The Journal of The Royal Astronomical Society of Canada

Journal

Le Journal de la Société royale d'astronomie du Canada

PROMOTING ASTRONOMY IN CANADA

October/octobre 2020
Volume/volume 114
Number/numéro 5 [804]

Inside this issue:

Last Great Visual Observer of Mars

Impact of the Brightness of Light

Comet NEOWISE

The Best of Monochrome.

Drawings, images in black and white, or narrow-band photography.

(Devoted in October to this one-off colour image of Comet NEOWISE.)

Ron Brecher imaged NEOWISE on July 17 from his SkyShed in Guelph, Ontario. He used a Canon 70D modified with a Kolari Vision astrophotography filter and a Canon 100-400-mm ƒ/4-ƒ/5.6 L lens at 100 mm, ƒ/5.6, and ISO 800 on a Sky-Watcher Star Adventurer mount, 30×20 second frames for a total of 10 minutes. All pre- and post-processing was done in PixInsight.

Journal
October / octobre 2020 | Vol. 114, No. 5 | Whole Number 804

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

contents / table des matières

Feature Articles / Articles de fond

196 Masatsugu Minami—the Last Great Visual Observer of Mars
by Bill Sheehan

205 The Biological Basis for the Canadian Guideline for Outdoor Lighting 2—Impact of the Brightness of Light
by Robert Dick

214 Pen and Pixel: Aurora and Comet NEOWISE / Comet NEOWISE / Comet NEOWISE Coma / Comet NEOWISE, Aurora, and STEVE
by Garry Stone / Klaus Brasch / Mark Kaye / Notanee Bourassa

Columns / Rubriques

211 Observing: Comet NEOWISE
by Chris Beckett

216 Skyward: Reflections of a Comet and Reasons to Join Your Local Astronomy Club
by David Levy

218 Astronomical Art & Artifact: Claude Mellan's Moon in Pierre Gassendi's Printed Letters: Clues to Changes in Perceptions of Accuracy?
by R.A. Rosenfeld

224 Binary Universe: Losing the Night
by Blake Nancarrow

227 John Percy's Universe: Young Stellar Objects and their Variability
by John R. Percy

229 Dish on the Cosmos: Neutron Star Sleuthing
by Erik Rosolowsky

232 Imager's Corner: Equipment Review—Optolong L-eNhance Filter Review
by Blair MacDonald

234 Celestial Review: Draconids, Orionids, Leonids, and Mars
by Dave Garner

Departments / Départements

190 President's Corner
by Robyn Foret

191 News Notes / En manchettes
Compiled by Jay Anderson

234 Review / Critiques
Compiled by Dave Turner

240 Astrocryptic and August Answers
by Curt Nason

iii Great Images
by Tenho Tuomi

Comet NEOWISE, which was only discovered in March 2020, made a surprisingly wonderful display for skywatchers in July. Sheila Wiwchar was able to photograph both the ion and dust tail from Kaleida, Manitoba, July 17 using a Canon 6D on a Optics Star 71 scope. Total exposure was 7×30 seconds at ISO 4000.

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.

Editor-in-Chief
Nicole Mortillaro
Email: editor@rasc.ca
Web site: www.rasc.ca
Telephone: 416-924-7973
Fax: 416-924-2911

Associate Editor, Research
Douglas Hube
Email: dhube@ualberta.ca

Associate Editor, General
Michael Attas
Email: attasm1@mymts.net

Assistant Editors
Michael Allen
Martin Beech
Dave Chapman
Ralph Chou
Ralph Croning
Dave Garner
Patrick Kelly

Production Manager
James Edgar
Email: james@jamesedgar.ca

Advertising
Adela Zyfi
Email: mempub@rasc.ca

Contributing Editors
Jay Anderson (News Notes)
Chris Beckett (Observing Tips)
Dave Garner (Celestial Review)
Mary Beth Laychak (CFHT Chronicles)
David Levy (Skyward)
Blair MacDonald (Imager's Corner)
Blake Nancarrow (Binary Universe)
Curt Nason (Astrocryptic)
John R. Percy (John Percy's Universe)
Randall Rosenfeld (Art & Artifact)
Eric Rosolowsky (Dish on the Cosmos)
Leslie J. Sage (Second Light)
David Turner (Reviews)

Proofreaders
Michael Attas
Margaret Brons
Angelika Hackett
Michelle Johns
Barry Jowett
Alida MacLeod

Design/Production
Michael Gatto, Grant Tomchuk
Email: mgatto0501@gmail.com,
granttomchuk@eastlink.ca

Printing
Cansel
www.cansel.ca

Her Excellency the Right Honourable **Julie Payette**, C.C., C.M.M., C.O.M., C.Q., C.D., Governor General of Canada, is the Viceregal Patron of the RASC.

The *Journal* of The Royal Astronomical Society of Canada is published at an annual subscription rate of $93.45 (including tax) by The Royal Astronomical Society of Canada. Membership, which includes the publications (for personal use), is open to anyone interested in astronomy. Applications for subscriptions to the *Journal* or membership in the RASC and information on how to acquire back issues of the *Journal* can be obtained from:

The Royal Astronomical Society of Canada
203 – 4920 Dundas St W
Toronto ON M9A 1B7, Canada

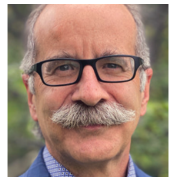
Email: nationaloffice@rasc.ca
Web site: www.rasc.ca
Telephone: 416-924-7973
Fax: 416-924-2911

Canadian Publications Mail Registration No. 09818
Canada Post: Send address changes to 203 – 4920 Dundas St W, Toronto ON M9A 1B7

Canada Post Publication Agreement No. 40069313

We acknowledge the financial support of the Government of Canada through the Canada Periodical Fund (CPF) for our publishing activities.

President's Corner



by Robyn Foret, Calgary
(arforet@shaw.ca)

As I write this, we are five months into our COVID-19-induced reality, and I hope all of you and yours are keeping yourselves and those around you safe.

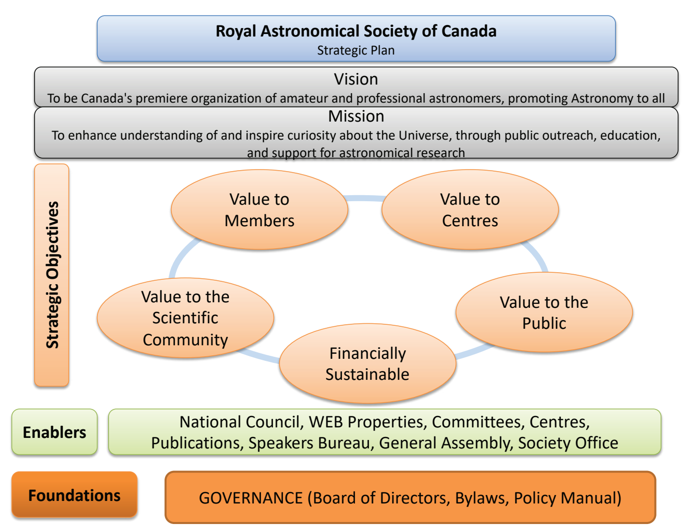
The RASC has embraced the need for rapid change, addressing how we do what we do and tweaking what we do as well.

