The Journal of The Royal Astronomical Society of Canada

Journal

Le Journal de la Société royale d'astronomie du Canada

PROMOTING ASTRONOMY IN CANADA

February/février 2024
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Charles Smallwood, Amateur Astronomer (Part 2)

Rho My!

Great Images

by Steve Leonard

A winter favourite, the Orion Nebula (M42) shines brightly in this image by Steve Leonard. Steve says he collected three hours of RGB data under the Bortle 9 skies just north of Toronto—without a light pollution filter. "The heavy light pollution forced me to shoot sub-exposures of only 30 seconds, which in the case of Orion, is beneficial because such short sub-exposures help to prevent overexposing the core of the nebula. If you look carefully in the core, you will see the four stars of the Trapezium cluster," he says. Steve used an Astro Tech AT115EDT 4.5" triplet refractor at F5.6 on an EQ6-R mount, N.I.N.A., an ASI 1600MM Pro camera, with Astrodon RGB filters. The final image was processed in Pixinsight.

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Société Royale d'Astronomie du Canada

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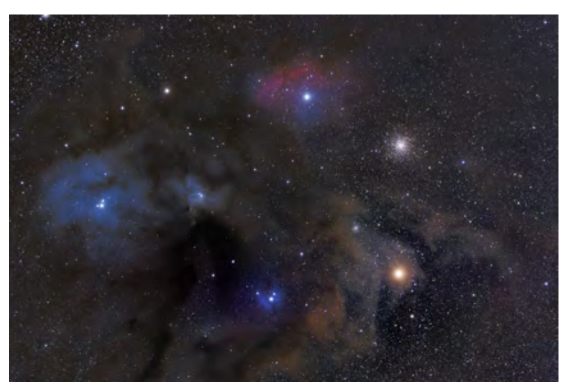

This stunning image of Rho Ophiuchi is brought to us by Adrian Aberdeen. Adrian imaged this during Starfest, an annual star party held by the North York Astronomical Association near Mount Forest, Ontario. "This is a target I've always wanted to capture since starting my astro journey. My first try was an absolute disaster, so when the opportunity presented itself at Starfest 2023, I took it! Although quite low in August, I was able to capture just over 6 hours of data over 2 nights despite the turbulent air/clouds and people walking into my shots," he says. Adrian used an Askar FMA230 Pro Telescope with a ZWO ASI2600MC Pro Camera taking 46×500-s exposures.

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

Who Runs the RASC?

by Michael Watson, President
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The origins of astronomical study in what became Canada are a little obscure, but it is commonly accepted that the first formal meeting of astronomically inclined former Upper Canadians took place at the then Mechanics' Institute building (site of the current Toronto Public Library) on 1868 December 1. Eight individuals, including a maker of optical instruments, a drawer of constellation star patterns, and a U.S. college astronomy lecturer, met and resolved to form "The Toronto Astronomical Club," as the minutes of that meeting show (Albert D. Watson, "Astronomy in Canada," *JRASC, Vol. XI, No. 2*, Feb. 1917; articles.adsabs.harvard.edu/pdf/1917JRASC..11...47W).

From that beginning, what is now The Royal Astronomical Society of Canada (yes, "The" is part of its official name) blossomed into a society that currently consists of 30 Centres that are located in 9 of the 10 provinces plus the Yukon Territory. The oldest Centres, other than Toronto, were established in 1908 (Hamilton), 1910 (Winnipeg and Regina), 1914 (Victoria), and 1918 (Montréal). The most recent addition is the Fraser Valley Centre, which the Society welcomed into its family in 2020. The RASC has about 4,100 dues-paying members and some additional hundreds of family members. The fascinating history of our Society is told in exquisite detail by former national President and Society historian Peter Broughton in his 1994 book *Looking Up – a History of The Royal Astronomical Society of Canada* (www.rasc.ca/sites/default/files/ardocuments/LookingUp.pdf).

Who runs this Canada-wide Society? It's tempting to say that it's the national Board of Directors, of which I am a member. But I don't think that's right, or at least it's not the most important part of the story. *The RASC is really run by volunteers at both the national and Centre levels*. The deep involvement and dedication of Centre volunteers is not surprising, because the Centres are truly the lifeblood of the Society. It is the Centres that hold monthly meetings, organize Centre member and public star parties, go out into their communities and schools to give astronomy talks and courses—to fan the initial sparks of interest that most children have in the sky, and build and operate impressive observatories for both members and the public.

The national Society is a charitable, not-for profit body, which was incorporated in 1890 in Ontario, and was re-incorporated federally in 1968 under its current name. Until 2012, the RASC was governed at the national level by a "National Council" (the "NC"), which consisted of the elected officers of the Society, the chairs of standing committees, and one or more (depending on the number of members of a Centre) National Council Representatives (NCRs) representing each Centre.

In 2012 the Society was required by law to be continued under the new federal *Canada Not-for-Profit Corporations Act*, and this resulted in what I consider to be the most significant change in our governance structure. Under the statute, with which I think all national and Centre directors, councillors, officers and NCRs should be familiar, and under the Society's Articles of Continuance, the RASC is now governed by a Board of Directors consisting of nine directors who are elected by the entire voting membership. The directors serve three-year terms, which are staggered so that three positions become open for election at the Annual General Meeting every year. Any voting member of the Society is eligible to be elected as a director.

There were two other important changes to our governance structure in 2012. First, the NC ceased to be the decision-making body for the Society, which was of course a consequence of the statute requiring a Board of Directors to run every federally incorporated not-for-profit corporation. Second, the officers of the Society—the President, the First and Second Vice-Presidents, the Secretary, and the Treasurer—are all now appointed by the Board of Directors, as is the case for all business corporations in Canada, rather than being elected by the Society's membership as they were previously.

So what has become of the NC, which ran the national affairs of the RASC for more than a century? Under the Society's new By-Law, which was adopted by the membership at the 2013 Annual General Meeting, "The National Council is a consultative and advisory body. It cannot bind the Board to any of its recommendations or decisions." It's also fair to say that for the last decade the NC and its members have quite understandably been somewhat frustrated by the dramatic change in the NC's position within the RASC, and have been trying to determine an appropriate "consultative and advisory" role for itself. I also think it's fair to say that the national Board of Directors has been remiss in not properly and adequately consulting with the NC before making decisions that affect the Centres and their members.

In the last year the national Board has come to realize that it needs to consult much more diligently and consistently with the NC, and to report to the NC more regularly on such vital matters as the Society's finances. The Board has been encouraged to do this and has been assisted in doing so by the NC's talented and dedicated Chair and Vice-Chair, Judy Black of the Halifax Centre and Jim Fairles of the Kitchener-Waterloo Centre, respectively. The plain fact is that the Society cannot function to its full potential without close collaboration between the Board and the NC. This reflects the fact that the NC is best placed to be a conduit of information, ideas, and member needs between the Centres and the national Board. This vital role of the NC also requires that the Centres' National Council Representatives appreciate the importance of their roles in reporting regularly and in detail to their Centre councils and members what is happening at the NC and Board levels. The NC cannot discharge its critical function within the Society without both regular consultation with the Board and a dedicated group of NCRs.

There is another very important group of individuals who perform vital functions for the Society. They are the members of various Society committees, and the editors of the Society's publications, such as the *Observer's Handbook* (James Edgar), the *Journal* of the RASC (Nicole Mortillaro, Editor-in-Chief), the *Observer's Calendar* (Chris Beckett) and others. The committees are numerous, and include Finance, Awards, Inclusivity and Diversity, Astroimaging, Education and Public Outreach, and Information Technology.

Let me make a final observation. All of these members of the Society who perform their valuable functions are volunteers. Apart from modest honororia (and they are quite modest) for the publications editors, no one at any level of the RASC's governance structure is paid anything for their services to the Society and to the Centres. This reflects our members' dedication and the real nature of our much-loved astronomy club.

So who runs the RASC? Volunteers, that's who. ✶

The April 2024 *Journal* deadline for submissions is 2024 February 1.

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

News Notes / En manchette

Compiled by Jay Anderson

Milky Way satellites are only drop-in visitors

Commonly thought to be long-lived satellites of our galaxy, a new study now finds indications that most dwarf galaxies might, in fact, be destroyed soon after their entry into the galactic halo. Thanks to the latest catalogue from ESA's *Gaia* satellite, an international team lead by François Hammer of the l'Observatoire de Paris has demonstrated that dwarf galaxies might be out of equilibrium. The investigation, which studies how the relationship between the internal structure of globular clusters and dwarf galaxies is related to their orbits in the Milky Way halo, opens important questions on the standard cosmological model, particularly on the prevalence of dark matter in our nearest environment.

It has long been assumed that the dwarf galaxies around the Milky Way are ancient satellites that have been orbiting our galaxy for nearly 10 billion years. This longevity required that they contain huge amounts of dark matter to protect them from the enormous tidal effects due to the gravitational pull of our galaxy. It was assumed that the same dark matter caused the large differences observed in the velocities of the stars within these dwarf galaxies.

The latest *Gaia* data has now revealed a completely different view of dwarf galaxy properties. Astronomers from the Paris Observatory-PSL, the Centre National de la Recherche Scientifique (CNRS), and the Leibniz Institute for Astrophysics Potsdam (AIP) were able to date the history of the Milky Way, thanks to the relationship that connects the orbital energy of an object to its epoch of entry into the halo—the time they became first captured by the Milky Way's gravitational field. Objects that arrived early, when the Milky Way was less massive, have lower orbital energies than recent arrivals.

The orbital energies of most dwarf galaxies are, surprisingly, substantially larger than that of the Sagittarius dwarf galaxy that entered the halo five to six billion years ago. This implies that most dwarf galaxies arrived much more recently, less than three billion years ago. Such a recent arrival implies that the nearby dwarfs come from outside the halo, where almost all dwarf galaxies are observed to contain huge reservoirs of neutral gas. The gas-rich galaxies lost their gas when they collided with the hot gas of the galactic halo; the ensuing violence of shocks and turbulence in the process completely changed the dwarf galaxies.

Beyond about 1,000 light-years, almost all dwarf galaxies are gas-rich, while inside that limit, they are largely gas-poor. If the nearby dwarfs arose from the more distant population, they would have been stripped of their gaseous component due to ram pressure as they encountered the gas in the galactic halo. This loss of material would have been accompanied by a lower gravitational force and the stars within the infalling dwarf would then have adopted expanded orbits as they responded to the gravitational decline. While the previously gas-rich dwarf galaxies were dominated by the rotation of gas and stars, when they are transformed into gas-free systems, their gravity becomes balanced by the random motions of their remaining stars. This combined effect of gas loss and gravitational shocks nicely explains the widespread observed velocities of the stars within the dwarf galaxy remnant.

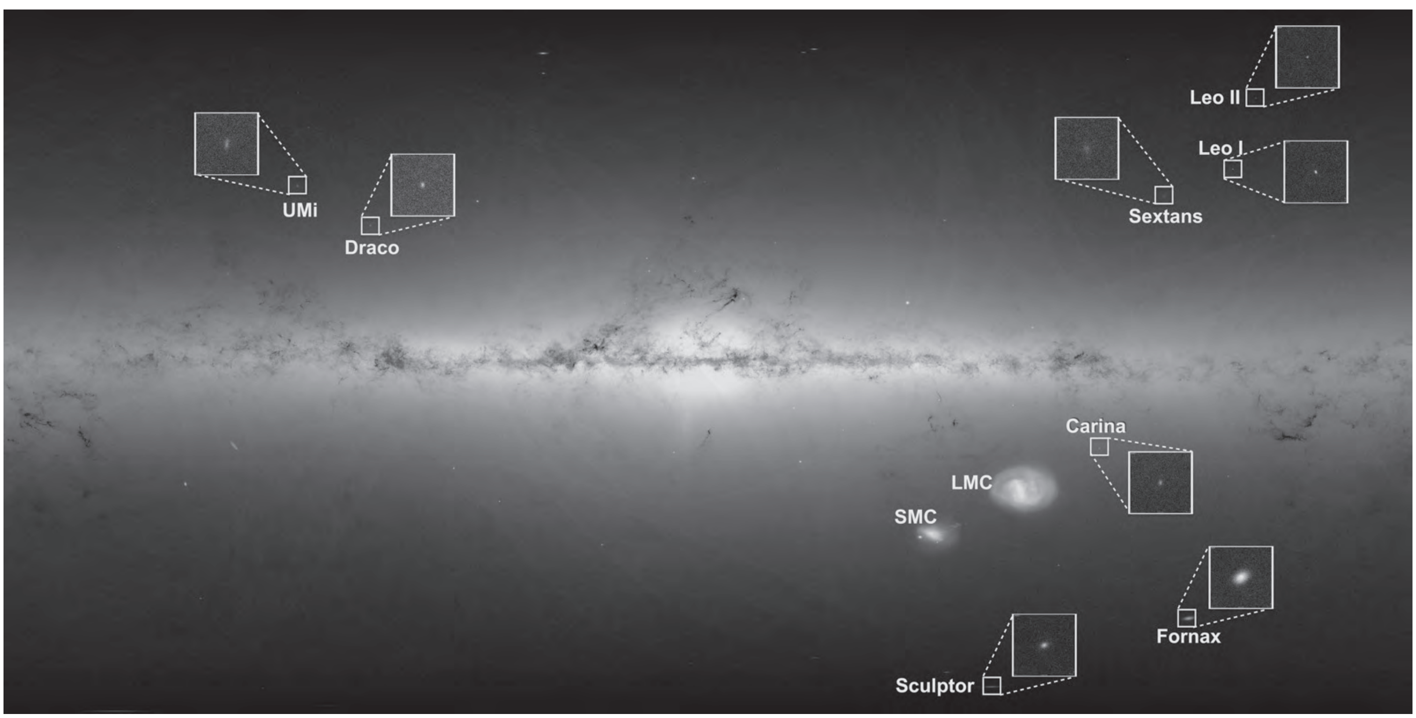


Figure 1 — Dwarf galaxies around the Milky Way. Credit: ESA/Gaia/DPAC

A consequence of this tidal expansion is the gradual evaporation of stars from the dwarf galaxies and from globular clusters. Around 27 percent of low-surface-brightness globular clusters exhibit tidal tails compared to only 3 percent of the high-surface-brightness clusters. The authors predicted that most Milky Way dwarf galaxies would be characterized by an internal velocity distribution modulated by ram-pressure stripping, many stars in their outskirts, and only a small fraction of young stars.

One of the curiosities of this study is the role of dark matter. First, the absence of an equilibrium in the orbital motions prevents any estimation of the dynamical mass of the Milky Way dwarfs and their dark-matter content. Second, while in the previous scenario, dark matter protected the supposed stability of dwarf galaxies, invoking that dark matter becomes rather awkward for systems that are out of balance. In fact, if the dwarf contained a lot of dark matter, it would have stabilized its initial rotating disk of stars, preventing the dwarf's transformation into a galaxy with the random stellar motions that are observed.

Many questions now arise from this study: Where are the many dark-matter-dominated dwarf galaxies that the standard cosmological model expects around the Milky Way? How can we infer the dark matter content of a dwarf galaxy if equilibrium cannot be assumed? What other observations could discriminate between the proposed out-of-equilibrium dwarf galaxies and the classical picture with dark-matter-dominated dwarfs?

Compiled with material provided by the Leibniz Institute for Astrophysics, Potsdam.

Number 30 is not what it seems

In 2023, amateur astronomer Dana Patchick was looking through images from the *Wide-field Infrared Survey Explorer* archive and discovered a diffuse, circular object in the constellation of Cassiopeia. He found this apparent nebula interesting because it was bright in the infrared portion of the spectrum but virtually invisible in visible light. Dana added this item to the database of the Deep Sky Hunters amateur astronomers group, believing it was a planetary nebula (PN)—the quiet remnant of stars in mass similar to the Sun. He named it PA 30, as it was his 30th PN discovery.

However, professional astronomers who picked it up from there realized that this object is far more than it first seemed. It is, they now believe, the remnant of a lost supernova that was observed in 1181—and an extremely rare type at that.

In early August of 1181 CE, a "guest star" appeared in the constellation we now know as Cassiopeia. To the Chinese astronomers of the time, it was known as Chuanshe. They and Japanese astronomers recorded the appearance of the star and stated that it remained visible for 185 days, unmoving

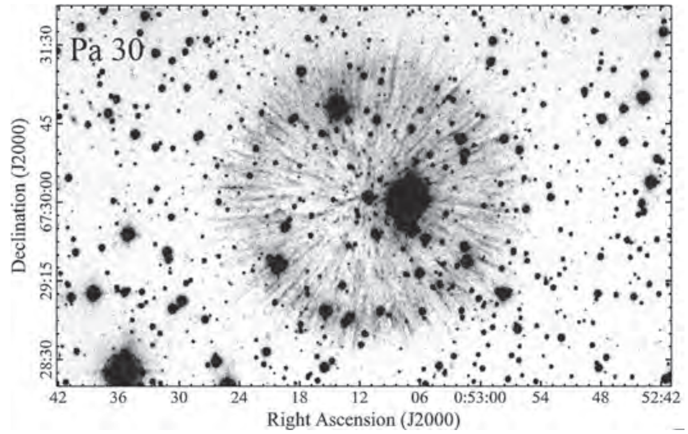


Figure 2 — An SII image of Pa 30 revealing a highly filamentary and radial morphology. Image: Robert A. Fesen, Bradley E. Schaefer, and Dana Patchick (Robert A. Fesen et al 2023 ApJL 945 L4).

with respect to other stars. In 1971, astronomers first realized that this guest star was almost certainly a supernova due to the length of time that it remained visible in the night sky. This made the initial observation an extremely rare report of a historical supernova.

Supernovae are believed to occur, on average, about once per century in galaxies like the Milky Way, but they may be invisible if they are on the far side of the galaxy and obscured by the heavy dust lanes.

Ultimately, this made SN 1181 one of less than a dozen suspected supernovae in recorded history prior to the rise of modern astronomy. And of those, only four had been previously tied to an observational remnant. While astronomers are confident that all these historical supernovae were indeed supernovae, without having an identified remnant, it is impossible to determine the type.

Previously, SN 1181 had been potentially associated with a pulsar known as 3C 58, but attempts at determining the age of this object suggested it was far too old to be associated with the Chinese records.

Although PA 30 was initially flagged as a potential planetary nebula, it quickly became apparent that it was anything but. With planetary nebulae, the central star has shed most of its outer layers, exposing its extremely hot core. The radiation from the core will heat the surrounding nebula (the cast-off atmosphere), giving rise to characteristic emission lines in the spectra. These emission lines were absent in the spectrum of PA 30.

Follow-up observations were conducted in 2016, revealing winds at "unprecedented" speeds of 16,000 km/sec (five percent of the speed of light) from the central star; it is also the hottest known star (>220,000 K). Emission lines from the star were characterized by highly ionized oxygen and carbon atoms but both the central star and nebula lacked signs of hydrogen and helium. The nebula was expanding with speeds of roughly 1,100 km/sec—as much as 100× the expansion speed of a typical planetary nebula.

However, these features don't entirely line up with the expectations for a supernova either. First off, the expansion speed of the nebula was lower than most supernovae ejecta. Second, in most supernovae, hydrogen and helium should still be present, as they are in the outer layer of the stars and are ejected in the explosion.

In 2019, astronomers suggested that the supernova was caused by the merger of two white dwarfs that were both already depleted of these lighter elements as they had released their atmospheres at the end of their main-sequence lifetimes. Specifically, astronomers proposed that PA 30 was the merger of a white dwarf containing a carbon/oxygen atmosphere with one with an oxygen/neon atmosphere, thus creating an exceptionally rare type of supernova known as a Type Iax.

This proposition solves both of the problems. The earlier loss of the atmospheres explains why hydrogen and helium were not present. Type Iax supernovae also do not have as big a bang as other types, explaining the lower-than-anticipated expansion rate.

Digging deeper into the observational data, the study team found that the spectra had higher than anticipated abundances of neon and magnesium, which arise from the fusion of carbon atoms in the stellar interior. This made PA 30 the only known supernova of this type within our galaxy. The early research also suggested that the stellar remnant may have extremely strong magnetic fields that powered the strong winds but more recent modelling has suggested the remnant boasts only a modest magnetic field.

But is PA 30 really associated with SN 1181?

A deeper dive into the historic records conducted by Bradley Schaefer (Louisiana State University) certainly makes it seem likely. Records from China and Japan indicate that the star was "in the Kui lunar lodge," near the "fifth star of Chuanshe," "beside [the constellation of] Ziwei," and "near [the constellation of] Wangliang." Taken together, these descriptions form a series of constraints describing the area in which the supernova remnant should be found. PA 30 falls within it, while the other candidate, 3C 58, does not. Schaefer derives a distance of 2460 ly from *Gaia* data.

Furthermore, Schaeffer's research looked for observations of the central star unwittingly captured in archival photographic plates beginning in 1889. The subsequent discovery of previous images allowed astronomers to piece together the more recent history of how the star had faded. According to the historical records and recent declines in brightness, SN 1181 is believed to have had a peak magnitude between 0 and –1.4, consistent with the rate of fading of PA 30 in more recent times. The date of SN 1181 also matches a backward extrapolation of the current rate of expansion of the remnant.

Ultimately, all signs point to PA 30 as the remnant of SN 1181. This makes it the fifth supernova remnant that has been positively associated with an observation of a supernova within our own galaxy. Its proximity will allow the aftermath to be studied in unprecedented detail for this rare type of supernova.

Chalk up another one for citizen science.

Compiled with material provided by Universe Today

AI helps to build a Sun

Scientists are turning to artificial intelligence (AI) to view the Sun's poles—or at least produce an educated guess of what the Sun's poles might look like, since they've never been observed before.

"The best way to see the solar poles is obviously to send more satellites, but that is very expensive," said Benoit Tremblay, a researcher at the U.S. National Science Foundation (NSF) National Center for Atmospheric Research (NCAR). "By taking the information we do have, we can use AI to create a virtual observatory and give us a pretty good idea of what the poles look like for a fraction of the cost."

The new technique will also help researchers model a 3-D Sun. This will provide a more complete image of our closest star and how its radiation impacts sensitive technologies on Earth like satellites, the power grid, and radio communications.

Currently, observations of the Sun are limited to what is seen by satellites, which are mainly constrained to viewing the star from its equator. The proposed AI observations provide a missing link, enabling scientists to improve our understanding of the Sun's dynamics and connect that knowledge to what we know about other stars.

Tremblay began working on this challenge through the Frontier Development Lab (FDL), a public-private partnership that accelerates AI research. FDL sponsored the event that was essentially an eight-week research sprint that brought academia and industry experts together to tackle interesting science questions. He was assigned to a team tasked with exploring whether AI could be used to generate new perspectives of the Sun from available satellite observations.

To do this, Tremblay and his colleagues turned to neural radiance fields (NeRFs), which are neural networks that take 2-D images and turn them into complex 3-D scenes. Because NeRFs have never been used on extreme ultraviolet (EUV) images of plasma, a type of observation that is useful for studying the solar atmosphere and catching solar flares and eruptions, the researchers had to adapt the networks to match the physical reality of the Sun. They named the result Sun Neural Radiance Fields, or SuNeRFs.

The group trained SuNeRFs on a time series of images captured by three EUV-observing satellites viewing the Sun

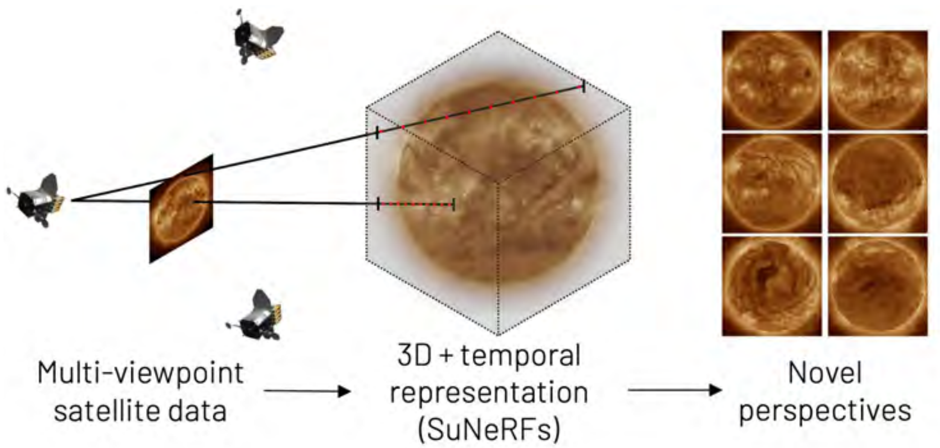


Figure 3 — A visualization of how 2-D satellite images are transformed into 3-D scenes that provide never-before-seen perspectives of the Sun. Image: NCAR & UCAR

from different angles. Once the neural network was able to accurately reconstruct the Sun's past behaviour for areas with satellite coverage, the researchers had a 3-D model of the star that could be used to approximate what the solar poles looked like during that time period. Tremblay, with his international team, posted the details of their process and the importance of their work. While the model produced by AI is only an approximation, the novel perspectives still provide a tool that can be used in studying the Sun and informing future solar missions.

Currently, there are no dedicated missions to study the Sun's poles. *Solar Orbiter*, a European Space Agency mission that will take close-up pictures of the Sun, will fly near the poles and help validate SuNeRFs as well as refine reconstructions of the poles. In the meantime, Tremblay and his fellow researchers are planning to use NSF NCAR's supercomputer, Derecho, to increase the resolution of their model, explore new AI methods that can improve the accuracy of their inferences, and develop a similar model for Earth's atmosphere.

"Using AI in this way allows us to leverage the information we have, but then break away from it and change the way we approach research," said Tremblay. "AI changes fast and I'm excited to see how advancements improve our models and what else we can do with AI."

Compiled with material provided by NCAR and UCAR.

Local galactic supercluster has urban and rural environments

Why is the vast supergalactic plane teeming with only one type of galaxy? This old cosmic puzzle may now have been solved.

