early morning of October 21, Uranus and Jupiter are high above in Taurus, The Bull, joined by the waning gibbous Moon. Mars is to the southeast among the stars of Gemini.

Continues on page 212

The Sky October/November

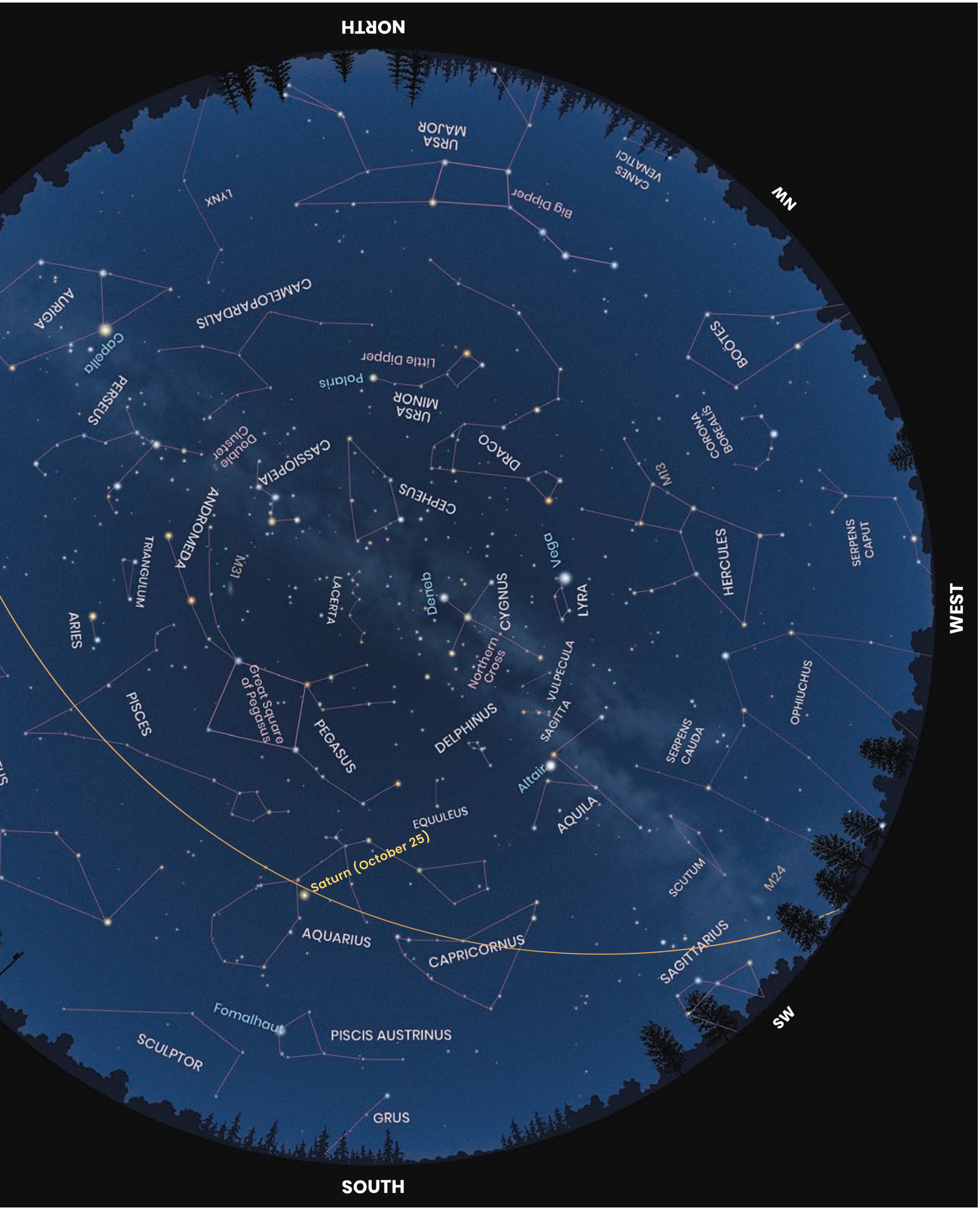
Compiled by James Edgar with cartography by Glenn LeDrew

Celestial Calendar
(bold=impressive or rare)

Oct. 2	new Moon at 2:47 p.m. EDT (lunation 1259)
Oct. 2	Moon at apogee (406,516 km)
Oct. 5	**Venus 3° north of thin crescent Moon**
Oct. 6	Antares 0.2° north of Moon
Oct. 10	Moon at first quarter
Oct. 16	Moon at perigee (357,174 km) *Large tides
Oct. 17	full Moon (largest in 2024) at 7:26 a.m. EDT
Oct. 21	Orionid meteors peak at 2:00 a.m. EDT
Oct. 21	Jupiter 6° south of waning gibbous Moon
Oct. 23	**Pollux 1.7° north of last-quarter Moon**
Oct. 23	Mars 4° south of last-quarter Moon
Oct. 24	Moon at last quarter
Oct. 29	Moon at apogee (406,161 km)
Nov. 1	new Moon at 8:47 a.m. EDT (lunation 1260)
Nov. 3	Daylight Saving Time ends
Nov. 3	Mercury 2° north of thin crescent Moon
Nov. 3	**Antares 0.08° north of thin crescent Moon**
Nov. 4	**Venus 3° north of waxing crescent Moon**
Nov. 5	S. Taurid meteors peak at 2.a.m. EST
Nov. 9	Moon at first quarter
Nov. 10	**Mercury 2° north of Antares**
Nov. 10	**Saturn 0.09° south of waxing gibbous Moon**
Nov. 11	**Neptune occulted by waxing gibbous Moon**
Nov. 11	N. Taurid meteors peak at midnight
Nov. 14	Moon at perigee (360,109 km)
Nov. 15	full Moon at 4:29 p.m. EST
Nov. 15	Uranus 4° south of full Moon
Nov. 16	**Moon among Pleiades (M45)**
Nov. 16	Mercury greatest elongation east (23°)
Nov. 17	Leonid meteors peak at 5 a.m. EST
Nov. 19	**Pollux 1.9° north of waning gibbous Moon**
Nov. 20	**Mars 2° south of waning gibbous Moon**
Nov 22	Moon at last quarter
Nov. 26	Moon at apogee (405,314 km)
Nov. 27	**Spica occulted by waxing crescent Moon**

Planets at a Glance

	DATE	MAGNITUDE	DIAMETER (″)	CONSTELLATION	VISIBILITY
Mercury	Oct. 1	−1.7	4.8	Virgo	Evening
	Nov. 1	−0.3	5.2	Libra	Evening
Venus	Oct. 1	−3.9	12.2	Libra	Evening
	Nov. 1	−4.0	14.2	Ophiuchus	Evening
Mars	Oct. 1	0.5	7.5	Gemini	Morning
	Nov. 1	0.1	9.2	Cancer	Evening
Jupiter	Oct. 1	−2.5	42.2	Taurus	Evening
	Nov. 1	−2.7	46.1	Taurus	Evening
Saturn	Oct. 1	0.6	19.0	Aquarius	Evening
	Nov. 1	0.8	18.4	Aquarius	Evening
Uranus	Oct. 1	5.7	3.7	Taurus	Evening
	Nov. 1	5.6	3.8	Taurus	Evening
Neptune	Oct. 1	7.8	2.3	Pisces	Evening
	Nov. 1	7.8	2.3	Pisces	Evening


NORTH
URSA MAJOR
CANES VENATICI
NW
LYNX
Big Dipper
AURIGA
CAMELOPARDALIS
Capella
Little Dipper
Polaris
URSA MINOR
BOÖTES
PERSEUS
Double Cluster
DRACO
CORONA BOREALIS
CASSIOPEIA
M13
CEPHEUS
ANDROMEDA
TRIANGULUM
M31
Vega
HERCULES
SERPENS CAPUT
WEST
ARIES
LACERTA
Deneb
CYGNUS
LYRA
Northern Cross
VULPECULA
Great Square of Pegasus
PISCES
PEGASUS
DELPHINUS
SAGITTA
OPHIUCHUS
SERPENS CAUDA
Altair
AQUILA
EQUULEUS
Saturn (October 25)
SCUTUM
M24
AQUARIUS
CAPRICORNUS
SAGITTARIUS
SW
Fomalhaut
PISCIS AUSTRINUS
SCULPTOR
GRUS
SOUTH

Continued from page 209

November Skies

The Moon is new on November 1. Fleeting Mercury is 2 degrees north of the Moon on the 3rd, but visible only for an instant at sundown. Later that same evening, Antares is occulted for Southern Hemisphere viewers–0.08 degrees away for northerners. A very slender Moon makes these events almost impossible to detect. Venus is involved in another close approach, 3 degrees north, but again, it's hard to see the sliver of a 2-day-old Moon. Mercury and Venus are both south of the ecliptic, and so is the Moon. With the ecliptic almost horizontal, it sets shortly after the Sun, and by then the planets have already set. On the 10th, Saturn is occulted for southern viewers; for the north, the Ringed Planet is 0.09 degrees south of the Moon. Neptune is very close by on the 12th, occulted for North American observers. You'll need a telescope to see that one. The Moon is full on the 5th, with Uranus 4 degrees to the south and the stars of the Pleiades form a backdrop. On the 17th, Jupiter is 6 degrees south of the Moon, high in the southeastern sky. Pollux is next, 1.9 degrees north on the 19th; Mars is right behind on the 20th, 2 degrees south. The last occultation of November occurs in the early morning of the 27th, when Spica, the bright star in Virgo, is overtaken by the waning crescent Moon–viewable from most of North America.

Mercury is noted above, being close by the Moon on the 1st, but so too is the Sun–a non-event. On the 9th, Antares is 2 degrees south of Mercury right at sunset–a real challenge! The speedy planet reaches greatest elongation east on the 16th, offering the best time to view it, but still hampered by the shallow ecliptic.

Venus is also nearing its greatest elongation east, but not for a couple of months. It shines right after sundown in the southwest as the brightest object in the night sky. You should be able to see Venus even before sunset, it's that bright. This is the best apparition for Southern Hemisphere observers.

Mars gets closer and closer to Earth, brightening while apparently growing in size. The Red Planet is joined by the Moon on the 20th (see above).

Jupiter is in northern Taurus, retrograding against the starry background. The gas giant is high in the southern sky all through the night, giving ample opportunity for binocular or telescope users to track the four Galilean moons: Io, Europa, Ganymede, and Callisto. It's a good way to watch that part of the Solar System as Galileo saw it over 400 years ago.

Saturn has been retrograding and slows to a stop on the 16th. Then it begis to slowly move eastward in prograde motion in eastern Aquarius. The Moon makes a very close pass on the 10th.

Uranus is at opposition (directly south) on the 17th, its highest altitude since the 1950s.

Neptune makes a good telescope challenge in the evening, among the stars of Pisces.

The zodiacal light is visible before eastern morning twilight for the first two weeks of November.

Daylight Saving Time ends on Sunday, the 3rd; the **south Taurid meteors** peak on the 5th.

The **north Taurid meteor shower** peaks on the 11th. ✶

Figure 2 — November 21: Uranus remains steady high above near the Pleiades, while Jupiter, also in Taurus, is retrograding westward. Mars and the waning gibbous Moon bracket the cluster M44.

Continued from page 208

Figure 3 – Katelyn Beecroft imaged both the Trifid and Lagoon Nebulae from her home in London, Ontario. She says the image was made from a mix of broadband RGB and narrowband Hα and OIII. She says, "I was able to mix data from both the broadband R filter and the Hα filter, as well as combine the OIII into the green and blue filter data. I really loved the framing that shows off the lagoon but also includes the Trifid and IC 4685 (which I think looks like a little paw)." She used an Askar FRA400, 72-mm aperture, ƒ/5.6 with a ZWO ASI2600mm pro. 18 × 300s Antlia 4.5 nm Hα filter; 22 × 300s Antlia 3nm OIII filter; 69 × 120s Antlia V-Series Blue; 66 × 120s Antlia V-Series Green; 64 × 120s Antlia V-Series Red. Processed in PixInsight and Adobe Photoshop.