Starting with changes in methodology, last edition I noted the use of social media and virtual meetings to deliver our General Assembly and Annual General Meeting. Continuing on the theme of virtual events, I'm happy to report that we have a busy events calendar hosting regular installments of The Insider's Guide to the Galaxy, Self-Isolation Star Parties, Speaker Series and Explore the Universe Online. Check out what's up and coming and how to access archived sessions at www.rasc.ca/covid. Thanks to all the contributors for making this happen with a special shout-out to our own Jenna Hinds, RASC Host and Influencer extraordinaire.

Communications has seen an uplift too, with The RASC Bulletin appearing in members' inboxes monthly along with a frequent push of "What's happing at the RASC," highlighting upcoming astronomical events, virtual sessions, and local RASC Centres' events from across the country.

While the RASC Board of Directors provide governance and direction for the Society, the development and delivery of programs and other tangibles related to our mandate and strategic objectives is the work of our committees, our staff, and our working groups.

Changes in technology, delivery methodology, and our role in addressing pressing social challenges helps us refine our objectives at the committee, staff, and working-group level.



Here's an update relative to these:

Our Observing Committee offers programming that develops the knowledge and skills for first-time observers through to advanced amateurs and professionals; Astroimaging helps visual observers obtain the techniques and rigour to hone imaging skills; Robotic Telescope brings state-of-the-art image capture; Education and Public Outreach brings astronomy to the masses; Publications provides current and topical content; Light-Pollution Abatement supports and sponsors stewardship of the nocturnal environment; Inclusivity and Diversity ensures that our Society encompasses and welcomes everyone; Next Generation provides for the needs of our youth and young-adult demographic; IT ensures we have the right tools and platforms; and History ensures that we stand on the shoulders of our past leaders and contributors. Our Society Office, led by Dr. Philip Groff, our Executive Director, spearheads Marketing, Communication, Fund Raising, Youth Programming, and Administration, offering these Services to all Centres and Committees and ensuring consistent Branding and Messaging across all disciplines and target audiences.

Many thanks to go out to our committees, to our staff, and to our volunteers who continue to embrace change and find new and creative ways for our Society to realize its vision and mission.

To our readers, please feel free to engage and share with us your ideas as to how we might better deliver our values in these challenging times. ✶

News Notes / En manchette

Compiled by Jay Anderson

New revelations of a galactic magnetic field

Magnetic fields are a ubiquitous part of galaxy structure. They play an important role in regulating gas flows, in maintaining the structure of a galaxy's interstellar medium (ISM), in the commencement of star formation, and in the distribution of cosmic rays. Even so, the source of galactic magnetic fields is a bit of a puzzle, possibly created by a dynamo formed by turbulent motions and differential rotation.

Teasing out the shape and importance of galactic magnetism requires high-resolution observations and complex modelling and interpretation. Recently, an international team of European, American, and Canadian radio astronomers has used data from National Science Foundation's Karl G. Jansky Very Large Array (VLA) in New Mexico to generate a detailed map of the magnetic field of NGC 4217, an edge-on, Milky Way-like spiral galaxy located about 60 million light-years away in the constellation of Canes Venatici. The edge-on character of NGC 4217 allowed the astronomers to view the shape of the magnetic field above and below the galactic plane.

The team used radio data at two frequencies, 6 GHz (*C*-band) and 1.5 GHz (*L*-band), from the VLA, supplemented with lower-frequency 150 MHz observations from LOFAR, a network of 20,000 small antennae distributed across Europe in 48 clusters, mostly in the Netherlands). The structure of the magnetic field was reconstructed from polarization characteristics of the radio emission.

"This VLA image clearly shows that when we think of galaxies like the Milky Way, we should not forget that they have galaxy-wide magnetic fields," said Dr. Yelena Stein, an astronomer at the Centre de Données astronomiques de Strasbourg and the lead author on the study.

The team's work showed that NGC 4217 possesses a large-scale X-shaped magnetic field structure, extending over 20,500 light-years outward from the galaxy disk and connected to the diffuse, hot gas surrounding the galaxy. Many filamentary structures as well as loops, shells, and at least one superbubble-like structure were visible in the *C*-band radio continuum. A helical outflow structure was in the part of the galaxy that extended nearly 7 kiloparsecs into the halo. Superbubbles typically arise from congregations of hot, rapidly evolving O-type stars where frequent supernovae expand into the surrounding gas.

"It is fascinating that we discover unexpected phenomena in every galaxy whenever we use radio polarization measurements," said co-author Dr. Rainer Beck, an astronomer at the

Figure 1 — This composite image shows the edge-on spiral galaxy NGC 4217. Magnetic field lines (green), revealed by the VLA, extend far above and below the plane of the galaxy. Image credit: Y. Stein, Centre de Données astronomiques de Strasbourg / NRAO / SDSS / KPNO / J. English, University of Manitoba / R.-J. Dettmar & A. Miskolczi, Ruhr-Universität Bochum / R.J. Rand, U.N.M. / J. Irwin, Queen's University.

Max-Planck-Institut für Radioastronomie. "Here in NGC 4217, it is huge magnetic gas bubbles and a helix magnetic field that spirals upwards into the galaxy's halo."

Written in part with material provided by Ruhr-Universitaet-Bochum.

Dusty swirls map new-born planets

A remarkable set of photos obtained by the 8-metre Gemini South telescope using the Gemini Planet Imager (GPI) reveals detailed images of the dusty debris around young stars. The images illustrate the variety of shapes and sizes that stellar systems can take during their infancy. Unexpectedly, the majority of these systems display evidence of planet formation.

These remarkable portraits of dusty disks are a selection from 26 new images of debris disks and highlight the diversity of shapes and sizes that these disks can take. The young stars imaged, which range from tens of millions to a few hundred million years old, are at the ideal age to settle down and raise planets. The forming planets sculpt the dust disk and leave behind gaps and warps that are indirect clues to their existence and motion.

While debris disks have been imaged before, this new cohort of disks represents one of the largest samples to be imaged with highly uniform data quality. This enables detailed comparison of the observations, a unique breakthrough in debris-disk surveys. Thirteen of the disks form a perfect natural laboratory, all belonging to the Scorpius–Centaurus stellar association, roughly 400 light-years from Earth. The group of stars, which were born in the same region at roughly the same time, enables astronomers to compare the architectures of a variety of young planetary systems developing under different conditions.

GPI was able to capture these dusty disks with the help of some ingenious astronomical engineering. GPI is sensitive to the polarization of light, allowing it to distinguish dust-scattered light, which is polarized, from the unpolarized light emanating from the stars. This gives GPI the impressive ability to improve the contrast of images and capture disks that are 10 million times fainter than their parent stars. Measuring polarization is only one of GPI's tricks, however—the instrument also exploits a coronagraph and adaptive optics to get the most from its observations.

GPI's precision is in large part due to its perch on the Gemini South telescope on Cerro Pachón in Chile. The dry conditions, high altitude, and dark skies are perfect for cutting-edge astronomical research. By combining this exquisite location with some engineering ingenuity, GPI is able to capture images as sharp as those from the *Hubble Space Telescope*—and detect objects up to three times closer to the host stars.