Our own Milky Way Galaxy is part of a much larger formation, the local Supercluster structure, which contains several massive galaxy clusters and thousands of individual galaxies. Due to its pancake-like shape, which measures almost a billion light-years across, it is also referred to as the Supergalactic Plane. The Supercluster is defined locally by the Virgo and Fornax clusters but extends across a somewhat larger distance (~270 Mly) in the local Universe as an excess of bright elliptical galaxies. This peculiar segregation of galaxies in the Local Universe, which has been known since the 1960s, features prominently in a recent list of "cosmic anomalies" compiled by renowned cosmologist and 2019 Nobel laureate Jim Peebles.

Most galaxies in the Universe fall into one of two categories: Firstly, elliptical galaxies, made mostly of old stars and typically containing extremely massive central black holes, and secondly, active star-forming disk galaxies, with a spiral-like structure similar to the Milky Way's. Both types of galaxies are also found in the Local Supercluster, but while the Supergalactic Plane is teeming with bright ellipticals, bright disk galaxies are conspicuously absent. Disk galaxies grow in isolation by ingesting a continuous supply of cool gas to fuel star formation. In denser regions, higher ambient temperatures and the massive sizes of the resident galaxies restrict the inflow of gas, eventually shutting off star formation.

Now an international team led by University of Helsinki astrophysicists Till Sawala and Peter Johansson appear to have found an explanation. In an article published in *Nature Astronomy*, they show how the different distributions of elliptical and disk galaxies arise naturally due to the different environments found inside and outside of the Supergalactic Plane.

"In the dense galaxy clusters that are found on the Supergalactic Plane, galaxies experience frequent interactions and mergers, which leads to the formation of ellipticals and the growth of supermassive black holes. By contrast, away from the plane, galaxies can evolve in relative isolation, which helps them preserve their spiral structure," says Till Sawala.

In their work, the team made use of the SIBELIUS (Simulations Beyond The Local Universe) simulation, that follows the evolution of the Universe over 13.8 billion years, from the early Universe to the present. It was run on supercomputers in England and on CSC's Mahti supercomputer in Finland.

While most similar simulations consider random patches of the Universe that cannot be directly compared to observations, the SIBELIUS simulation aims to precisely reproduce the observed structures, including the Local Supercluster. The final simulation result is remarkably consistent with the observations.

"By chance, I was invited to a symposium in honour of Jim Peebles last December, where he presented the problem

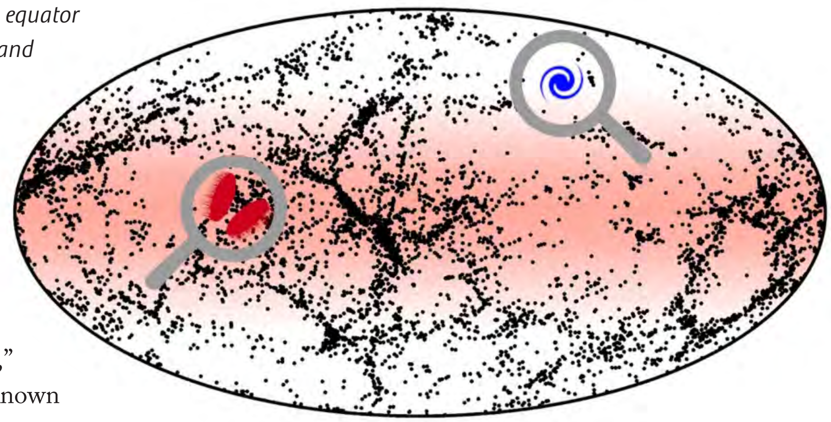


Figure 4 — In the supergalactic plane, which lies on the equator of the picture, galaxies experience frequent interactions and mergers, leading to the formation of massive elliptical galaxies (red). By contrast, galaxies away from the plane evolve in relative isolation, allowing them to preserve their disk-like structure (blue). Image: Till Sawala.

in his lecture. And I realized that we had already completed a simulation that might contain the answer," comments Till Sawala. "Our research shows that the known mechanisms of galaxy evolution also work in this unique cosmic environment."

Next to the physics department, the University of Helsinki's Kumpula campus hosts a large statue showing the distribution of galaxies in the Local Supercluster. It was inaugurated 20 years ago by the British cosmologist Carlos Frenk, who is one of the co-authors of this new study. "The distribution of galaxies in the Local Supercluster is indeed remarkable," says Frenk of the new results.

"But it is not an anomaly: our result shows that our standard model of dark matter can produce the most remarkable structures in the Universe."

Compiled in part with content provided by the University of Helsinki.

A chunk off the ol' Moon

In 2021, a team of University of Arizona astronomers suggested that a recently discovered near-Earth asteroid, Kamo`oalewa, could be a chunk of the Moon. Now, two years after the discovery, another UArizona research group has found that a rare pathway could have enabled this to happen. Kamo`oalewa (2016 HO3) is a tiny moon, 46–58 m in size, travelling along with the Earth in a 366-day orbit. Its closest approach to our planet is about 13 lunar distances.

Kamo`oalewa was discovered by the PanSTARRS telescope in Hawaii in 2016, and the name—found in a Hawaiian creation chant—alludes to an offspring that travels on its own. Due to its orbit, Kamo`oalewa can only be observed from Earth for a few weeks every April. Its relatively small size means that it can only be seen with one of the largest telescopes on Earth. Using the UArizona-managed Large Binocular Telescope on Mount Graham in southern Arizona, a team of astronomers found that Kamo`oalewa's spectrum matches lunar rocks from NASA's *Apollo* missions, suggesting it originated from the Moon.

So far, only distant asteroids from beyond the orbit of Mars have been considered a source of near-Earth asteroids, said Renu Malhotra, Regents Professor of Planetary Sciences and a senior author on the paper. "We are now establishing that the Moon is a more likely source of Kamo`oalewa," Malhotra said. The implication is that many more lunar fragments remain to be discovered among the near-Earth-asteroid population.

UArizona researchers decided to study Kamo`oalewa for two reasons. Kamo`oalewa is uncommon in that it is Earth's quasi-satellite, a term used for asteroids whose orbits are so Earth-like that they appear to orbit Earth even though they actually orbit the Sun.

The other peculiar aspect of Kamo`oalewa is its longevity, said Jose Daniel Castro-Cisneros, the study's lead author and a graduate student in the Department of Physics. Kamo`oalewa is expected to remain Earth's companion for millions of years. This is its remarkable feature, Castro-Cisneros said, unlike other known objects that stay in these very Earth-like orbits only for a few decades. There are currently 21 known co-orbiting bodies travelling with the Earth.

The 2021 study found that Kamo`oalewa's spectrum was unlike that of other near-Earth asteroids but matched most closely that of the Moon. Based on this, the team hypothesized that the asteroid could have been ejected from the lunar surface as a result of a meteoroidal impact.

In the new study, Malhotra and her team wanted to determine the feasibility for a knocked-off piece of the Moon to get into this quasi-satellite orbit—a phenomenon that is quite unlikely, Malhotra said. Moon fragments that have enough kinetic energy to escape the Earth–Moon system also have too much energy to land in the Earth-like orbits of quasi-satellites, she said.

With numerical simulations that accurately account for the gravitational forces of all the Solar System's planets, Malhotra's group found that some lucky lunar fragments could actually find their way to such orbits. Kamo`oalewa could be one of those fragments created during an impact on the Moon in the past few million years, according to the study. The most favourable conditions for entry into a quasi-satellite orbit involves launch velocities slightly above escape velocity from impacts on the trailing lunar hemisphere.

Throughout its history, the Moon has been bombarded by asteroids, which is evident in the numerous impact craters preserved on its surface, explained Malhotra. Impact craters are

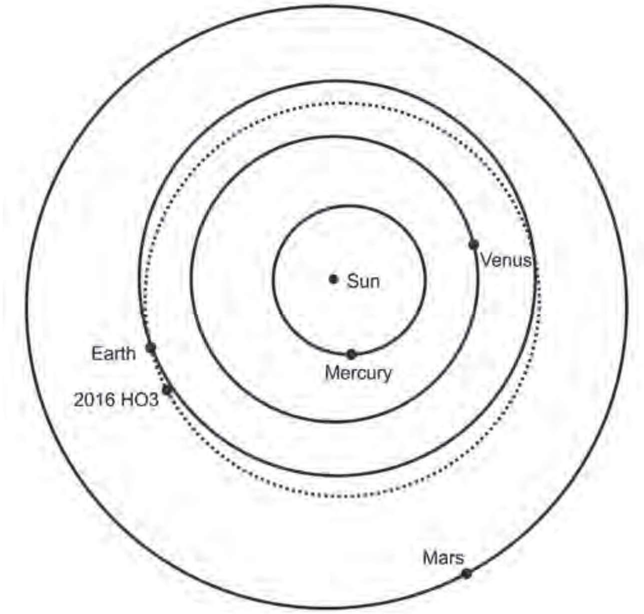


Figure 5 — Orbit of Kamo`oalewa (2016 HO3) in the inner Solar System

created when asteroids or meteorites crash into the surface of a planet or the Moon. Impacts cause lunar material to be ejected from the Moon's surface, but most of that material usually falls back on the Moon, she said. Past studies have indicated that ejecta of Kamo`oalewa's size would only come from craters at least 30 km in size.

Some of the ejected materials fall on Earth, and that's how we get meteorites from the Moon, Malhotra said. But a small fraction could escape the gravity of both the Moon and the Earth and end up orbiting around the Sun like other near-Earth asteroids. Numerical simulation suggests that Kamo`oalewa could be one of even tinier fractions that gained entry into the hard-to-reach Earth's co-orbital space.

The study's findings could help us understand more about near-Earth asteroids, which are considered a hazard to Earth, Malhotra said. More detailed studies of Kamo`oalewa and determining this asteroid's origin in a specific impact crater on the Moon will provide useful insights on impact mechanics, she said.

In the future, Castro-Cisneros said the team is planning to identify the specific conditions that allowed the orbital pathway of Kamo`oalewa. The group is also aiming to work on determining Kamo`oalewa's exact age, he said.

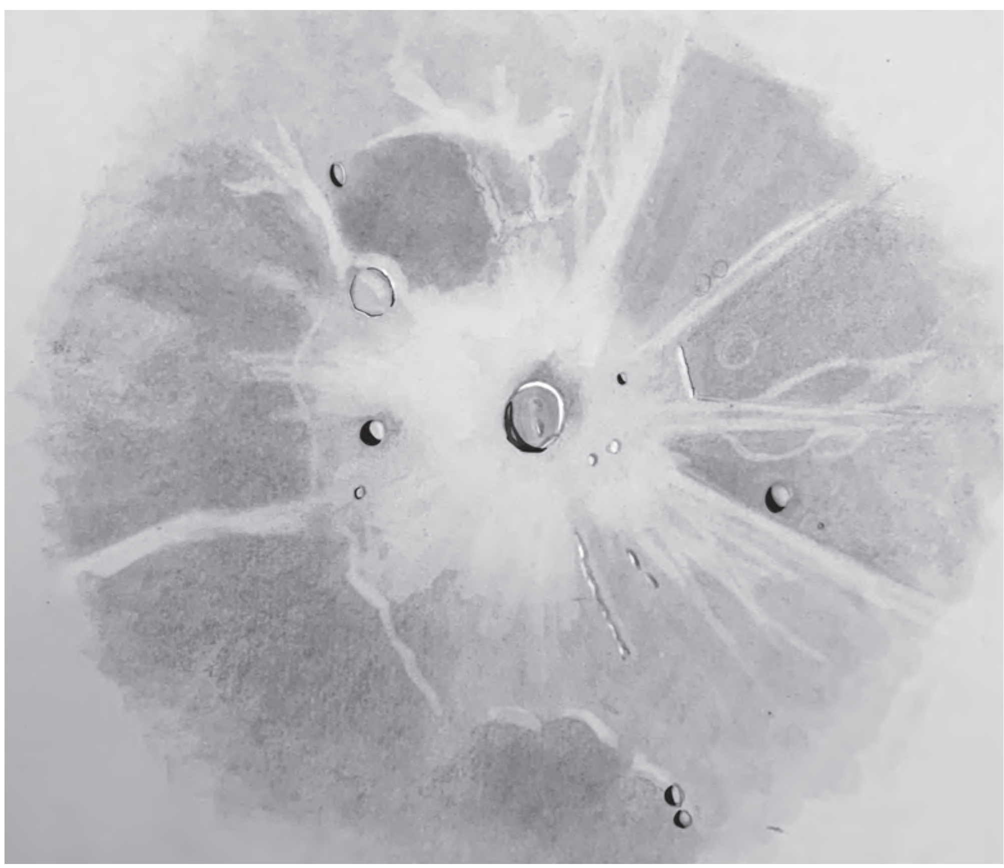
"We looked at Kamo`oalewa's spectrum only because it was in an unusual orbit," Malhotra said. "If it had been a typical near-Earth asteroid, no one would have thought to find its spectrum and we wouldn't have known Kamo`oalewa could be a lunar fragment." ✶

Compiled in part with material provided by the University of California, San Diego, and the University of Arizona.

Great Images

by Michael Gatto

Michael Gatto sketched this view of crater Kepler on a warm but dewy night, 2023 October 26. Kepler is #57 in the RASC Explore the Moon *Program; a list of lunar features to observe with a telescope. The sketch was done in about 45 minutes, under good to excellent seeing conditions with an 8" ƒ/7.5 Newtonian reflector and a 17mm EP, from Dartmouth, Nova Scotia. Michael noted in his observing report: the key here was capturing a sense of the rays. Very complicated patterns, at the top and right, almost look like these were looping structures. The sketch was done in pencil at the eyepiece, then scanned and some additional shading was added in* Procreate *on an iPad.*



Feature Article / Article de fond

Charles Smallwood, a Canadian amateur astronomer of the mid-19th century (Part 2)

by Peter Broughton (pbroughton@rogers.com)

Abstract

Charles Smallwood (1812–1873) is well known as an early Canadian meteorologist and possessor of a very valuable "Fraunhofer" refractor, 17 cm (7 inches) in diameter and 3.35 m (11 feet) in length. Here, for the first time since Smallwood's time, some more details are provided about the telescope and the observations he made with it in the 1850s including planets and their satellites, minor planets, double stars, clusters and nebulae in the Messier catalogue.

Introduction

Charles Smallwood (1812–1873) was introduced in the previous issue of *JRASC* where his observations made with naked eye or very modest equipment were outlined. The focus here is on a remarkable telescope and the observations that he made with it in 1856–58 at his home at St.-Martin on Isle-Jésus near Montréal.

Almost anything written about Smallwood, or any source after 1856 that refers to him, mentions his telescope. The minimal information in these accounts derives from one or more very similar articles either written by Smallwood or using information that he supplied. They speak of a "seven-inch achromatic telescope, 11 feet focus. The object glass, by Frauenhofer of Munich, is mounted equatorially and possesses right ascension and declination circles; and observations are taken on the heavenly bodies as often as there are favourable nights."[1] The brevity of these two sentences presents problems of omission and commission:

"Frauenhofer" is an aberrant spelling found frequently in 19th-century texts, referring to Joseph von Fraunhofer (1787–1826), the renowned Bavarian optician and physicist. During his short life, he was best known for producing near-flawless flint glass that allowed the firm he helped to establish to produce achromatic lenses up to 38 cm in diameter (see Figure 1). Residual chromatism remained which could be minimized by producing lenses of large focal ratios.

Smallwood's syntax suggests that the object glass was equatorially mounted; surely he meant the telescope. A form of equatorial mounting, commonly known now as a German mount and a clock drive, were other important Fraunhofer innovations and, though Smallwood did not specifically say anything about a clock drive, it is almost certain that the telescope that he used was equipped with one, otherwise it would have been nearly impossible to find objects like minor planets using their coordinates.

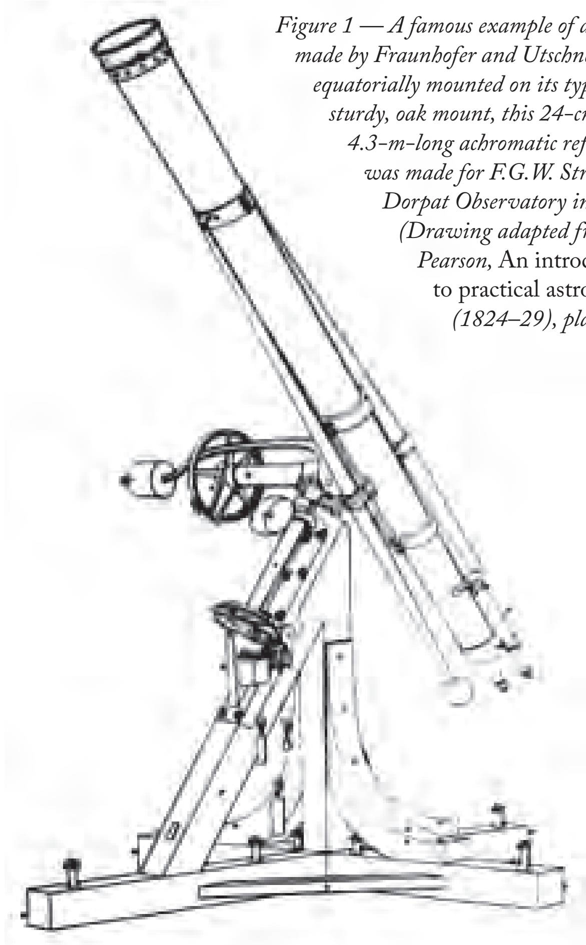


Figure 1 — A famous example of a telescope made by Fraunhofer and Utschneider, equatorially mounted on its typical, sturdy, oak mount, this 24-cm, 4.3-m-long achromatic refractor was made for F.G.W. Struve at the Dorpat Observatory in 1824. (Drawing adapted from W. Pearson, An introduction to practical astronomy *(1824–29), plate VII)*

Elsewhere, Smallwood speaks about a "stand and pedestal" (see Letter 1, below) and that the pedestal is a temporary structure and "not quite as steady as one might wish" (Letter 2). Perhaps the pedestal resembled the one shown in Figure 1, a style found on other large Fraunhofer telescopes. Setting up such a large and heavy telescope on a nightly basis is very problematic but Smallwood gave no indication that it was housed. The observatory depicted in the previous instalment would not have been appropriate. It did have a slit along the roof ridge allowing Smallwood's transit telescope to see the meridian but that would not have worked for general viewing.

Though much remains unanswered, four newspaper items, transcribed below, provide some further information about the provenance of the telescope and interesting details of what Smallwood observed with it. We learn from these accounts that Smallwood did not own the telescope. It was lent to him by a William Townsend for approximately two years April 1856–April 1858.

Who was William Townsend?

According to research on www.ancestry.com, William Atkins Townsend was born near London, England, on 1807 January 18. Apparently, he, his wife, and children emigrated to Montréal in 1843. The earliest mention in the Montréal newspapers was in a series of ads in April 1843 stating that "W.A. Townsend Manufacturing Jeweller from London [had taken over premises at the] corner of Notre Dame and St.

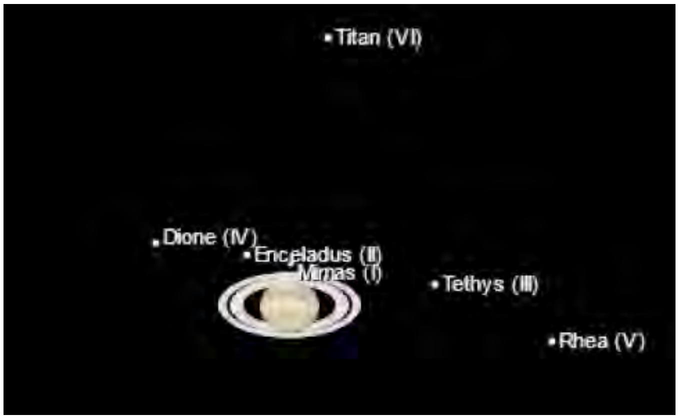


Figure 2 — The arrangement of the satellites of Saturn, 1856 April 18 at 21:15 LMT. North is up and east is on the left. The magnitudes of the satellites are: (I, 13.0), (II, 11.9), (III, 10.4), (IV, 10.5), (V, 9.8), (VI, 7.6). Smallwood likely saw the last five, Mimas being too faint. The orientation of the planet is not realistic in this Sky View Café *image.*

Joseph Streets."[2] Following his death on 1867 July 26, another jeweller from England purchased his stock and occupied the same store on Notre Dame Street until 1890[3]. Brief obituaries of Townsend described him as a prominent citizen and a one-time city councillor [1856–57][4]. On 1867 December 24, an advertisement in the *Montreal Daily Witness* placed by Henry J. Shaw, auctioneer, announced an estate sale of the library of the late W.A. Townsend but no telescope was mentioned.

Townsend and Smallwood were both active in the Anglican cathedral community in Montréal and were both members of the St. George's Society. Both are buried in Mount Royal Cemetery.[5] Other than those connections, I found nothing directly linking the two men. I can only surmise that Townsend had acquired the telescope in his business and looked to Smallwood, the only person in the Montréal area who apparently had the required expertise to evaluate the instrument and its capabilities so Townsend could resell it with testimonials. I could find no indication that Townsend ever used the telescope himself.

The published records of Smallwood's observations with the Townsend telescope

The first relevant article to describe Smallwood's observatory and equipment in detail was quoted in the previous *JRASC* issue but because that newspaper article made no mention of the telescope that interests us here, we can be confident that Smallwood only acquired it after the date of publication, 1856 March 28.

Four more newspaper items are quoted below; each mentions the telescope or observations made with it. They include what may be the earliest instances of anyone in British North America observing minor planets, double stars, and several Messier objects. While Smallwood was no doubt getting pleasure exploring the heavens in this way, his motivation was to test the capabilities of the "Townsend telescope." From the limited extracts of his journals presented in these letters, it seems that the instrument in his hands could nearly reach its theoretical resolving power of 0.″65 but fell at least 1.5 magnitudes short of its theoretical limiting magnitude of 14.

Where did Smallwood get the necessary information, especially the coordinates (RA and Dec) needed for many of the objects he observed? He would have already had annual volumes of the *Nautical Almanac* on hand to get the coordinates of stars needed to find his local time with his transit telescope. This source would also have furnished him with the positions of the planets, especially useful in locating Uranus and Neptune and the minor planets[6]. As for the double stars and Messier objects, Smallwood most likely used W.H. Smyth's (1844) *Cycle of Celestial Objects*[7]. Its second volume bore the subtitle "The Bedford Catalogue," named for the city in England where Smyth lived and had his own private observatory from 1830–39. There, using a fine 15-cm Tully refractor, he made micrometric measurements on "the most interesting double and multiple stars" and observed "a selection of clusters and nebulae from the works of the two Herschels—and the *élite* of Messier's list.…" His list of these objects with their right ascensions, declinations, and annual precession is accompanied by many interesting details about the stars and nebulae, the origin of their names, and opinions of earlier observers about the separations and appearances along with his own observations and measurements.

The newspaper articles, in the form of letters to Townsend from Smallwood are quoted below in their entirety. He used the term "St. Martin's Astronomical Time," meaning his local mean solar time reckoned from noon. Thus, for example, 13h means 1 a.m. on the following day. In transcribing these articles, I have interposed my own comments *[in italics in square brackets]*. For the double stars, I have used several sources, including Smythe, to get an idea of the actual separation of the components at the time of Smallwood's observations.

Unfortunately, as my interpolated comments show, there are many problems, especially with the first letter. Letter 3 does offer the explanation that since only excerpts of his journal were published the omissions removed the meaning or context. So, I will assume that Smallwood actually made the observations but that some of the times (at least as published) must be wrong. It is a great pity that we have only the snippets in these letters to rely on since Smallwood's original records have not been found. The obvious place to look—his meteorological journals—do not contain any telescopic observations.

Letter 1[8]

St. Martin, April 21, 1856.

My Dear Sir, - I enclose herewith a short extract from my Journal on the working and capacity of the "Townsend" Telescope.

Believe me,

Yours faithfully.

Charles Smallwood, M.D.