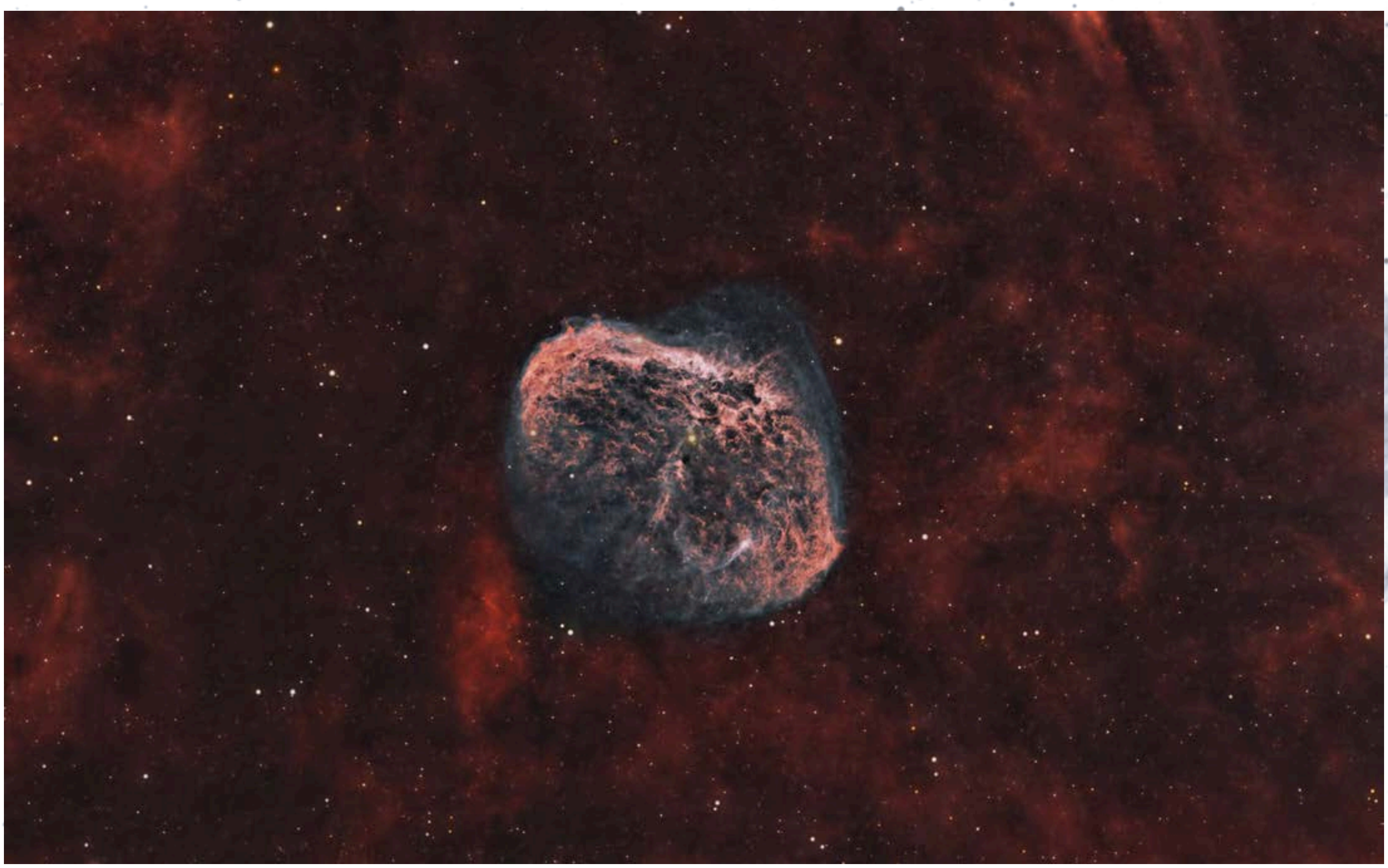


Figure 4 – "It is a very unique target with interesting detail," says Shelley Jackson about the Crescent Nebula. "Floating in a sea of glowing hydrogen gas and enveloped in a shell of excited oxygen, this emission nebula is a great summer target… Some say it looks more like a brain or mushroom. I've even heard it being described as the 'facesucker' … from Alien. Thank you for that visual. To me it looks like a pink sea sponge, oozing blue body wash and THAT'S the visual I will keep." Shelley used an Askar V at 80 mm with flattener (FL 495mm) on an EQ6-R pro mount, with a ZWO ASI183MM CMOS camera and a 50-mm guide scope, ZWO 120 mono guide camera. Filters were Hα, S2, OIII, combined as Hα SII/OII OIII. Final image was stacked with PixInsight, and all processing and editing was also done with PixInsight.

Astronomical Art & Artifact

J.R. Collins's Competent Moon, and the Great Photographic Void in the Archives

by R.A. Rosenfeld, FRASC,
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Abstract

J.R. Collins (1865–1957) produced the best astrophoto by an amateur member of The Royal Astronomical Society of Canada in the early years of its existence. The circumstances of his lunar image are discussed, and the astronomical career of its creator is sketched. The existence of his image highlights the paucity of other early astrophotos by amateur members in the present Archives, and the poor quality of what little survives. What this could mean is explored. A possible inspiration for the attractive star charts for his newspaper column is suggested.

An odd thing about archives…

No archive is ever complete, balanced in its holdings, and immediately forthcoming of all it may contain of relevance to a search. The stuff of which an archive is made is generated by human activity, but there is usually a temporal gap separating the activity from the creation of the archive. Not everything is preserved at the time of its creation, or saved at all, and not everything enters a collection. An archive is as much a place of loss and forgetting, as it is a reservoir of remembrance. Even when an archive appears reasonably complete, it takes work to discover all that is of interest within. And records are like parables; work is required to draw out their meaning.

Balance, and likewise imbalance in the proportion of the types of record in a collection is particularly hard to interpret. Does the weak representation, or absence of a certain type of record indicate that the associated human activity which ought to have generated it didn't happen? And does the absence of artifacts accurately reflect an absence of interest on the part of the group whose existence is chronicled by the archive? Ideally one would compare the archives of similar groups from the same period, to ascertain if the proportion of the types of record is typical (balanced), or not, but often one is reduced to an educated guess.

There is a noticeable absence of astrophotographic records in the RASC Archives from ca. 1868 through to the 1930s. The Archives hold many more astrosketches, although even that number may well be a fraction of what was created. Astrophotography was certainly a much more demanding activity for a beginner a century, or century and a half ago, than it is today. They were few automatic settings, and no electronic algorithms, and applications of artificial intelligence to make the choices for the astrophotographer, and ease the way to capturing starlight. Exposure, *f*/stop, critical focusing, guiding, and choice and handling of the recording media, were all manual procedures, relying on the skill and experience of the imager.

Figure 1 — J.R. Collins, photographic portrait, 1917. Reproduced courtesy of the RASC Archives.

Among early Society members there was great interest in the results of professional astrophotographers—Jules Janssen's photographs of solar granulation, Isaac Roberts's nebular photographs, and E.E. Barnard's photographs of anything were things of wonder.[1] The interest in astrophotography was not merely passive. In 1892, a committee of the Society recommended to the Rev'd T.H.E.C. Espin, the literary executor of the Rev'd T.W. Webb, that he add a section on celestial photography to the next edition of *Webb's Celestial Objects for Common Telescopes* (the 5th of 1893), the standard amateur observing manual of the day (Sparling 1893, 23; Rosenfeld 2020). There were astrophotography handbooks aimed at amateurs (some quite good, but none by Canadians; Waters 1921). The sheer technical challenge of the pursuit could partially explain the low number of astrophotographs in the RASC Archives by members during this period, but there were members who did try their hand at the art, such as Dr. J.J. Wadsworth (1842–1905), the Rev'd Dr. D.B. Marsh (1858–1933), and J.S. Plaskett (the most accomplished of the Society's early astrophotographers, but he was a professional).[2]

Beyond their sparsity, another characteristic of the Archives' holdings of early members' astrophotographs is the poor quality of most of them. Over or underexposure, poor guiding, and soft focus seem to be the order of the day. None of the images remotely approach the quality of what the best amateurs elsewhere achieved.[3] J.R. Connon's (1862–1931) oeuvre in the collection illustrates this well. Connon was a professional photographer, and quite good at photographing challenging landscapes, yet mastery of the simplest astrophotography to capture the great luminaries seemed beyond his skills. Consequently, when an early image in the RASC Archives is neither under nor overexposed, shows undistorted features, and is reasonably sharp, it stands out. J.R. Collins's image of the full Moon is one such image.

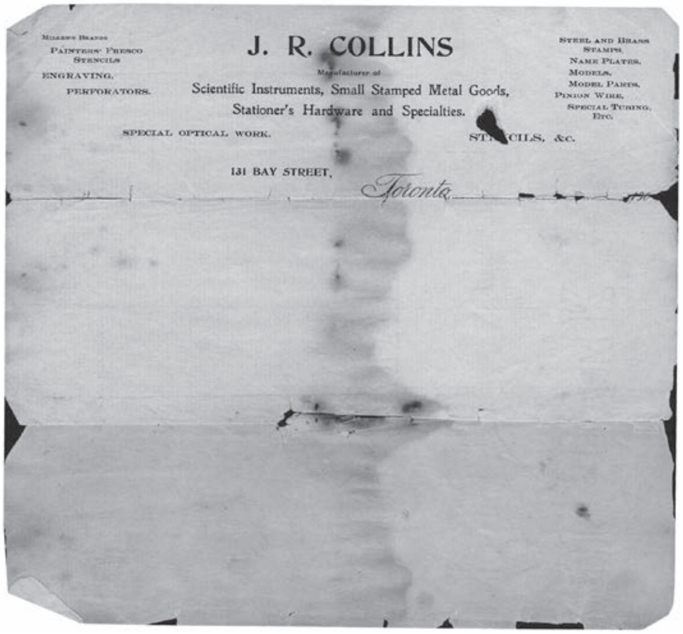

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Figure 2 — J.R. Collins letterhead, undated. Reproduced courtesy of the RASC Archives.

Who was J.R. Collins?

By the time of his death as a nonagenarian, John Robinette Collins (1865–1957) had enjoyed one of the longest continuous affiliations with the Society, having been a member for 64 years (Figure 1; Kennedy 1958). Born in Ontario, his sole post-secondary education was of a peculiarly light sort, being a "diploma from the Chautauqua College [*recte*: Institution] in New York State" (Kennedy 1958, 1). This was a form of adult education, whose main vehicle in Collins's day was a summer school in New York (the site of the recent attack on Sir Salman Rushdie). Under enthusiastic auspices, the bare rudiments of subjects were imparted over the course of five weeks or less, depending on the topic. The goal was to produce a better class of Sunday school teacher, and, in general, more genteel protestants. It exerted a largely benign cultural influence in the United States, and wielded a surprising cultural influence. Chautauqua offered some science instruction, including very basic astronomy through a Christian lens (as in Bishop Warren's *Recreations in Astronomy* 1879), although science was not the Chautauqua Mission's *forte*. How well this served Collins with a structured astronomical background is hard to say—but at least it was a route available to him (Kniker 1969; Bonnell 1988; Buihte 2007).

He eventually occupied high office in the Society, first as Secretary (1902–1917), then as National President (1920–1921). His tenure as Secretary was unusually long. The Secretaryship at that time was possibly more significant than it later became. His pen was the official channel of communication with the rank and file membership, honorary members and prospective honorary members, and the external world writ large. This meant that he was in correspondence with some of the most significant figures in astronomy at the time, such as the Astronomer Royal, the Director of the Observatoire de Paris, G.E. Hale, E.E. Barnard, Sir William Huggins, Sherburne Wesley Burnham, Agnes Mary Clerke, and Camille Flammarion. By virtue of that correspondence he would become the Society member best known to many of them by name. He must have given satisfaction in the post, although the shallowness of his astronomical grounding was occasionally visible in the epistolary exchanges.[4]

Early in his tenure he was one of the Society officers who successfully petitioned Edward VII for permission to add the designation "Royal" to the Society's name. And he was a fairly regular speaker at Centre meetings, and an occasional contributor to this RASC *Journal*. His best "serious" publication may have been his paper on "Radium, and Its Bearing on Astronomical Physics," for which he communicated with some of the outstanding names in the field, such as Sir William and Lady Margaret Huggins, Sir William Crookes, Sir Oliver Lodge, and Frederick Soddy, Rutherford's collaborator at McGill (who went on to win the Nobel Prize in Chemistry in 1921), and illustrated his talk with samples of pitchblende, carnotite, radium compounds, and some radiographs (Collins 1904)—but the result in print hardly glowed. In a more popular vein, from 1900 to 1948 he wrote the "Stars of the Week" column for the Tory broadsheet the *Toronto Telegram* (the name varied).[5] Later in life he was the chair of the Society's planning committee for the solar eclipse of 1932 August 31 (Kennedy 1931). He was rewarded by his peers with election as a Fellow of The Royal Astronomical Society of Canada (during the original form of the honour, ca. 1900–1944; Rosenfeld 2021). At best, he seems to have contributed to the RASC's advancement in a steady but modest way; he was not an amateur astronomer of the calibre of an A.F. Miller, let alone a J. Miller Barr (Percy 2015).