"The Gemini instrument program continues to provide unique science opportunities. This combination of GPI mounted upon a large ground-based telescope is delivering exciting new details about the process of how planets form," said Martin Still, National Science Foundation (NSF) Program Manager for the Gemini Observatory partnership.

The survey concluded in 2019, but the investment and technical capability of the Gemini Planet Imager will continue with an upgrade to GPI's hardware to improve its resolution and sensitivity. The new "GPI 2.0," is slated for a future installation at Gemini North atop Maunakea in Hawaii, where it will search the less-observed Northern Hemisphere skies for more exoplanets and debris disks. GPI 2.0 will also continue the work of scouting out targets for the next generation of exoplanet missions, setting the scene for new insights into the mystery of planet formation.

Written with material provided by Gemini Observatory.

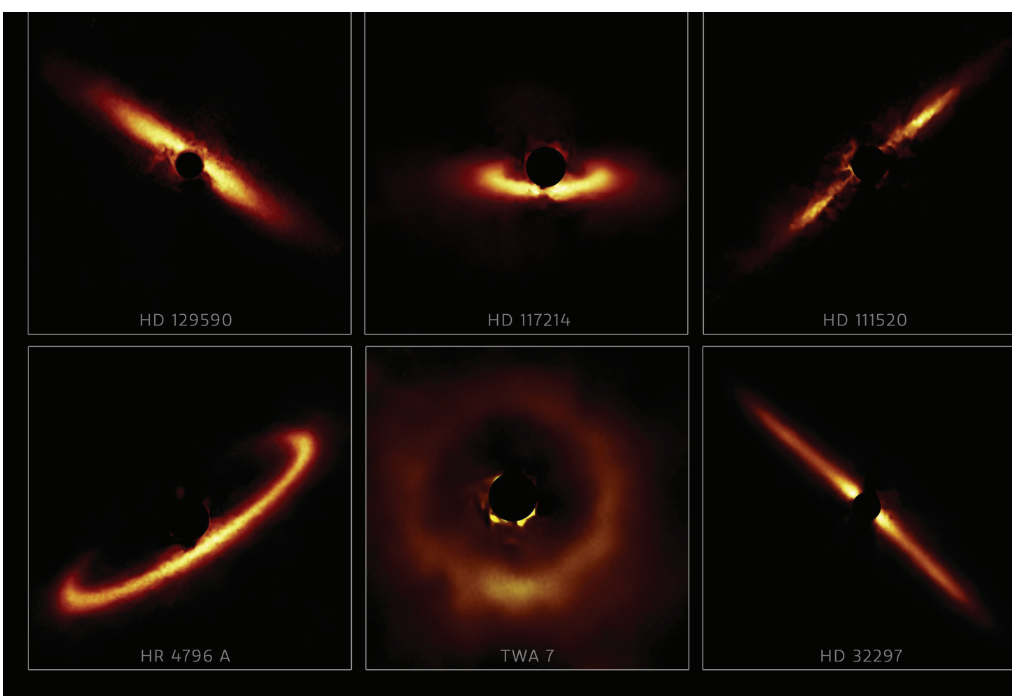


Figure 2 — Six circumstellar disks selected from the larger sample of 26 disks obtained with the Gemini South telescope in Chile using the Gemini Planet Imager (GPI). These images highlight the diversity of shapes and sizes that these disks can take and show the outer reaches of star systems in their formative years. Image: International Gemini Observatory /NOIRLab/NSF/AURA/T. Esposito (UC Berkeley) Image processing: Travis Rector (University of Alaska Anchorage), Mahdi Zamani & Davide de Martin.

Gas umbilical feeds growing stars

For the first time, astronomers have observed a conveyor belt from the outskirts of a star-forming dense cloud directly depositing material near a pair of young, forming stars. Scientists at the German Max Planck Institute for Extraterrestrial Physics (MPE) and the French Institut de Radioastonomie Millimétrique (IRAM) found that gas motions in the conveyor belt, dubbed a "streamer," generally follow the gravitational pull of the innermost part of the core, near the protostar pair. The streamer delivers a large amount of gas with chemicals recently produced in the mother cloud surrounding the star-forming region directly to the young protostars at the centre of the core. These results are striking evidence that the large-scale environment around forming stars has an important influence on small-scale disk formation and evolution.

In the general picture of star formation, a dense and cold region (called an envelope) forms inside a much larger and fluffier molecular cloud. Cloud material swirls and flows inward towards the centre of the envelope, where a future star will be born, the material becomes even more dense and flattens into a disk. Young protostars at the centre of the disk feed and gain their mass directly from the disk. Now, for the very first time, a bright streamer of material connecting the outermost part of the envelope to the inner region where disks form has been observed in the Perseus Molecular Cloud. With the streamer helping to resupply the disk-scale region with more material as it is consumed by the binary system, the mother cloud can continue to help the young protostars and their protoplanetary disks to grow.

"Numerical simulations of disk formation usually focus on single protostar systems," explains Jaime Pineda from MPE, who led the study. "Our observations take the idea one step further, by studying a streamer of chemically fresh material from large distances down to scales where we expect a disk to form around a close pair of young protostars." The astronomers used the Northern Extended Millimetre Array (NOEMA) in the French Alps to study the young Per-emb-2 (IRAS 03292+3039) proto-stellar binary system. The binary system has shown some variability or flickering in past observations, hinting that it may be an interesting target to study the impact of the environment on small-scale star formation.

The astronomers observed several molecules, which allowed them to measure the gas motions and discover a flow of material along the streamer from the outer regions of the envelope at a distance of about 10,500 AU down to the disk-forming scales. Both the locations and the speed of the gas were well matched by a theoretical model of a stream of material free-falling from large to small scales, confirming that the streamer's dynamics are controlled by the most-dense central region of the system. "It's not that often that theory and observations match up so clearly. We were excited to see this confirmation of what the telescope's images were trying to tell us," says co-author Dominique Segura-Cox from MPE. Estimates of the mass of material streamed into the inner core range from 0.1 to 1 solar mass, which is a substantial fraction of the total mass in the dense star-forming cloud (about 3 solar masses).

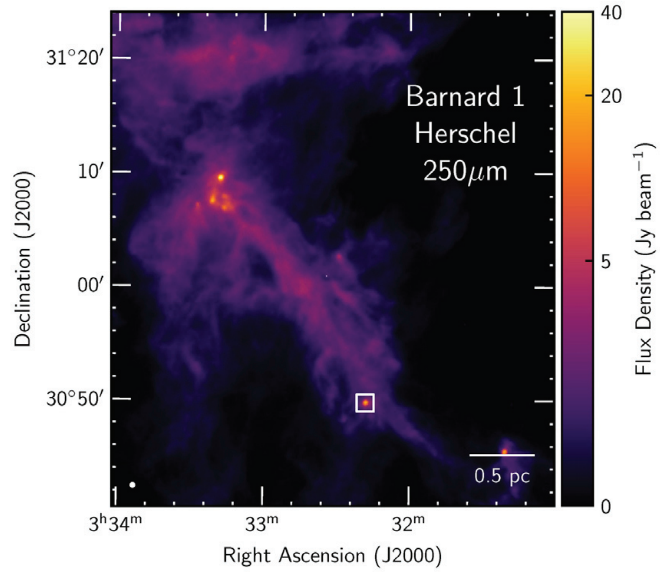


Figure 3 — At a distance of just about 1000 light-years, the young star-forming systems in the Perseus molecular cloud can be observed in detail with high-resolution telescopes. The streamer flowing into the bright core supplies gas to the newly forming stellar system, Per-emb-2, located in the box marked in the image. Image MPE.