To Wm. Townsend, Esq,

Montreal

Tuesday, April 15th, 11 hours 30 min., St. Martin's Astronomical Time. – The stand and pedestal very steady; horizon somewhat hazy. Saturn pretty distinct; the body of the planet and its ring pretty well defined; colour very perfect; saw only 4 of its moons, with a power of 160, – the higher powers do not show it very distinct. *[Discussion: Saturn was only 2° above the western horizon; Surely even the brightest satellites of Saturn with magnitudes between 8.5 and 10.5 could not have been glimpsed.]* 13 hours.—Mars gibbous, with a power of 160, its disc is well defined; its equatorial region was white and contrasts well with its ruddy margin; colour seems well brought out, although upon the whole it is a little *winged*, – the erect eyepiece of 85 power shows it very well; the light is somewhat intense. *[At 1 a.m. on the 16th, Mars was well up in the southern sky and its disc was 99% illuminated—it was definitely not gibbous. Smallwood's "winged" comment suggests that Mars was not central in the telescope's field of view and that coma was distorting the image.]*

Friday, April 18th, 3 hours, St. Martin's Astronomical Time.—Brought the "Townsend" to bear on the Sun; with the inverting eye-piece of 160 power only one small spot upon its surface, near its N.E. limb. *[This is consistent with Heinrich Schwabe's drawing of the Sun on the same date.]* 9 hours 15 min.—Saturn very splendid; to-night put on the 290 power; ring very beautifully defined, and the interval between the body of the planet and its ring very distinct; the shadow of the body of the planet upon the ring well defined, and the interval between the body of the planet and its ring very distinct; the shadow of the body of the planet upon the ring well defined—colour very perfect; saw 5 of its moons very distinct; 4th Satellite (which is the largest) was seen with a power of 160 and gibbous. ****** *[Saturn was in the western sky with an elevation of 23°. Figure 2 shows the position of the satellites relative to the planet.]* 12 hours.—The Nebula in the sword of Orion was brought upon the field with a power of 290 and exhibited a splendid appearance; several distinct stars were resolved and the whole of the Nebula; with the 456 power seems strewed with point of bright light; it is probable that the object glass would bear a higher power. The tube of the Telescope is dripping with moisture. *[M42 had set by 9 p.m.]* 13 hours 15 min.—Mars, with the 290 power somewhat winged and gibbous; its white centre contrasts strongly with its ruddy limb—colours seem very distinct. *[Mars was in the southwest with an altitude of 32°and 98.5% of its disc illuminated; same comments as before.]* 14 hours.—The small star which accompanies *Polaris,* was seen with the 290 power as a bright speck of light, its distinct colour well brought out, it was S.E. of its primary. *[Polaris A and B, with apparent visual magnitudes of 2.0 and 8.7 were separated by 18″ but with B southwest of A.]* 15 hours.—The double star, A Gemini, was resolved with the same power; its angle could have been well measured. *[α Geminorum is actually a sextuple system; the two brightest components with apparent visual magnitudes of 1.9 and 3.0 were separated by about 5″ at the time.]* 15 hours 30 min. — The Nebulous mass Presepe *[Praesepe]* in Cancer, was well shown with the 290 power. *[Both α Gem and Praesepe had set by 2 a.m.]*


This Day,
VALUABLE
OIL PAINTINGS.
Mr. LEEMING has been instructed by
MR. TOWNSEND
TO SELL,
The larger portion of his collection of
OIL PAINTINGS.
[About 60 in number] by
POSITIVE SALE,
AT AUCTION
In consequence of his change of Residence.
The Sale will take place at Mr. T.'s present Residence, Notre Dame Street,
On WEDNESDAY, the 14th April,
At TWO o'clock.
Catalogues will be prepared, and the collection will be on view on Monday and Tuesday.
Sale at TWO o'clock,
JOHN LEEMING,
Auctioneer.
60

This Day,
TELESCOPE,
BY THE LATE CELEBRATED
"FRAUNHOFER," of MUNICH.
MR. TOWNSEND, having been requested to offer his Celebrated
TELESCOPE,
AT HIS SALE OF PAINTINGS,
ON WEDNESDAY NEXT, 14TH INST.,
To prevent disappointment, the upset price will be £125. The Instrument cost $1000.
JOHN LEEMING,
Auctioneer.
83

Figure 3 — Advertisement in the Montreal Gazette, *1858 April 14.*

Letter 2[9]

We are indebted to Mr. Townsend for the privilege of furnishing our scientific readers with the following interesting account of his fine Telescope, from the pen of Dr. Smallwood, of St. Martin:-St. Martin, Isle-Jesus.

March 21, 1857.

My Dear Sir,—I fear you will, ere this, have charged me with neglect in not furnishing you with a report of the working of your Telescope. I may remark that the past year was one of unusual interest; the whole of the old planets were visible, besides many of the later discovered ones,—and besides having directed it to the objects. I have also constantly employed it as a "Comet Seeker," which it is eminently qualified for, possessing so large an aperture. *[The telescope's small field of view would certainly not qualify it as a comet seeker. However, its large focal ratio would make it suitable for observing known comets.]*

The average number of nights for observation, from May 1856 to February 1857 inclusive, have been but 10 per month. During the month of January there were 13 nights suitable, but the intense cold rendered it next to an impossibility to follow up any continued observations. I have made a few extracts from my journal which may interest you, and show you some of the capabilities of the "Townsend."

May 5, 1856—9h. 14m. near *[mean]* time, brought Mars into the field of view; disc well defined, with a power of 290, the dark centre very well brought out, the contrast of brightness of the Southern Pole, was very distinct and well seen. *[Mars was at an altitude of 44° in the southern sky and the south polar cap would have been quite evident.]*

Nov. 28—8h. 35 m. mean time *[All the outer planets except Mars were well positioned for viewing, though obviously Smallwood could not have viewed them all at the specified time.]* Jupiter was brought into the field of view, with the 160 power [the] disc [was] very bright and well defined. The equatorial belts, five in number, very well brought out, the attendant satellites very sharp and well defined; with the 270 power, the belts were shining of a deeper shade, the difference in color of the body of the planet and the belts was very apparent; the view of the planet with the whole aperture was very fine. *[Jupiter's four known satellites were well-spaced on one side of the planet.]*

Uranus —The planetary disc well defined with the 290 power; the satellites not visible. *[Of Uranus's satellites, Titania, was the brightest at magnitude 13.8, barely brighter than the telescope's expected limiting magnitude of 14.]*

Neptune—The planetary disc visible and well defined; the satellites not visible with the 290 power. *[Neptune's angular diameter was 5" and the brightest of its satellites, Triton, was the brightest at magnitude 13.6, barely within theoretical reach.]*

Venus is a splendid object for observation, the crescent shape well defined with the 160 power; it is necessary to reduce the aperture, the light being too intense. *[Venus was not visible on this date, being close to superior conjunction with 83% of its disc illuminated.]*

Saturn is very high, the double ring very visible, the belts on the body of the planet well brought out, the shadow of the planet in the ring is also well shown, 3 of the satellites well defined with the 290 power. *[Which three satellites is unknown.]*

I have also obtained views of fifteen of the later discovered *[minor]* planets. They have exhibited well-defined discs; with the 160, 290 and 450 power the difference of color of these telescopic planets is very well shown. *[Only 42 minor planets had been discovered by the end of 1856[10]. Smallwood could not have discerned any of their physical discs as they are too small.]*
The following among the list of double stars, have furnished interesting views, with the different powers and by using means to contract the aperture: Eta Herculis *[not a true binary; companion has m_v = 12.5 and current separation almost 2']* and Gamma Coronae Borealis *[magnitudes 4 and 6 but with a separation of about 0.5"[11]]*, Mu Bootis *[Lying 1.8' away from the main mv= 4.3 star is a very close pair separated by about 1". It is not clear what Smallwood was referring to.]*, Alpha Lyrae *[Long thought to be double, the "companion" star, BD+38 3238D, was about 43" away.]*, Kappa Geminorum *[magnitudes 4.7 and 8.2 separated by about 6"]*, Delta Geminorum *[magnitudes 3.6 and 8.2 separated by about 7"]*, Zeta Herculis *[third and sixth magnitudes separated by about 1"[12].]*, Pi Aquila *[magnitudes 6.3 and 6.8 separated by 1.5"]*, Gamma Leonis *[magnitudes 2.4 and 3.6 separated by about 3"]*

The following form some of the nebulae which have been satisfactorily seen: the Annular Nebula in Lyra, 53 and 64 of Messier's catalogue, Coma Berenices, 13 Hercules, 5 Libra *[within the modern boundaries of Serpens, but close to Libra]*, and 29, near Gamma Cygnis. I have not yet been able to separate the double star Epsilon Bootes. *[Epsilon Boötis has orange and blue components with mV 2.6 and 4.8 respectively, separated by 3".]* The nebula in Cancer *[Praesepe]* was viewed with a power of 290 and resolved much of the nebulous mass into stars.

Figure 4 — A close cousin of the Townsend telescope is this Merz instrument used by Dembwoski at his observatory near Milan. The telescope's original stone pier forms the headstone of Dembowski's grave. The mounting shown here is a reconstruction of those used by Italian astronomers in 1874 to observe the transit of Venus from India. (Courtesy of INAF-Astronomical Observatory of Padua, Museum La Specola)

The chromatic and spherical aberration appears well corrected, and by regulating the diameter of the aperture, well-defined images of the celestial bodies are well brought out.

I have not at present been able to make any measurement with it, for you are aware it has no micrometer, and the pedestal is not quite as steady as I could wish it, being only a temporary structure.

In the occultation of stars by the moon I have found it work*[s]* very satisfactorily. The Moon furnishes a very interesting object for observation; with the different powers the light and shade of the lunar mountains and cavities are very finely brought out. The solar spots, with the 160 power are well defined; the edges sharp and satisfactorily shewn.

In conclusion, allow me to express a hope that before the meeting of the American Association for the Advancement of Science, which takes place in your city in August next, it may be placed in a fixed observatory, and that the European and American Astronomers may no*[t]* leave Montreal without obtaining some satisfactory views of the celestial orbs in the Canadian firmament.

With many thanks for your past kindness,

Believe me to remain,

Yours faithfully,

Charles Smallwood, M.D., L.L.D.

To W.A. Townsend, Esq.,

Montreal.

Letter 3[13]

In this letter, Smallwood rebuts comments in a paper called the Globe, *made by someone calling himself "Merak." I have not found any Merak in the Toronto* Globe *or in any other Canadian newspaper to which I had access. Reference is also made to The New York [City] Crystal Palace Exhibition. It ran from 1853 July 14 to 1854 November 1. The Official catalogue of the New York Exhibition of the Industry of All Nations [1853] includes two telescopes but nothing comaprable to the "Townsend" instrument.*

(To the Editor of the Globe.)

Sir,—My attention has been called this day to a letter signed "Merak," and inserted in your valuable paper, dated 2nd April instant, containing some reflections on a friendly letter addressed to Mr Townsend, and inserted by him in the Montreal Herald, consisting of a few scattered and detached remarks taken from my journal, tending "to show the capabilities" of a telescope Mr Townsend was kind and generous enough to place in my hands about a year ago. The letter alluded to will be at once seen to be a disconnected one. The letter to Mr. Townsend contained dots (…) in many places, (which I perceive were omitted in the *Herald*) showing omissions that were deemed uninteresting to Mr. Townsend, but which might have been satisfactory to "Merak," as explaining some points to which he refers.

He says: "The aperture of the instrument is not given, but its performance is so excellent on some occasions, and so different on others, that I think some further explanation is called for from Mr. Smallwood." In answer—1st, the aperture is seven inches *very nearly*; its focal length is eleven feet; it is equatorially mounted, and is from the celebrated maker, Fraunhofer of Munich, and is said to have been made expressly for the New York Crystal Palace Exhibition. Secondly, the difference in its performance is by "Merak" confined in two distinct charges—1st as respects *Epsilon Bootes*." Now, this expression occurs in a distinct paragraph from the observations on the "double stars," and the "yet" applies here to the *opportunity*, and not to the power or capability of the telescope, and the sentence quoted is in a distinct paragraph from the allusion made to double stars. As to the second charge—as having seen only three of Saturn's moons, – the paragraph is easily seen to have been an extract from a Journal, and only requires the dots alluded to, to make it perfectly intelligible, for as far back as the 18th of April, 1856, I obtained a good view of five of Saturn's satellites, which Mr. Townsend well knew from a previous correspondence, and compte rendu.

I have, Mr. Editor, neither time nor inclination to say more, but intend (using "Merak's" expression) "poking" among the stars so long as I am favoured by the liberality of my friend Mr. Townsend, notwithstanding the censorship of one of the guiding stars of the great Northern Constellation, "Merak."

I almost forgot to remark that the unsteadiness of the pedestal lately has been owing to the intense frost.

I am, sir,

Yours faithfully,

Figure 5 — The 175-year-old 15-cm f/11 refractor by Merz seen inside the beautiful octagonal dome of William Brydone Jack Observatory, UNB. (Larry Dickinson, MyNewBrunwick.ca)

Charles Smallwood, M.D.

St. Martin, 14th April, 1857.

Advertisement

The advertisement in the Montréal *Gazette* of 1858 April 14, shown in Figure 3, more or less speaks for itself. Townsend was hoping to get the telescope auctioned off and thus Smallwood would no longer be using it. As we shall see, the telescope was probably not sold at this time.

More about "Fraunhofer" telescopes

Bearing in mind that Fraunhofer died in 1826, it is doubtful that Townsend's telescope, or even its objective lens, was made by Fraunhofer. It is much more likely that it was made by one of the companies who carried on the Fraunhofer tradition, commonly said to be "made by Fraunhofer." For instance, in the autumn of 1858, Isabella Trotter and her husband visited the U.S. Naval Observatory in Washington, D.C., where "Professor B" [A.D. Bache] showed them the telescope and views through it. She wrote, "The instrument is a very powerful one, and, like the smaller one we looked through before, was made by Fraunhofer, a famous optician at Munich." (Trotter 1859) It is well known that the main refractor in Washington, 24 cm in diameter, was ordered from Merz and Mahler in Munich in 1844, yet Bache must have told his visitors that it was made by Fraunhofer.

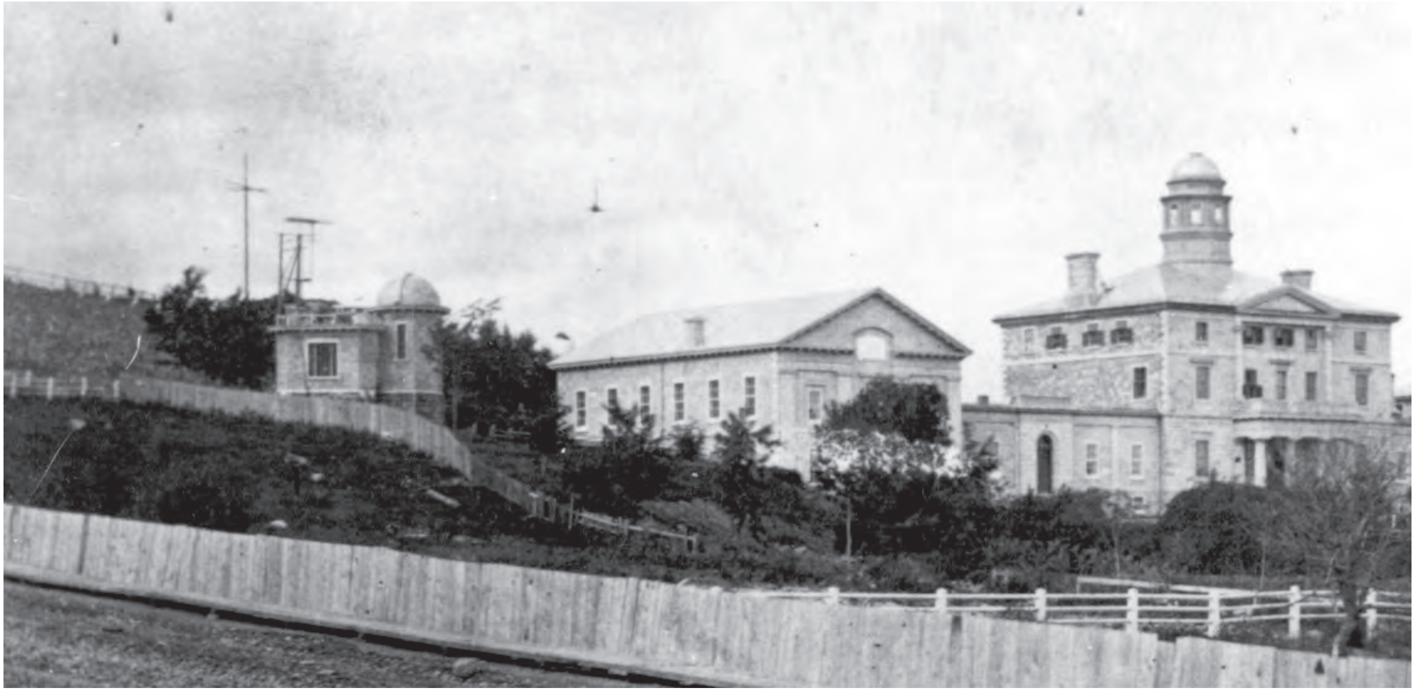


Figure 6 — In this 1860's photo of McGill University, the small, domed observatory is seen to the left of the main Arts building. The masts of some of Smallwood's meteorological equipment are visible near the observatory. (McGill University Archives PR013449)

Kost (2015) lists the many names of Fraunhofer's successor firms and the engraved identifications that they applied to the equipment they made. Joseph Mahler was a partner until his death in 1845. From 1847–1858, the owners were Georg, Ludwig, and Sigmund Merz, but they proudly recognized their heritage in the company name "Merz, Utzschneider and Fraunhofer in Munich" and (at least sometimes) applied that label to their telescopes. Using the account books of the Merz firm at the Stadtmuseum in Munich, Kost carefully transcribed all the entries for telescopes in which the customers are named along with the equipment supplied and at what cost. Townsend's name does not appear as a purchaser. Of the 58 refractors or objective lenses sold between 1830 and 1856, 10 were larger than Townsend's telescope, 3 were close in size, and the rest were smaller.

The three that were similar in size show what a highly prized piece of equipment Townsend owned. One of the close matches was a 17-cm Merz refractor used to measure double stars by Ercole Dembowski at his observatory near Milan (see Figure 4). In fact, many of the double stars that Smallwood observed were measured by Dembowski (1864) at roughly the same time. Some of Dembowski's measures of separation of the components can shed some light on Smallwood's observations. For instance, two of the closest pairs that Smallwood presumably resolved were γ CrB and ζ Her. Dembowski was unable to separate the components of γ CrB, noting only a vague elongation in the star's image in July, 1862. The same was true most of the time for ζ Her but Dembowski did record separations of 1.1″ and 1.2″ in 1858 and 1856. So, if Smallwood really did resolve these pairs, he was doing at least as well as a very-experienced double star observer with similar equipment, though, in Dembowski's case, permanently mounted. A second close match was a telescope recently described by Petterson (2019). It was a 19-cm refractor with a focal length of 300 cm ordered from Merz in 1853 by Christopher Hansteen and installed in 1857 at the university observatory in Christiania [Oslo], Norway.

The other near match for the Townsend telescope was a 17-cm, 3-m-long refractor purchased in 1850 for a college observatory in Shelbyville, Kentucky. Significantly, it was described by a contemporary as a "Fraunhofer Telescope … the fourth in magnitude and power in America.[14]" It was transferred to Laws Observatory at the University of Missouri in 1880 where it is still found, restored and refitted with a new, slightly larger lens. The original objective is in storage.[15]

The only Merz and company purchase in British North America was a 15-cm achromatic telescope bought in 1847 and installed in 1849 by King's College, Fredericton, N.B. (now the University of New Brunswick) (see Figure 5). The Townsend telescope was, therefore, somewhat larger and was likely the largest telescope in British North America at the time.

Smallwood's move to the city

Several factors enhanced Smallwood's reputation as a Canadian scientist. The publication of his meteorological observations in newspapers and periodicals made his name familiar to the public. Formal recognition came in the spring of 1856 when the convocation of McGill College awarded Smallwood an honorary doctor of laws degree and the Natural History Society of Montréal named him an honorary member.

Smallwood was soon named as Professor of Meteorology at McGill, but as the college was strapped for cash, he was not paid and, in fact, continued to live and observe at Saint-Martin. Each year, the college calendar announced that he would give a short course on meteorology but whether any students took up the offer in these early years is unknown. By the end of 1862, he had relocated to the city. His medical office was on St. Antoine Street and his residence was at 20 Beaver Hall Place, a newly-constructed terrace for the upper-middle class, not far from the college. The move also allowed him to become increasingly active in diocesan affairs of the Anglican church, as an office-holder and eventual president of the Natural History Society, and in the College of Physicians. For his role in promoting medical studies in Montréal, the University of Bishop's College awarded him an honorary D.C.L. degree in 1864.

An important reason for Smallwood's move to the city was the opportunity to transfer his scientific apparatus to a new stone observatory being built on the McGill campus. The Grand Trunk Railway (GTR) financed its construction to fulfill their need for accurate time service. Previously this had been provided by Thomas D. King who carried out transit observations in a rather makeshift structure using equipment belonging personally to Thomas E. Blackwell, vice-president of the GTR.[16] But once the McGill observatory was complete and Blackwell's equipment transferred there, Smallwood's duties expanded to include timekeeping as well as meteorology.

By 1863, Smallwood had set up operations at the observatory. His meteorological observations continued to be published, though somewhat sporadically.[17] In the university calendar for 1863/4 reference was made to the observatory "at the west end of the college buildings" (see Figure 6). About the same time, a description of the observatory and apparatus appeared in a Montréal newspaper, and was republished elsewhere.[18] Here, we learn that the astronomical equipment comprised only two small telescopes—a 7.5-cm Dollond achromat for observing sunspots and eclipses along with a meridian instrument to time the transit of stars (for timekeeping).

Back to astronomy

Accurate local solar time required precision timing of stars crossing the north-south meridian. After some calculations, these observed or apparent times were converted to local mean time. Any error in the observatory clock was thus known and an accurate signal of noon could be given and transmitted electrically to the train station, or to the time ball in the port, or to jewellers, firehalls, churches, or any place in the city that required accurate time. If the time was going to be useful to travellers, the accurate longitude of Montréal was also required; this became possible after Lieutenant E.D. Ashe (1859) of the Québec Observatory used telegraphic signals to link a number of cities to the standard station at Cambridge, Massachusetts. The coordinates that Smallwood used for the Montréal observatory were: latitude 45°31′, longitude $4^h\,54^m11^s$. Google maps give the co-ordinates at the rear of the Leacock Building (on the site of the old observatory) as 45°30′17″, $4^h54^m19^s$.

Figure 7 — Notman's photographs of the partial phases of the solar eclipse of 1869 August 7, as seen in Montréal. A centimetre ruler indicates the scale of the images. Assuming this was a contact print, the images are consistent with a telescope of focal length 1.3 m (from The Canadian Naturalist and Quarterly Journal of Science*, IV, 3 (September 1869), opposite p. 249).*

In spite of Smallwood's fervent hope that the 7-inch Townsend or other large telescope would occupy the revolving dome atop the observatory, nothing approaching that size materialized until six years after his death.[19] Nonetheless, at least on one occasion, a 7-inch telescope, presumably Townsend's, was loaned to the observatory. Smallwood (1866) described the view of the lunar eclipse of Good Friday (March 30–31), 1866, through both the Dollond achromat (150×) and the 7-inch (180×).

The solar eclipse of 1869

Townsend's death in 1867 seems to have put an end to observations with his telescope and, in fact, Smallwood specifically stated that he only had smaller telescopes for the solar eclipse of 1869 August 7. In the days leading up to the eclipse, he provided a local newspaper with approximate times for the beginning, middle, and end of the eclipse.[20]

Immediately following the actual eclipse, Smallwood wrote a paper describing his observations of the partial phases, along with photos by William Notman (see Figure 7), for presentation at the annual meeting of the American Association for the Advancement of Science in Salem, Massachusetts. His account, delivered on his behalf by fellow Montréaler and AAAS member, J. Baker Edwards, was "received with marked respect and gave rise to an interesting discussion upon the phenomena observed;" his paper was subsequently published in Canada (Smallwood 1869 and 1870). Smallwood was well-informed about recent developments in solar science in the United States and overseas and also knew (probably with some envy) that the Canadian government had financed an expedition to Iowa enabling Lieutenant E.D. Ashe and a couple of assistants from the Québec observatory to witness and photograph the eclipse from the path of totality. He was well-aware that photographing the partial phases was "only of a secondary and less important character." A lot of Smallwood's article was concerned with meteorological, magnetic, and electrical measurements during the eclipse. He noted that

> the Observatory possesses no telescope which could be used with advantage: a 42 in. Dollond, 3 in. aperture, with a power of 40, was the only one which was available. A small comet-seeker, of about the same power, possessing a large field, was also brought into requisition. The screen glasses [filters] used in both cases during the whole time were red. …ere was a slight agitation of the sun's limbs a second or two before the first contact occurred: it seemed as though the edge of the sun became suddenly lighted up as it were with rose-coloured prominences, shooting out coruscations of the same rose-coloured light towards the sun's bright disc, which display instinctively led to the strict observance of the position of the first point of contact. The contrast between the sun's bright disc and these rose-coloured protuberances was very distinct and well marked. The colour (as seen through the red screen) reminded me much of the Strontian light in the display of fire-works. These prominences increased, seeming to precede the moon's dark edge as a narrow band during the whole time, and preserving the same distinct rose colour.
>
> The magnitude of the obscuration was 9½ digits, and was on the south side of the sun. The greatest obscuration occurred at 6 hours 6 min. 41 sec. The final contact, which occurred at 6 hours 58 min. 41 sec., was, from its position, hid from view. Mr. [William] Notman the photographic artist, made, at my suggestion, (as he kindly did in 1860,) some photographs of these appearances. He likewise exposed a collodion plate to the sun, moving it forward every five minutes, to show the effect of the sunlight on the sensitive surface *[see Figure 7].* A like exposure of sensitive paper was made at the Observatory, with remarkably similar results. A piece of chromotype paper was there also exposed in a similar way, and formed a complete photometer scale, showing the action of the sun light in the production of photographic effects.
>
> On the Thursday previous, two large dark and prominent spots were observed on the sun, among others less conspicuous, but on the Saturday (the day of the Eclipse) only one of these was visible on N.W. aspect, and the progress of the moon across this spot was hid from view, owing to the passage of a somewhat dense *Cumulus* cloud. … The change in the aspect of surrounding objects, and of the landscape generally, was very apparent, giving to the buildings (mostly of grey lime-stone) a peculiar lurid yellow hue, quite unlike the grey dawn of twilight.

Figure 8 — Dr. Charles Smallwood photographed by William Notman, 1872. (McCord-Stewart Museum, I-73424)

Smallwood's reported magnitude of the eclipse agrees very well with modern calculations but the time of maximum was late by over three minutes. More serious is his baffling description of "prominences" and "protuberances." The Sun would naturally have looked rose-coloured since Smallwood was observing through a red filter, but in his day, such features on the limb of the Sun were only seen during a total solar eclipse when all of the Sun's glare was hidden. If the screen or filter that he used was in or near the eyepiece rather than covering the objective lens of the telescope, there could have been internal reflections of the brilliant light of the Sun within the optics or tube. Perhaps this could account for his strange observations or perhaps there were other reasons.