J.R. Collins had a brother, Zoro, who had joined the Society at the same time (1893 August 22),[6] and was the Society's Librarian, and official printer for a brief period (ca. 1902–1903).[7]

The Collins brothers were probably best known to members of the Society as telescope makers. The earliest mention of them as telescope builders dates from 1895 July 2, in the report of the first meeting of the Lunar Section of the Astronomical and Physical Society of Toronto held on the grounds of the Toronto Magnetic and Meteorological Observatory: "a 6-in. reflector, by Messrs. J.R. and Zoro M. Collins, who had made the instrument and stand throughout" (Lumsden 1895, 1).[8] Four years later they were involved in an attempt to claim priority for the invention of tilted-component telescopes of the Schupmann type, with their "Monoplane Achromatic Telescope." It didn't end well; their effort foundered on the facts, and it did nothing for the international standing of the Society (Rosenfeld 2013). And there is a record of his giving advice in 1906 to Joseph Pope, Undersecretary of State (and formerly Sir John A. Macdonald's private secretary) on adjusting his telescope to improve its performance (Pope 1906).

It seems that J.R. Collins attempted to set up as a professional optician, as witnessed by his surviving letterhead (unfortunately not dated; Figure 2):

"J.R. Collins, Manufacturer of Scientific Instruments, Small Stamped Metal Goods, Stationer's Hardware and Specialties. Miller's Brands, Painters' Fresco Stencils, Engraving, Perforators, Special Optical Work, Stencils, &c. Steel and Brass Stamps, Name Plates, Models, Model Parts, Pinion Wire, Special Tubing, Etc. 131 Bay Street Toronto."

The letterhead suggests a certain lack of success in attracting scientific trade. It was a long-established practice for opticians to offer a range of goods clearly related to scientific or technical activity, such as mathematical or philosophical instruments, but Collins's list is anomalous in its deviation from the tools for doing or learning science. What successful optician would willingly diversify to such unrelated areas? While this could reflect the limited market in Toronto for such goods, it is more likely a sign of Collins's limited ability to capture a share of that market. Charles Potter, active before Collins, had no such difficulty (Smith 1993).

Unfortunately, none of the instruments by the Collins brothers survive, so no direct evaluation of the quality of their instruments is possible. Collins's lunar image may serve as a proxy indicator of what he was capable of—with reservations.

J.R. Collins's full Moon

Collins's photograph of the full Moon survives today in the form of a magic-lantern slide (Figure 3). Its inscription reads: "THE FULL MOON. PHOTO BY J.R. COLLINS." It is not dated, but an entry in a published version of the RASC's lantern-slide collection provides a *terminus ante quem* of 1904 for the production of the slide, and by implication, its lunar image (Howell 1905, 7). It is orientated with south at top (following the usual convention for maps before 1961; Vaniman 1991, 60; Manasek 2023, 14).

The magic lantern slide was a technology current from ca. 1849 to ca. 1960. A glass positive transparency (usually), it consisted of an image recorded on a film of silver salts in albumen, collodion, or gelatin fixed to the face of a square or rectangular glass plate, with a glass cover of the same size to protect it, the whole sealed by a suitable adhesive cloth tape around the borders of the glass plate and cover (Hannavy 2008). It developed from the application of "new" photographic technology to the older generation of hand-painted lantern slides, or hand-coloured lithographic lantern slides, either of which could be geared to represent the movement of heavenly bodies in their courses. The slides were projected through a magic lantern, a technology that antedated the invention of photography by about two centuries (Huygens 1891, 269).

Figure 3 — Full Moon, by J.R. Collins, 1904 (or earlier), lantern slide. Reproduced courtesy of the RASC Archives.

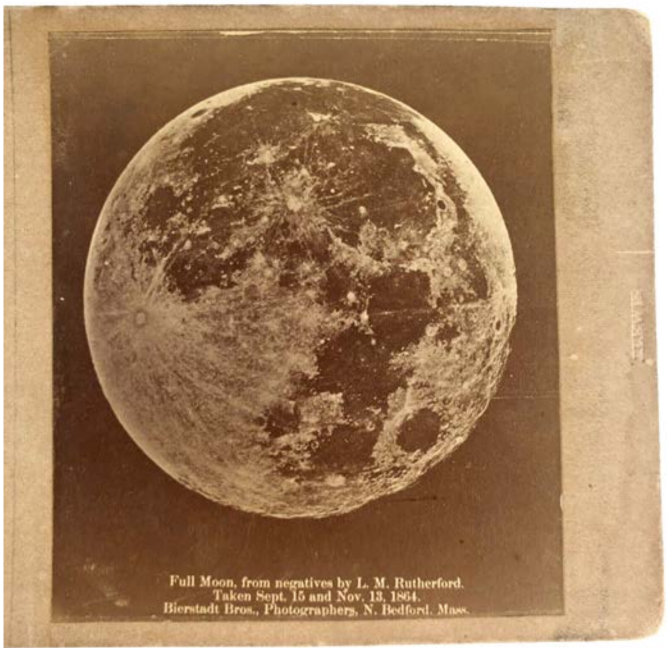


Figure 4 — Full Moon, by Lewis M. Rutherfurd, 1864, from a stereoview issued by the Bierstadt Brothers. Reproduced courtesy of the Specula astronomica minima.

A magic lantern typically had a reflector, a source of illumination, a condensing lens, the image to be projected (the slide), and a focusing-lens assembly. Due to the materials of construction, and, in particular, the sources of illumination, the magic lanterns could at times function as unintentional incendiary devices, adding unplanned excitement to a presentation. Electric lanterns were considerably safer (the Society acquired one in 1900 at the urging of the then President, George E. Lumsden; Lindsey 1901a, 6; 1901b, 9).

How good an image was Collins's lunar photograph in the context of its time? As stated above, in the setting of the RASC, his image is the best quality astronomical photograph in the Archives by an amateur member of the Society from around 1900. It is better than Wadsworth's lunar image (www.rasc.ca/moon-18960222), or Marsh's (www.rasc.ca/moon-1906). Where does it fit in the wider world of selenographical photography? It's sharper than some of John Adams Whipple's and James Wallace Black's images from 1857–1860 taken with the 15-inch Great Refractor of the Harvard College Observatory (Fineman & Saunders 2019, figure 15), yet is noticeably less sharp than Warren de la Rue's and Robert Howlett's images from ca. 1858 with a 13-inch Newtonian (Fineman & Saunders 2019, figure 19), or Lewis Morris Rutherfurd's from 1864 with an 11.25-inch refractor (Figure 4). It is about equal to an image taken by William Crookes in 1858 (perhaps with an instrument of smaller objective than any of the above?; Thomas 1997, 201). Had Collins produced his image half a century earlier he could have just been included in the echelon of those advancing the frontiers of astrophotography. As it was, in 1904 he was head of the amateur RASC pack engaging in portraiture of the Moon. It was a distinction, if only a local one.

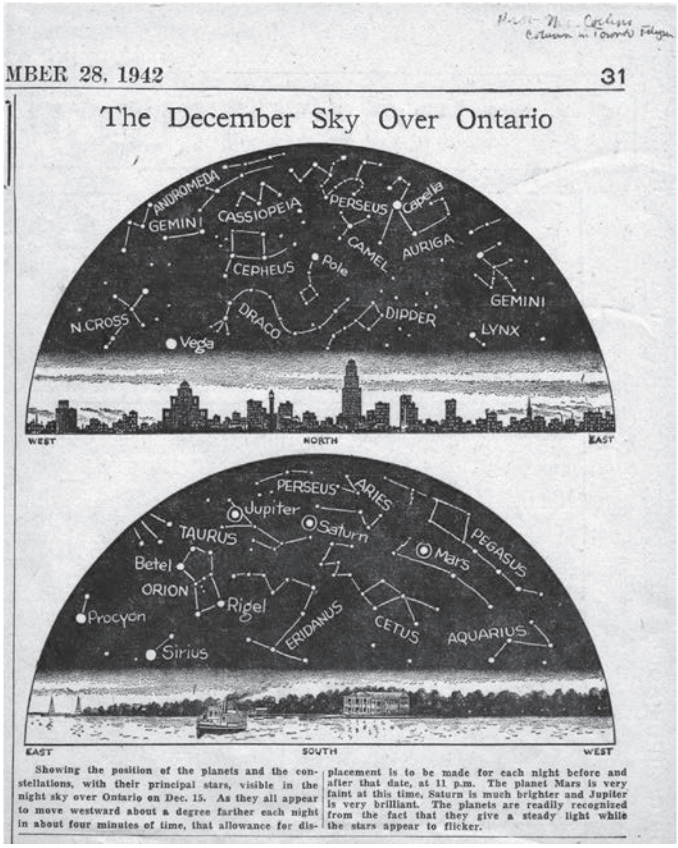
None of the technical details of how Collins produced his photograph are known. Based on the details recorded by other contemporary astrophotographers, one can hazard some guesses as to what these were, without risk of going too far astray. Collins would have required a good equatorial mount, accurately aligned, and with reasonably accurate gearing. He would have to have guided the exposure, although a clock drive would not at all be necessary (Waters 1921, 44–45). It doubtless appears little short of miraculous to amateur astrophotographers now, but accurate tracking for exposures of up to five hours or more over several nights were possible by experienced astrophotographers (Touchet 1929, 298). Fortunately, to capture the full Moon with the photographic media then employed, exposures of 1/20th or 1/25th of a second were sufficient. Most of the instruments available to Society members at that time were fairly modest—the so-called "common telescopes," such as 3-inch $f/15$ refractors, or 6-inch $f/8$ reflectors.

As none of the telescopes he and his brother produced are known to have survived to the present, his competent photograph of the Moon can stand as a proxy indication for competence in technical procedures, such as telescope making. The competent photograph raises the possibility that the Collins brothers could have been competent telescope makers.

But none of this goes anyway toward answering the questions posed earlier; why are there so few astrophotos by amateur members of the Society in the RASC Archives from ca. 1868 through to the 1930s, and of those in the Archives, why are so many of them such poor specimens of the art? Why is there a great photographic void in the RASC Archives for those years?

Appendix: the origins of the design of the *Toronto Telegram's* monthly star charts

The design of the monthly star charts in J.R. Collins's astronomy column for the *Telegram* features charming topographical vignettes above the horizon (Figure 5). The map of the northern sky shows the Toronto skyline as seen from a vantage point south of Front Street (possibly in the harbour), and the map of the southern sky looks toward the Royal Canadian Yacht Club's clubhouse, and their private launch, the Kwasind (perhaps a graphic sign of the paper's political allegiance). The northern map features landmarks such as the



[illegible] Mr. Collins
Column in Toronto Telegm

MBER 28, 1942 31

The December Sky Over Ontario

Showing the position of the planets and the constellations, with their principal stars, visible in the night sky over Ontario on Dec. 15. As they all appear to move westward about a degree farther each night in about four minutes of time, that allowance for displacement is to be made for each night before and after that date, at 11 p.m. The planet Mars is very faint at this time, Saturn is much brighter and Jupiter is very brilliant. The planets are readily recognized from the fact that they give a steady light while the stars appear to flicker.

Figure 5 — Wood block(?) star charts for December 1942, to accompany J.R. Collins' astronomical column in the Toronto Telegram *(1942 November 28), probably by Vic Childs. Reproduced courtesy of the RASC Archives.*

Figure 6 — Wood block star chart for December, looking north over London, from Edwin Dunkin's The Midnight Sky, *1869 (p. 90). Reproduced courtesy of the Specula astronomica minima.*

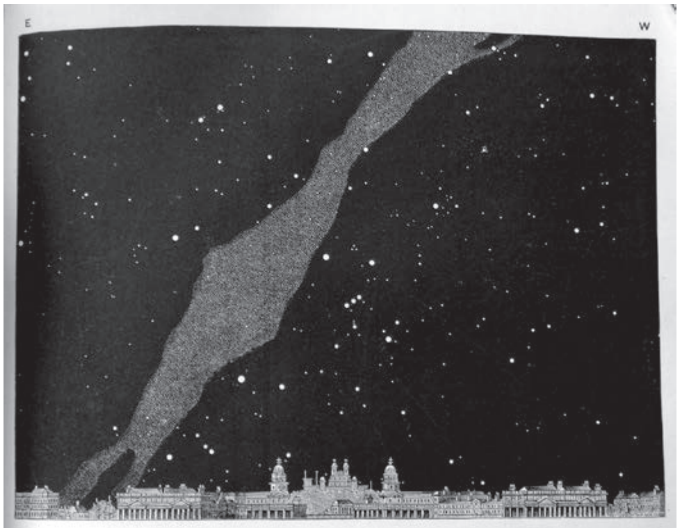


Figure 7 — Wood block star chart for December, looking south over London toward the Royal Observatory Greenwich, from Edwin Dunkin's The Midnight Sky, *1869 (p. 91). Reproduced courtesy of the Specula astronomica minima.*

Figure 8 — Chromolithographic star chart for the December solstice, looking north over Paris, by Émile Guillemin & Philippe Benoist, from Amédée Guillemin's Le Ciel, *5th ed., 1877 (plate 34). Reproduced courtesy of the Specula astronomica minima.*

Royal York Hotel, the campanile of the City Hall, the tower of the Canadian Bank of Commerce, and the spire of St. James Cathedral. "Mysteriously" excised from the skyline is the imposing headquarters of the paper's press and political rival, the *Toronto Star*. The graphics were probably done by Victor ("Vic") Childs, "Telegram artist."