"The streamer must indeed bring in chemically fresh material from the outer regions on a relatively short timescale," adds Pineda. "The clear identification of such a large reservoir of fresh material in almost free-fall is remarkable." This clearly shows that new material might shape the morphology and motions of the gas in young stellar systems. "The chemical composition of the growing and evolving protoplanetary disks will also be affected by this new phenomenon," concludes Paola Caselli, director at MPE and part of the team. "The molecule which allowed us to discover the streamer has three carbon atoms (HCCCN), which will then be available to enrich organic chemistry (on its way toward pre-biotic compounds) during the phase of planet assembly." This new way to deliver material to the central region has important implications on the way young disks are formed and grow. However, it remains unclear how frequent and for how long this process could occur in the evolution of young stellar systems, so more detailed observations of young proto-stars are needed.

Prepared with material provided by the Max Planck Institute

Three spacecraft head for Mars

The human appetite for Mars shows no sign of tapering off, as the Red Planet's latest close approach has spawned yet another set of three Earth-based scientific mosquitos.

First into space was the United Arab Emirates Mars Mission with its *Amal* (which translates to "hope" in English) spacecraft on 19 July. *Amal*'s goal is to search for a connection between current Martian weather and its ancient climate, track the behaviour and escape of hydrogen and oxygen gases to space, investigate how the lower and upper levels of the Martian atmosphere are connected, and create a planet-wide picture of how the Martian atmosphere varies throughout the day and year.

To conduct such a wide-ranging survey, *Amal* will enter an elliptical orbit, roughly 22,000 × 44,000 km with a period of 55 hours and a 25-degree inclination. The lowest point of the orbit is near the equator. Two years of science operations are planned, beginning in May 2021, with a possibility of a two-year extension to do more science into 2025.

To accomplish these goals, *Amal* carries three major instruments: an infrared spectrometer, an imaging camera, and an ultraviolet spectrometer. The first will study the distribution of dust, ice clouds, water vapour, and temperature, much as geostationary weather satellites do around Earth. The imager will measure the optical depth of water-ice clouds, the abundance of ozone, and provide visible images of the planet. The UV spectrometer will study carbon dioxide and oxygen in the upper atmosphere.

The second probe at this opposition is China's *Tianwen-1*, which launched a few days after *Amal*. *Tianwen*, whose name means "questions to heaven," consists of both an orbiter and a lander. On reaching Mars, the lander will remain with the orbiter for several months before descending to the surface at Utopia Planitia, a large basin formed by an impact far back in Mars's history (and close to where NASA's *Viking 2* lander touched down in 1976).

The orbiter will operate in a polar orbit in order to map Mars's morphology and geological structure while using a Mars-Orbiting Subsurface Exploration Radar instrument to investigate soil characteristics and water-ice distribution, while measuring the ionosphere and the electromagnetic and gravitational fields. *Tianwen-1* will also provide a radio relay for the lander. The rover will investigate the surface soil characteristics and water-ice distribution with its own Subsurface Exploration Radar, and will also analyze surface material composition and collect data to characterize the Martian climate and environment at the surface.

For this opposition, the perennial U.S. launch to Mars is named *Perseverance,* a rover, studded with 7 scientific instruments, 23 cameras, and a pair of microphones. No solar panels

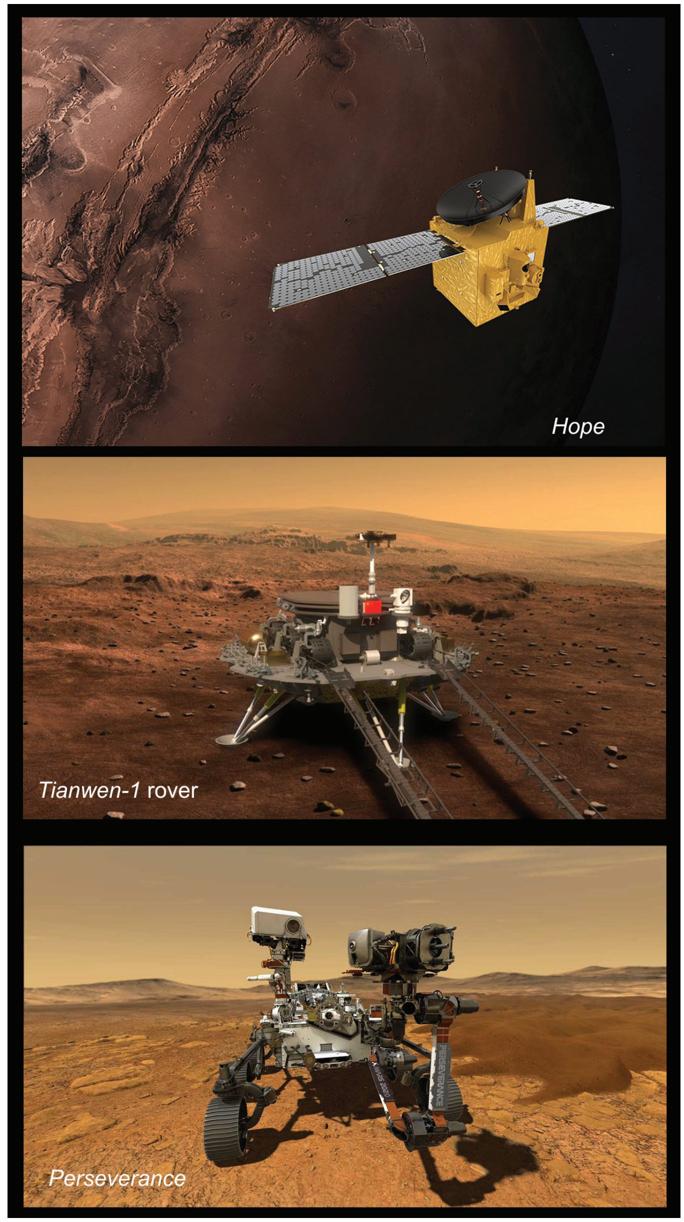


Figure 4 — Three Mars explorers. Images: (top) Mohammed Bin Rashid Space Centre, (middle) CNSA, (bottom) NASA.

this time—the rover has a nuclear heart consisting of nearly 5 kg of plutonium dioxide that will generate 120 watts of electrical power. This "go cart" will be able to operate at night and through the winter.

Among its instruments, *Perseverance* carries an X-ray fluorescence spectrometer to determine surface composition, a ground-penetrating radar, a set of meteorological instruments, an instrument suite to study surface chemistry and minerology, a stereoscopic camera, and a UV spectrometer. The most unusual instrument, however, is a small 1.8-kg helicopter that will be used for scouting (and no doubt, for photo ops—it contains only a camera). It's expected to fly for only three minutes at a time, though it can make five flights each day.