Dissenting opinions of Smallwood

Thomas D. King, evidently the observer for the GTR mentioned earlier, wrote an eight-page polemical pamphlet, highly critical of Smallwood (though always calling him, rather scornfully, the "Director of the Montréal Observatory"), the observatory, and the university authorities (King 1872). The whole screed as well as a rebuttal and counter-rebuttal can be easily found (King 1873). Suffice it to say, King asserted that the observatory was so badly situated "that if it were demolished it would be a boon to Science." Because of this and Smallwood's crude instruments and their bad placement, his published meteorological observations were "unreliable." Furthermore, the mean time of noon that Smallwood supplied was often in error, sometimes by three minutes—potentially disastrous for ships setting their chronometers. One could look for a vindictive motive, since King had supplied this service himself before the observatory opened, but the evidence he supplied does seem rather convincing. Backing this up, as Sheets-Pyenson (1996) noted, the founding director of the Meteorological Service in Canada, H.R. Kingston, complained to the principal of McGill, J.W. Dawson, of Smallwood's "numerous and frequent errors in arithmetic," saying that he "felt ashamed of Canada when I forwarded the Montreal telegrams to Washington." He even went so far as to say that Smallwood had proved to be "utterly disqualified for scientific work." It should be recognized that these criticisms were only voiced near or after the end of Smallwood's life. One can only hope that his earlier work at Saint-Martin was carried out more carefully; the location of his observatory and the instruments was certainly better. With the exception of the two eclipses of 1866 and 1869, all of Smallwood's astronomical observations described in both parts of this paper were made in Saint-Martin.

Remembering Smallwood

In the century and a half since Smallwood's death, meteorologists and climate scientists have not forgotten Smallwood's contributions (see portrait, figure 8). McGill meteorologists have been proud to acknowledge Smallwood as a founder of scientific studies at the university and most recently, Victoria Slonosky (2018) is making his work an important part of her study of the Canadian climate in colonial times. Journalists and historians, too, have written newspaper articles incorporating Smallwood's work into broader stories about meteorology and timekeeping in Montréal. Authors of more comprehensive histories, like Jarrell (1988), Thomas (1991), Thomson (1978), and Zeller (1987) have all included some aspects of Smallwood's work without much criticism.

The cumulative effect of these bits of positive publicity made an impact on civic officials in the City of Laval which now incorporates the old village of Saint-Martin. In 2001, they named a street in a new subdivision rue Charles-Smallwood. Whether it is at the precise location of Smallwood's long-vanished home and observatory is unknown, but it is an appropriate reminder of one of Laval's notable citizens of days gone by.

As I carried out this research, the astronomical aspect of Smallwood's work seemed almost illusory at times but it was, after all, not his main interest and the records of what and how he observed are incomplete. This situation is both tantalizing and frustrating—a lesson to serious observers even now to record accurate time, equipment and technique along with their images. Paul Markov's section on "The Observing Logbook" in the RASC Observer's Handbook, is an excellent guide.

The story of Smallwood and the Townsend telescope is certainly incomplete. In fact, I have become aware of two articles relevant to part 1 since completing the first instalment only two months ago. One cites Smallwood's earliest weather notes made at Huntingdon, Québec, in 1833–35, before he settled in Saint-Martin. Smallwood even mentioned having a "good view of Hawley comet" on 1835 October 11 and 12.[21] In another recent article by photographic historian Joan Schwartz (2022), I learned that nine separate albumen prints by Notman showing the partial phases of the solar eclipse of 1860 do survive in an album compiled by none other than T.E. Blackwell.[22] I am grateful to her for sharing scans of these images with me as well as to Randall Rosenfeld, RASC archivist, and to Victor Gaizauskas, retired solar scientist, for sharing their insights into some aspects of Smallwood's work. ✶

Endnotes

Canadian heritage content can be accessed online at canadiana.org and astronomical periodicals at adsabs.harvard.edu while the Montreal *Gazette* can be accessed at www.newspapers.com and the *Montreal Herald and Daily Commercial Gazette* at numerique.banq.qc.ca/patrimoine

1 The original, shorter account seems to be in the *Annual report of the Board of Regents of the Smithsonian Institution … for the year 1856*, 316, but the quote used here comes from *The Canadian Journal of Industry, Science and Art*, 3 (1858), 285.

2 *Gazette* (Montreal), 27 April 1843, p.3, for example

3 *Gazette* (Montreal), 20 December 1892, p.2

4 *Montreal Herald and Daily Commercial Gazette*, 26 July 1867.

5 Mount Royal Cemetery plot numbers forTownsend #108210855, and for Smallwood (G1, G45).

6 *The Nautical Almanac and Astronomical Ephemeris for the Year 1859, to which is added a supplement, containing ephemerides of Ceres, Pallas, Juno, and Vesta, and approximate ones for the newly discovered planets, for the year 1856* was published in 1855.

7 Smyth's Cycle can be found online at archive.org/details/cycleofcelestial01smytrich/page/424/mode/2up?view=theater The provenance of this particular copy is interesting. It belonged to Sherburne W. Burnham, renowned American double-star observer, who (years after Smyth's death) was extremely critical of Smyth and the Bedford catalogue. The controversy had extensive consequences (see Mary T. Brück's biographical article on Smyth in the *Biographical Encyclopedia of Astronomers*). The book was subsequently donated by the estate of R.G. Aitken (who produced a revised edition of Burnham's double-star catalogue in 1932) to the University of California Library where it was eventually scanned by archive.org

8 "The Townsend Telescope," *Montreal Herald and Daily Commercial Gazette*, April 23 1856, p.1, cols. 8-9

9 "The Townsend Telescope," *Montreal Herald and Daily Commercial Gazette*, March 31 1856, p.2, cols. 5

10 en.wikipedia.org/wiki/List_of_minor_planets:_1%E2%80%931000_

11 I have used a variety of sources for double stars including Rachel Matson, "Double and Multiple Stars," RASC

Observer's Handbook, James Kaler, stars.astro.illinois.edu/sow/sowlist.html and Smythe's *Bedford Catalogue* to get an approximate idea of the separation of the components in 1856. A table in Comstock (1921), shows the separation of the components of γ CrB at the time was between 0.42″ and 0.54″.

12 Measured separations by Ercole Dembowski in the 1850s, using a Merz telescope closely resembling the Townsend telescope, were between 1.0″ and 1.2″as reported by Doberck (1897).

13 "The Townsend Telescope," *Montreal Herald and Daily Commercial Gazette*, April 30 1857, p. 2, column 6

14 *The Church review and Ecclesiastical Register* 10 (1857–58), 117 accessed at archive.org

15 For details and a photo of the telescope as it is now, see Shelbyville-Laws history: physics.missouri.edu/laws-observatory and physics.missouri.edu/laws-observatory

16 Canada. *Commission Appointed to Inquire into the Affairs of the Grand Trunk Railway. Report of the Commission Appointed to Inquire Into the Affairs of the Grand Trunk Railway*, 78

17 The observations for 1864 were published in *The Canadian Medical Journal* and at least from 1868 to 1873 in *The Journal of Education for the Province of Quebec.*

18 *Journal of education for Upper Canada Vol. 17, No. 3* (Mar. 1864), 43–4]

19 Charles Seymour Blackman (1837–1906), at one time a next-door neighbour of Smallwood, donated his 16-cm refractor in 1879. Though an American by birth and up-bringing, in 1860 he married Sarah Jane, daughter of Edwin Atwater (1808–74), a Montreal businessman and alderman whose name is still very familiar to residents of Montreal. *Annual report of the McGill University, Montreal, for the year 1879*, 6,7, and Appendix.

20 "The Partial Eclipse of the Sun," *Montreal Herald and Daily Commercial Gazette*, August 3 1869, p.1, cols. 8–9

21 "McGill Observatory is the 'Greenwich Observatory' of the Dominion," *The Montreal Daily Star*, 20 June 1925, p. 17 (which includes photos of two meridian transit telescopes) and p. 30 (where Smallwood's old notebook is discussed). On October 10–13, P/Halley would have been a 2nd-magnitude comet visible throughout the night, according to ssd.jpl.nasa.gov/horizons/app.html# ephemeris generator.

22 Thomas Evans Blackwell, *Reminiscences of North America I* [Blackwell Album]. Library and Archives Canada, Item ID number:139644.
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Dish on the Cosmos

Resolving the Supergiants

by Erik Rosolowsky, University of Alberta
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One of the fundamental challenges in studying space and astronomy is understanding just how large the distances between objects are. We try to grapple with this understanding using large numbers or scale models. Indeed, one of my standard activities in my astronomy classes here in Edmonton is to describe a scale model of the Solar System: if the Sun is the size of a tennis ball, the Earth is orbiting about four metres away. Neptune is a healthy walk across campus. Where students frequently stumble is when I ask them "where is the nearest star beyond the Sun?" The answer is "almost to Red Deer," almost an hour and half driving on the highway. The scale of the space between the stars is so far beyond our intuitive comprehension that we struggle to have any sense of it, even with these poor models. While this scale frustrates our ambitions of interstellar travel, it also shapes astronomy because it means that our observations of stars usually see them as just tiny, unresolved points of light. We only ever see our Sun as a resolved sphere. No one can change their eyepiece to zoom in on the starspots on Sirius.

However, there are a few times when research telescopes can resolve the disks of stars. We achieve these results by striving for the best confluence of circumstances: we look at the largest, nearest stars. Specifically, this means the red giants and supergiants that are nearest to the Sun in our own galaxy. While the images are not the most inspiring views of the cosmos that we can achieve, the mere feat of seeing the resolved surface of another star is exciting since we start to overcome the challenges of the vastness of space.

Even with the most favourable of conditions, we still require resolutions of milliarcseconds or better and this resolution requires interferometry. Interferometry operates by simultaneously observing a light source with two or more telescopes. The individual telescopes precisely track the phase of the light arriving, meaning the timing of the peaks and troughs of the energy wave. Then they compare the relative phases of the light arriving at different telescopes to infer the precise direction from where the light arrives at the telescope. This process shares a lot of features of how a single telescope brings light to a focus. The shape of a telescope mirror is designed so that light waves coming from a certain direction will all arrive at one point in a focal plane in phase, allowing all the light that falls on the telescope from that direction to go to a single point and get collected by a camera or an eye. Away from this focus point, the waves arrive out of phase, so their energy is diminished, and no light arrives at this point. While interferometers may seem overly complex, both types of telescopes are using the relative phases of light to map out the sky at high resolution. The main advantage of an interferometer is that the resolution of the telescope is determined by the distance between the telescopes rather than the size of a single telescope. The main constraint though is that the telescopes must still be big enough to detect the relatively faint astronomical light and measure the phases of the waves.

Here, red supergiant stars provide a perfect target: they are luminous and large, and there are several possible targets nearby. Red supergiants are medium- and high-mass stars (larger than the mass of our Sun) that are at the end stages of stellar evolution. These stars are also called asymptotic giant branch (AGB) stars, given where they appear in a Hertzsprung-Russell diagram. They have depleted their reserves of the hydrogen that powered their light for most of their lives through fusion of that hydrogen into helium. Those stars then fused their helium into carbon and oxygen and now have largely run out of the main sources of nuclear fuel. The most massive stars can undergo brief periods of fusing carbon into heavier nuclei, but the nuclear energy sources are largely depleted. The centres of the stars are the inert ash of nuclear fusion. Around these inert cores, there are shells where nuclear fusion continues in a desperate attempt to fight the effects of gravity. These thin regions of nuclear fusion fuse rapidly and create a huge local injection of heat into the nearby gas inside the star, causing its outer layers of material to swell up. These outer layers become huge and relatively cool when compared to the surface temperatures of ordinary stars like the Sun. Despite being cool, red supergiants are producing energy far more quickly than they did when the same star was just fusing hydrogen. This set of physical circumstances leads to AGB stars being luminous, cool, and huge, making them an ideal target for interferometry.

The most obvious target for interferometer observations of a star is Betelgeuse, an AGB star with a radius 1,000 times larger than the Sun. Betegeuse is only 170 parsecs away, placing it within reach for observing with interferometers. Figure 1 shows an image of Betelgeuse made using the ALMA interferometer, where the non-circular shape and change in colour across the image are tracing the strange shape of the star. The surfaces of AGB stars are unstable, and the flows of gas in these visible layers are constantly turning over in convective eddies, like water boiling in a pot. The dimming of Betelgeuse in 2022 is also connected to these flows of gas where the star ejected a vast plume of carbon-rich gas from the interior that then cooled into dark dust grains that blocked the light in the direction of Earth. AGB stars are known to undergo great dimming events with some stars decreasing in brightness by five magnitudes (a factor of 100) because of a

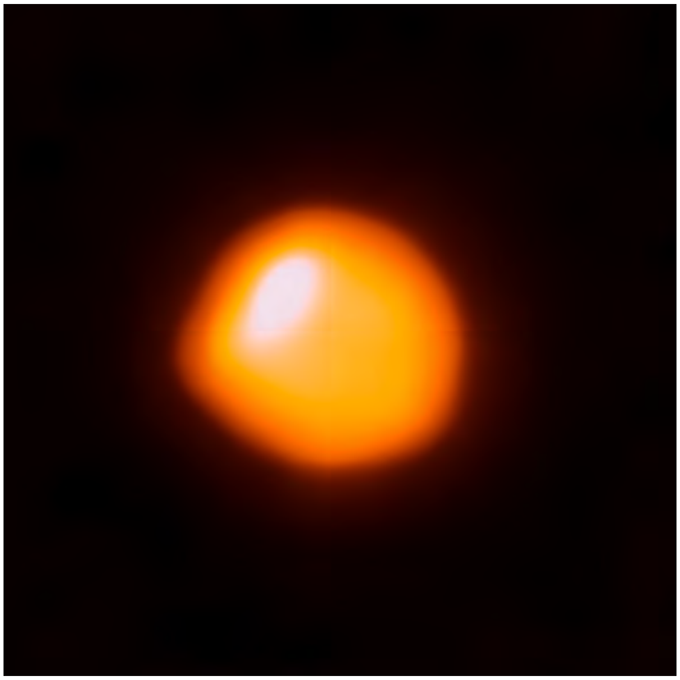


Figure 1 — ALMA image of Betelgeuse. The size of the star is comparable to the size of Jupiter's orbit and the uneven shape shows the unstable surface of the star.

ALMA (ESO/NAOJ/NRAO)/E. O'Gorman/P. Kervella

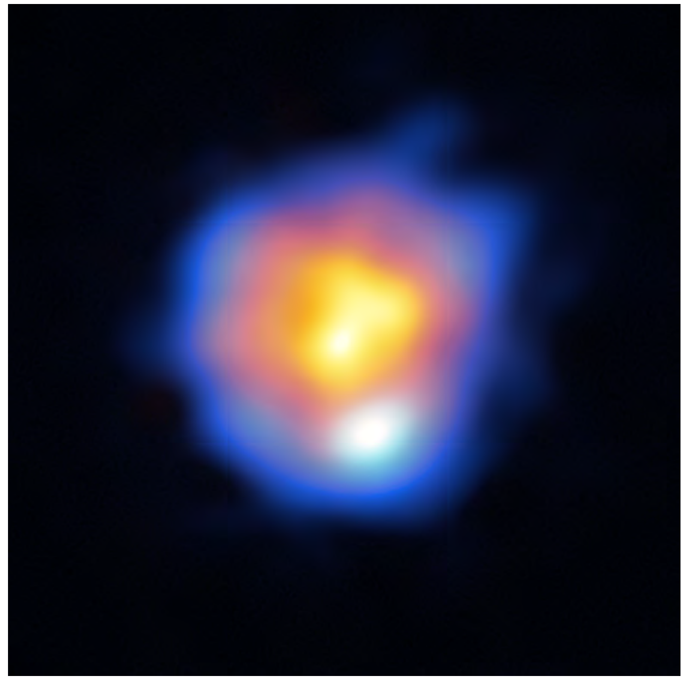


Figure 2 — ALMA image of R Leporus, an AGB star found in the constellation Lepus. The star is seen to be ejecting material in a ring around its bright surface.

dust-cloud ejection. These resolved images of the stars can be used to monitor the surfaces of stars and study how AGB stars boil and eject material.

More recently, ALMA was used to create an image of a more distant star, R Leporus, a variable star in the constellation Lepus. The target star is also an AGB star that is undergoing periodic pulsations, which led to its variable-star designation. The ALMA image is shown in Figure 2, which shows the surface of the star. The bright spot in the bottom right part of the star shows where maser emission is found, where masers are microwave-frequency lasers. This maser emission only occurs in relatively low-density gas with strong infrared radiation. Thus, the maser is likely tracing material as it is being blown off the surface of the star. There is also a ring of gas visible around the star in the image. We are seeing the star blow off its outer layers. The image is technically impressive: this is the highest resolution image possible using ALMA alone and the technical team behind the observations had to use a clever set of calibration techniques to counter the distorting effects of Earth's atmosphere.

Both star images are tracing the important end stages of a star's life. The sizes of these stars are so large that their surface gravity is relatively weak. The bubbling and pulsing surfaces carry enough momentum to push material all the way out of the star, leading to significant mass loss. This material will eventually be blown off to form planetary nebulae or to presage the early phases of a supernova explosion. While these images aren't the most compelling visions of the cosmos, seeing the surfaces of stars and how they are shifting around will tell us how stars end up returning their gas back into the vastness of space at the end of their lives.

Read more at https://arxiv.org/abs/2310.09664 ✶

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.

Figure 1 – As Canadians, we're fortunate to be in a great location to see the northern lights. Jason Dain imaged the aurora near Whitehorse in October 2023 with a Nikon D850 and 24-mm ƒ/1.4 lens. In the image, pillars stretch upward with the Pleiades and Taurus to the right, just above the clouds.

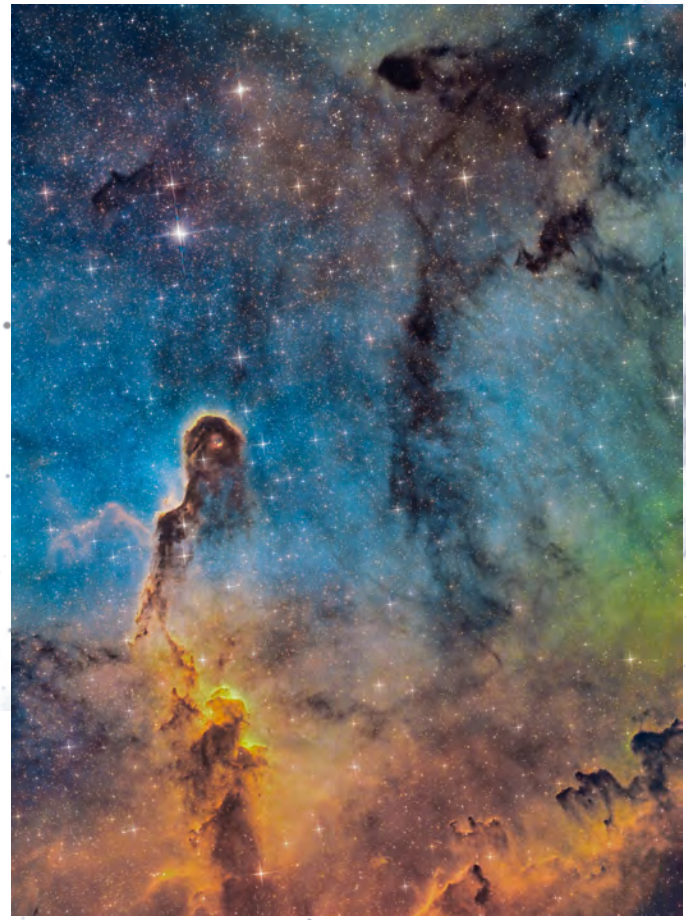


Figure 2 – This image of the Elephant Trunk Nebula (IC 1396) was taken by Rob Lyons from his rooftop in Vancouver. He used a Sky-Watcher Quattro 150P (518-mm ƒ/3.45) telescope, ASI183MM Pro camera (20 MP), and Antlia 3-nm narrowband filters, on an ZWO AM5 mount for a total of 27.7 hours of exposure.

Continues on page 27

What’s Up in the Sky?

Feb/Mar 2024

Compiled by James Edgar and Scott Young

Observing Highlights for February 2024

Solar System Highlights

Saturn disappears into the sunset twilight this month—what is the last day you can spot it with the unaided eye? Conjunction occurs on February 28 as the planet passes around the far side of the Sun.

Jupiter is high in the south as darkness falls, setting around local midnight by month’s end. Still at a favourable altitude in the early evening, the giant planet is far enough past opposition to make for some interesting views and pairings of the Galilean Moons. Moons passing behind the planet merge into shadow and don’t reappear until some distance from the planet, fading in and out over the course of several minutes.

Venus is low in the southeast during morning twilight as February begins, and slowly sinks into the Sun’s glare throughout February. Venus has a close conjunction with Mars on the morning of February 22, but this will be very low and difficult to observe from Canadian latitudes.

Mercury disappears into morning twilight early into the month, and swings around the far side of its orbit this month. Superior conjunction is on February 28, after which the innermost planet heads into its best evening apparition for Northern Hemisphere observers next month.

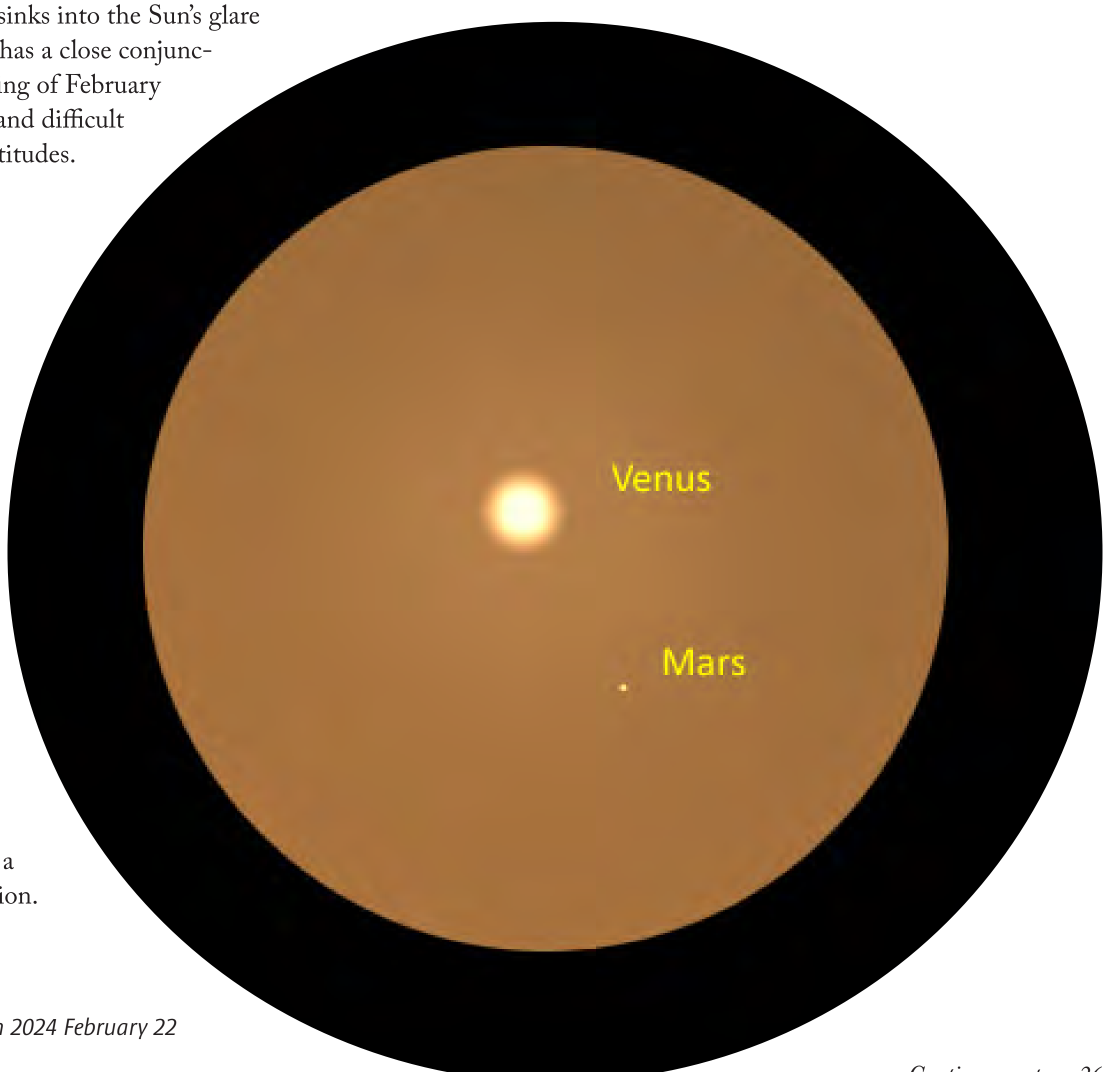
Mars slowly emerges from the morning twilight in February, but is still too low and too faint to be easily visible. It passes Venus on the 22nd in a likely unobservable conjunction.

The Moon passes near the planets and some bright stars as it orbits Earth. Some of the more interesting and observable events include:

- Feb. 7 (morning): The waning crescent Moon is very low below Venus.
- Feb. 14 (evening): The waxing crescent Moon is close to Jupiter.
- Feb. 16 (evening): The first-quarter Moon is close to the Pleiades star cluster.

Other Events

Zodiacal Light: Toward the end of February, the zodiacal light becomes visible from dark locations. This ghostly cone of light rises into the sky from the horizon along the ecliptic, with its broad end roughly centred on the sunset point on the horizon. The light is the combined glow of myriad dust particles in the plane of our solar system, being backlit at just the right angle to be seen from Earth. See Roy Bishop’s excellent article on this dust on p. 268 of the 2024 *Observer’s Handbook*.