As charming as the skylines are, they are not an idea originating with either Collins, or Childs. They are almost certainly an adaptation from the monthly charts in Edwin Dunkin's (1821–1898) *The Midnight Sky* of 1869, the northern charts of which feature the skyline of London looking north to St. Paul's Cathedral from the Thames, while the southern charts show the skyline looking south toward Flamsteed House from the dock at Greenwich (a very apropos subject! Figures 6 & 7). It appears that "his son" was the artist (Dunkin 1999, 156). The major part of Dunkin's astronomical career was spent at the Royal Observatory, where he eventually rose to become Chief Assistant. It is known that the Society had purchased a copy of *The Midnight Sky* in 1901, so a copy of Dunkin's work would have been conveniently available to Collins.[9]

Dunkin's charts were first created for a periodical, *The Leisure Hour*, in 1868, before they were republished as part of his book. Yet he wasn't the originator of the idea of using local skylines for star charts any more than were Collins, or Childs.

Four years before Dunkin's charts first appeared, the French journalist and science promoter Amédée Guillemin

Figure 9 — Chromolithographic star chart for the December solstice, looking south over Paris, by Émile Guillemin & Philippe Benoist, from Amédée Guillemin's Le Ciel*, 5th ed., 1877 (plate 35). Reproduced courtesy of the Specula astronomica minima.*

(1826–1893) published the first edition of his highly successful *Le ciel* (1864). It didn't feature monthly star charts; instead it presented star charts for the March and September equinoxes, and June and December solstices as seen from Paris. The northern chart shows part of the northern outskirts of the city where it melds into the countryside, and the southern chart toward the dense cityscape with Notre Dame de Paris and the Pantheon clearly identifiable (Figures 8 & 9). These were the work of Émile Guillemin (1841–1907) and Philippe Benoist (1813–1881), both prominent artists at the time.

It is not at all unlikely that Dunkin copied the idea from Guillemin. Dunkin was known to be fluent in French—although that precondition for accessing Guillemin's text wouldn't have been necessary, for Norman Lockyer came out with a translation of the second edition in 1867, the year before the first edition of Dunkin's book (Dunkin 1999, 66–67; Guillemin 1867). In his autobiography Dunkin emphasizes the difficulty in producing the charts, "The preparation of these small maps was very troublesome, as the position of every star was inserted after a special calculation of its position in altitude and azimuth," but claims no novelty for the arrangement, or mentions where he got the idea from—but neither does Collins mention his source (Dunkin 1899, 151).

Collins's charts appear to be wood blocks, and Dunkin's certainly were (Dunkin 1999, 156), whereas Guillemin's were chromolithographs. As scientific art, Guillemin's charts were an order of magnitude more effective and impressive than Dunkin's, and Dunkin's likewise were a more significant achievement than Collins's. All of them retain their attractiveness, and they must have added considerably to their authors' presentations, and the attractiveness of these works to respective purchasers. ✶

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Endnotes

1. Several of Janssen's photographs are included in the TAPST Album 1892, Roberts donated an inscribed copy of his *Selection of Photographs of Stars, Star-Clusters and Nebulæ* (Sparling 1896, 51–52; Roberts 1893, 1899), and in 1920 Barnard was invited to Toronto by the RASC to lecture on astrophotography at the Empire Club of Canada (Barnard 1923). And one of the Yerkes photographs of a section of the Moon featured as the frontispiece to the Society's *Transactions* for 1900; Yerkes Observatory 1901.
2. Plaskett's photographs of M13 and M57 with the 72-inch telescope at the Dominion Astrophysical Observatory were considered good enough to be offered for purchase in the Royal Astronomical Society's prestigious slide series, as nos. 288 and 289; Broughton 2018, 198, and note 77 on p. 461. And Marsh's photographic skill can be assessed through Marsh 1906.
3. As is painfully evident from the comparative material in Hughes 2013, 110–131, 224–253, 539–616, 739–765, 1271–1304.
4. This is can be seen in his epistolary exchange with Edward Keeler (then Director of the Allegheny Observatory) in 1896 before Collins assumed the office; RASC Archives, J.R. Collins *fonds*, Keeler to Collins 1896 January 20. And it should be noted that his handwriting could at times be abysmal, as when he deputized for the Society's Recorder!; Collins 1902.
5. When Collins retired from the position in 1948, the celebratory review of his column in the *Telegram* consistently gave his first name as "James," rather than John!; RASC Archives, J.R. Collins *fonds*, undated clipping.
6. Sparling 1894, 82.
7. The reasons for his brief tenure of both offices are not fully known at present. As is so often the case in the early records of the Society, sufficient detail is almost never provided, and anything of an unpleasant nature, such as a Society project miscarrying, is passed over in silence. On 1902 January 24, the Council appointed "a committee to obtain tenders for printing the Report" (Webber 1902, 172), and on February 21 "The tender of Z.M. Collins for the printing of the Transactions... was accepted" (Webber 1902, 175). There is no evidence that any other tenders were sought, or received. In due course the *Transactions of The Toronto Astronomical Society for the Year 1901 Including Twelfth Annual Report* (1902) appear, with Z.M. Collins prominently listed as "Publisher to the Society" on the cover. In 1903, the Council decides that "the publication of the Annual Transactions of the Society [are to] be omitted" (Collins 1903), yet *The Royal Astronomical Society of Canada Selected Papers and Proceedings 1902 and 1903* (1904) appears with Z.M. Collins listed again as "Publisher to the Society." That same year "The Council requested the Secretary [Zoro's brother J.R.!] to communicate with Morang and Company, Limited [an established Toronto publisher], respecting the handling by that Company of the Transactions of the Society," "It having been arranged...that the [Morang] Company should handle the Transactions for public sale...the Company to dispose of them at whatever price may be necessary to cover actual expenses" (Dent 1904a-b). What is the story here? Was Zoro Collins the saviour of the Society, stepping in to see that the predecessor of the *Journal* actually appeared during a tight spot, and then judiciously withdrawing when the task could be handed to a more experienced publisher, or did the glitter of assuming the title "Publisher to the Society" induce him to undertake a venture for which he was ill-prepared, and necessitate his replacement? Zoro seems to drop out of all active involvement with the Society at about this time, although he retained his membership. Whatever happened, his brother's reputation in the Society appears to have been unaffected.
8. This was the second Toronto Magnetic and Meteorological Observatory of 1853-1855, designed by Frederick Cumberland, located off King's College Road in 1895; it is now known as the Stewart Observatory on Hart House Circle, and the historic building is currently being redeveloped by the University of Toronto (for what end has not yet been revealed).
9. "Moved by Mr. Paterson, and seconded by Mr. Miller, that the copy of Duncan's "Midnight Sky," for sale by Mr. Britnell, be purchased for $1.50. Carried"; Sparling 1901.

Imager's Corner

Chasing "True Colour"

by Blair MacDonald, Halifax Centre
(b.macdonald@ns.sympatico.ca)

The idea for this edition's column came from a discussion on the Nova Scotia Astrophotography Facebook group. Like many such groups it is a great resource with many skilled astrophotographers as well as novices among its members. Although the name says Nova Scotia Astrophotography, there are members from all over the world, united over a love of imaging the night sky. In this edition we will take a look at chasing "*true colour*" in our images. Like most astrophotographers, I go to great lengths to get colourful images of red nebulae and bluish galaxies with red Hα regions, but you won't hear me claim that these are *true colour*.

Figure 1 — Typical galaxy photo. Note the red Hα regions scattered throughout the spiral arms.

While somewhat faithful to the true spectrum of the emitted light, these are not the true colour of many of these objects, even after colour calibration, despite what many image processing packages would have you believe. As Dr. Roy Bishop is fond of saying, and I'm paraphrasing here, there is no true colour because colour is truly in the eye of the beholder. To put this on a little more scientific footing, there is a difference between colour and emitted spectrum. They are indeed related, but not the same thing at all. The spectrum consists of various emitted levels over the frequency range detectable by the human eye, while colour is the human eye/brain response to the spectral stimulus. As we will see, this distinction is important in determining the *true colour* of what we see. Let's start by examining the emitted spectrum of the Orion Nebula as an example of a large Hα region in our own galaxy and by extension the Hα regions of external galaxies as well.

From this spectrum we might expect the nebula to be red, as the Hα line is stronger than the sum of the rest of the major emission lines. Indeed images taken on film, glass plates, and with electronic imaging systems show this to be true. Why then does M42 appear a distinct bluish green when observed with a telescope large enough to show colour in this object? I have personally observed M42 in scopes ranging from 4 inches to 40 inches (~1 metre), and when the aperture was large enough, I can attest to the bluish-green colour. I start to see the colour in a scope with an aperture of 16 inches; it's obvious at 25 inches and vivid in a 40-inch aperture.

The explanation for this apparent contradiction lies in the definition of colour and the systems we use to display images, as well as the fact that Hα regions are narrow-band sources and do not present a black body spectrum. Remember that colour is a function of the human eye/brain, so the colour as seen must take the response of the human eye into account. In addition, Hα regions are not wide-band sources, but instead they typically emit narrow lines at specific frequencies and these do not necessarily line up with the wavelengths emitted by monitors or reflected by film.

The first step in understanding true colour is to take a look at how the human eye perceives colour. What follows in the next few paragraphs is my definitely layman's description.

The eye contains two types of photo-receptors, rods and cones. The rods are responsible for our scotopic, or night vision and do not produce the sensation of colour. We have three types of cones that work together to produce our photopic, or colour vision. There are cones that are sensitive to red, some to green, and some to blue. The table below shows the normalized relative response of both photopic and scotopic vision.

The cones are sensitive to broad bands of wavelengths around their peak sensitivity, and along with the emitted spectrum, it is the relative responses of the red, green, and blue cones plus the brain's processing that determines the colours we see. Figure 3 shows the normalized response of each of the three types of cones.

It is well known that the eye has a logarithmic response to absolute intensity, but it is not well understood if this is true for red, green, and blue ratios making up a particular colour. There is some evidence that the eye is very sensitive to small changes in RGB ratios. "Researchers estimate that most humans can see around one million different colors. This is because a healthy human eye has three types of cone cells, each of which can register about 100 different color shades, amounting to around a million combinations" (source www.pantone.com/articles/color-fundamentals/how-do-we-see-color#:~:text=HOW%20MANY%20COLORS%20CAN%20HUMANS,to%20around%20a%20million%20combinations).

Now, back to the emission spectrum of M42, shown in Figure 2, the strongest line is in the deep red at 650 ηm due to Hα emission. The next strongest line is at 500 ηm in the beginning of the green part of the spectrum and is from oxygen emission with a smaller oxygen line close by at 496 ηm.