Figure 5 — An illustration showing an ASTHROS high-altitude balloon ascending into the stratosphere. When fully inflated, these balloons are 150 metres wide and reach an altitude of 40 kilometres. Image: NASA Goddard Space Flight Center Conceptual Image Lab/Michael Lentz

Two microphones may seem like two microphones too many, but they were installed after a campaign by the Planetary Society. The justification is entirely for public interest, following a suggestion made by Carl Sagan in 1996. Whatever the justification, its recordings will likely gather a few hits in social media.

NASA reaches for a lower altitude

We typically associate the acronym NASA with space—the Solar System, the planets, and the Universe, but in the ASTHROS project (Astrophysics Stratospheric Telescope for High Spectral Resolution Observations at Submillimetre-wavelengths), the space agency is going into space by staying in the atmosphere.

ASTHROS is an ambitious new mission that will carry a cutting-edge 2.5-metre telescope high into the stratosphere on a balloon. Tentatively planned to launch in December 2023 from Antarctica, ASTHROS will spend about three weeks drifting on air currents above the icy southern continent to observe several targets in the Milky Way. ASTHROS observes far-infrared light and will need to reach an altitude of about 40 km to be high enough to observe light wavelengths blocked by Earth's atmosphere.

The mission team recently put the finishing touches on the design for the observatory's payload, which includes its telescope, its science instruments, and such subsystems as the cooling and electronic systems. In early August, engineers at JPL began integration and testing of those subsystems to verify that they perform as expected.

"Balloon missions like ASTHROS are higher risk than space missions but yield high rewards at modest cost," said JPL engineer Jose Siles, project manager for ASTHROS. "With ASTHROS, we're aiming to do astrophysics observations that have never been attempted before. The mission will pave the way for future space missions by testing new technologies and providing training for the next generation of engineers and scientists."

ASTHROS will carry an instrument to measure the motion and speed of gas around newly formed stars. During flight, the mission will study four main targets, two star-forming regions in the Milky Way, a young star surrounded by a disk of dust and gas, and the galaxy M83. It will detect and map the presence of two specific types of nitrogen ions. These nitrogen ions can reveal places where winds from massive stars and supernova explosions have reshaped the gas clouds within the star-forming regions.

In a process known as stellar feedback, such violent outbursts can, over millions of years, disperse the surrounding material and impede star formation or halt it altogether. But stellar feedback can also cause material to clump together, accelerating star formation. Without this process, all the available gas and dust in galaxies like our own would have coalesced into stars long ago.

When fully inflated with helium, the balloon will be about 150 metres wide, or about the size of a football stadium. A gondola beneath the balloon will carry the instrument and the lightweight telescope as well as a series of mirrors, lenses, and detectors designed and optimized to capture far-infrared light. During flight, scientists will be able to precisely control the direction that the telescope points and download the data in real time using satellite links.

Because far-infrared instruments need to be kept very cold, ASTHROS will rely on a cryocooler, which uses electricity (supplied by solar panels) to keep the superconducting detectors close to minus 268.5 °C—a little above absolute zero. The cryocooler weighs much less than a large liquid helium container that ASTHROS could use to keep its instrument cold for the entire mission, making the payload lighter and extending the mission's lifetime.

The team expects the balloon will complete two or three loops around the South Pole in about 21 to 28 days, carried by prevailing stratospheric winds. Once the science mission is complete, operators will send flight termination commands that separate the gondola, which is connected to a parachute, from the balloon. The parachute returns the gondola to the ground so that the telescope can be recovered and refurbished to fly again.

Prepared with material supplied by NASA. ✶

Feature Articles / Articles de fond

Masatsugu Minami—the Last Great Visual Observer of Mars.

by William Sheehan, RASC Honorary Member

Abstract

Even after the introduction of the photographic plate in astronomy at the end of the 19th century, revolutionizing the study of stars and nebulae, visual observation of the Moon and planets continued to remain supreme. The eye was able to register features revealed in flashes of good seeing while the several seconds needed to register an image by the plate inevitably led to blurring. However, recording what was vouchsafed in those brief intervals involved the brain and hand as well as the eye, and skill and style varied widely, making the resulting records difficult to interpret. With the introduction of the charge coupled device in planetary imaging in the late 1980s, the eye at last had its equal—if not master. In general, visual planetary observers tended to admit defeat. However, one singular observer, Masatsugu Minami of Japan—the man with CCD-like sight—remained a master of visual observation of Mars, and produced a record which was as prolific as it was accurate between 1984 and 2014. He will always be remembered as one of the greatest visual observers of Mars of all time, and it is unlikely that his achievement will ever be equaled, much less surpassed.

Recalling the Golden Age of Visual Planetary Observations

In the December 2019 issue of the JRASC, Randall. A. Rosenfeld discusses the long and fascinating history of sketching at the eyepiece (Rosenfeld, 2019, 252-256), especially during the "golden age" of visual observation when the eye was faster and more adept at capturing fine detail on the surfaces of the planets than the sluggish if persistent photographic plate. For a long time, the competition between eye and plate was rather like that between the tortoise and the hare in the fable. Each had his particular sphere of advantage. For lunar and planetary detail, the eye was the hare, and able to keep up with the moment-to-moment shifting of the image and capture the fine detail blurred in the relatively long exposure times of the plate. But the plate, like the tortoise, slow but steady, gathered photons cumulatively over many minutes or even hours to register faint stars and objects of the deep sky that were beyond even the most sensitive eye's ability to capture.

Not until the late 1980s, with the advent of CCD, did the eye's long reign over the plate for lunar and planetary detail finally come to an end. Though there remain, as Rosenfeld points out, an array of good reasons to continue to sketch—not the least of which is that by doing so, one is forced into an active rather than passive role and so sharpens the ability to perceive—there is no doubt that for purposes of routinely recording the features and variable phenomena such as dust clouds or atmospheric features on the planets, the CCD (not to mention spacecraft) has achieved an insuperable advantage. Those observers who continue to sketch as their preferred method of recording detail on the planets become fewer and fewer and may seem sometimes like hopeless romantics, rather like John Henry with his hammer in the edge of the steam hammer. But they have a proud history, and one must continue to admire their dedication and skill.

Rosenfeld discusses the philosophy of sketching at the eyepiece of a number of practitioners of the 19th century. Many of them would have agreed, in general, with Charles Piazzi Smyth, himself one of the most skillful of astronomical artists, who in 1843 wrote: "One of the great objects to be attained in astronomical drawing is the absolute fidelity of the details, and in this it differs materially from nature, where [no more than] the accuracy of the *general* resemblance is the great point to be aimed at" (Smyth, 1843, 278).