Venus and Mars on 2024 February 22

Continues on page 26

The Sky May/June

Compiled by James Edgar with cartography by Glenn LeDrew

Celestial Calendar

(bold=impressive or rare)

Feb. 1 Spica 1.7° south of waning Moon

Feb. 2 Moon at last quarter

Feb. 7 Venus 5° north of crescent Moon

Feb. 8 Mars 4° north of crescent Moon

Feb. 8 Mercury 3° north of thin crescent Moon

Feb. 9 new Moon at 5:59 p.m. EST (lunation 1251)

Feb. 10 Moon at perigee (358,088 km) Large tides

Feb. 10 Saturn 1.8° north of thin crescent Moon

Feb. 15 Uranus 3° south of waxing crescent Moon

Feb. 16 Moon at first quarter

Feb. 16 Moon 0.6° south of Pleiades (M45)

Feb. 22 Venus 0.6° north of Mars

Feb. 24 full Moon (smallest in 2024) 7:30 a.m. EST

Feb. 25 Moon at apogee (406,312 km)

Feb. 25 Zodiacal light visible in west after evening twilight

Mar. 3 Antares 0.3° south of last-quarter Moon

Mar. 3 Moon at last quarter

Mar. 8 full Moon (smallest in 2024) 13:28 p.m. EST

Mar. 8 Mars 4° north of waning crescent Moon

Mar. 8 Venus 3° north of waning crescent Moon

Mar. 10 Daylight Saving Time begins

Mar. 10 Moon at perigee (356,894 km) Large tides

Mar. 10 new Moon at 5:00 a.m. EDT (lunation 1252)

Mar. 13 Jupiter 4° south of waxing crescent Moon

Mar. 14 Moon 0.4° south of Pleiades (M45)

Mar. 17 Moon at first quarter

Mar. 19 Pollux 1.5° north of Moon

Mar. 19 Spring Equinox at 11:07 p.m. EDT

Mar. 23 Moon at apogee (406,294 km)

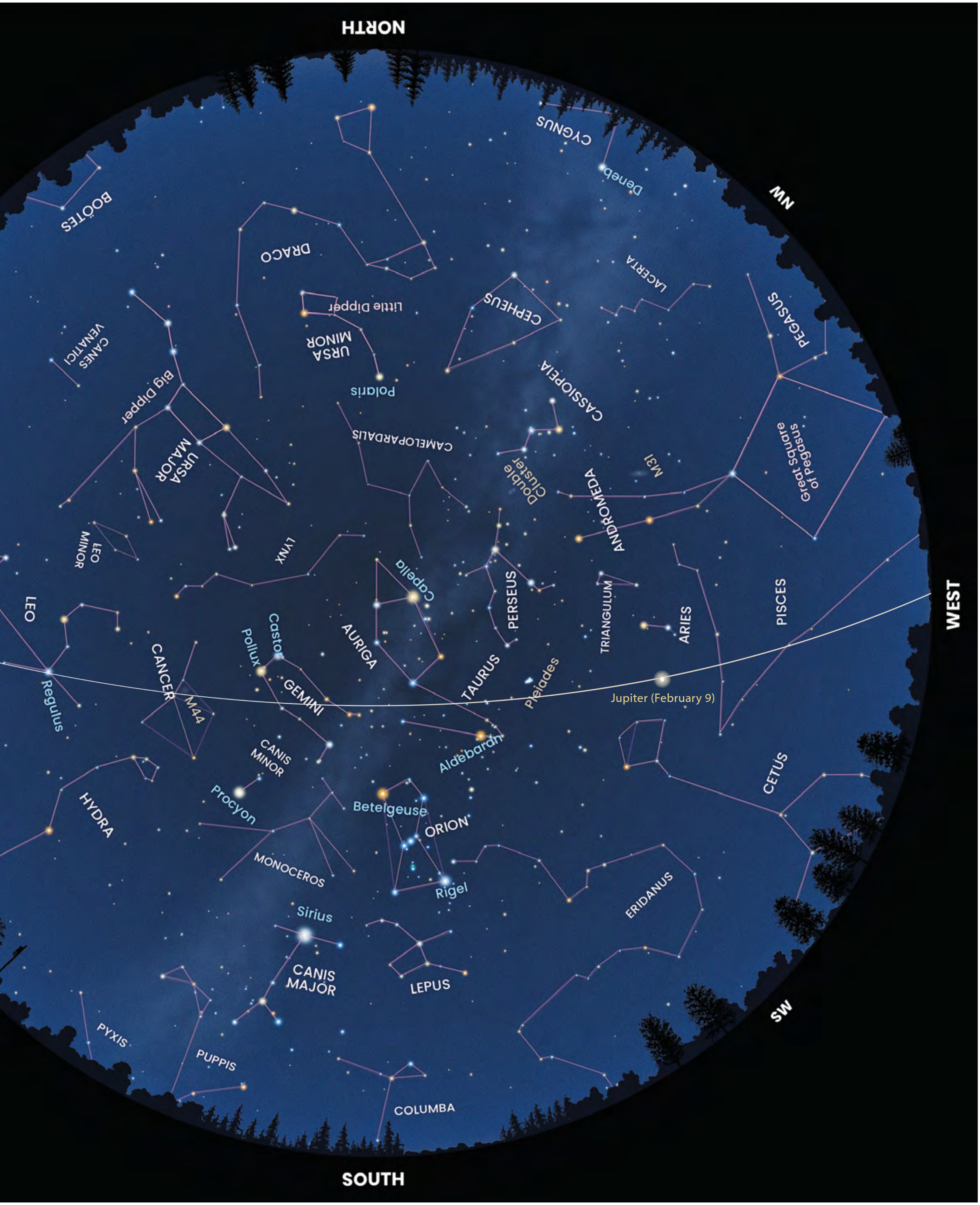
Mar. 25 full Moon at 2:00 a.m. EDT

Mar. 25 Penumbral lunar eclipse

Mar. 27 Zodiacal light visible in west after evening twilight

Planets at a Glance

	DATE	MAGNITUDE	DIAMETER (″)	CONSTELLATION	VISIBILITY
Mercury	Feb 1	—	5.2	Sagittarius	—
	Mar 1	—	4.9	Aquarius	—
Venus	Feb 1	–4.0	12.2	Sagittarius	Dawn
	Mar 1	–3.9	11.1	Capricornus	Dawn
Mars	Feb 1	1.3	4.0	Sagittarius	Morning
	Mar 1	1.3	4.2	Capricornus	Morning
Jupiter	Feb 1	–2.4	39.7	Aries	Evening
	Mar 1	–2.2	36.4	Aries	Evening
Saturn	Feb 1	1.0	15.7	Aquarius	Evening
	Mar 1	—	15.5	Aquarius	—
Uranus	Feb 1	5.7	3.6	Aries	Evening
	Mar 1	5.7	3.5	Aries	Evening
Neptune	Feb 1	7.9	2.2	Pisces	Evening
	Mar 1	—	2.2	Pisces	—


NORTH
SOUTH
WEST
NW
SW
CYGNUS
Deneb
BOÖTES
DRACO
LACERTA
PEGASUS
Little Dipper
URSA MINOR
CEPHEUS
CANES VENATICI
Big Dipper
Polaris
CASSIOPEIA
URSA MAJOR
CAMELOPARDALIS
Great Square of Pegasus
M31
Double Cluster
ANDROMEDA
LEO MINOR
LYNX
Capella
PERSEUS
TRIANGULUM
ARIES
PISCES
LEO
Castor
Pollux
CANCER
AURIGA
GEMINI
TAURUS
Pleiades
Jupiter (February 9)
Regulus
M44
CANIS MINOR
Aldebaran
CETUS
HYDRA
Procyon
Betelgeuse
ORION
MONOCEROS
Rigel
ERIDANUS
Sirius
CANIS MAJOR
LEPUS
PYXIS
PUPPIS
COLUMBA

Continued from page 23

Observing Highlights for March 2024

Solar System Highlights

There is a penumbral lunar eclipse on March 25th visible across Canada; details are on p. 126 of the 2024 *Observer's Handbook.*

Mercury is at its best evening apparition of the year for Canadians, peeking up above the western horizon in evening twilight about the 12th and rising higher each night until greatest elongation from the Sun with occurs on the 19th. Probably easiest to see on the few days around March 16 when it is at its brightest and near its highest above the horizon.

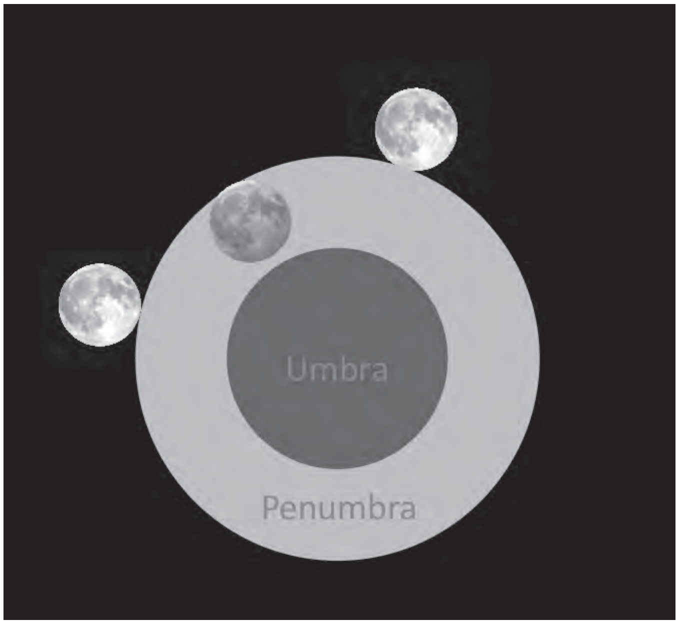
Venus remains very low in the south-southeast just before sunrise, only visible because of its great brilliance. It passes very close to Saturn on the mornings of March 21 and 22, but the shallow angle of the ecliptic with the morning horizon at this time of year makes this likely unobservable.

Mars is higher than Venus in the pre-dawn sky but much fainter, making it effectively unobservable until perhaps the end of the month. Mars will return to prominence in the second half of 2024 but until then it remains a less-than-impressive object.

Jupiter is visible in the west-southwest after sunset and sets before midnight local time. Telescopic observers will want to catch it early before it sinks into the turbulent air near the horizon.

Saturn is invisible for most of the month after its February 28 conjunction with the Sun. It reappears in the morning sky toward the end of the month, very low in the southeast before sunrise.

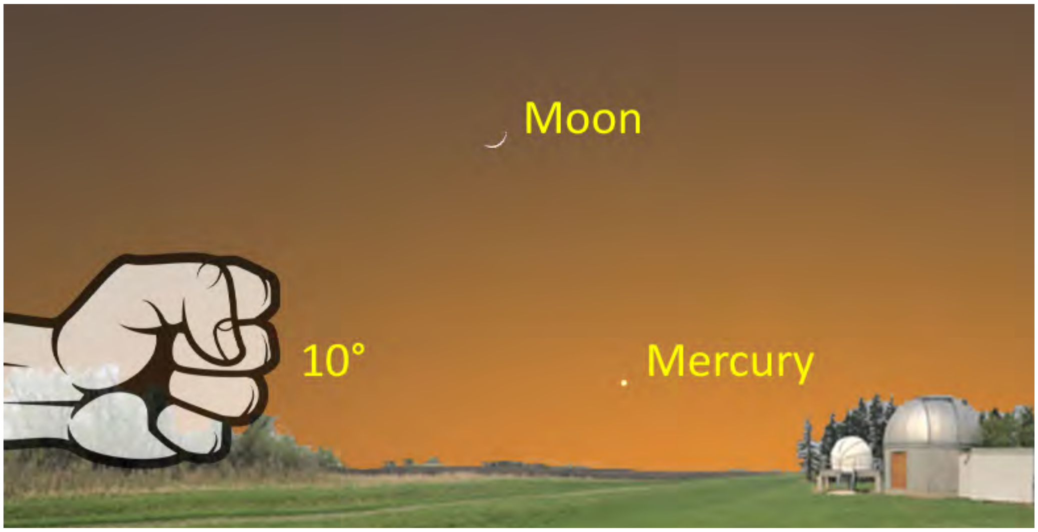
Neptune reaches solar conjunction on the 17th and is unobservable for the month.



Penumbral lunar eclipse of 2024 March 25

The Moon passes near the planets and some bright stars as it orbits Earth. Some of the more interesting and observable events include:

- Mar. 3 (morning): The last-quarter Moon is just below the bright star Antares low in the southeast. Observers in the southeast United States will see a grazing or total occultation as the Moon passes in front of the star.
- Mar. 8 (morning): The razor-thin waning crescent Moon is very low below Venus and Mars, a sight likely only visible from farther south.
- Mar. 13 (evening): The waxing crescent Moon is to the west of Jupiter.
- Mar. 14 (evening): The waxing crescent Moon is close to the Pleiades star cluster, with those observers farther west seeing a closer approach.



The Moon and Mercury on 2024 March 11

Other Events

Daylight Saving Time begins: Remember to set your non-internet clocks forward 1 hour late on Saturday March 9 or after midnight on Sunday, March 10, to ensure your circadian rhythms are as messed up as everyone else's. Except for Saskatchewan, where they realize that it's a 24-hour world and that lighting represents an ever-smaller part of the electrical grid's requirements. ✶

Continued from page 22

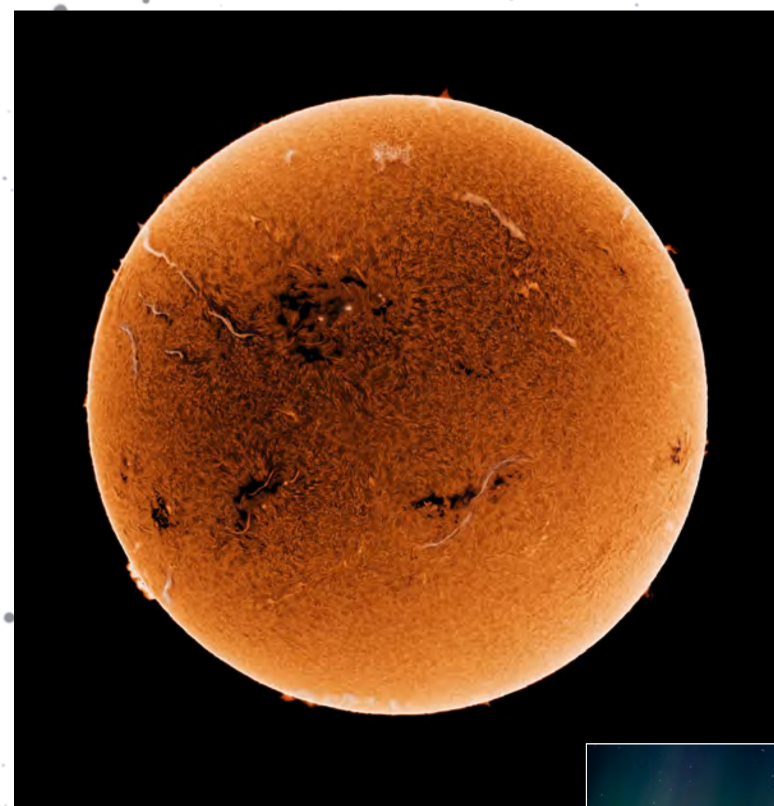


Figure 3 – Who doesn't love a spectacular image of our Sun? Shelley Jackson used a Lunt 60-mm pressure tuned Hα solar telescope, LS50FHa Front Mount, 50-mm DoubleStack solar filter, with a Player One Mars mono camera on a Meade 10″ SCT and an LX200 mount. "The number of filaments and sunspots that day were amazing," she says. "The surface detail was spectacular. Some of the filaments seemed to creep along the surface toward the limb then erupt into a prominence."

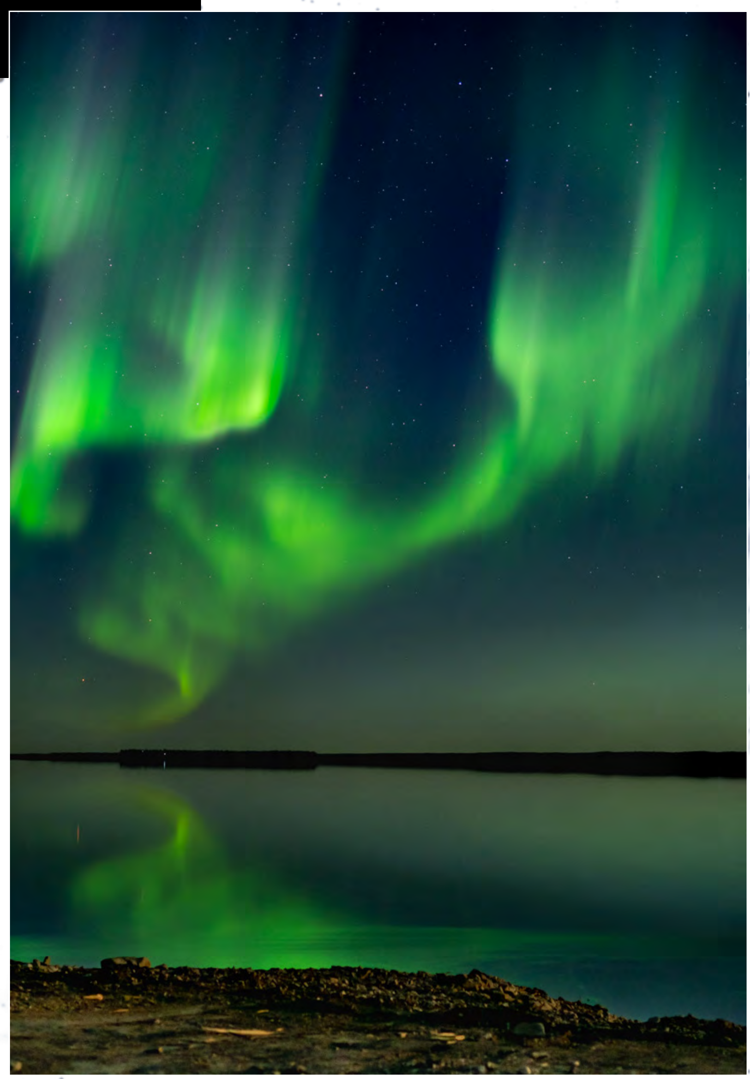


Figure 4 – Taken at Norman Wells, NT, September 2018. Standing on the Coast Guard Dock watching the aurora over the Mackenzie River. I had many opportunities to photograph the aurora while working in the Northwest Territories and was gifted with several unforgettable experiences. This is a memory of one of them.

Image obtained using a Sony A7iii camera with a Sigma 50-mm Art lens @ƒ2.2, ISO 1600, 10-second exposure.

From the Astroimager's site at rascastroimaging.zenfolio.com/ Kevin Metz of the Okanagan Centre has graciously allowed us to use his image in the Journal.

Blast From the Past

Compiled by James Edgar
james@jamesedgar.ca

With this Department, we bring to life an article from a previous Journal, *most of which are available at the NASA ADS site (Astrophysics Data System). The site is searchable in several ways, one of which is by publication. In our case, search or "JRASC" at ui.adsabs.harvard.edu.*

[Continued from Dec. 2023]

Progress in Astronomy and Astrophysics During 1906.

by C. A. Chant

(President's address, annual meeting, 1907 January 8)

Professor Hale states, that the spectroscopic laboratory on Mt. Wilson is equipped with means for obtaining, as nearly as possible, temperatures, pressures, &c., similar to those in the sun, and a photograph of the outfit shows well, how far modern research goes! In addition to the 60-inch reflector now possessed by the Solar Observatory, Mr. John D. Hooker of Los Angeles, has offered to defray the cost of constructing one of diameter 100 inches. The work will be performed by Prof. G. W. Ritchey, who made the other one, and it will likely require about four years to do it.

Professor Vogel has shown the advantage for photographic purposes, of using a reflector with short focal length. With one having an aperture of 40 cms. and focal length of 93 cms. he obtained as great detail as the Crossley reflector gave with eight times the exposure. Comparison with Dr. Roberts' telescope gives results equally favorable to the new one.

Another advance is called for by Professor E. C. Pickermg. He has published a plea for a large international reflector in the southern hemisphere. He suggests an aperture of 7 feet and focal length of 44 feet, and that a good location would be in South Africa. The cost would be approximately $-500,000. Who shall say when this project shall be realised?

The Work of The Society During the Year.

Regular Meetings.

During the year eighteen regular meetings were held. Mrs. S. D. Keran presented a thoughtful paper on "Some Differences in Ancient and Modern Science." Mr. R. M. Stewart, of Ottawa, described the "Time-service of the Dominion Observatory," explaining the wide usefulness of the Observatory in distributing accurate time throughout the public buildings. Our honored patriarch, Mr. Andrew Elvins, gave thoughtful discussions on "Terrestrial Magnetism" and on "Astronomical and Geological Periods." It is an especial pleasure to have Mr. Elvins with us to-night; he is our most regular attendant. Mr. Stupart gave a valuable paper showing the relation of Magnetic Disturbances to the Aurorae observed in 1905. Professor De Lury gave an account of "Physical Theories of the Universe," and Mr. J. R. Collins discussed the "Age of the Earth," while Mr. F. L. Blake gave a lucid account of the ordinary views held as to the Earth's evolution. A very enjoyable paper on the "Stonyhurst College Observatory" was given by Rev. Father Kavanagh, of Montreal, who spent some time studying at that well-known institution.

Professor Kirschmann proposed some problems as to the Earth's interior and some novel views regarding transmutation of the elements. Two interesting papers on double stars were presented, one by Mr. W. E. Jackson, in which were given some measurements made with the 6-inch telescope of the Toronto Meteorological Observatory; the other by our accomplished observer Mr. A. F. Miller. The subject "Astronomy and the Bible" was treated in most instructive manner by Mr. J. E. Maybee; and Mr. L. H. Graham gave a comprehensive review of work done on the planet Mars. Another paper, showing great industry as well as literary and scientific taste, was by Mr. John A. Paterson, on "The Astronomy of Shakespeare"; and the account of determining the Alaskan boundary by Mr. F. A. McDiarmid, contained much of interest as well as of permanent value.

In addition to the regular papers as announced by programme, some valuable reports of observations were recorded and many helpful and stimulating discussions took place. The interest throughout the year was well sustained, and the increase in membership was substantial.

Special Lectures.

During the months of March and April, a course of six elementary lectures on the "Physical Constitution of the Heavenly Bodies" was given by your President. By courtesy of the University authorities these were held in the Chemical Building, and throughout the entire course the attendance was excellent and the interest most encouraging. This elementary course has now become almost a by-law of the Society, and we hope to have another one this season.

The Society and the University.

In my address a year ago, I outlined a plan for co-operation between the University and our Society, which appeared to have received the commendation of all parties. The proposal which had been made, was that the University supply suitable accommodation for the library and the instruments belonging to the Society, and a so allow a convenient lecture room to be used for our ordinary meetings; the University, on the other hand, to have the use of the library and instruments. On account of inadequate accommodation, the plan as a whole has not been put into execution, though a part of it, namely, the use of the instruments for purposes of instruction in the University, has been. But on the completion of the Physics Building, now being erected, I hope the entire plan will be carried out. I am convinced that it will be of decided value, both to the University and the Society.

The study of astronomy in the University is certainly not declining in popularity. As I suppose many of you know, the Society offers annually to the University a gold medal for high standing on graduation in the course in Astronomy and Physics; and last June the first award was made. The successful student, was Mr. W. E. Harper, whose home is in the County of Grey, and the present speaker had the pleasure of informing Mr. Harper, on the day of his graduation, that he had been appointed to the Dominion Astronomical Observatory. Dr. King, the director of the Observatory, was present at the graduating ceremonies and courteously showed the speaker a telegram he had just received, conveying the information of Mr. Harper's appointment. The work in astrophysics at the Observatory is being vigorously prosecuted by Mr. John S. Plaskett, and Mr. Harper is rendering effective assistance in it. There is an impression abroad, that when a person enters the Civil Service he at once resigns himself to a life of indolence and withering ambitions, but from the many reports I hear from our national Observatory, I am led to believe that at that institution the impression referred to is not verified. The ability, energy and unremitting application of the workers found in that beautiful edifice, will certainly in the near future produce results which will reflect the highest credit on our country.

Extending Our Society.

Our Society is national in name, and we earnestly desire to make it national in character. In 1905, the Ontario Government encouraged us greatly by substantially increasing our grant; and during 1906 upon showing what we had already done and explaining our high aims, the Dominion Government generously recognised our work by giving us a grant of $1000 a year. In carrying out our plans for extension, we decided to issue, first, a Canadian Astronomical Handbook, containing astronomical predictions and other information, arranged in a form especially suited to the needs of Canadian observers; second, a bi-monthly periodical, which we propose shall contain papers presented to the Society, minutes of our meetings with some of the discussions, reviews of current scientific articles and of new books, and other matters of interest. We think that a daily companion, carried in the pocket or placed on the desk, such as we hope our Handbook will prove to be, and a periodical visitor bringing up-to-date information on astronomical effort throughout our Country and the world at large, should attract to our ranks, intelligent students of natural phenomena from every part of Canada.

The Handbook is now ready for distribution. It was intended to send it to the members before the New Year, and the failure to do so cannot be charged against the editor. The bi-monthly—which we hope will become a monthly before long—will be called The Journal of the Royal Astronomical Society of Canada, and the first number will be ready early in February. All the publications will be sent free to all members, and we are looking for a great increase of membership during 1907.

The annual fee for membership is $2.00; and to encourage the formation of Sections of the Society·at various centres, the Council proposed, and the Society sanctioned the suggestion, that when a local organisation has been satisfactorily accomplished, one half of the fees of the members of that Section be remitted to meet local expenses.

In December last, a Section was organised in Ottawa on these lines, and a revision of our constitution is now under consideration in order to provide for local autonomy in the Sections, and at the same time perfect union of interests in the Society as a whole. The Ottawa Section will undoubtedly give a highly creditable account of itself.