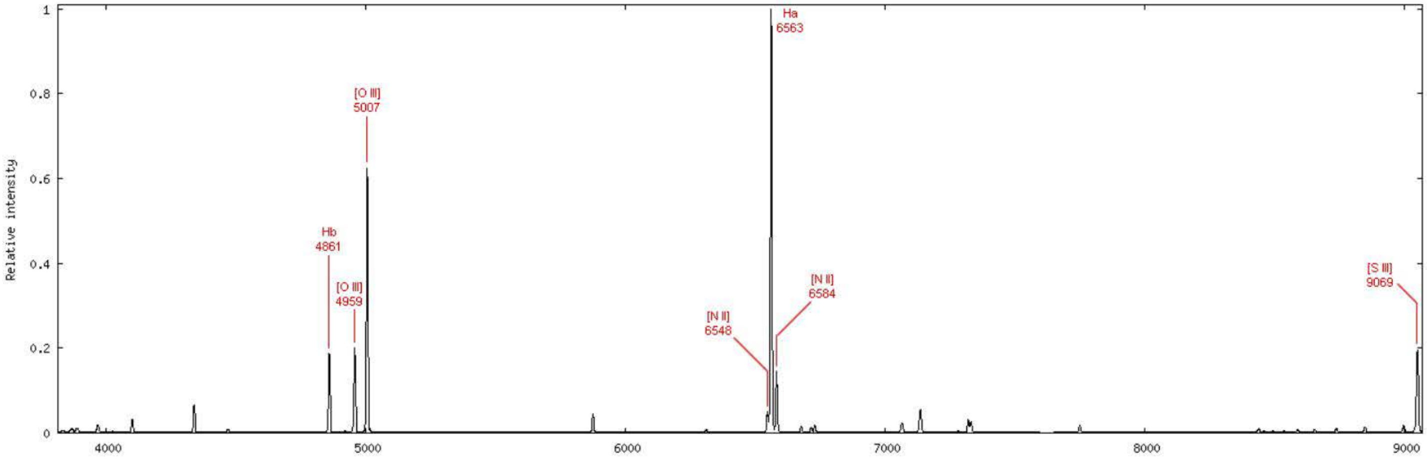
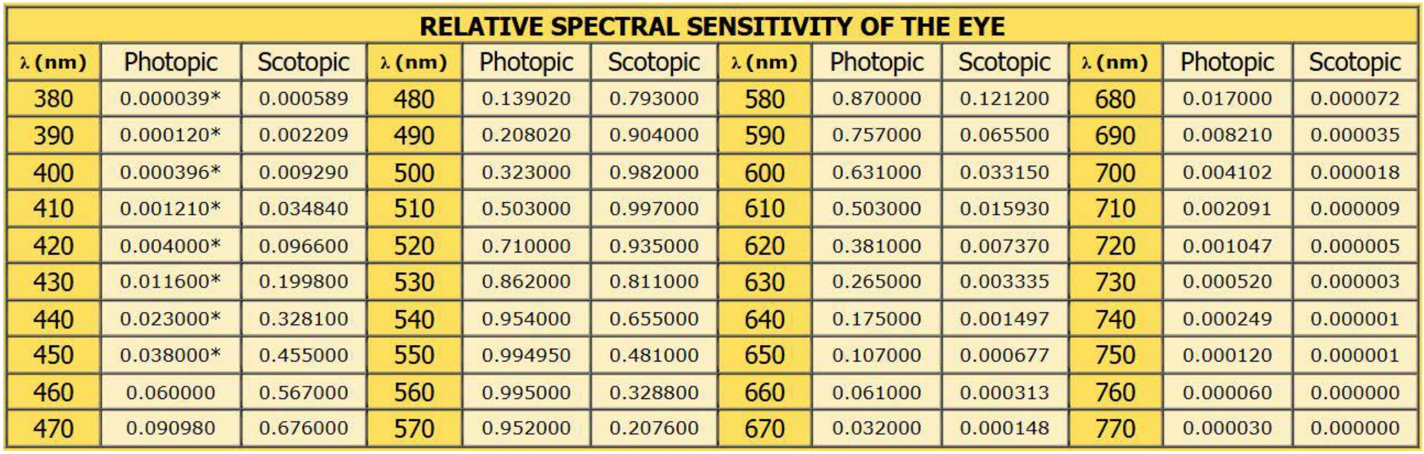


Figure 2 — Orion Nebula spectrum measured from the Castanet-Tolosan Observatory by Christian Buil published at www.astrosurf.com/buil/nebula/HII/m42/m42.html.



RELATIVE SPECTRAL SENSITIVITY OF THE EYE											
λ (nm)	Photopic	Scotopic	λ (nm)	Photopic	Scotopic	λ (nm)	Photopic	Scotopic	λ (nm)	Photopic	Scotopic
380	0.000039*	0.000589	480	0.139020	0.793000	580	0.870000	0.121200	680	0.017000	0.000072
390	0.000120*	0.002209	490	0.208020	0.904000	590	0.757000	0.065500	690	0.008210	0.000035
400	0.000396*	0.009290	500	0.323000	0.982000	600	0.631000	0.033150	700	0.004102	0.000018
410	0.001210*	0.034840	510	0.503000	0.997000	610	0.503000	0.015930	710	0.002091	0.000009
420	0.004000*	0.096600	520	0.710000	0.935000	620	0.381000	0.007370	720	0.001047	0.000005
430	0.011600*	0.199800	530	0.862000	0.811000	630	0.265000	0.003335	730	0.000520	0.000003
440	0.023000*	0.328100	540	0.954000	0.655000	640	0.175000	0.001497	740	0.000249	0.000001
450	0.038000*	0.455000	550	0.994950	0.481000	650	0.107000	0.000677	750	0.000120	0.000001
460	0.060000	0.567000	560	0.995000	0.328800	660	0.061000	0.000313	760	0.000060	0.000000
470	0.090980	0.676000	570	0.952000	0.207600	670	0.032000	0.000148	770	0.000030	0.000000

Table 1 — The spectral sensitivity of the eye's photopic (colour) and scotopic (night) vision. Note that at Hα wavelengths (650 ηm), the eye is very insensitive to light with only about 10% of its peak response in the green part of the spectrum.

The biggest oxygen line is about 60% of the Hα emission level. Finally there is a line at 486 ηm from Hα emission at the low-frequency edge of the blue part of the spectrum. This line is about 20% of the Hα emission levels. All other lines are smaller than these, or well outside the wavelengths to which the eye is sensitive.

If we map the narrow-band emission lines to red, green, and blue (realizing that there is overlap in the spectral response of the cones in the retina) we get the following levels in each colour channel R=1, G=0.6, and B=0.2. Here I have mapped the Hα to red, the OIII to green, and the Hα to blue (a typical mapping used in astrophotography). Taking the eye's response (from Table 1) at these wavelengths into account we have R=1*0.107, G=0.6*0.323, and B=0.2*0.139, which gives R=0.107, G=.194, and B=0.028. Scaling this for a typical 8-bit monitor we get R=27, G=49, and B=7, a decidedly green colour.

In actual fact, as shown in Figure 3, the oxygen emission stimulates both the green and blue cones leading to a slightly bluish-green colour. So the calculated colour lines up well with the visual appearance as seen through a large scope, but this still leaves a contradiction where images taken of M42 shows it as red to pink.

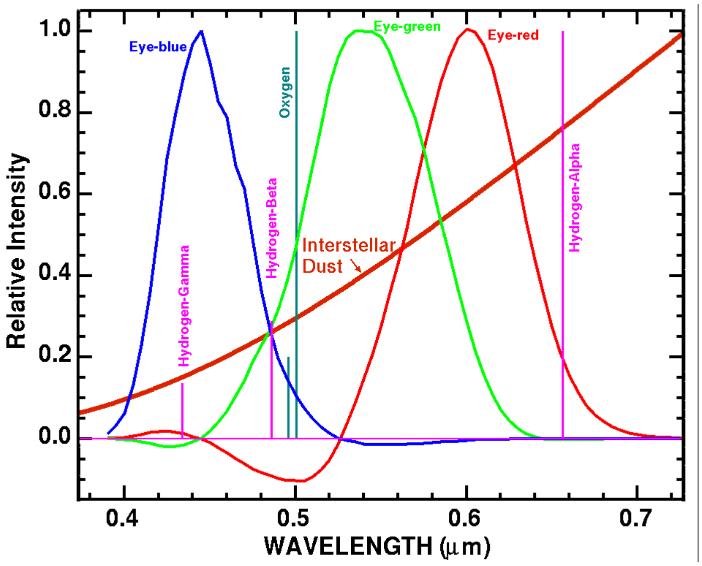
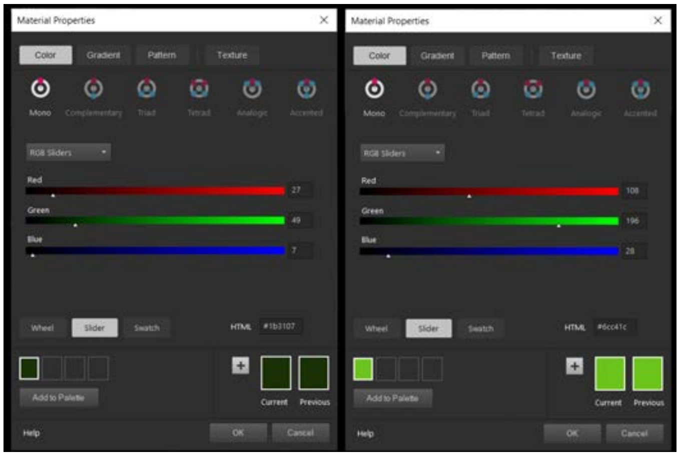


Figure 3 — Normalized spectral response of the three types of colour sensitivity rods in the human eye (source Dr. Roger N. Clark, clarkvision.com/articles/color.of.nebulae.and.interstellar.dust/).



Red 27
Green 49
Blue 7
HTML #1b3107

Red 108
Green 196
Blue 28
HTML #6cc41c

Figure 4 — The colour as calculated is shown on the left, while each colour channel has been multiplied by 4 on the right to brighten the green while keeping the same hue for presentation purposes.

The last part of the mystery has to do with the fact that the nebula emission is not broad band, but instead a sequence of narrow emission lines from hydrogen and oxygen. Of the three largest are the lines that we used in the previous paragraph: Hα at 650 ηm, OIII at 500 ηm, and Hα at about 480 ηm, the Hα emission is by far the largest of the three. From our previous discussion, remember that the nebula has relative emission line strengths of R=1, G=0.6, and B=0.2. These are detected by the imaging camera, which of course also has a spectral response. My Zwo ASI2600MC Pro is typical and has the following spectral response.

Each of the colour channels has a wide bandwidth with OIII emission picked up by both the green and blue channels. Both the green and blue channels are also sensitive to Hα emission. The incoming narrow-band signals are weighted by the camera sensitivity, but again since Hα dominates the emitted spectrum, the red channel is substantially larger than green or blue. Finally this colour is displayed on a computer monitor that also emits three narrow-band wavelengths. An sRGB monitor is defined to emit red at 612 ηm, green at 549 ηm, and blue at 465 ηm at approximately equal levels, but different devices emit at slightly different wavelengths. Here are some typical spectral outputs for several different display systems.

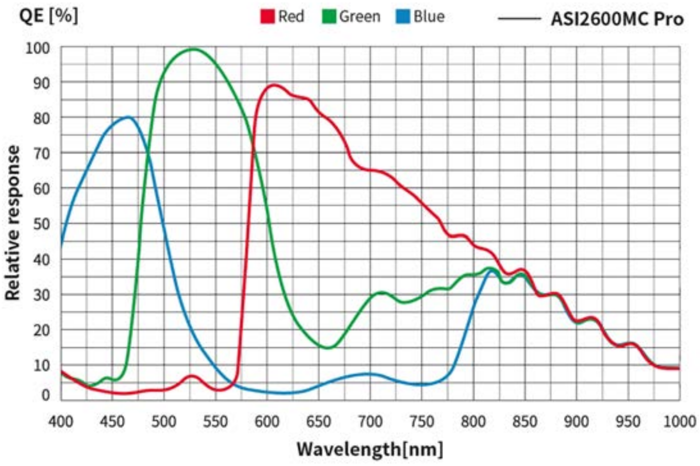


Figure 5 — Typical spectral response of an OSC astrocam.

Note that the peak wavelengths of each colour channel do not line up with the peak wavelengths of the emitted signal, so the RGB values recorded are remapped to the peaks of the monitor output. For the laptop or iPad displays shown in Figure 6, the peak in each colour band is as follows: R=580 ηm, G=525 ηm, and B=450 ηm. After calibrating a monitor, the three emission peaks are approximately equal in level to produce a proper white balance, but the emission peaks do not correspond to the recorded data from narrow-band sources such as Hα regions. This wavelength shift, particularly in the red part of the spectrum, completely changes the colour of the displayed image as the red light is shifted to an area of the spectrum where the eye is much more sensitive to light. Indeed the shift from 650 ηm to 580 ηm increases the eye's sensitivity by over 8 times, giving us those pretty red nebulae.

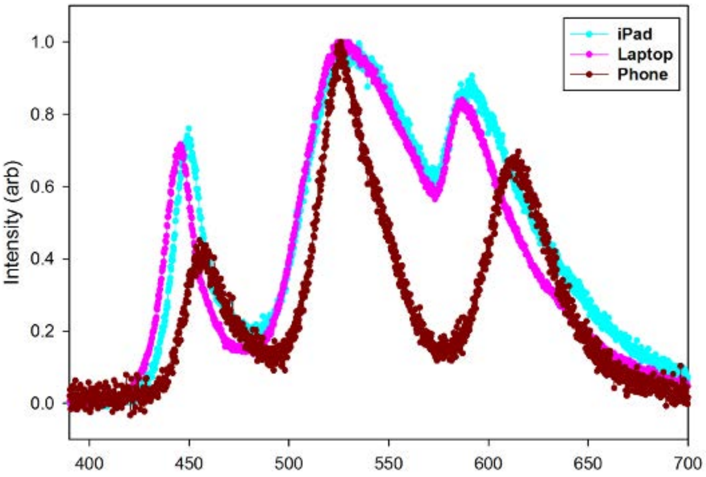


Figure 6 — Typical LED monitor tablet and cell phone output spectra.

When we properly colour-calibrate our data, we get values for red, green, and blue that may be an accurate indication of the emitted spectral levels, but because of the frequency shift caused by our monitors and print processes, this produces anything but *true colour* as seen by the human eye.