Absolute fidelity of the details seems like a good mark to strive for, but rather begs the question. It presents something similar to the conviction of an Evangelical preacher that the Bible is the literal word of God, full stop, with utter disregard of any of the developments in the field that are owing to the methods of higher biblical criticism. An image, alas, does not simply speak its truth unequivocally and unambiguously from on high. One needs to apply "higher criticism" to it. What does "absolute fidelity of the details" even mean, and is it, any more than any other "absolute," attainable to finite and imperfect human skill—as, for example, the effort to determine the exact moment a star transited the wires of a transit instrument, which had led F.W. Bessel to the discovery of the "personal equation" between different observers? This is especially true in that a planet is not in any way a "still life," like a bowl of fruit, but is constantly blurring in and out of focus because of the effects of the atmosphere, and as a result of this, the eye—whose image-processing ability is actually rather slow, only about 8 frames per second in terms of today's digital imaging jargon—has a hard time following it to good purpose.

What did the skillful portrait artist and leading Mars observer Nathaniel Green mean when, at the height of the late 19th-century furor over the canals of Mars, he said, "A remark has been made in this room [Barnard's Inn Hall, Holborn] to the effect that I prefer an artistic drawing to a correct one; but I know no difference between the two. Especially in drawing astronomical objects the highest accuracy belongs inseparably to the highest art"? (Green 1892–1893, 367).

Green was responding to the comments, made a few years before, by the Rev. T.W. Webb, who compared and contrasted the 1877 Mars map made by Giovanni Schiaparelli with that made by Green. He found it difficult to reconcile the two:

> There is a general want of resemblance that is not easily explained, till on careful comparison, we find that much may be due to the different mode of viewing the same objects, to the different training of the observers, and to the different principles on which the delineation was undertaken. Green, an accomplished master of form and colour, has given a portraiture, the resemblance of which

as a whole, commends itself to every eye familiar with the original. The Italian professor, on the other hand, inconvenienced by colour-blindness, but of micrometric vision, commenced by actual measurement of sixty-two fundamental points, and carrying on his work with most commendable pertinacity, has plotted a sharply-outlined chart, which, whatever may be its fidelity, no one would at first imagine to be intended as a representation of Mars. His style is as unpleasantly conventional as that of Green indicates the pencil of the artist; the one has produced a picture, the other a plan. (Webb 1886, 213).

In other words, Green's insistence that there was no difference between an artistic and a correct one, there clearly was a personal equation for planetary observers as well as for those who observed transits of stars. The difference between observers shaped the response to the Mars stimulus into two camps—one that followed Green and one that followed Schiaparelli, the artists and the draftsmen or (perhaps we should say) the *kanji* school vs. the *kana* school. This difference continued to make itself felt right up to the dawn of the spacecraft era. In general, there were perhaps a dozen artists, who tended to represent the planet in terms of "canals," to every artist, who rendered the planet into more nuanced and natural shapes. And now that we actually know what the planets look like (from CCD imagery, the *Hubble Space Telescope*, and orbiting spacecraft), we can definitively say—as those who studied planets visually in the old days without being able to "check the answer" in the back of the book as it were—that the artists came closer to capturing the reality

Figure 1 — Tsuneo Saheki, left, and a young Masatsugu Minami at the observatory of the Fukui City Museum of Natural History 20-cm f/12 GOTO refractor in 1985, just after the installation of that instrument. Courtesy: Masatsugu Minami.

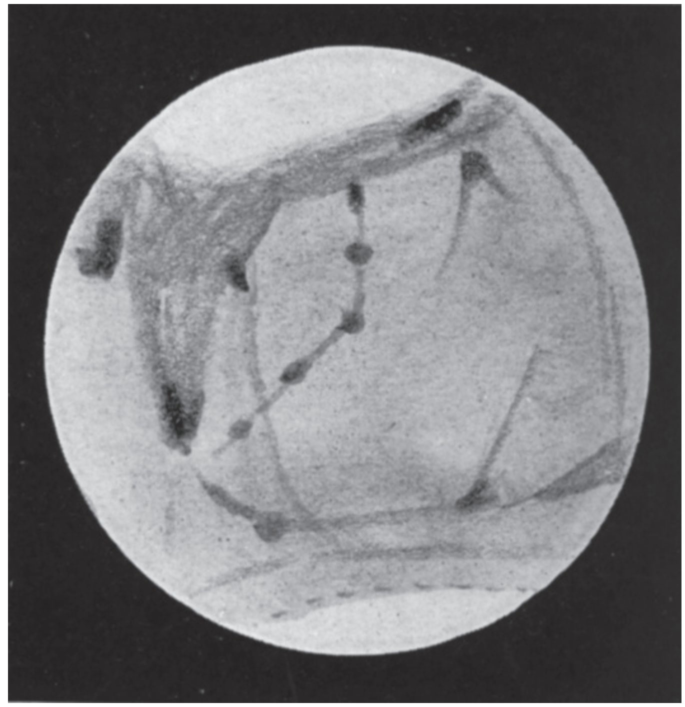


Figure 2 — A drawing from 1922, showing the typical work of the Japanese Mars observer Kaname Nakamura. W.H. Pickering, who corresponded with Nakamura, published this drawing in his "Mars report No. 23" in Popular Astronomy for 1925. This drawing is typical of those made during that era.

of Mars. This was demonstrated to the author in a series of experiments in which Mars was observed with the Lick 91-cm refractor at the favourable opposition of 2003. (Sheehan and Misch, 2003.) The observers consisted of some, such as myself, who were old hands at Mars observation and intimately familiar with the features and nomenclature of the planet. Others were "naïve" observers who knew hardly anything about Mars but were well trained and highly skilled artists. It wasn't meant as a competition, but one result appeared immediately: the artists did much better in rendering details on the planet (as compared to CCD images and *Hubble Space Telescope* images) than the astronomers. It seems to me that this result also is borne out when one considers the historical record of Mars observations. There are perhaps 10 or 12 observers of Mars with sufficient artistic skill to have produced records of the planet that have "fidelity," in the sense called for by Smyth and Green and others. They are good naturalistic representations of the planet that can be profitably compared to modern images of the planet. The rest are largely of historical interest; emphasizing geometry, they are rather like abstract art.

The Last of the Great Visual Observers of Mars

Among the great artist-astronomers who have rendered Mars must be included Secchi, Trouvelot, Green, Antoniadi—above all Antoniadi—with arguably a handful of others. They form an overlapping series going back to the 1850s and continuing until 2018, when the last of them so far, and quite possibly the last observer to devote almost all his or her effort to visually observing and sketching the planet, died. Masatsugu Minami was one of the greatest Japanese observers of Mars of all time, and likely the most prolific observer of the planet ever. He first observed Mars in 1954, with Nakajima and the legendary

Japanese Mars observer Tsuneo Saheki, at the age of only 15, and even then he showed remarkable precocity—he made at least one drawing showing that a Hellas dust storm reported by Toshihiko Osawa (1935–2001) did not appear to exist. (Osawa was only 19 at the time, and had become famous when, at the age of 15, he detected 3 remarkable dark spots on the North Equatorial Belt of Saturn with his homemade 15-cm Newtonian altazimuth reflector.). On this occasion, he was right and Osawa was wrong. That was a remarkable thing for an observer of 17 to have realized.