Soon, we hope to have similar organisations in Montreal, Winnipeg and other places, and I trust you will not think the spectacles through which I look to be too rosy, when I say, that I see before me a long and honorable career of usefulness for our Society. The greatness of a nation does not consist in mere material bigness, or in the magnitude of its trade returns; rather must we attend to the intellectual, the moral and the spiritual attainments of the people, if we are to reach true distinction. I believe the Royal Astronomical Society of Canada, will in the coming years, be a great power in the development of the higher faculties of the Canadian people. ✶

Skyward

Caroline Herschel's Galaxy

by David Levy, Kingston & Montréal Centre

This month, let us explore one of the seminal galaxies in the night sky, NGC 253, or the Sculptor Galaxy. It shines deep in the southern portion of the sky, south of the bright star Beta Ceti and southeast of the even brighter star Fomalhaut. This is one of my favourite galaxies, largely because of the beautiful story that is associated with its discovery.

This galaxy, which I call Caroline Herschel's Galaxy, is a starburst galaxy. It is so named because it is undergoing a burst of formation of new stars. This process was set off relatively recently—at least in cosmic timekeeping. About two hundred million years ago, a smaller dwarf galaxy probably collided with this larger one, and it set off this cacophony of new stars being formed. That other galaxy was probably rich in gas, which provided the raw material for the births of the new stars. There is one thing that this galaxy does not share with other starburst galaxies, however. Usually, these galaxies exhibit frequent exploding stars or supernovae. This one, however, has only one recorded supernova, in 1940.

This galaxy is aligned at almost right angles to our Milky Way. When you look at it, it appears as a thick pencil-like structure.

While searching for comets during the year 1783, Caroline stumbled across this long, slender galaxy hanging above the southern horizon. Duly recorded in her log "the Bills and Rec.ds of my comets," she also began and maintained a list or catalogue of the many objects she and her brother William had discovered, including beautiful drawings of most of them. As a young girl, Caroline was close to her father, who brought her outdoors on cold evenings to observe some winter constellations like Orion. It is possible that this was one of the special moments during which she began her love of the night sky.

As much as Caroline enjoyed working with her brother William, there were some issues. One night Caroline fell upon one of the large iron hooks that helped support the telescope on its mount. The accident left a large gash in her thigh. Her brother, not seeing his telescope moving, yelled out, "Make haste!" to which Caroline cried out, "I am hooked!" William immediately rushed over to help his sister, and she eventually recovered, with lots of rest and ointment.

When William married Mary Pitt in 1788, there was an obvious increase in tension among the Herschels. Caroline continued working with her brother, although the increased "family dynamics" did cause a problem. William very much wanted his sister to continue helping with his observing, and he was successful in arranging a royal stipend for her.

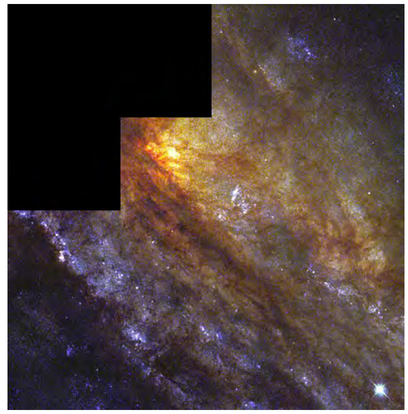


Figure 1 — NGC 253, or the Sculptor Galaxy. Credit: NASA/ESA/Hubble

In 1802, the Royal Society published the catalogue that Caroline had kept over many years. However, the publication in Philosophical Transactions of the Royal Society was credited to William, even though it was her catalogue. Over a long period of time, thanks to the work of later astronomers like John Louis Emil Dreyer, the almost 8,000 objects now comprise the New General Catalogue.

The woman who discovered the wonderful galaxy in Sculptor certainly enjoyed a remarkable life and career, living until she was almost 98 years old. In the 1980s, Caroline's eight comet discoveries were surpassed by Carolyn Shoemaker, in what was seen at the time as the highlight of Carolyn's career. However exciting that achievement might have been, it was completely eclipsed by her discovery of Comet Shoemaker-Levy 9 in March of 1993. That comet gave humanity its first lesson in what happens when a comet strikes a planet, and by inference, how comet collisions can lead to the origin of life on a world. As I gaze upon Caroline Herschel's galaxy on these winter nights, I imagine life forms there looking back, trying as we do, to share our cosmic heritage. ✶

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

Astronomical Art & Artifact

Eclipse Viewers—Technology, History

R.A. Rosenfeld, FRASC, National Member
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Abstract

A first attempt at sketching the history of the solar-eclipse viewer, and earlier technologies for viewing solar eclipses with the simplest means, from antiquity to the present.

Affording a clear view, but with an unclear past

Solar-eclipse viewers have become a common sight whenever people gather along the path of totality. The eclipse viewer is a relatively humble piece of astronomical equipment with which to experience one of the grandest of astronomical phenomena, but it suffices. It is probably also the least expensive item of commercially produced astronomical equipment in regular production. Most amateurs and professionals who use and distribute eclipse viewers, while they have some idea of the historical development of their telescopes, eyepieces, and cameras, would be hard pressed to give even the most summary account of the history of the eclipse viewer. There are few if any treatments of the history of the device in recent eclipse literature, professional or popular, in print or online. This is to a certain degree understandable—there are very considerable gaps in the documentation for such technologies, with few images, and often fewer surviving artifacts. It's not an easy history to write.

Basic questions regarding the past of these simple tools are easy to ask, but not so easy to answer: "When did eclipse viewers become commercially available?" "How similar are they to what is available today?" and "What did people use before eclipse viewers were commercially produced?" This paper will address them, and some myths encountered along the way. This effort will be successful if it spurs others to render this account obsolete.

Antiquity

The *Natural Questions* (*Questiones naturales*) of the younger Seneca (ca. 4 BCE–65 CE), the Roman statesman and stoic philosopher, provide as good a starting point as any. He describes the use of catoptric technology, that is, a reflective mirror surface, for safe and optically adequate observation of a solar eclipse:

> We use basins filled with either oil or pitch, when we wish to observe an eclipse of the Sun, as a thick fluid is not so easily agitated, and for that reason it holds the images it receives. Images, moreover, cannot be seen unless in a motionless liquid. We are accustomed to note how the Moon (with its body interposing) places itself in front of the Sun, so that it may conceal it (despite the disparity in size), sometimes partially, if it happens that it intrudes onto its side, and sometimes totally. An eclipse is said to be perfect, if it reveals the stars and cuts off the light; this happens when each orb lies in the same plane (Seneca *Nat. Ques.*, lib. I, 12.1–2).[1]

The liquid mirror is one of the two simplest devices used for eclipse viewing (Figure 1).

Figure 1 — Use of a liquid mirror as an eclipse viewer in the 1st century CE, according to the description in Seneca's Natural Questions *(book I, chapter 12.1–2). Modern reconstruction. Reproduced courtesy of the Specula astronomica minima.*

The other simple method attested in antiquity is the pinhole camera. At its simplest, this consists of a narrow opening through which an inverted image of the Sun is projected. Most people who have been present in the path of totality for a total solar eclipse will have seen multiple pinhole cameras at work, in the guise of foliage, or any other device offering interstices through which the Sun can project (Figure 2).

The pinhole camera presents us with our first historical myth. Many, many sites on the internet begin their accounts of the technology by citing Aristotle (384–322 BCE) as their earliest historical source to show knowledge of the technology (a recent search returned 2.590×10^6 such results!). There are two problems with this. The first is that the sites that cite "Aristotle" forget to cite a text by Aristotle (the minimum that would be required to support such a statement). The second is that there is no reference to the technology among Aristotle's authentic writings. There is, however, a pseudo-Aristotle text that does do so, but it was compiled over the course of the millennium following the Philosopher's demise (3rd century BCE–early 7th century CE).

Figure 2 — Photograph taken 1932 August 31 at Peacock Point, Québec, showing multiple images of the Sun in eclipse projected by foliage acting as natural pinhole cameras. Photographer unknown. Reproduced courtesy of the RASC Archives.

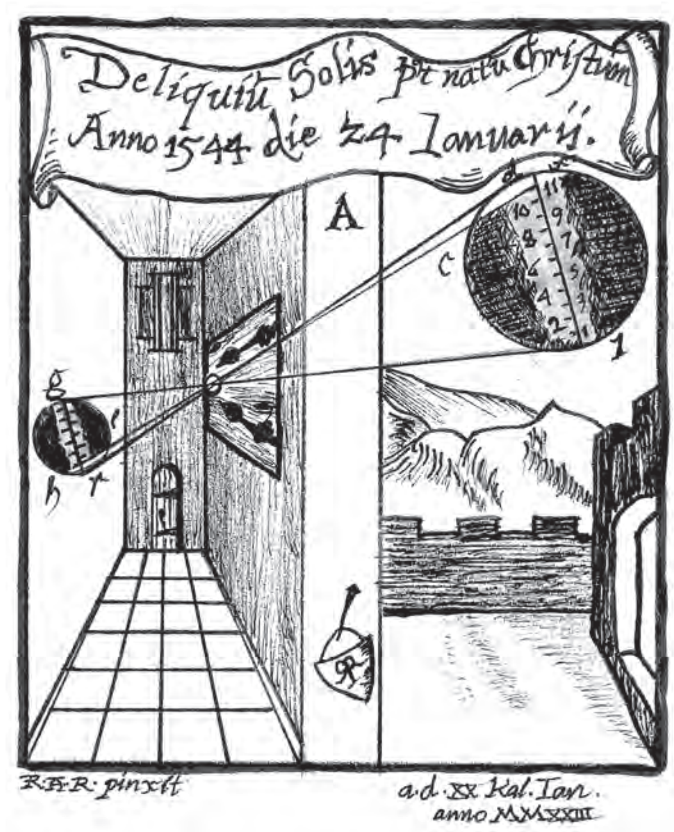

Figure 3 — Diagram of a Renaissance camera obscura. Copy after Daniele Santbech Noviomagus, Problemata astronomicorum... *(Basil: Heinrich Petrus & Pietro Perna, 1561), p. 47. Reproduced courtesy of the Specula astronomica minima.*

The part of the text describing the *camera obscura* effect reads:

> Why, when Sunlight passes through quadrilaterals, for instance through wickerwork, does it not produce shapes that are rectangular, but circular ones?"… Why, during eclipses of the Sun, if one makes observations of them through a sieve or through leaves (of a plane tree or another broad-leaved tree, for example) or by joining the fingers of one hand to those of the other, the beams become crescents on the ground? (Pseudo-Aristotle, *Problemata* lib. XV, 6).[2]

and it occurs in a rudimentary discussion of geometrical optics regarding how a theory of the rectilinear propagation of light could account for a non-circular aperture producing an image that was either circular (the uneclipsed Sun), or sub-circular (the stages of an eclipse).

If one arranged for the projected image to be protected from extraneous light, by directing the light rays into a box (whose dimensions could range from something that could fit in a hand to a room), one would have in essence a *camera obscura* (Figure 3).

Continuous use of the mirror and the pinhole camera throughout antiquity cannot be documented, but there is no reason to think that both weren't employed wherever there were people to observe eclipses. Neither Seneca nor the anonymous authors of the *Problemata* present the technologies as anything new. Among the chief recommendations of these observing methods were the ready availability of their constituent materials, their low cost, simplicity of installation, and presumed safety (more on that presently). In their most basic forms they were so uncomplicated that one could imagine them just happening without human intervention—all that was required was a calm body of water, or a leafy tree in the path of totality.

Middle Ages and Early Modern Period

Both techniques can be found in the Middle Ages, in the Islamicate world, Byzantium, and Europe. Surviving texts attesting to an awareness of them were more abundant in these cultural spheres than in antiquity. The *camera obscura* received considerably more attention in learned writings, ostensibly starting from eclipse observations, than did the mirror, and the context was usually that of geometrical optics, as was the case with the pseudo-Aristotelian *Problemata*. Writers such as ibn al-Haytham († after 1040), Roger Bacon (ca. 1219–ca. 1292), Abp. John Peckham (ca. 1230–1292), and Gersonides (1288–1344) moved well beyond the ancient material, and did so with some insight, and in the case of al-Haytham and Gersonides, genius (Raynaud 2016; Lindberg 1970; Goldstein 1985; Mancha 1992, 289–297).[3] Gersonides is particularly interesting because he provides some details about his instrument beyond what the others tended to offer.

Here two authors will be cited to give some indication of how the technologies for viewing eclipses are presented in the texts.

The first text is Roger of Hereford's (last quarter of the 12th century):

> If, on the day of the event, you wish to observe the whole eclipse without injury to your eyes—that is, its commencement, its duration, and the degree to which the Sun will be eclipsed—you should observe [by projection] the diminution of the solar rays through some round aperture. Observe attentively, and the rays perfect the projected image in the place over which it diminishes. When you will see the rotundity of the [projected] circle eclipsed in some part you will know that at the same time this is happening to the body of the Sun, but on the part opposite to that in the image, for when the eclipse happens [on the eastern side of the image], then the Sun is eclipsed on the western side [Roger is referring to the well-known effect that a *camera obscura* inverts the projected image]. And when the rotundity of the projected image decreases, the eclipse increases proportionally, according to its degree. For as many digits of the solar diameter are eclipsed, as digits of the projected image vanish, which the rays of the Sun form in the place of its diminution after it crosses over through the middle of the round aperture.[4] (The magnitude of an eclipse was then measured in units of "digits." A linear digit was a 12th of the apparent diameter of an eclipsed body, whereas the area digit was a 12th of the area of the apparent disk of an eclipsed body; Neugebauer 1975, 134).

The second is by William of Saint-Cloud (end of the 13th century; Poulle 1981):

> ...no solar eclipse, unless it should cover more than half of the Sun, can be observed with the eye, unless it occurs at Sunrise or Sunset, for then the light of the Sun will be sufficiently weakened by the [Earth's] atmosphere, but this rarely happens. Here I present a certain method whereby any eclipse of the Sun may be observed, however little the Sun may be eclipsed, even if for only a part of an instant, to forestall through a failure of vision the imputation of error to [my] *Almanach* because some predicted eclipse is not seen. I have in mind what happened to many in the year of our Lord 1285, on the fourth day of June, when they looked directly at the Sun for a brief period during the eclipse. A certain darkness overcame the eyes of those who had boldly looked at the Sun, similar to what commonly happens to those entering the shade after they have been in the brilliance of Sunlight. For that darkness persisted in the eyesight of certain people for two days, in others for three, and in others for longer, according to how intently and long they had viewed the Sun, and perhaps also according to the degree to which their eyes were more or less susceptible to such darkness. From this it can be seen that somebody may look at the Sun so that they become utterly blind, according to that saying of the Philosopher [i.e. Aristotle]: the superiorities of sensible things may ruin the sense; the cause of that incident is demonstrated elsewhere.
>
> Some are accustomed, moreover, to view an eclipse of the Sun in water placed in a basin, but that is not adequate [for safety], since the light of the Sun is reflected by the water, and however much the reflected Sunlight may be weaker than direct Sunlight, it too may bring about the same effect in the eyes, notwithstanding that it is weaker. All the same, if anyone insists on viewing the Sun that way, it ought to be done properly in clear water placed in a deep vessel, standing in a calm place.
>
> That the above said injury to the eyes might be utterly avoided, another method is set forth here, through which not only can a solar eclipse be observed without injury to the eyes, but the time of its beginning and also of its end as well as its extent may be punctually measured, and also certain other aspects that are treated in another place.
>
> Cause an aperture to be made in either the roof or a window of an enclosed room facing the direction in which the solar eclipse is expected. The size of the aperture should be like to that of the aperture from which wine is drawn out of wine jars. Then prepare a plane surface at a distance of 20 or 30 feet from the aperture, so that such light of the Sun will fall perpendicularly on the surface of that device. When the light strikes the prepared surface it will be utterly round, even if the aperture might be angular. Also, the further from the aperture the plane surface will be placed, the larger the image will be. Note, however, that it will be dimmer than if the plane surface were placed closer to the aperture.[5]

Next to nothing is known about Roger, but we're a little better informed about William. He is one of a handful of astronomers from the 13th and 14th centuries whose observations survive, and whom we know designed instruments. A leading astronomer of the next generation, Jean de Murs (1290/1300–after ca. 1357), accorded William high praise in about 1318: "William of Saint-Cloud, a man great in name and deed, diligent in the science of astronomy, eager to restore to the way of truth any thing unknown, or hidden."[6]

What is striking about both Roger's and William's instructions compared to the ancient descriptions is their concern for the viewers' safety. The circumstantial evidence for optical injuries incurred during the 1285 eclipse is also of interest, as are the constructional details for the *camera obscura*. And the health and safety cautions seem to be something new. It's fascinating to note that one of those simple devices, the camera obscura, became an instrument for exact qualitative measurement in the hands of some medieval astronomers, such as William of Saint-Cloud, and Gersonides. They developed ways to use measurements of the projected solar image to quantify the solar eccentricity at apogee and perigee.[7] They were followed in this by leading Renaissance astronomers such as Tycho Brahe, and Johannes Kepler, and it was Kepler who in 1604 in light of his eclipse experience with the camera obscura modelled an optical theory of its workings, which is now recognized as correct (Kepler 2000, 55–71).[8]

The major technical development to the *camera obscura* occurred in the 1620s, when it became possible to fit an effective singlet objective, or a telescope to the aperture. Gassendi made significant observations this way (Turner & Gomez 1992, 148–155; Horrocks 2012, xv–xvi). But this development moves us beyond a survey of the simplest tools for eclipse observation.[9]

Eighteenth century

All of the techniques described thus far are for "safe," indirect viewing of eclipses. By the early 18th century for the first time there were direct viewing methods, which were then considered as "safe." None of the earlier techniques vanished, either.

In one of the broadsides prepared for the eclipse of 1715 April 22, William Whiston (1667–1752), Newton's immediate successor in the Lucasian chair of Mathematics at Cambridge (who had been expelled from that appointment five years previously), cited four different methods for viewing the eclipse:

> I here suppose that no Person will be so weak as to expect any thing extraordinary from looking on this Eclipse as reflected in Water; or will venture to look at it much with y^e Naked Eye; and much less through a bare Telescope, excepting it be very near Total; and I say there are these several safe and good ways of Viewing it. (1) By making a Pin hole in a piece of paper, and looking at y^e Eclipse thrô y^e same. (2) By holding a Glass so long in the flame of a Candle, till it is smoked or sooted over, and then looking at y^e Eclipse thrô it; either with y^e naked Eye, or thrô a Telescope. (3) By letting y^e Rays of y^e Sun thrô a small hole into a dark Room, and so viewing y^e Picture of y^e Eclipse upon a Wall, or upon Paper[.] (4) By transmitting y^e Image of y^e Eclipsed Sun thrô a Telescope, either inverted, as usual, when y^e Telescope has Four Glasses; or erect when it has Two; and receiving it Perpendicularly on a Circle or paper or Pasteboard. But Note that y^e Circle must be of a due bigness, its Circumference must be divided into 360 Degrees; it must have Six other equidistant and Concentric Circles upon it for y^e 12 Digits; and it must have its Vertical line (whence ye divisions of y^e Circle must begin) kept in its due posture. This last method is much y^e best. For in case every quarter of an hour three Pin points be made, two at y^e limb, and one near the middle of y^e limit, or Circular boundary of Light and Shadow, for y^e drawing of y^e Circles of y^e partial Eclipses afterwards, it may be sufficiently exact for y^e purposes of even y^e Astronomers themselves; and is used by them accordingly in such cases. You must observe that thô y^e Telescope may be used in y^e Light, yet must the other rays of y^e Sun, before y^e Eclipse be Total, be some way kept off from y^e Projected Image; otherwise it will not Appear so vivid and distinct as might be expected (Whiston 1715).[10]

Methods 1 and 2 are for direct viewing, and both would be considered unsafe today, 1 particularly so. The mirror technique using the medium of water he considers inadequate, and he mentions the *camera obscura* as a safe method at 3. 4 is projection through a telescope onto a surface prepared with a reticle for taking quantitative measurements of the progress of the eclipse. He considers this indirect method superior to all the others, direct or indirect. The smoked glass, 2, is a neutral density filter (and sometimes variable, depending on the manner of preparation), and amongst the direct methods one of the most popular from this time up to the early 20th century.

Despite such strictures, people continued to make use of the liquid mirror for viewing solar eclipses. In the very centre of an anonymous oil painting from the first decades of the 18th century, two groups of people drawn from various classes observe the eclipse of 1715 May 3 reflected from the surface of water in buckets, with the Bâtiment Perrault (1667–1672) of the Observatoire de Paris for background.[11] Why not? The constituent materials of the technology were as readily available then as they were in Antiquity, their cost was low, and the apparatus remained easy to use.

Robert Smith (1689–1768), the Plumian Professor at Cambridge, in what became the dominant English treatise on optics after Newton's for the 18th century, had this to say on smoked glass:

> This is the way used by some astronomers, in observing eclipses of the Sun and spots upon his body; which may also be observed in looking through the telescope, by applying a plane smoaked glass to the eye, or by smoaking the eye-glass it self. In the other way the image will appear brighter if the end of the telescope be put through a hole in the window-shutter of a dark room. And then if the round image upon the paper be equal to the aperture of the object-glass, it will appear as bright as if the paper was illustrated by the direct light of the Sun… (Smith 1738, ch. 4, remarks upon Art. 120–123, 23).

He is chiefly concerned with the telescopic use of the smoked-glass filter, rather than the naked-eye use. It is startling to read the alternative advice to smoke the eyepiece itself!

More circumstantial details on the preparation of smoked-glass filters come from the fifth Astronomer Royal, the Rev'd Nevil Maskleyne (1732–1811), in his advice to observers of the 1769 June 3 transit of Venus (also a type of eclipse):

"She [i.e. Venus] will be visible to sharp Eyes without a Telescope, only defended by the Interposition of a dark Glass; but will appear much more beautiful, and may be observed to much more Advantage, with the Help of a Telescope. Here the Precaution of interposing a dark Glass between the Eye and the Telescope is absolutely necessary to be taken, without which the Sight may be destroyed, or greatly impaired; but, thus shielded, it will be perfectly secure from Danger or any Inconvenience…It has been remarked above, that dark Glasses should be used to defend the Eye from the Intensity of the Sun's Light. Transparent Glasses smoaked over the Flame of a Candle or Lamp, and applied to the Telescope, will give a more distinct and agreeable Vision of the Disks of the Sun and Venus than any tinged or coloured Glasses will do. Provide some Pieces of clear Glass, not too thick (the common Crown Glass used for Windows may do as well as any) cut two of them into equal Rectangles of convenient Lengths, and wipe them clean and dry, and warm them a little by the Fire, if the Weather be cold, to prevent their Cracking when applied to the Flame of the Candle; then draw one of them gently, according to its whole Length, through the Flame, and Part of the Smoke will adhere to the Glass; repeat the same Operation, only leaving a little Part at one End now untouched; repeat the Operation, leaving a further Part at the same End untouched; and so each Time leave a further Part of the same End untouched, till at last you have tinged the Glass with several Dies [=dyes=tinctures], increasing gradually in Blackness from one End to the other; smoke the other Glass in like Manner, and apply the two Glasses one against the other, only separated by a rectangular Border cut out of Brass or Card Paper, the smoked Faces being opposed to each other, and the deepest Tinges of both placed together at the same End; and tie the Glasses firmly together with waxen Thread; and they are ready for Use. The Tinge at one End should be the slightest possible, and at the other End so dark that you cannot see the Candle through it. By this Contrivance applied between your Eye and the Telescope, you will have the Advantage, not only of seeing the Sun's Light white, according to its natural Colour, and his Image more distinct than through common dark Glasses, but also of being able to intercept more or less of his Light, as you please, and the Clearness or Thickness of the Air requires it, by bringing a lighter or darker Part of this combined dark Glass before your Eye, which will be a great Convenience at all Times, but particularly when the Brightness of the Sun is liable to sudden Changes from flying Clouds. This dark Glass ought to slide in a Groove fixed to the Eye End of the Telescope, in order to relieve the Observer from the unnecessary Trouble of holding it in his Hand, and, when not used, should be kept in a dry Place, or well covered up from the Air, else the Moisture of the Air will penetrate between the Glasses, and spoil the Smoking. This Point should be examined, and the Glasses new smoked, if necessary, a few Days before the Transit (Maskelyne 1768).

Maskelyne provides the first mention of coloured glass filters ("any tinged or coloured Glasses") among the texts presented here (but that does not mean that this is anything novel—the ability to vividly colour glass was in the repertoire of glassblowers in antiquity). He does not favour the use of coloured glass for eclipse observations.

He reserves his highest recommendation for smoked-glass filters, and advises the use of "clear" glass for them, such as the "common Crown Glass used for Windows," which "may do as well as any." This is a surprise; 18th-century opticians who specialized in achromats for serious use, or the speculum metal for mirrors, were very concerned about the uniform quality of glass and metal blanks for their craft. Yet crown glass as used for windows in the period was very uneven, and full of bubbles and striations. Is it possible that those imperfections in the substrates for smoked filters didn't really matter for the types of observations being undertaken? This is a question that could benefit from actual experimental recreations.

The procedure for making smoked-glass filters consists of:

1. cut the crown-glass substrate into two identical rectangles (no indication of size is given);
2. prepare each by wiping them clean (presumably with a solvent of some sort), and then drying them;
3. if the weather is cold, warm them gradually by a fire to prevent their cracking during smoking;
4. smoke the rectangular substrates by "gently" drawing them along their whole length through a candle flame;

5. repeat the draw, but progressively stop the process further along the substrate each time to produce a filter with increasing levels of opaque neutral density in steps "increasing gradually in Blackness from one End to the other;"
6. mount the rectangles parallel with the smoked surfaces facing each other inward, with the darkest parts aligned. The opacity is sufficient if the density of the darkest part of the opposed rectangles should entirely exclude a candle being seen through them;
7. separate the rectangles with a "border" (also acts as a spacer), and bind them together with "waxed thread" (presumably the thread would be wrapped along the top and bottom, or the sides);
8. a grooved mount should be fit at the ocular end of the telescope to receive the smoked glass;
9. the smoked glass should be stored in a dry place when not in use, and if moisture should penetrate and degrade the soot deposit, the procedure should be repeated to restore the graduated neutral density.