All this said, I will continue to produce red nebulae shots and galaxies with red Hα regions because they look more pleasing to my eye than green. But I won't refer to them as *true colour* images.

Remember, this column will be based on your questions so keep them coming. You can send them to me at b.macdonald@ns.sympatico.ca. Please put "IC" as the first two letters in the topic so my email filters will sort the questions. ✶

Blair MacDonald is an electrical technologist running a research group at an Atlantic Canadian company specializing in digital signal processing and electrical design. He's been an RASC member for 20 years and has been interested in astrophotography and image processing for about 15 years.

John Percy's Universe

Reflections on Undergraduate Astronomy Education

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

I stopped teaching formal classes when I "retired" in 2007, though I still supervise undergraduate research projects, in part to keep in touch with students. However, I continue to follow with interest the undergraduate and graduate course and program developments in my department. At a more general level, I serve on my university's President's Teaching Academy, which wrestles with the larger issues in university education. The following reflections were motivated by the annual meeting that the academy has with the President and the Provost, to discuss these larger issues, and by my department's ongoing commitment to further enhance and improve its undergraduate teaching.

These are challenging times for undergraduate education. There are overarching problems such as inequality, democracy, the environment, and climate change. There's the need for students to learn to distinguish between information, misinformation, and disinformation. Students need to learn how to address these positively through polite discourse, debate, and action. And how can teachers and students make the most positive and effective use of technologies such as AI? Students' mental health is declining, in part because they have lived and studied through a pandemic. We must somehow provide meaningful mentorship and support public funding of universities and student tuition revenue have both been cut and then frozen, while demand for university education (including astronomy) remains high. Many costs have skyrocketed since the pandemic, especially for repairs, renovations, and new buildings. My own department's building is a perfect example.

When I started in 1967, professors received little or no training in teaching, supervision, and mentorship, other than what had been done to them as students. I am happy to say that things have improved—somewhat. Effective teaching is encouraged and supported through workshops and conferences, and recognized through salary increases and by awards. An interesting development has been to create separate faculty teaching-stream positions, with (almost) the same benefits as research-stream positions. This has helped to create a population of professors who are expert at teaching their students, and also at helping to develop teaching excellence among their colleagues, especially younger ones. It has also, in a sense, "ghettoized" the teaching aspects of the university's mission, but there are lots of teaching-award-winning professors in the research stream.

The Undergraduate Curriculum

My department's curriculum is typical of other large research universities in North America; see (1) for an overview and links. There is a large stand-alone course in Introductory Astronomy for "non-science" students, generically "astro 101," though we divide it into half-courses—astro 101/201—in planets and stars, and galaxies and cosmology. Each enrols over 1000 in the winter—they maxed at about 1500 each during the pandemic—plus 150 or more in the summer. Then there are major and specialist programs, with courses for "science students." Enrolments in these programs and courses have doubled in the last five years. And there are a few topical stand-alone courses such as a very popular (enrolment above 400) Astrobiology course, sometimes an Indigenous or Cultural Astronomy course, and an interdisciplinary course with St. Michael's College on "The Bible and the Big Bang." For astro 101/201, there are well-established textbooks and other resources, lots of research on best practices, and small-group tutorials.

Figure 1 — A cheerful work party of RASC and University of Toronto astronomers, completing the installation of a half-metre automated telescope at the RASC's E.C. Carr Observatory. Source: Jeff Booth, RASC.

When I was an undergraduate, there was a single astronomy program—Astronomy and Physics. Not all students in this program went on to graduate school in astronomy. Many went into related disciplines and careers, including school teaching. The introduction of a separate major program, less intense and more flexible, was partly to cater to these students. But there are also students who take the major program because they also want to take programs in math, physics, or other subjects as well, and still intend to go on to graduate school and careers in astronomy. There's a small "minor" program for STEM students who want a small dose of astronomy. We try to be flexible and meet students' needs.

Curriculum Renewal

As part of a university-wide process, my department is currently assessing and revitalizing its curriculum, starting with programs, and continuing with courses, one by one. Building a program is much like building a house. It's made of parts—courses—which should fit together, starting with a foundation and building, level by level, to a peak. A foundation course, introduced many decades ago, is the First-Year Seminar (in our case labelled astro 198/199) in which students learn and use academic skills that they will need throughout their program. The problem is that these are small-enrolment classes, and there are not spaces for every student. In building a program, the "peak" is often a "capstone course" in which students integrate their knowledge and skills from across their program, often through an original research project.

Individual courses therefore need to provide well-defined outcomes—knowledge, skills, applications, and attitudes. They should fit with other courses, without excessive overlap. They should be pedagogically effective. And they should meet the needs and expectations of students, the university, and society.

One strategy is to collaborate with other departments. We have always collaborated with Physics and Mathematics, at least in principle, since we use their courses in our programs, or as prerequisites for our courses. In the last few years, we have also collaborated with the Department of Statistics. We have two joint faculty members, and occasional joint graduate courses and seminars. Our undergraduates can take statistics courses to help build their expertise in data sciences, which is an important part of astronomy and other STEM disciplines today.

In my undergraduate days, there were no research opportunities as part of our program. Since then, we created astro 425—Research Topic in Astronomy , a full-course research project, and astro 424, a half-course version (but see below). My department would like every specialist student to have not just one but two or more research experiences, to make them competitive for graduate school, and to give them additional research skills so they can succeed there. There are research opportunities other than astro 425: the summer undergraduate research program (SURP); the Research Opportunity Program (astro 299) in second year, which provides course credit; the work-study program, which provides a salary, among others. The problem in every case is that demand far exceeds supply; I typically have 30+ applicants for my one work-study-position. In the last five years, the enrolment in astro 424/425 has tripled to almost 50. There are simply not enough supervisors. One strategy has been to make astro 424 into a literature study course, rather than a research project course, and assign one faculty member to oversee it. But even astro 425 is so large that there may need to be grade-point "filters" to restrict it to the best students.

Students feel better when they belong—including to their academic department and discipline. When I was in fourth year, we eight program students spent Wednesdays at the Dunlap Observatory, where we took classes, attended the weekly colloquium, and mixed with the faculty and graduate students. That's where we got to know our inspiring professors. Nowadays, many program students have not been integrated into the department. Student numbers are larger, and our students' academic programs and interests are diverse. This is one of many "student experience" challenges that we must deal with today.

There should be more than courses and programs in a student's undergraduate experience, including clubs, and course-related employment in winter or summer. My university has an active Astronomy Students Union, and ASX—the Astronomy and Space Exploration Society. In my day, there was only the more general Math & Physics Society. Upper-year students can also work as teaching assistants for the large introductory courses, and get training and experience in teaching, and a good salary. Or they may take part in our many outreach activities for members of the public, young and old.

A Cross-Over Course

Astro 101/201 was a dead-end course. But there were an increasing number of the thousands of students who took it who were interested in going further and actually *doing* astronomy, like the science-stream students did. After all, there is no clear division into "science students" and "non-science students"; many students are interested in both. A few years ago, my colleague, Michael Reid, led the development of astro 301—Observational Astronomy. In this class of up to 50 students, students learn what astronomers do by doing themselves—imaging and data collection and analysis in a hands-on way. It can provide a capstone course for a short Minor Program in astronomy for "non-science" students that is presently being considered and developed.

An Exciting Partnership with the RASC

And what about facilities for undergraduate observation and research? For 50 years, my department has had a 0.2-m refractor and a 0.4-m reflector on campus, plus telescopes at the Dunlap Observatory until 2008, but sky conditions are far from perfect. These telescopes are now largely used for outreach. There exists lots of archival data, of course, but nothing is more satisfying to students than data they obtain themselves. (In my day, it was taking your own photo of the Moon!). Last year, my department installed an automated half-metre telescope at the RASC Toronto Centre's E.C. Carr Observatory, at a relatively dark-sky site in the Blue Mountains northwest of Toronto (Figure 1). Students can operate this telescope remotely, from campus (or elsewhere) or they can operate the telescope on-site, in the old-fashioned way. There is on-site sleeping accommodation for a dozen or so observers. This new facility will provide enhanced opportunities for students to do imaging and research, in instrumentation or research or observation courses, as well as for projects. It will continue our partnership with the RASC, which goes back for more than a century.

Have We Progressed?

In 1958 when I started, university participation rates were low—but rising. Admission was based on a standardized provincial exam. Student diversity was minimal. Teaching was by lecture and cookbook lab (one year, my wife had 39 hours of classes a week). Year-end marks were based on exams; labs, essays, etc. counted for little or nothing. Largest enrolment was in general (three-year) arts, with many of those students bound for school teaching.

Now, as I have outlined above, much has changed, and improved. Student diversity is high, so equity, diversity, and inclusion need to be high priorities. Government support is unfortunately at its lowest. Luckily, my administrative colleagues, past and present, have done an excellent job of leadership, and promoting our cause. Astronomy, and astronomy education is still alive and well at the University of Toronto. It's still an exciting time to be an astronomer—or astronomy student.

Acknowledgements

I thank my colleague, Professor Michael Reid, for his inspiration and his helpful comments on a draft of this paper. Thanks also to Jeff Booth for Figure 1, and to Andrew Apong for providing me with recent course enrolments. ✶

Endnotes

1 astro.utoronto.ca/prospective-students

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

Skyward

The 2024 Adirondack Astronomy Retreat

by David Levy, Kingston & Montréal Centre

Come gentle night, come loving black-brow'd night,
Give me my Romeo, and when I shall die,
Take him and cut him out in little stars,
And he will make the face of heaven so fine
That all the world will be in love with night,
And pay no worship to the garish sun.

For the first time in the almost two years since my wife Wendee died in September 2022, at this year's Adirondack Astronomy Retreat, at last I felt that life was returning to my bones. We did not have the best weather, with only one clear night, but what a night! And what a summer experience.

The primary reason for this change of spirit happened on the AAR's first day. After spending the last year refurbishing Minerva, my primary telescope, Ed Baker, with assistance from Mark Zdiarski, arrived with this truly beautiful and magnificent little telescope that he had carefully refurbished with care and with love, and with which I completed six hours of visual

Figure 1 — Minerva, the author's primary telescope.

Figure 2 — Overlooking the pond at Twin Valleys campsite

comet hunting on the single clear night. I was so moved by my first look at this telescope that I interrupted the closing question of Ed Genther's lecture to thank Ed Baker and offer to him the few Shakespearean lines that begin this article. The night prior was not clear but there were clear spots through which David Rossetter and I got a good first light on Jupiter. The first light, in 1967, I could not see Jupiter, my favourite planet, but I did catch the Moon. It was satisfying to have, at last, a proper first light for Minerva.

This little telescope is 57 years old. It arrived on 1967 May 18, the day after I was almost expelled from the Montréal Centre of The Royal Astronomical Society of Canada. I have used it for each one of those 57 years.

The other reason is the people who gather each year. They are the most intelligent people I have ever known. Their only difficulty is that except for two, they are all in my generation or the one following. Those two, Sophie and Mark Scattolin, are just beginning their lives but they still have a sense of wonder about them, and about the night sky.

"In the fall," Sophie writes, "I will be starting a master's in environment and sustainable development at the Université de Montréal. My specialization within my program is biodiversity management, as I am quite passionate about conserving biodiversity. As for my plans after this program, I have none for now; I'm figuring it out as I go." Sophie's brother Marc also wrote. "I am involved in an honours project at Concordia University in Montréal. Ideally, I would get a job in natural language processing." This field belongs to the challenging field of artificial intelligence. Sophie, please keep figuring it out as you go. It took me half a century to figure out my own professional field in relating my passion for the night sky to the richness of English literature. And Marc, may your work in AI bring this difficult field of study to a happier and more productive state.

There is a third reason for the healing magic of our retreats, and that is the Twin Valleys campsite itself. There are places on Earth that are tied for its beauty, and maybe some that are more spectacular. But for the tranquility and peace of the site that hosts our Adirondack Astronomy Retreat, there is no place as stunning. May it forever let us celebrate the stars. ✶

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.*

Dish on the Cosmos

A Bad Neighbourhood for Star Formation

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

The supermassive black hole Sagittarius (Sgr) A* lies at the centre of our galaxy. With a mass 4 million times that of our Sun, it is the most massive black hole in our galaxy, and its gargantuan presence shapes the surrounding environment. Recent radio observations from the Event Horizon Telescope have revealed the material near the black hole, highlighting the shadow of the event horizon. However, the discovery and early characterization of this black hole relied on studying stars in orbit around Sgr A*. The 2020 Nobel Prize in physics was awarded for decades of careful measurement of stellar orbits, with the key observations coming from a star called S2 (Figure 1). S2 orbits the black hole on an orbit with a size of 970 au, where 1 au is the distance from Earth to the Sun. This is a small distance cosmically with the typical separation between stars being closer to 100,000 au. This tight orbit, with a 16-year period, showed that S2 was orbiting around an object with a mass of 4 million solar masses, but with no visible light being emitted. Despite the best attempts of contrarian theoretical studies, we are unable to come up with any other explanation other than this must be a massive black hole. While S2 was key to this determination, the star itself presents another question: how did S2 get there?