What might be called the era of his Mars monomania, in which his studies of the planet superseded everything else, began only in the 1980s, when he began to maintain surveillance of the planet around its oppositions for the entire period when its disk was larger than 4–5″ in diameter. Each apparition produced an output in the hundreds and, in some years, as many as a thousand drawings. In all he made over 10,000 drawings of Mars—a record probably unrivaled for completeness and quality by any visual observer, and unlikely, in this era of video-imaging and Registax, ever to be surpassed.

Influences

Though perhaps unrivalled for dedication and skill, Minami was able to draw upon a rich legacy of Japanese Mars observations. As is well known, before turning with a will to Mars at the opposition of 1894, Percival Lowell visited Japan on four occasions between 1883 and 1893. It was not Lowell but his at-first collaborator and later rival, William Henry Pickering, who deserves to be called the "father of Japanese Mars studies." Through the "Mars Reports" Pickering published from Mandeville, Jamaica, in *Popular Astronomy* in the late 1910s and early 1920s, he invited the contributions of many amateurs, among whom was Kaname Nakamura (1904–1932). Nakamura began observing Mars from the observatory at Kyoto University in 1922, at the age of 19, and Pickering published some of his drawings in his Mars Report No. 23. These drawings are not very exceptional though they are at or even somewhat above the usual standard of work that Pickering published—including Pickering's own singularly maladroit drawings.

Nakamura also published his own report on the 1924 Mars opposition in *The Heavens* (journal of the Oriental Astronomical Association, founded in 1920), and was a skillful mirror-maker as well as a dedicated observer. After his sudden suicide in 1932, there was a brief gap, but he inspired several younger observers, including Shigemaro Kibé (1912–1990), Eitaro Daté (1912–1953), Haruhisa Mayeda (1914–1952), and Tsuneo Watanabe (1916–1986); the latter changed his name to Saheki, his wife's maiden name, after his marriage in 1942. (Minami 2009).

Though Nakamura had followed the Lowell/Pickering style of drawing Mars, this changed with Mayeda, who hailed from Shichijoh-shinchi (now Gojo Rakuen), then a famous red-light district in Kyoto City. In addition to having a good telescope, Mayeda somehow came into possession of a copy of E.M. Antoniadi's *La Planète Mars* as well as some Section Reports of the British Astronomical Association that included some of Antoniadi's drawings. Mayeda, following Antoniadi's style, was an excellent artist, who produced a series of excellent pastel renderings of the planet in Antoniadi's style at the oppositions of 1935 and 1937.

In general, Japanese observers ever since have regarded Antoniadi as the master, trying as far as possible to emulate his style and representing the "canals," if at all, as broad dusky streaks rather than as fine sharp lines. There was no canal school as was prominent among American and British amateurs (and some professionals) right up to the spacecraft era.

The most direct influence on Minami was Saheki. The latter observed at the opposition of 1933, when he was only 17, and every opposition thereafter except that of 1939, when he was serving in the Japanese military on the China front in what became known as the second Sino-Chinese War, until the mid-1970s when his eyesight and health began to fail.

Saheki became internationally known in the 1950s, when he was attached to the Osaka Planetarium and using a fine 22-cm reflector with a mirror made for him especially by Kibé. On 1951 December 8, he reported seeing a brilliant short-lived flare at Tithonius Lacus. Its cause was much debated at the time. Saheki himself suggested that it was probably a volcanic eruption, which dovetailed nicely with the theories of active volcanism on Mars being suggested by University of Michigan astronomer Dean B. McLaughlin to explain the caret shape of some of the markings and the changes then widely thought to be due to vegetation. More sensationally, though less plausibly, some suggested that the Martians had set off an atomic bomb. (Remember, this was only a few years after Hiroshima and Nagasaki.) Saheki observed another flare, not quite as spectacular, at Edom Promontorium in July 1954. (Minami always preferred the term "glint" phenomenon to "flare.")

Minami, according to his wife Tomoko, might have been destined to become

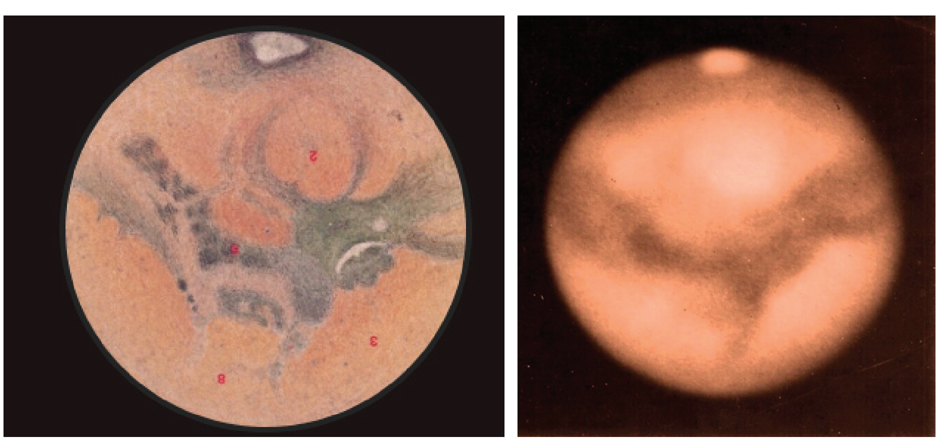


Figure 3 — The work of the "Master." (Left) E.M. Antoniadi's drawing of Mars with the 83-cm refractor at Meudon Observatory, on the night of 1909 September 20. (Right) For comparison, a nearly simultaneous image taken by E.E. Barnard with the 102-cm refractor at Yerkes Observatory. Credit: William Sheehan collection.

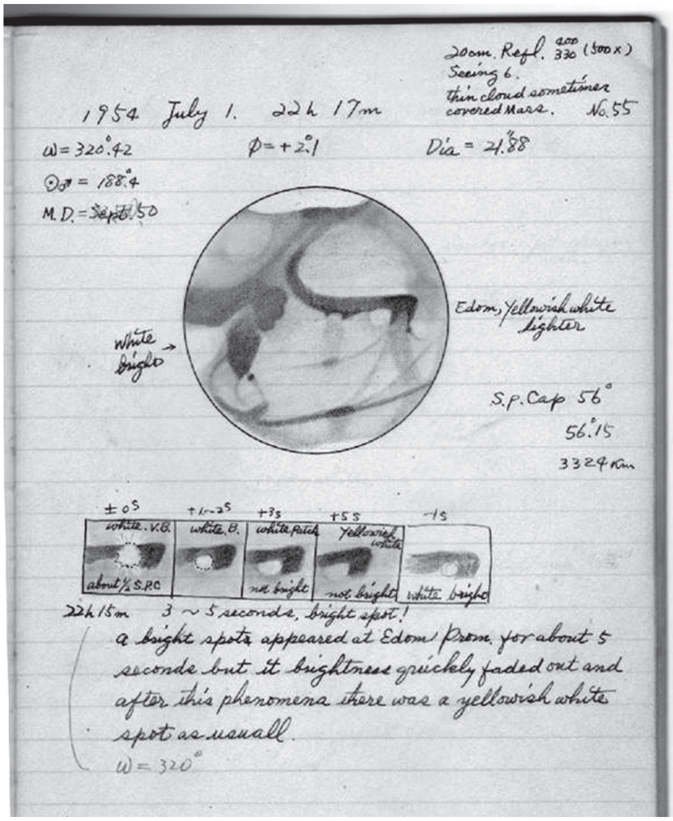


Figure 4 — The "glint" phenomenon observed by Tsuneo Saheki with his favourite telescope, a homebuilt 20-cm f/10 reflector, on 1954 July 1. Courtesy: Masatsugu Minami.

fixated on Mars from an early age. She writes (personal communication, 2020 January 21), "OO-chan" is the most popular way in Japan to make a nickname for children. OO is usually the first wo morae of one's first name (or often lengthened first mora as in the case of Masatsugu Minami. Thus my husband was called 'Maa-chan' when he was a kid, which would be the same pronunciation most Japanese who aren't familiar with astronomy would use for 'Martian.' Born in the year of the great opposition of Mars (1939) and with a childhood name 'Maa-chan,' he must have been destined to be fixated on Mars, and surely lived a happy life accepting this destiny."