Although his primary audience is philosophically minded telescope users, Maskelyne's procedure would result in a very neat and flexible smoked-glass filters for naked-eye observation of a solar eclipse. One has the impression that the average smoked-glass filter casually produced by the public would be rather rougher affairs, without the ability to provide consistently different levels of opacity.

The materials and techniques to produce smoked-glass filters were available in Antiquity, as they were in the Middle Ages, and in the Early-Modern Period. They would have been a useful device for eclipse observation in all those periods. Why, then, wasn't the smoked-glass filter developed millennia earlier? Even when glass was a relatively rare luxury, there would have been glass wastage through production and post-production accidents; where there is glass, there is broken glass. Even if earlier evidence for the existence of the technology is found, it was clearly never in widespread use. Why?

Maskelyne's mention of "any tinged or coloured Glasses" brings to mind several artifacts in museums and private collections, which have been identified as "18th-century eclipse viewers." The majority of such artifacts consist of circular glass "lenses," which are very dark—black or almost so—mounted in cells of wood or ivory atop turned handles (in general form they resemble magnifying glasses that are still readily available today. Stylistically their dating is broadly reasonable). Their identification, though, posses a problem. They are invariably presented without any account of a reliable chain of provenance that can prove their 18th-century use as "eclipse viewers," nor are they displayed with texts contemporary with them that unequivocally attest to the existence of objects with those features. With a single exception known to me, they are not shown with any 18th-century iconographical proof that can bear out their identification as purpose-made "eclipse viewers." [12] What are these objects?

In readiness for the solar eclipse of 1764 April 1, the noted mathematical practitioner (instrument maker) Benjamin Martin (1704–1782) advertised "…dark Glasses, Telescopes, etc. for viewing the Eclipse to the best Advantage" (Millburn, 1986, 35). This could be a reference to what modern collections have labelled "18th-century eclipse viewers," but it could also be a reference to smoked-glass filters, for in the work by Maskelyne quoted above the term is used to describe both "tinged or coloured Glasses," and smoked-glass filters.

The other possibility is that the artifacts labelled "18th-century eclipse viewers" in present-day museums and private collections are in fact a variety of Claude mirror. This was a dark glass, often (though not always) convex, which was used by people in search of the picturesque, who thought that landscapes reflected in the dark surface of the glass were imbued with the tonal values found in the paintings of Claude Lorrain (1600–1682) (Maillet 2004). The poet Thomas Gray popularized their use. A Claude glass could have been used to observe a solar eclipse by reflection, but that would be a secondary usage.

Until more and better information is available, the label "18th-century eclipse viewer" in most cases should be qualified to indicate the provisional nature of such identifications.

That aside, the passage from the 1764 advertisement by Benjamin Martin is possibly significant. All of the simple eclipse-viewing devices described up to this time were non-commercial, that is, they were made by the viewers themselves. Martin's retailing of "dark Glasses… for viewing the Eclipse to the best Advantage" break with that long tradition, for one could now purchase a simple eclipse viewer marketed by a professional instrument maker. This innovation, if it was that, existed in a world where the great majority of simple eclipse viewers were still made by their users. And it's possible that Martin's commercial viewer was not much different if at all from the DIY product. Perhaps one with an impeccable and unimpeachable 18th-century identity will surface some day to render us better informed. It should be noted, however, that there appear to be very, very few eclipse viewers that survive from before the 1920s. They might have been viewed as a sort of material ephemera.

Nineteenth century

Simple eclipse viewers for popular use in the 19th century were pretty much what they were in the 18th century. Smoked-glass filters almost certainly remained the dominant technology; in some ways little changed. With the growth of capitalism, and an efflorescence of consumer goods, and people to sell nearly everything, one might have expected

Figure 4 — Eclipse viewer distributed with copies of the Boys' Magazine*, for the 1927 June 29 eclipse in England. Reproduced courtesy of the Specula astronomica minima.*

*Figure 5 — "*Ecliptoglass*" marketed for the 1927 June 29 eclipse in England. Reproduced courtesy of the Specula astronomica minima.*

commercial eclipse viewers to noticeably start to marginalize the non-commercial "product," but that didn't happen. It seems that traditions of making things for oneself remained strong throughout the century. One innovation also bears a posthumous (and confected) association with Claude Lorrain. In addition to the Claude mirror that debuted in the 18th-century, the Claude glass was offered in the 19th century. The typical version of the device consisted of an array of stackable coloured glass filters that could fold into the handle, which might be made of ivory, metal, tortoiseshell, or wood. Instead of looking at a landscape reflected in a dark mirror, one looked at a landscape through a Claude glass, that is, through one or more of the filters. In the 19th century they were primarily an artist's tool. But they could be stocked by vendors who specialized in other wares.

In 1856, the firm of Benjamin Pike, jr. (1809–1864) published the second edition of a large catalogue of the optical, mathematical, and philosophical instruments they traded in. They sold both "Claude Black Glass Mirrors," and "Claude Lorraine [sic] Glass." They describe the latter as:

> Claude Lorraine Glass...This consists of a variety of different colored glasses, about one inch in diameter, mounted in horn frame and turning on one centre, for producing a great variety of colors and showing their combination ; it also will be found both pleasing and useful for viewing eclipses, clouds, landscapes, &c. (Pike 1856, 193).

The use of the Claude glass as an eclipse viewer is certainly presented as a secondary application. Was it done just to increase sales, or could it have worked? Something very similar in design can be seen in the coloured filters provided on marine sextants for shooting the Sun. The Claude glass might have offered the same level of protection if the filters were stacked. This can only really be answered by measuring the light transmission of the filters.

Mary E. Byrd (1849–1934), the Director of the Smith College Observatory, expressed her preference for double-stacked dark glasses, with the option to smoke them if they required more opacity:

> In all observations connected with the Sun, spectacles with dark glasses are better than a piece of smoked glass held in the hand. The inexperienced observer gets a steadier view and both hands are left free. Two pairs of spectacles are needed when watching for Sunspots and even then the glasses, unless they are very dark, must be smoked (Byrd 1894, 220).

A contemporary, John L. Lanneau of Wake Forest, North Carolina, constructed smoked-glass eclipse viewers remarkably like those recommended by Nevil Maskelyne well over a century earlier:

> Last May a trivial addition to our outfit for the various observations made, was a number of neatly prepared smoked glasses for naked-eye views of the progress of the eclipse. Each of these eye protectors consisted of a piece of clear glass put over the smoked surface of a like piece, the two held together securely by paper pasted along their edges (Lanneau 1901, 67).

It seems unlikely that he would have been familiar with Maskelyne's description.

Twentieth century

At the turn of the century, and well into it, the cumulative sum of the earlier techniques for simple viewing of solar eclipses was available to all. Such a continuity seems hardly worth noting—but it should be noted, for it is a factor

Figure 6 — Pair of eclipse viewers for the 1927 June 29 eclipse in England, patterned after contemporary eyeglasses. Reproduced courtesy of the Specula astronomica minima.

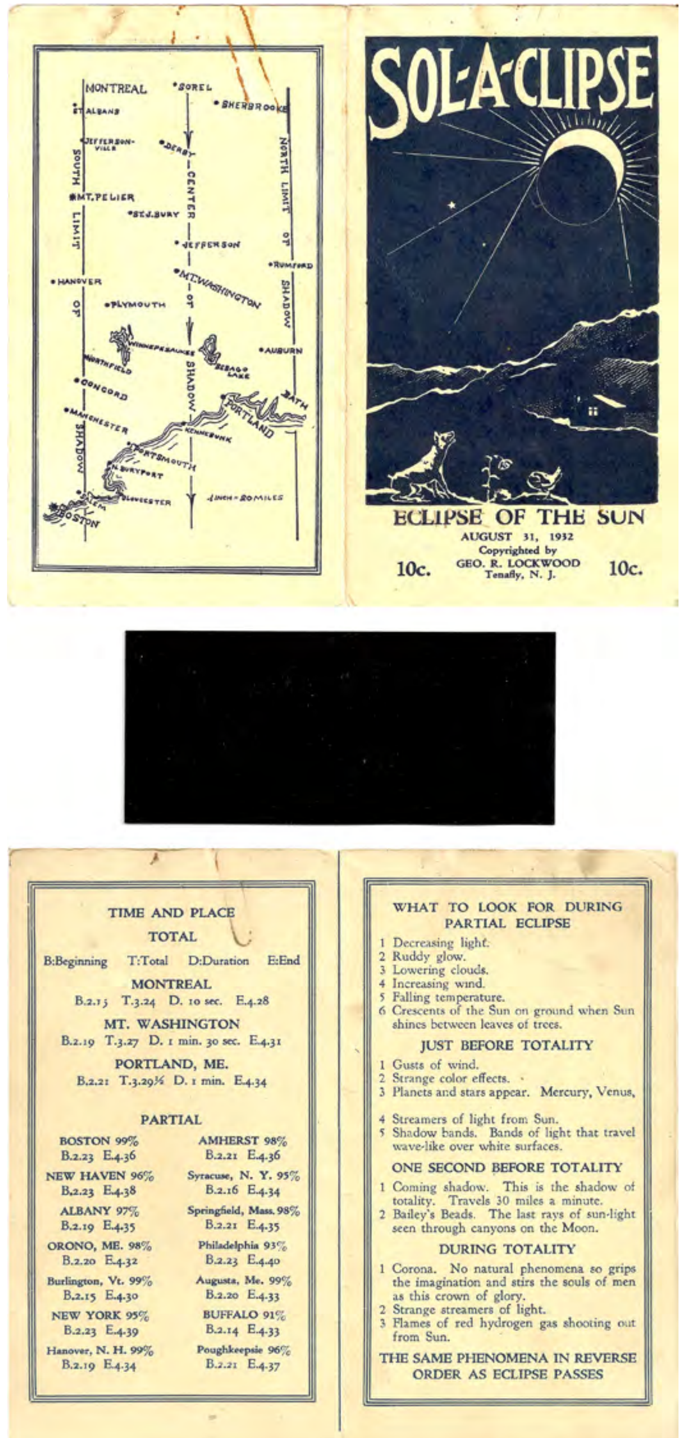

Figure 7 — SOL-A-CLIPSE marketed by George R. Lockwood for the eclipse of 1932 August 31. Reproduced courtesy of the Specula astronomica minima.

characterizing much popular science. In the course of the second and third decades of the century, however, a major change did occur, namely the development off-the-shelf eclipse viewers, and it caught on very quickly. It led to the technological and commercial landscape we are familiar with for simple eclipse viewing.

The story of continuity is easy to substantiate:

> Those who have neither opera-glasses nor telescopes, and will be obliged to observe with the naked eye, may obtain a good view of the eclipse by looking at the Sun reflected from a blackened mirror, but a much better view will be procured by the customary method of observing through a smoked glass. Some precaution is necessary in smoking the glass to avoid cracking it by heating any one portion too suddenly. The glass should be smoked lightly at one end over a candle (or better, over a little piece of camphor gum burning in a saucer), and the shade gradually deepened to almost total blackness at the other. It can then be shifted along past the eyes until the most suitable tint is found, giving a clear view without dazzling. By this simple means, preparing a smoked glass and using it in the manner described, a very satisfactory view of the eclipse may be obtained if clouds do not prevent, besides making the light safe for the eyes, and with an opera-glass bringing out clearly the spherical aspect of the Sun's globe (Bartlett 1918, 365–366).

Much of that could be found in 18th-century instructions.

The creation of the modern commercial market for eclipse viewers happened over seven years, beginning with the solar eclipse of 1925 January 24, visible in the northern States and parts of southern Canada, and showing vigorous growth at the 1927 June 29 eclipse visible over part of England, and equally at the 1932 August 31 eclipse seen over parts of Québec, Maine, New Hampshire, Vermont, and Massachusetts. What was established over those seven years has continued to develop to this day. The chief evidence lies in the nature and number of the surviving artifacts from those three eclipses. The contrast with what went before is striking.

For the 1925 eclipse, Thorp & Martin Company, stationers operating out of Boston Massachusetts, produced an attractive

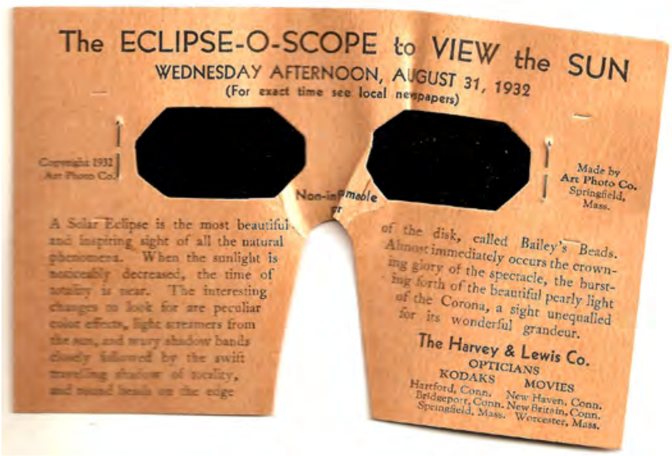

Figure 8 — *ECLIPSE-O-SCOPE sold by The Harvey & Lewis Opticians for the eclipse of 1932 August 31. Reproduced courtesy of the Specula astronomica minima.*

Figure 9 — *The envelope for the Harvey & Lewis ECLIPSE-O-SCOPE. Reproduced courtesy of the Specula astronomica minima.*

brochure on heavy stock, which provided the local circumstances of the eclipse (invoking the authority of Harvard College Observatory—with licence one trusts!), and provided a black-and-white graphic of what to expect at the greatest extent of the eclipse, and contained commercially produced spectacles for viewing the eclipse. The lenses were dark red, which certainly raises doubts now about their efficacy and safety.[13] No price is printed on the opening of the brochure, and it seems from the wording: "WE INVITE YOU TO WATCH THE ECLIPSE OF THE SUN JAN. 24, 1925 With Greater Comfort Because of Using These T & M COLORED GLASSES" that they were complimentary, a form of advertising looking for notice on the back of the celestial event. These were unlike the usual eclipse viewers seen up to then; they were commercially produced and not made by their users out of commonly available materials, and they bore commercial identities. It would take little to turn these into a saleable product.

At least one entrepreneur thought that was a good idea. George R. Lockwood of Montclair, New Jersey, offered his SOL-A-CLIPSE, a brochure with circumstances of the eclipse for the major locales in the path of totality, and for other places that had to be content with a partial eclipse, and several panels describing the phenomena for lay people. Naturally, it contained a viewer, which was a piece of exposed 35-mm film. All that for 10¢.

Several different models of eclipse viewer appeared in time for the 1927 eclipse in England. The commercial aspect was certainly present. *The Boy's Magazine* offered a "free" eclipse viewer to the purchaser of the publication; the magazine and the glasses would cost 2d (Figure 4).

The "Ecliptoglass" was available from the *Journal & North Star* out of Newcastle, for 6d. It was branded with the newspaper's advertising, promises of "special" articles on the eclipse for readers, and the topically silly slogan "THE SUN MAY BE ECLIPSED but NOT the Journal and North Star." The "Ecliptoglass" was also available without the branding, for viewers who preferred discretion (Figure 5). It was still 6d.

There are images of many groups of people toggled up to see the eclipse; some of the more notable ones show nurses sporting eclipse goggles patterned after eyeglasses of the period.[14] Some of those survive (Figure 6). Again, these were obviously not made by the users (although they don't bear any text identifying the manufacturers, or retailers).

The trend toward the production and availability of commercial eclipse viewers is firmly established by the 1932 August 31 eclipse. Noticeably more designs of commercial viewer, by more producers survive than for all the previous eclipses (yet these are still relatively rare artifacts, which now go for a premium). George R. Lockwood was back, and merely had to update the information to reissue his SOL-A-CLIPSE (Figure 7). And The Harvey & Lewis Opticians produced an ECLIPSE-O-SCOPE, retailing for 10¢ a piece, or 12 for $1 (Figure 8). These presented an attractive eclipse map on the front of the envelope, and an explanation of eclipse phenomena on the front of the viewer (Figure 9).

People still made their own viewers after the widespread availability of commercial models in the wake of the 1927 and 1932 eclipses, but it seems that fewer and fewer observers did so. Now, almost no one does. Part of the reason is the present low cost of safe viewers. The other is that fear of damaging one's vision through using a faulty viewer runs high.

What brought about the advent of commercial eclipse viewers for the solar eclipses of 1925–1927–1932? Could it have been increased health concerns about the traditional technologies used to make viewers? Thus far such concerns haven't been found from those seven years. Was there a technological change that made it easier to mass produce eclipse viewers at that time? Every one of the eclipse viewers illustrating this article employs exposed silver nitrate film. Was there a new technical aspect of its production, or a change in its availability that made it an attractive technological choice spurring the rise of commercial eclipse viewers? What of other, larger factors? The 1920s and 1930s saw an acceleration in consumerism, which the Great Depression only momentarily and incompletely interrupted (Stearns 2006, 47–65). Could that have been a contributory cause? Whatever the case, that change in those years led directly to the dominance of the commercial eclipse viewer today.

Nonetheless, some of the older technologies remain viable. A case in point is Roy Bishop's recommendation that people consider "mirror projection," a combined use of a simple mirror with a *camera obscura* (and a masking refinement) for viewing the 2024 April 8 eclipse (Bishop 2023). His is an inventive and intelligent use of a long heritage. It's an encouraging way to look forward. ✶

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Endnotes

1 Quotiens defectionem solis uolumus deprehendere, ponimus pelues quas aut oleo aut pice implemus, quia pinguis umor minus facile turbatur et ideo quas recipit imagines seruat. apparere autem imagines non possunt nisi in liquido et inmoto. tunc solemus notare quemadmodum soli luna se opponat et illum tanto maiorem subiecto corpore abscondat, modo ex parte, si ita competit ut in latus eius incurreret, modo totum. haec dicitur perfecta defectio, quae stellas quoque ostendit et intercipit lucem, tunc scilicet cum uterque orbis sub eodem libramento steti; Seneca 1996, 37–38. Translation by R.A. Rosenfeld.

2 Διὰ τί ὁ ἥλιος διὰ τῶν τετ ραπλεύρων διέχων οὐκ εὐθύγραμμα ποιεῖ τὰ σχήματα, ἀλλὰ κύκλους, οἷον ἐν ταῖς ῥίψιν…Διὰ τί ἐν ταῖς τοῦ ἡλίου ἐκλείψεσιν, ἐάν τις θεωρῇ διὰ κοσκίνου ἢ φύλλων, οἷον πλατάνου ἢ ἄλλου πλατυφύλλου, ἢ τοὺς δακτύλους τῆς ἑτέρας χειρὸς ἐπὶ τὴν ἑτέραν ἐπιζεύξας, μηνίσκοι αἱ αὐγαὶ ἐπὶ τῆς γῆς γίνονται; Aristotle 2011, pp. 462–463, 470–471.

3 Majority opinion at present is not yet with Raynaud in re-evaluating the possibility of Ibn al-Haytham's *Shape of the Eclipse* having any impact on medieval science

4 Si autem die qua sol eclipsabitur totumque eclipsim conspicere uolueris absque oculorum lesione, hoc est, quando incipit et quanta sit et quamdiu durat solis eclipsis, obserua casum solaris radij per medium alicuius rotundi foraminis. Et circulum clarum quem perficit radius in loco super quem cadit diligentius inspice; cuius circuli rotunditatem cum in aliqua parte uideris deficere scias quod eodem tempore deficit claritas in corpore solis ex parte opposita illi parti; nam cum in circulo claro incipit rotunditas deficere [ex parte orientis], tunc incipit sol eclipsari in parte occidentis. Et semper dum decrescit rotunditas circuli clari crescit eclipsis et proportionaliter secundum quantitatem; quot enim digiti diametri solis eclipsantur, tot pereunt digiti circuli clari quem figurat radius solis in loco casus sui postquam transierit per medium foramins rotundi;" Mancha 1992, 275. Translation by R.A. Rosenfeld. I have translated "radius" as "rays" and altered the number to fit, but for Roger's meaning it might be better to translate it as "radius."

5 ...eclipsium autem solarium nulla nisi medietatem excedat potest ad oculum obseruari nisi contingat eam esse circa ortum uel occasum solis, ita quod propter oppositionem uaporum lumen solis debilitetur, quod tamen raro accidit, ideo intendo hic experimentum quodam ponere per quod poterit quelibet eclipsis solis quantumcumque parua notari, etiam si solum medietas puncti deficeret, ne forte si propter defectum uisus aliqua talis eclipsis in almanach posita uideri non posset imputaretur errori, ne etiam ipsas eclipses obseruantibus contingat illud quod pluribus accidit anno domini 1285, quarta die iunij, scilicet quod propter fortem intuitum solis per paruam quantitatem eclipsis accidit illis qui sic solem fortiter inspexerant quedam in oculis tenebrositas, que communiter accidit intrantibus umbram postquam fuerint in claritate solis; que quidem tenebrositas in quibusdam remansit per duos dies, in alijs per tres, in alijs etiam per plures, secundum quod intensius et diucius solem inspexerant, et forte etiam secundum quod plus uel minus apti erant eorum oculi ad huiusmodi tenebrositatem. Unde uidetur quod intantum posset aliquis solem aspicere quod penitus excecatur, iuxta illud dictum Philosophi: excellencie sensibilium corrumpunt sensum; causa autem illius accidentis alibi declaratur. ¶ Solent autem aliqui eclipsim solis in aqua posita in pelui aspicere, sed illud non sufficit; quia ab aqua reflectitur lumen solis, licet debilius sit lumen reflexum quam lumen proprium, et etiam predictum accidens induceret licet debilius. Si tamen fiat, proprie debet fieri in aqua clara et uase profundo existente in quieto loco. ¶Ut igitur predictum accidens penitus euitetur, experimentum aliud explanetur per quod non solum eclipsis solis absque lesione oculorum poterit obseruari, sed etiam hora initij eius et finis necnon et quantitas punctaliter mensurari et etiam quedam alia que alibi locum habent. ¶Fiat igitur in domo clausa foramen in tecto uel fenestra uersus partem illam in qua debet eclipsis solis euenire. Sit autem quantitas foraminis sicut est foramen a quo extrahitur uinum a dolijs. Lumine ergo solis per huiusmodi foramen intrante, ad distantiam foraminis 20 pedum uel 30 aptetur aliqua res plana, ut pote asser unus, ita quod huiusmodi lumen solis super illius rei superficiem perpendiculariter cadat. Videbitur autem lumen in suo casu super huiusmodi superficiem penitus rotundum, etiam si foramen angulare esset. Erit etiam maius foramine, et quanto magis distant huiusmodi res plana a foramine tanto lumen super ipsam cadens latius apparebit; erit tamen debilius quam prope; Mancha 1992, 279–280. Translation by R.A. Rosenfeld.

6 Guillaume de Sancto Clodoaldo vir magnus nomine atque re, studens in astronomie scientia, cupiens aliquam ignota, vel occultam ad viam veritatis reducere; Harper 1966, 2. Translation by R.A. Rosenfeld.

7 It should be noted that the mirror method (in the form of a basin of water) could also be used for quantitative observations, as was done by 'Ali ibn Amājūr at Baghdād(?) for the solar eclipse of 928 August 18; Said & Stephenson 1997, 35.

8 Jarosław WŁodarczyk (2007) has argued that Copernicus also used the technique for solar eclipse observations.

9 The significance of this technology becomes immediately apparent when one realises that the monumental meridians as precision solar observatories in some Italian, French, and Portuguese churches of the 16th–18th centuries are basically *camerae obscurae*; Heilbron 1999.

10 The instrument maker Benjamin Martin (1704–1782) in his tract for the eclipse of 1764 April 1 also describes four different methods of viewing a solar eclipse: 1. with a small telescope or opera glass fit with a dark glass filter; 2. singlet object glass with a long focal length mounted in a scioptic ball set in an aperture of a window shutter in a large room; 3. replacing the singlet object glass with a small telescope in the scioptic ball; 4. by projection through a (Gregorian?) reflector on to a screen. Martin calls 4 the best method, because of its superior image, and that the telescope needn't be placed in a darkened room to be effective; Martin 1764, 15. So Whiston 2 ≈ Martin 1, and Whiston 4 ≈ Martin 4.

11 Paris, Observatoire de Paris, "Vue de l'éclipse du Soleil MDCCXXIV" (=1715 May 3, a partial eclipse), Inv.I.103, oil on canvas, artist unknown (http://tinyurl.com/ytu9kvpf).

12 The iconographical exception that might support the interpretation of such objects as eclipse viewers is in the Collection of Eclipse Viewers assembled by Luke Cole, and now fittingly at Williams College (astronomy.williams.edu/hopkins-observatory/eclipse-viewers). The image can be found at: astronomy.williams.edu/files/DSC_7040.jpg. The image looks as if it might be from an 18th-century copper-plate engraving, but, unfortunately its source is not identified, nor is it shown with any text to provide contextual context.

13 I am aware of only one surviving example, which belongs to a private collection. It is also just possible that the right-most figure in the painting cited in note 11 is using one of these mystery "dark glasses" for viewing the eclipse of 1715 May 3 at Paris.

14 www.cbc.ca/news/multimedia/how-people-watched-solar-eclipses-in-the-last-century-1.4243992.

CFHT Chronicles

Working with the Hawai'i Community

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

I am taking a one-issue hiatus from our normal column content to talk a bit about an essential aspect of my job, connecting with community across Canada, France, and Hawai'i.

Hawai'i

CFHT staff continue to engage with students in the A Hua He Inoa internship project and expanded the collaboration in Fall 2023. The 2022–2023 A Hua He Inoa cohort took up A Hua He Inoa interns working at 'Imiloa. The tour was part of their yearlong internship. In addition to visiting the summit, the students interviewed CFHT executive director Jean-Gabriel Cuby and myself on the effects of light pollution for an upcoming 'Imiloa display created by the students.