The reason why S2 is a thought-provoking object is because it is a massive blue star, about 15 times that of the Sun. Massive stars are luminous, which makes them easy to observe even through the dense clouds of dust that block the light from the centre of the galaxy. That brightness comes with a cost in terms of stellar lifetime: such massive stars have lifetimes that are 0.1% that of the Sun. A massive star must have formed relatively nearby, which raises two possibilities. Either S2 formed quite close to Sgr A* and has been in roughly similar conditions since its formation, or it formed farther away and has migrated close to the black hole. Both ideas have their merits and will give us insight into the lives of stars as they progress in the neighbourhood of the black hole.

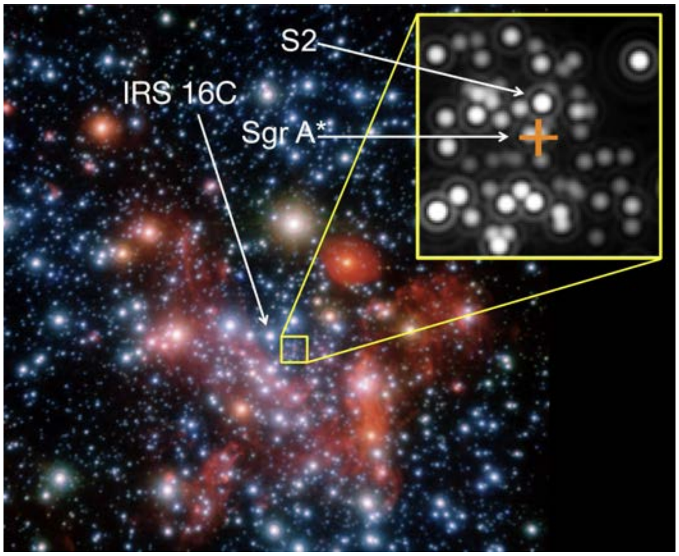


Figure 1 — The nuclear star cluster in the Milky Way viewed in the infrared. The star, S2, is a young massive star found in a tight orbit around the black hole Sgr A. Since S2 must be relatively young, there are several open questions as to how it came to be so close to a supermassive black hole. Image credit: ESO/MPE/S. Gillessen et al.*

The most natural explanation is that S2 formed from gas that was accreting into the black hole. If the gas is relatively cool and dense, then it would normally be possible for the self-gravity of the gas to cause the cloud to collapse and form a population of stars. However, the presence of the black hole changes the equation significantly through the effects of tidal forces. Tides arise around any massive object from the "shape" of the universal law of gravitation. The shape of the gravitational force is such that the force of gravity gets stronger as you get closer to an object. An object near a black hole will experience different gravitational forces on one side of the object vs the other simply because the near side of the object is closer to the black hole than the far side. This difference in force pulls harder on the near side of the object, and if the object's internal forces are not strong enough, these tides will end up ripping the object apart.

Tidal forces are a generic phenomenon near any massive object, not just black holes but also stars and planets. The ocean tides arise from the tidal effects of the Moon on the Earth. The side of the Earth that is closest to the Moon will feel a stronger gravitational pull compared to the centre of the Earth. This pulls that part of the Earth upward, and since the water is the part of the Earth that can move easily, the oceans rise in the direction that faces the Moon leading to a high tide. There is also a high tide on the side of Earth opposite the Moon because the gravitational forces pull on the centre of the Earth more than the far side, pulling the planet away from the water on that side, causing an apparent rise. The gravity of the Earth is relatively strong, which prevents the planet from being pulled apart. The gravitational forces in star-forming molecular clouds are tenuous. The tidal effects of the massive black hole should suppress star formation, pulling apart any collapsing gas before it can form into a star like S2.

The alternative perspective is that S2 formed in a more benign environment, far enough away from Sgr A* that the effects of tides were minimal, and gas could collapse into stars as expected. Then the stars would migrate down close to the black hole and get collected there on small orbits. We see evidence for this process happening in other star clusters, where gravitational encounters between the crowd of stars tend to fling low-mass stars into the outskirts of the cluster, while the massive stars sink into small orbits in the cluster centre. This would naturally explain how massive stars like S2 get concentrated near the black hole. The problem with this theory is that the density of stars in the region is not high enough. Thus, stars do not have stellar encounters frequently enough to get a star like S2 to migrate down to a tight orbit around Sgr A*. If the star were less massive with a longer lifetime, it becomes plausible, but the migration process just isn't fast enough to get the star into place before it dies.

We have two conflicting pictures as to how the star S2 could get into place without a clear resolution. Some hints come from seeking out other indicators of star formation in the vicinity. One study recently used the Atacama Large Millimetre/submillimetre Array (ALMA) in Chile. In studying the cold gas in the region, the ALMA data revealed the signatures of outflowing gas from small regions that could be protostars. Gas outflows are always expected as a natural consequence when a star forms, as the angular momentum of the collected material twists up magnetic field lines, leading to ejections of gas (see my February 2018 column for more on this). These outflows seem to indicate that stars are indeed forming in the region affected by tides. We also see evidence from silicon-monoxide maser emission that is also usually associated with the hot, dense molecules that are usually found with star formation. Normally, this would resolve the question and show that the stars are forming where we don't expect them. There remain some confounding factors that could arise from the black hole. For example, the SiO emission could be from shock waves driven in the gas flows and the outflows might be misinterpreting the data. Hence, we continue to have a bit of a mystery here: how do the stars that are found in the nuclear cluster form? Continued observations with ALMA, JWST, and other radio telescopes will keep peering into this mystery.

Read more: arxiv.org/abs/1711.10573 ✶

Erik Rosolowsky is a professor of physics at the University of Alberta where he researches how star formation influences nearby galaxies. He completes this work using radio and millimetre-wave telescopes, computer simulations, and dangerous amounts of coffee.

Blast from the Past!

Compiled by James Edgar
james@jamesedgar.ca

THE EFFECT OF ATMOSPHERIC PRESSURE UPON THE EARTH'S SURFACE

by F. Napier Denison

[This article first appeared in the 1908 Journal, *Vol. 2, p. 293.]*

The object of the following notes is to bring before the members of the Royal Astronomical Society of Canada all account of certain earth movements observed on the Pacific Coast, which it is hoped may tend to explain the cause of some terrestrial phenomena not fully understood and also lead to a further investigation of the subject.

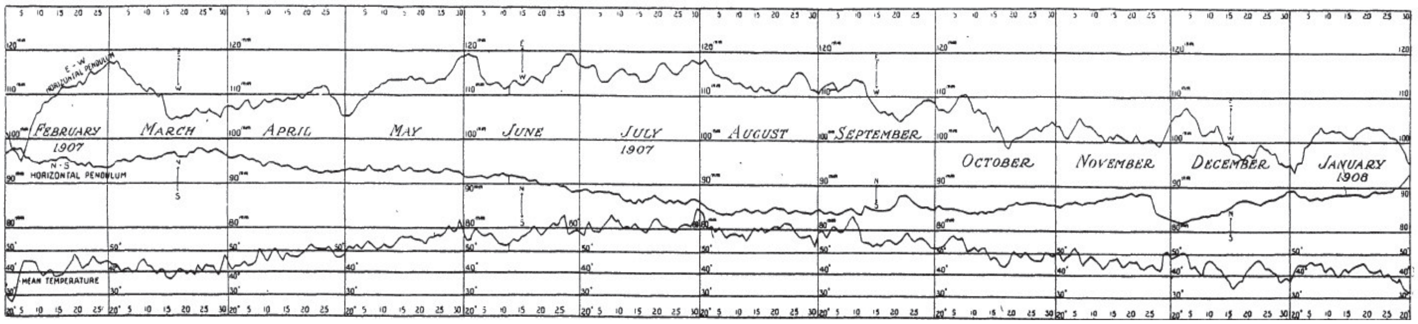
In the autumn of 1898 a Milne Horizontal Pendulum was installed at Victoria, B.C., in connection with our Meteorological Service, and from then to the present time continuous photographic records have been obtained from it. Apart from the shorter period undulations as earthquakes, tremors, etc., so graphically shown upon these traces, the writer became intensely interested in observing remarkable "wanderings" of the Horizontal Pendulum, first in one direction then in the other, often lasting for days, and sometimes sufficient to necessitate adjusting the levelling screw to keep the free end of the boom on the centre of the photographic paper. Thinking these movements were caused by changes of atmospheric pressure, the writer has kept a continuous daily record of these "wanderings," large and small, of the pendulum, and for several years beginning with January, 1899, he has tabulated and plotted a curve of these movements. By studying this curve in conjunction with the Synoptic Weather Charts of the Pacific Slope for the same period, the following information was obtained:–

When the barometer is low over the Pacific Slope from British Columbia to California, and low over the adjacent ocean, the Horizontal Pendulum is deflected eastward. When the barometer is high off the Coast and low over the Pacific Slope, the movement is towards the west.

The greatest movements occur during the stormy winter months, and the least during the summer type of almost continuous fine weather. These movements often commence some hours before the local barometer indicates an approaching change of air pressure.

In June 1901, a paper by the writer entitled "The Seismograph as a Sensitive Barometer" was read at a meeting of the Royal Meteorological Society, London, and in the Autumn of the same year he had the privilege of personally presenting further data on the same subject at the British Association meeting held at Glasgow, and also had the pleasure of laying these plotted curves before Sir George Darwin at Cambridge. Sir George Darwin was surprised to observe such large movements of the horizontal pendulum under changes. of air

EAST-WEST AND NORTH-SOUTH HORIZONTAL PENDULUM MOVEMENTS AT VICTORIA, B.C., 1907-1908



pressure, and the small effect due to the rise and fall of the ocean tides in this vicinity. He advised me to obtain more data, and to install a horizontal pendulum to swing North–South in order to study this direction of tilting along with the present East–West pendulum and the general changes of atmospheric pressure.

Although the writer has succeeded in keeping a continuous record of the movements of the East–West pendulum, it was not until January 1907, he was enabled to personally construct a simple form of Milne Pendulum and set it up (to swing North–South) in the basement of the Post Office Building upon the solid rock, and about 500 feet distant from the East–West pendulum. From then to the present time most interesting results have been obtained from these instruments.

I take pleasure in bringing before this Society plotted curves showing the daily movements of both pendulums and the mean daily temperature from February 1st, 1907, to January 31st, 1908.

The vertical lines indicate 24-hour periods and the horizontal ones millimetres; the upper curve represents the movements of the East–West pendulum whose period of vibration is 1.5 seconds and its angular value 0·76. The intermediate curve shows the movements of the North–South pendulum which, having only a 10-second period of vibration, is not so sensitive as the East–West instrument. The lower curve gives the mean daily temperature.

In studying these curves one cannot fail to observe a remarkable correspondence between the two pendulum plottings, that is, when the East–West pendulum swings west, the North–South one moves northward, and when the easterly swing is pronounced the other instrument travels to the southward.

Before describing the distribution of barometric pressure prevailing during several typical cases shown in these curves, the writer has found that when the barometric pressure is greatest from California northeastward to the Canadian Prairie Provinces, and low over the North Pacific Coast and British Columbia, the East–West pendulum moves east and the North–South instrument south.

When a vast area of high barometric pressure spreads southeasterly across Alaska to British Columbia and low barometric pressure prevails to the southward of this province, we find the East–West pendulum swings to the west, and the North–South one to the north, that is to say, both pendulums move in the direction of the greatest load on the earth's surface due to differences of atmospheric pressure.

The following are a few examples to more clearly explain this interesting phenomenon:–

Beginning with February 1st, 1907, and turning to the plotted curve already described, you will observe a rapid westerly swing amounting to 6 millimetres or 3″ in six days, while the other pendulum, which is not so sensitive, moved one millimetre towards the north. By turning to the Victoria Weather Charts for this period we find on the 1st of February a vast anticyclonic area (centre 31 inches) and cold wave over Alaska, while off the Coast of Vancouver Island there was an important low pressure area with a centre less than 29.80 inches. During the 2nd and 3rd the centre of the Northern High (over thirty-one inches) hovered over Alaska and the Yukon Territory, while the ocean cyclonic area spread towards the Coast where it caused an easterly gale. On the morning of the 6th the air pressure rapidly increased over the States of Oregon and Washington, and the Northern High area spread southeastward across the Rocky Mountains, giving place to low barometric pressure. This change caused the commencement of the remarkable easterly swing of 11 millimetres in four days, and a corresponding southerly movement of the other pendulum. From this date to the close of the month there was almost a continuance of high barometric pressure extending from the south and east of Vancouver Island, while to the west and north low pressure prevailed. The plotted curves for this period show a marked easterly movement and a moderate southerly swing.