Greg Barrick, one of our engineers, and I are working closely with the 2023–2024 cohort of A Hua He Inoa students. A Hua He Inoa roughly translates from 'ōlelo Hawai'i to "calling forth a name," and the program names astronomical objects using traditional naming practices. As part of their internship, the students will create a name for the VISION project based on traditional Hawaiian naming practices. VISION is our plan to co-mount our optical and infrared spectrographs with the end goal of simultaneous observations from the UV to near IR. Greg and I accompanied the students to the summit for a tour of CFHT and Keck before delving deeper into VISION. Greg took the students into the inner coudé to see the instruments. He and I talked in-depth with the students at Hale Pokahu, the astronomers' residence at 3,000 metres, about the instruments' characteristics, how they differ, what makes them unique, how VISION will work, etc. The students plan to meet Dr. Larry Kimura the week of December 11 to create three name options that they will share with CFHT. We plan to discuss the names internally and select one of them. The proper spelling, including diacriticals, will be used in all VISION materials moving forward, with exceptions made for computer code, which does not recognize diacritics markings.

Efforts to better engage with the UH Mānoa College of Engineering (CoE) continues. CFHT, Keck, and University of Hawai'i Institute for Astronomy participated in the virtual and in-person Spring and Fall Career Expos. Prior to the Spring Career Expo, CFHT staff Sam Barden, Andy Sheinis, Ivan Look, and Raycen Wong took ten students interested in learning more about opportunities with CFHT and Maunakea Spectroscopic Explorer (MSE) out to dinner. CFHT staff continue to engage with the Dean of the CoE, attending several events sponsored by the program in Hilo. The Maunakea Observatories, CFHT included, attended the April CoE Spring Banquet. All these efforts are intended to raise the profile of the MKOs within the CoE, showcasing astronomy as a viable post-graduate path for students and as a potential partner for the overall CoE. Similarly, CFHT staff attended a Fall Career Expo for students interested in careers in computer science and system administration.

Figure 1 — A Hua He Inoa students at Hale Pokahu with Greg and the author.

CFHT continued its back-to-school welcome for students at Waimea Elementary School. Many families park on the CFHT lawn for school drop-off while other students take the Nature Path behind CFHT to school. CFHT staff greeted families with back-to-school supplies, coffee, lunchbox snacks, and donuts. Despite the very windy conditions, parents and students said it helped them feel more excited about the first day of school.

CFHT continues to regularly visit classrooms, participate in middle/high school career fairs, host field trips, and offer summit tours, primarily on Hawai'i Island. We participate in the Climb HI portal, a "one-stop shop" for teachers to request classroom visits and career fair participants across the state. CFHT was recently recognized by Climb HI as a 2023 Outstanding Business for participating in at least 10 events. Overall, CFHT staff participated in at least 45 school visits, impacting over 7,000 students. Of note, CFHT was invited to two career fairs at Kamehameha Schools, a Native Hawaiian K–12 school funded by the endowment of Princess Bernice Pauahi Bishop, in large part because of our operations group manager, Ivan Look's connection to the school and the guidance counsellors.

CFHT continues to run the Maunakea Scholars program, where students at eight Hawai'i high schools can apply for observing time on the Maunakea Observatories for their own, independent research projects. Maunakea Scholars wrapped up the 2022–2023 school year with 34 students receiving telescope time and an additional 10 students receiving honorable mentions. The first MKS student, Ciana-Lei Bence from Kamehameha Schools Keaau, advanced to the International Science Fair last year. Ciana-Lei was also awarded the 2023 Hōkūala Scholarship. The scholarship goes to an outstanding MKS student who plans to major in astronomy. She started Yale in August.

Observations for the 2022–2023 students are wrapping up. Mary Beth and students conducted four IRTF observing runs in September and October observing Iapetus, Pluto, and Neptune. For Iapetus and Pluto, the students receiving the telescope time were able to conduct their own observations. The Neptune student was unable to visit the summit, so those observations were conducted by four undergrad students from the University of Hawai'i Mānoa astronomy program who were on the island.

The 2023–2024 school year has eight schools participating in MKS, including a new school, Kamehameha Schools Kapālama (Oahu). One of the students at Kapālama has already received telescope time on SPIRou to look for magnetic fields around Wolf-Rayet stars. Her work was inspired by a recent CFHT news release from Tomar Shenar and Gregg Wade who discovered a strong magnetic field around a massive helium star.

The longer-term impacts of MKS are beginning to be seen with alumnus in and graduating from college. The first MKS alumni with a degree in astronomy graduated last May, he's actively applying to graduate schools for admission next year. Two MKS alumni are now teachers; one elementary school teacher in Arizona and the other has started teaching at another MKS school, Kapolei HS, where she's taking over the MKS program from the current teacher who retires December 2023. Five MKS students participated in the Akamai internship program last summer, three with astronomy projects, one engineering, and one computer science.

Collective MKO community events like Astro Day in Hilo and Kona continued this year with CFHT staff attending both. Organizers estimate roughly 900 people attended the events. The Waimea Solar System Walk returned to its pre-pandemic format with participants starting the walk with the Sun, inner planets, and Jupiter/Saturn on the Keck HQ grounds before walking to Uranus/Neptune across from the Waimea Library (an event partner) and ending with the Kuiper Belt at CFHT. Participation was lower than pre-pandemic, but the event was held on a Sunday rather than Saturday as in years past. Participants enjoyed a BBQ after the walk and most stayed for the Solar System Walk Costume

Figure 2 — Ciana-Lei (centre) receiving Hōkūala Scholarship.

Contest. CFHT recently hosted our annual Winter Star Party after the Christmas Parade on December 2. The turnout was very large, approximately 250 people.

Between school visits and events for the public listed above, we estimate CFHT directly reached ~8,300 people this year.

CFHT and Keck have collaborated on two large community events in 2023. Run by Vibrant Hawai'i, Kau Kau 4 Keiki was a summer program designed to offset keiki (child) food insecurity on Hawai'i Island. CFHT and Keck staff picked up, packed, and distributed food for six consecutive weeks. The first three distributions were held at CFHT, the final three at Keck. CFHT and Keck were recently asked to co-sponsor the Santa Float in the Waimea Twilight Christmas Parade. Staff from both facilities collaborated on a float design to reflect the theme "E Lauhoe Mai Na Wa'a: Everybody Paddle the Canoe Together." The float included a canoe on loan from the Kawaihae Canoe Club with a sail that included Orion, the Makali'i (Pleiades), and the Milky Way. All indications show that the float was a success.

CFHT hosted two Akamai Interns over the summer with two previous interns returning. Noah Chung worked with Marc Baril to update the MKAM website. The project moved faster than originally anticipated, so Noah added modernizing the MKAM database to his work. He transformed the database into a much more user-friendly one that can be used to analyze weather trends over time.

Del Jordan worked with Ivan Look and Raycen Wong to design, fabricate, and install a MegaCam alignment fixture to guide MegaCam back into its correct position on the dome floor. The project underwent a design review and was installed in July 2023.

2022 Akamai intern Andrew Unger continued his work with Heather Flewelling analyzing the evolution over time of satellite constellations on MegaCam images. One of CFHT's

Figure 3 — The "mast" of the CFHT-Keck joint Santa Float for the Waimea Twilight Christmas Parade.

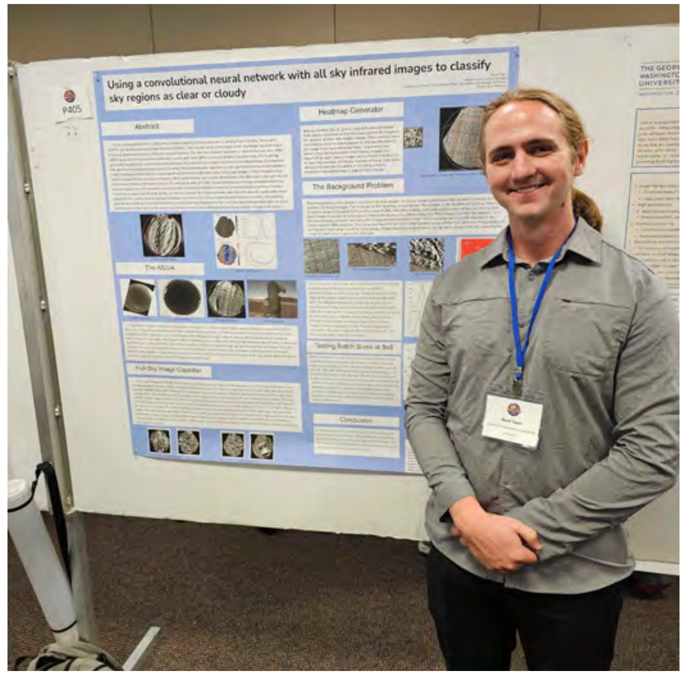

Figure 4 — Brock Taylor and his poster at ADASS.

other 2022 Akamai interns, Brock Taylor, returned this summer to work with Billy Mahoney. Last summer's project focused on upgrading the ASIVA camera. This year's project utilized the images from ASIVA, creating a convolutional neural network to determine if the image showed cloudy or clear skies. Brock's work was accepted as a poster at the November ADASS meeting in Tucson. He is an MKS alumnus who plans to graduate in May 2024.

CFHT supported numerous non-profit organizations over the course of the year. A large effort was made to support Maui-related efforts after the devastating August wildfires. Donations were made to the Hawai'i Community Foundation's Maui Relief Fund and 'Imiloa's back-to-school initiative. CFHT's support comes through sponsorships, purchase of needed items for local schools, or donated summit tours. Many of the donations are small, for example, CFHT sponsors the Waimea Middle School 6th-grade math teacher's pie incentive program. She rewards students who have reached math competency with a pie of their choice from the local grocery store.

Canada

I visited NRC and the Dominion Astrophysical Observatory in September 2023. I worked with the Friends of the DAO to give two talks at the public observing night and a teachers' workshop. The workshop focused on the Earth, Moon, and Sun relationship, a British Columbia educational standard. CFHT purchased a stuffed Earth, Moon, and Sun for the

Figure 5 — Workshop participants as the Sun, Earth, and Moon. Photo credit: Ben Dorman, FDAO.

classrooms of each participant. The Friends of the DAO were quite excited; participants from the local First Nations school district attended, a testament to the effort the organization has put into reaching out to First Nations schools. Mary Beth also talked to the local RASC chapter.

CFHT continued writing a column in the bi-monthly Royal Astronomical Society of Canada's Journal, entitled "CFHT Chronicles." The CFHT Chronicles debuted in the June 2015 edition. Prior to Laurie Rousseau-Nepton's departure from CFHT, she worked with the National Film Board of Canada on a web series called "Étoile du Nord." Designed for teenagers, the series explores Laurie as a complete person—her science, life, and First Nations culture. The team partnered with *Discover the Universe* to create an educational guide for teachers to use in their classrooms. The series has been exceptionally well received, garnering awards from several film festivals and outlets.

And no column on my work would be complete without mentioning the privilege I have to write this column for all of you!

I have mentioned in the past that these columns are written two months ahead of time. As I sit here in December, I hope you all have a great start to 2024! ✶

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

John Percy's Universe

Astrobiology, or "Are We Alone in the Universe?"

by John R. Percy, FRASC
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Astrobiology: a young interdisciplinary science, dealing with life in a universal context. "Are we alone in the universe?": an age-old question which has been addressed by scientists, philosophers, theologians, sci-fi and other writers, and increasingly by conspiracy theorists and other purveyors of misinformation. It is a subject that I occasionally choose for a public presentation. But which of the two versions and titles shall I adopt?

What Is Life?

Life is that which biologists or "life scientists" study; that's obviously a large part of astrobiology. Based on many decades of research and thought by life scientists, NASA has settled on the following definition of "life as we know it": "life is a self-sustaining chemical system capable of Darwinian evolution." Its ingredients are organic molecules, (primarily hydrogen, carbon, nitrogen, and oxygen), liquid water, a stable environment, and sources of energy.

Life scientists study everything from one-celled bacteria to us. At the same time, paleontologists have unraveled Earth's "tree of life," starting with three-billion-year-old organisms that were much simpler than the simplest bacteria today. Evolution was generally slow, but then came the Cambrian explosion, 530 million years ago, when the number and diversity of organisms exploded. Most eventually went extinct, but obviously not all. We are here.

There were also mass extinctions, such as the one 66 million years ago when the majority of species— including the dinosaurs—went extinct. It resulted from a giant meteorite impact on what is now the Yucatan Peninsula of Mexico. Other great extinctions may also have been caused by other meteorite impacts, or possibly by internal geological processes.

Now we are entering the *anthropocene*, when human activity is the greatest force affecting the evolution of life on Earth. We are also entering an era when technologies, ranging from robots to drones to computers to artificial intelligence (AI), are straining the definition of life as we know it. It would clearly be useful to have an even more fundamental understanding of the nature, origin, evolution, and diversity of life—a more "universal" picture.

What and when will be the end of life on Earth? Certainly, when the Sun swells into a red giant, five billion years from now. Or when another giant meteorite impacts our planet, probably tens of million of years from now. Or a climate crisis much sooner than that. Or a nuclear war. Fortunately, history suggests that life is resilient enough to survive in some form. Again, we are here.

The Origin of Life

In 1953, Stanley Miller (1953), a graduate student supervised by Harold Urey, published the results of a landmark experiment in which they subjected a mixture of simple molecules like methane and ammonia to electrical sparking, to simulate the effect of lightning energy. After several days, the simple molecules had reacted to produce complex organic molecules, such as the amino acids from which our proteins are made. Other scientists have built upon Miller and Urey's work, but they have not (yet) created life from non-life in the laboratory. This is the big gap in our understanding of how life originated and evolved on Earth.

At the same time, scientists have discovered *extremophiles* living in extreme conditions on Earth, such as hot geothermal vents and acidic volcanic pools. Life Life began not just in the "warm little ponds" that Charles Darwin and others envisioned. Scientists should look for life in very diverse environments, both on Earth and beyond.

Life in the Solar System

Exploration of the Solar System is well underway. Is there anywhere else in the Solar System where there is life, fossil life, or biosignatures such as complex organic molecules or unusual isotope ratios? Interestingly, there is material raining down on the Earth every day from elsewhere in the Solar System, in the form of meteorites. I am not aware of any life forms—alive or fossil—in any of these. Most meteorites are chips off asteroids, but there are a few lunar meteorites that were ejected from the Moon by giant impacts, and a very few meteorites which were ejected from Mars in the same way. They are cheap astrobiological samples.

Perhaps the most interesting meteorites are carbonaceous chondrites (Figure 1), left over from the formation of the Solar System, 4.5 billion years ago, and unchanged since then. They contain several percent of carbon, in the form of pre-biological molecules such as amino acids. Like the Miller-Urey experiment, they are evidence that pre-biological molecules—and perhaps life—can form easily and naturally in a variety of environments.

We now have Moon rocks, brought back by the Apollo Project. I have held one in my hand. I assume that it was not infectious! We have explored Mars with rovers, looking for evidence of present or past life, and we will soon have Martian samples brought back to Earth for more careful examination. No luck so far.

There are also interesting environments on Titan, a large but cold moon of Saturn, and other moons of the gas giants which may have subsurface oceans. Exploring these would be a difficult and expensive undertaking but, given our knowledge of extremophiles on Earth, we should keep an open mind about where life might be found.

Life beyond the Solar System

That covers a lot of ground. In the Universe, there are tens of billions of galaxies, each containing up to hundreds of billions of stars, many with planets, and some with Earth-like planets with temperatures at which water is a liquid. Furthermore, all these stars and planets obey the same laws of physics and chemistry as here on Earth and, with the exception of the oldest ones, are made of the same chemical elements that we know and love, including the elements of life—hydrogen, carbon, nitrogen, and oxygen. Furthermore, the process by which stars and planets form elsewhere in the Universe is observed to be similar to the process by which the Solar System formed: stars form surrounded by a disk of leftover gas and dust in which planets are built up through accretion, as dust grains stick together to form planetesimals, which gravity then gathers into planets.

It's therefore not surprising that planets, called *exoplanets*, have been discovered in great numbers around other stars, either through their gravitational pull on their star, or by a slight dimming as the planet passes in front of its star—called a *transit*—or, in a few cases, seen directly. In 2019, Michel Mayor and Didier Queloz won the Nobel Prize in Physics for the first discovery of an exoplanet (Mayor and Queloz 1995).

Interestingly, the first evidence of life outside the Solar System may come from spectroscopic observations of the atmosphere of an exoplanet. During a transit, some light from the star passes through the atmosphere of the exoplanet on its way to us, and imprints information onto the spectrum of the star. If the atmosphere contains biogenic elements such as oxygen, that's strong evidence for life on the planet; atmospheric oxygen rapidly reacts with surface minerals unless it is constantly replenished by life. But direct evidence of simple life on an exoplanet will not be available unless we can travel there.

Intelligent life is another thing. In 1961, radio astronomer Frank Drake proposed a famous equation that would estimate the number of intelligent civilizations in our Milky Way, based on the product of numbers representing the factors necessary for the development of intelligent life. Of course, the accuracy of the result that you get is no better than the accuracy of the numbers that you put in, but progress is slowly being made.

Interstellar Communication

It so happens that we live in a time—which may be short—when humans can and do produce electromagnetic radiation and use it for practical purposes such as radar and radio and TV communication. If there was any other civilization in our galactic neighbourhood that had similar technology, we could detect its radiation and in principle communicate with it. We would have to be patient, though; due to the finite speed of electromagnetic radiation, 300,000 km/sec, it would take

Figure 1 — The Tagish Lake meteorite, which impacted in the Tagish Lake area of northwest British Columbia on 2000 January 18. It is a carbonaceous chondrite, left unchanged since the birth of the Solar System. It contains pre-biological molecules such as amino acids, which indicate that the precursors of life—and perhaps life itself—can form easily and naturally. Credit: Courtesy of ROM (Royal Ontario Museum), Toronto, Ontario @ROM.

signals several years to reach us, even from the nearest stars. Radio waves are preferred for communication because, unlike light, they are not absorbed by the interstellar gas and dust that fills the disk of our galaxy.

Nevertheless, astronomers have searched the radio sky for signals. SETI (search for extra-terrestrial intelligence) and CETI (communication with extra-terrestrial intelligence) have been attempted by professional and amateur astronomers, mostly as volunteers, or through non-profit organizations such as the SETI Institute (www.seti.org).

What might they "hear"? The strongest signals routinely emitted by humans are military radars—evidence, I suppose, of our "advanced" intelligence. Should we send deliberate signals into the Universe? Is it safe? And if so, what should we say, and in what language?

Interstellar Travel

Might humans ever travel to other stars, or might aliens ever visit Earth? Of course, there is a large segment of the population that believes aliens have been visiting us for millennia, but the evidence is not there. Aliens are a multi-billion-dollar piece of the entertainment industry! There is also the question of why aliens would want to visit our planet anyway, especially at this time. As *Globe and Mail* columnist Andrew Coyne recently put it in a brilliant full-page column (1): "Of all the planets that aliens could have visited, they came here??" Would that I could write as well.

As for how to travel over interstellar distances, the challenges are even greater than for interstellar communication. Radio signals travel at light-speed and can be broadcast to wide areas of the sky. Spacecraft only go to one place at a time. And at best, they putter along at a few tens of km/sec—thousands of times slower than light. It would take millennia to reach even the nearest other star.

But futurists have speculated on how it might be done. By accelerating and expelling ions. By recycling obsolete nuclear weapons as an energy source (and thereby killing two birds with one stone). By somehow harnessing hydrogen fusion, and perhaps even collecting hydrogen fuel from the interstellar gas in transit. By using matter-antimatter annihilation (if they can figure out what to put the antimatter in, safely). By using a large but lightweight sail, pushed by a powerful laser back on Earth. Or by just sending thousands of people on a slow "generation starship"; their distant descendants will arrive at their destination after thousands of years. Or maybe just sending sophisticated robots with advanced AI. Or sending thousands of them to promising destinations all over our galaxy, hoping that a few of them reach intelligent but more benign civilizations than us. Lots to think about.

Personally, I would be delighted if extra-terrestrial life appeared on Earth, as long as it was not hostile and not infectious. I would even be happy just to know that it existed. But I would want the evidence to be as solid and verifiable as the evidence for other scientific phenomena, or at least strong enough that it would pass the test of high-quality investigative journalism. Maybe in my lifetime, who knows? ✶

Endnotes

1 www.theglobeandmail.com/opinion/article-of-all-the-planets-aliens-could-have-visited-they-came-here

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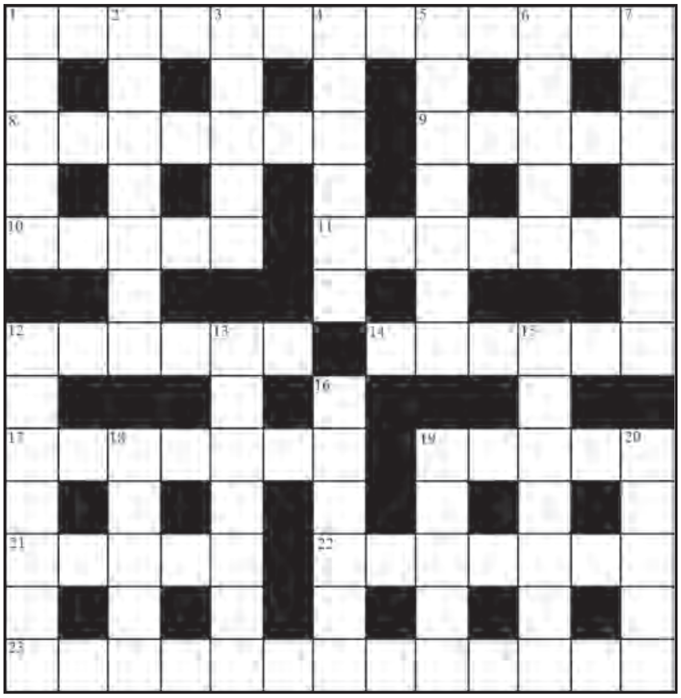
Astrocryptic

by Curt Nason



ACROSS

1. Nominal components of (20020) Mipach (4,4,5)
8. A piece of (2300) Phaethon was a highlight in December (7)
9. A name given to Pons when fifty debt memos were distributed (5)
10. Titan or another moon displayed in that laser light (5)
11. Write back with an air of a planet (7)
12. Messier stirred sauce of a fly in the sky (6)
14. ATM's mirror test becomes chronic with no end (6)
17. Heavy quark with ½ angular momentum makes tennis balls sink (7)
19. Our turn in frequency modulation is posted to the rasclist (5)
21. Upset the manor in search of a carpenter's square (5)
22. Pioneer of special relativity would look to lease Zellers first (7)
23. Carr handshake overturned the limit on white dwarf mass (13)

DOWN

1. Gamma conversion hot enough to melt rock (5)
2. The Lamplighter's stellar cascade (7)
3. Yearns to be among those around a U of Oregon observatory (5)
4. Sunday has no say in a family of asteroids (6)
5. Belafonte's style of orbiting Saturn (7)
6. Yoda's leading guru turns on a disturbed asteroid (5)
7. Jupiter's systemic activity doesn't end with equatorial period (7)
12. Mice scamper around, not back in, a lunar cycle (7)
13. First Greek character to lead research and development of a solitary star (7)
15. Kryoneri Observatory district possible source of Antikythera mechanism (7)
16. Does it inflate tires for southern stars? (6)
18. Common apparel for observing M42 in a park (5)
19. Gravitational attraction within Enif or Cebalrai (5)
20. After May first, a star in Boötes is in Ursa Major

Answers to previous puzzle

Across: 1 MOPRA (anag); **4** FORBUSH (anag); **8** GRANULE (g(anag)e); **9** MINOR (Mi(no)r); **10** EVENT (2 def); **11** DYNAMIC (anag); **12** IMPACT (hom); **15** BRIDGE (2 def); **18** FACULAE (an(Cu)ag); **19** GAMOW (2 def); **21** EMEND (e(anag)nd); **22** UNLINED (anag); **23** DESPINA (anag+in+a); **24** SPOKE (2 def)

Down: 1 MAGNETIC FIELD (2def); **2** PLAGE (2 def (F)); **3** ADULT (hid); **4** FIELDS (anag); **5** RAMAN (ram+an); **6** UNNAMED (anag); 7 HERSCHEL WEDGE (anag); **13** POCKELS (an(CK)ag); **14** CHLADNI (Ch+lad+rev); **16** REGULUS (rev+us); **17** NEBULA (anag); **20** MINEO (2 def)

Great Images

by Katelyn Beecroft

Katelyn Beecroft was able to capture this beautiful image of the Lobster Claw Nebula, found in Cepheus, and during a full Moon, no less. "Since I was imaging this during the full Moon, I knew I needed to pick a target towards the north that I could image in Narrowband and decided on the Lobster Claw as an appropriate end of summer target since the lobster reminds me of the beach," she says. She used an Askar FRA400 scope with ZWO ASI533MC camera on an HEQ5 mount. Filters included the L-Extreme (206 x 300s) for the nebula and the Astronomik L3 filter (28 x 120s) for the stars. The final image was processed in PixInsight using a false Hubble palette.

Journal

Nearby the Lobster Claw Nebula (see Great Images) lies the Bubble Nebula (NGC 7635). Scott Johnstone managed to take this spectacular image of the Bubble Nebula using a Sky-Watcher Quattro 150P on a Sky-Watcher HEQ5-Pro with an ASI533MC-P camera and Optolong L-eXtreme and ZWO UV/IR filters. He took 78 x 300 second lights with L-eXtreme and 20 x 120 second lights with UV/IR for a total of 7 hrs 10 min. The final image was processed in PixInsight and Photoshop.