In the month of March we find from the 2nd to the 17th a remarkable tendency for one pendulum to swing west and the other north. During this period a number of low barometer areas from the Pacific spread inland across California, while either over Vancouver Island or to the north and west of this the barometer was comparatively high and northerly winds prevailed.

A good illustration of a marked southerly movement is to be found on November 25th, 1907, when high barometric pressure prevailed from California eastward, and an important cyclonic area spread rapidly eastward to the north of Vancouver Island, this caused a steep barometric gradient over this province.

During the first few days of December there is a pronounced easterly and corresponding southerly swing, followed at the close of the month by a remarkable approach of the two curves, which is again even more pronounced at the close of January, 1908. During the latter movement a vast high barometer area and cold wave spread southeastward from Alaska. The mean daily temperature curve for this period shows a remarkable fall in temperature over this portion of the Province.

The mean temperature curve is given for the year under discussion to show the correspondence between it and the movements of the East–West pendulum movements, that is, when the former indicates a rising temperature, the latter, either at the time or shortly after, swings towards the eastward, and with a falling temperature towards the westward. A study of the synoptic weather charts shows that is what might be expected.

The following is a summary of information derived from the study of the two pendulums already described: –

At Victoria, situated upon the southern end of Vancouver Island, the movements of these pendulums demonstrate a tilting of the earth's surface in the direction where the pressure of the atmosphere is greatest.

These pendulums often commence and continue swinging in a certain direction hours, and sometimes more than a day, before the barometers along the Pacific Coast indicate the approach of great cyclonic or anti-cyclonic areas from the ocean.

These pendular movements are greatest during the stormy months of winter and least throughout the summer when the changes of barometric pressure are small throughout the Pacific Slope.

To arrive at the true connection between pendulum movements and air pressure changes, the latter must be studied with charts covering areas of from one to two thousand miles in extent, otherwise the local atmospheric conditions may appear to cause a tilting effect contrary to that indicated by the pendulums.

The loading of the Pacific Slope during the winter months with heavy rains on the lower lands and great quantities of snow upon the great mountain ranges of the interior may account for a small proportion of the easterly tilting. The curves under discussion clearly demonstrate, however, that pronounced westerly tiltings occur during the winter months, when vast areas of high pressure hover to the westward of this. The curve for the first half of March 1907, is a good illustration of this action.

From a careful perusal of the East–West Milne photographic record, the diurnal movement is found to be well marked upon fine days, and either absent or nearly so during overcast or rainy weather.

The loading effect upon the Coast due to tidal action is only noticeable upon the records, chiefly during the summer months, when little differences of barometric pressure prevail, and when extreme tides occur. During unsettled weather, when great differences of air pressure are taking place over the Pacific Slope, the tidal effect on the pendulum is completely masked by the greater deflecting force.

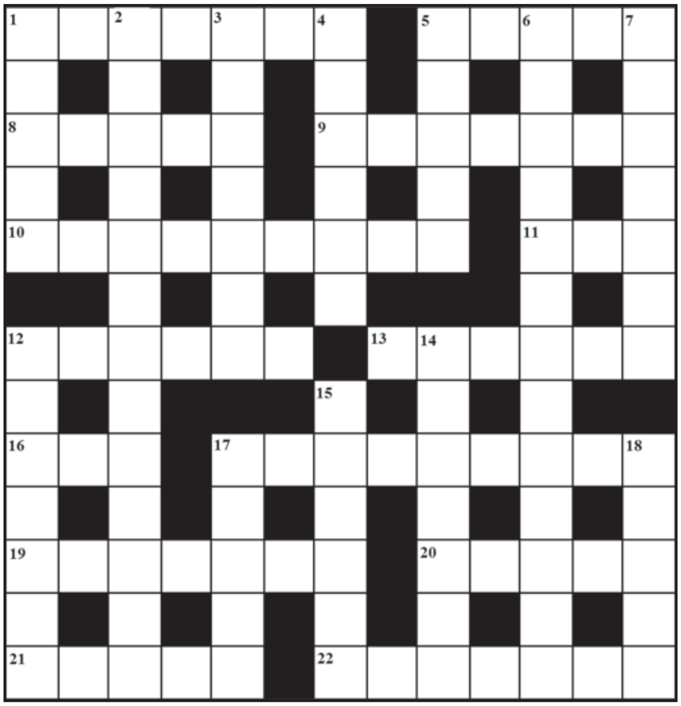
In conclusion, it is the writer's intention of increasing the value of future local observations of this phenomenon by installing another horizontal pendulum at the city of Vancouver, and through the courtesy of the Grand Trunk Pacific engineers at Prince Rupert, another under their supervision at that northern town.

It is hoped the above notes may throw further light upon a subject so ably treated by Sir George Darwin, Professor Milne and others, and may lead to a more complete study of this most interesting subject in other portions of the scientific world. ✶

Francis "Frank" Napier Denison, 1866 April 19–1940 June 24, was a Canadian meteorologist, inventor, seismologist, and astronomer. In the early 20th century he was known to thousands of Victoria's inhabitants as "our weatherman."

Astrocryptic

by Curt Nason



ACROSS

1. Nearest star within approximately ten parsecs (7)
5. Foolhardy victim of Hercules (5)
8. Anticipated observatory found with bottom in ruin (5)
9. Great comet of 1861 knocked Bet back on her ass (7)
10. His effect on interplanetary dust can vary sky. OK? (9)
11. Abbreviated constellation where one might see Vega (3)
12. I hear Montreal players would do this to film at Mont Mégantic (6)
13. Online agreements for New Year's lunar day (6)
16. Norse Mars nominally follows the Moon weekly (3)
17. Night hunter oddly unable to get out from under the bear (3,6)
19. Silently agreeing with the Moon's polar libration (7)
20. Bizarre place within Leo without Regulus (5)
21. Former president was on Pluto's moon first (5)
22. Pythagorean legacy had mother dancing out east (7)

DOWN

1. Our former president studied eclipsing binaries in hypercyclic orbits (5)
2. Comet founder with two PhDs heard why the night sky is dark (6,7)
3. Odd genius has nothing to do with old molten rocks (7)
4. Ptolemy's refiner presented Nagler with a dishevelled suit (2-4)
5. Astronomy for amateurs is half a telescope at McDonald Observatory (5)
6. Out East, bold cultures saw it as beheaded astronomers (6,7)
7. Red supergiants aren't as variable as this one (7)
12. Dragon's eye spun in tale about northern mythology (7)
14. She is in one pile of stars with her husband and daughters (7)
15. Soundly stares at strong photons (6)
17. Scorpion suffered three losses but still killed him (5)
18. A ray of sunshine across a ship (5)

Answers to previous puzzle

Across: 1 ASTRAEA (anag+ea); **5** FLARE (hom); **8** TRACE (anag-r); **9** ALSHAIN (anag); **10** OPHELIA (O+anag+rev); **11** UPSET (up+set); 12 HERTHA (H+anag); **14** GEMINI (G(em+in)I); **17** SPRAY (2 def); **19** ALMANAC (anag); **21** CEPHEUS (cep+he+us); **22** ORONO (Toronto-2T); **23** LISTS (2 def) **25** RESISTS (anag)

Down: 1 ASTROPHYSICAL (anag); 2 TEACHER (anag); **3** ABELL (2 def); **4** ACAMAR (anag); 5 FISSURE (hom); **6** ADAMS (anag); **7** EINSTEIN CROSS (2 def); **13** HUYGENS (2 def); 15 IGNEOUS (an(o)ag); **16** KAISER (2 def); **18** RUPES (anag+s); **19** MOONS (moose, s=n, rev)

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.

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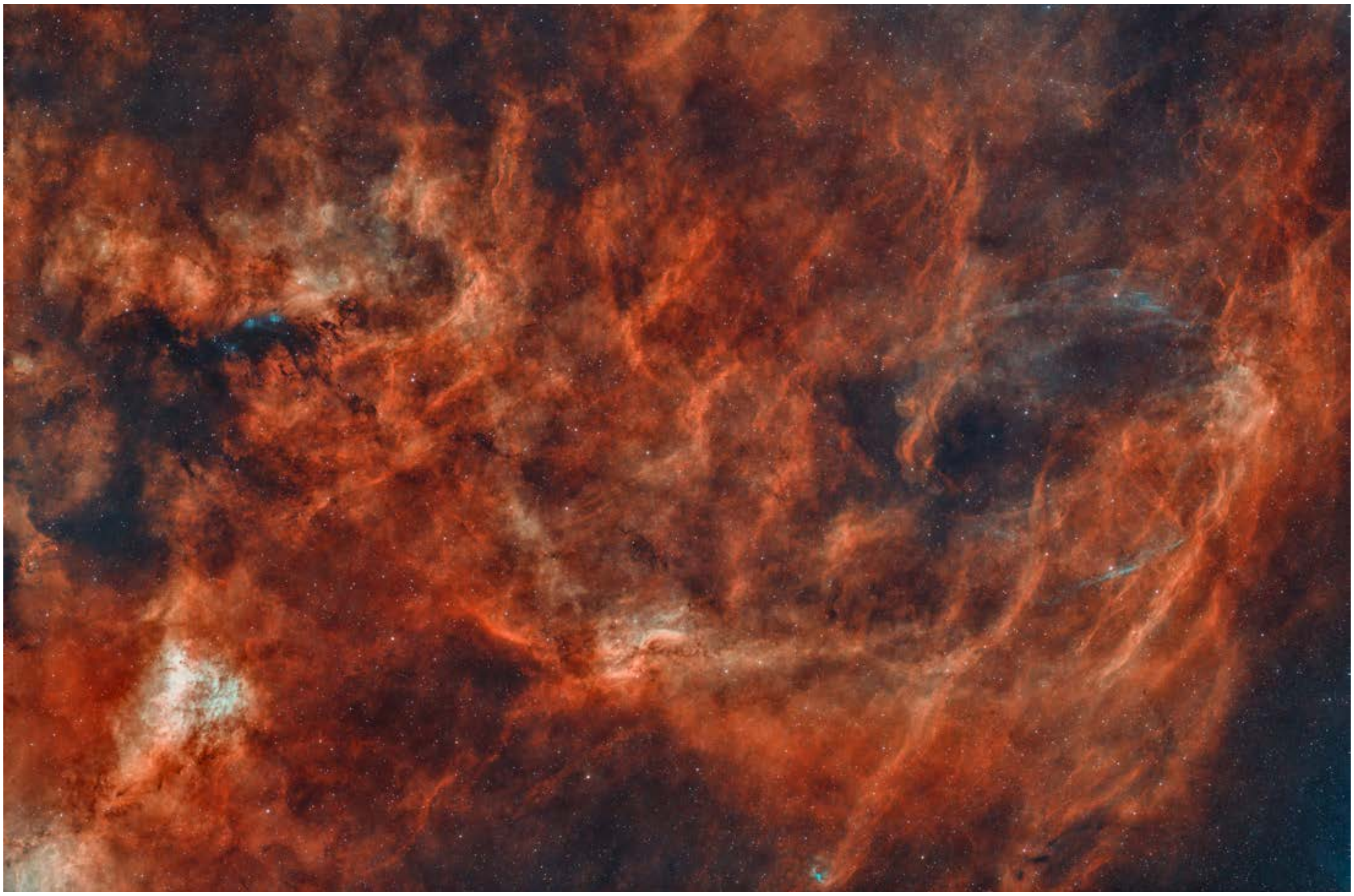
- Sharing knowledge and experience
- Collaboration and fellowship
- Enrichment of our community through diversity
- Discovery through the scientific method

Great Images

by Rob Lyons



"This is a wide-field view of the rich molecular clouds in Cygnus. In this image, we see NGC 6914, the Propeller Nebula, and what appears to be a massive supernova remnant on the right side of the frame," says Rob Lyons, who imaged this from the centre of Vancouver, a Bortle 9 sky. He used a Redcat 51 with an ASI2600MC Pro and Altair Hα/OIII filters plus SII/OIII 4 nm with a ZWO AM3 RC edition for a total integration time of 20 hours of 300-second sub exposures.

Journal

Claudio Oriani imaged the Rosette Nebula found in Monoceros from his backyard in Richmond Hill, Ontario. He used an Explore Scientific ED80 CF APO refractor, with a ZWO ASI533MC pro, and an Optolong L-eXtreme narrowband filter, plus a Starfield 1.0× flattener. Total integration was 69 minutes (23 × 180 seconds). He used an Explore Scientific ED80 CF on a Celestron AVX mount, and a ZWO ASI533MC pro (cooled at –10°C), and guided using an Orion Mini 50-mm finder scope, ZWO ASI224MC, IR-Cut filter, PHD2.