Maa-chan's interest in Mars was already in evidence by the time he was in junior high, when he read a book on Mars observations by Saheki. Rather boldly, Maa-chan wrote to him; the great Saheki wrote back. The correspondence led to a first meeting between the two in Osaka at the beginning of the 1954 Mars apparition. The seeds of later interest were planted, and Maa-chan also observed Mars in 1956, the year of the great dust storm that changed many astronomers' views about the planet. However, other activities, such as university studies and launching a career, intervened.

Minami studied particle physics at Kyoto University in the lab of the theoretical physicist and first Japanese Nobel laureate, Hideki Yukawa, and in 1966 began working as an assistant at the Research Institute for Mathematical Sciences. That year he also married Tomoko. Though he made some drawings with the 8-inch reflector with a mirror made by Saheki in 1969 and 1971, he did not produce any other records of Mars until the opposition of 1977–78, when he produced a very creditable 85 drawings. Then, in the 1980s, there was an exponential increase in his activity. The opposition of 1984 (opposition date May 11, apparent diameter 17.3″) was observed with the 20-cm f/12 refractor of the rooftop observatory at the Fukui City Museum of Natural History; it was the first at which he kept the planet under surveillance during the entire period when its disk diameter was more than 5″ across (from 1982 January 2 until 1985 February 7). During that opposition, he produced a remarkable 808 drawings. His program of keeping the planet under constant surveillance was in the tradition established by Percival Lowell at the turn of the 20th century. Despite the fiasco of the canals, Lowell was always one of Minami's heroes, and with Schiaparelli was a precursor of Minami's own belief in the need to keep Mars under constant observation far from opposition (Lowell 1905, xiii-xiv):

> Study of Mars at one opposition is material to its study at the next. Two causes conspire to such counsel of continuity. The first, common to all pursuits, consists in the training essential to skill. Experience makes expert, and perception eventually stands secure, where it but tiptoed at the start. The second cause, of even more import, is inherent in the subject-matter. For the planet is not inert. Constant change characterizes the aspect of its markings; and the records of one opposition do not of necessity reflect those of the next. What is seen at one time may or may not be visible at another.… At any one opposition we may scan Mars for but a few months, through only a fraction of its circuit of the Sun. Hence its annual history is presented to us piecemeal, and with the positions from different years at that. To acquire anything like a knowledge of the cycle of its year we must piece the parts together as best we may.
>
> What is more, each bit of the patchwork is of necessity imperfect, depend as it perforce must be upon terrestrial conditions for its revelation. The sad effect of such imperfection is minimized by observation of the planet at successive returns. For phenomena presented at one opposition are often repeated at a subsequent one, and what at first sufficed only for surmise takes on recognition when fitted to its place in a consistent whole. Such instructive iteration is the more likely in that the planet gains in season about two months only upon our own between returns; while for six months at each it is possible to hold it in view. To repeated study is thus vouchsafed a set of overlapping Martian seasonal cinematographs, each of which reviews in part its predecessor, in part extends our knowledge into the unknown.

Competing with the CCD

The timing of this surge in interest is not accidental, since the previous apparition, that of 1982, saw the end of the long-running International Planetary Patrol (IPP). Established in 1969, supported with NASA funds and managed by the Planetary Research Center at Lowell Observatory, the IPP involved an ambitious program of monitoring Mars and the other planets photographically as continuously as possible, on an hourly basis, from observatories distributed in longitude around the entire Earth. In 1969, the participating observatories

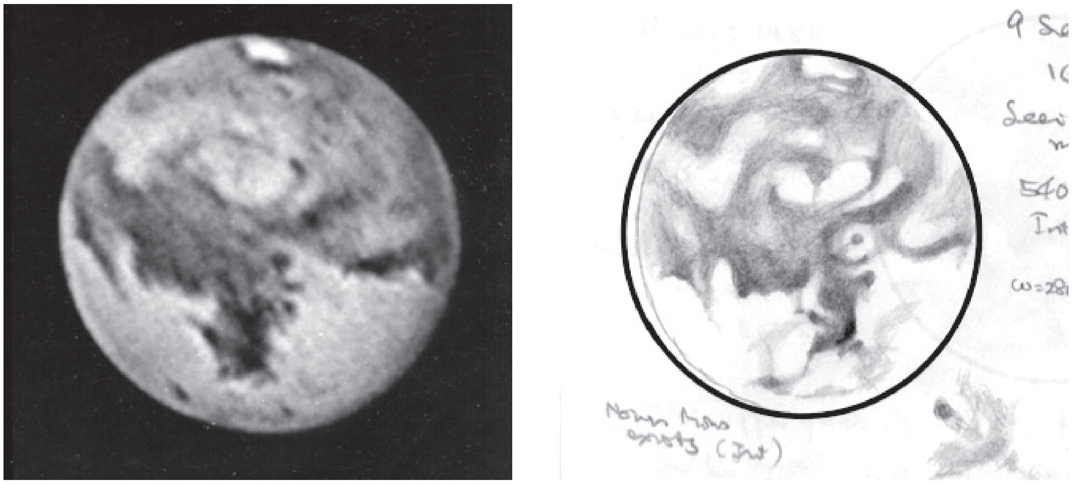


Figure 5 — (Left) Stephen Larson's CCD image with the 1.54-metre reflector at the Catalina Station of the University of Arizona Observatories, 1988 October 3. (Right) Minami's drawing 1988 September 9 with the 20-cm refractor of the observatory of the Fukui City Museum of Natural History. Courtesy Stephen Larson and Lowell Observatory archives

were Lowell, New Mexico State University, Mauna Kea in Hawaii, Cerro Tololo in Chile, Republic Observatory in South Africa, and Mount Stromlo Observatory in Australia. In 1971, when ground-based observations captured the planet-encircling dust storm that initially prevented *Mariner 9* from carrying out its surveillance from Martian orbit, New Mexico State had dropped out but the Kavalur Station in India and the Perth Observatory in Western Australia had signed on. After 1973, the program was gradually reduced in numbers of observatories and in length of observing runs. In 1977, in order to help fill the increasing gaps in the longitudinal coverage, the San Vittore Observatory, an amateur group in Bologna, Italy, joined the network. By 1982, when funding ran out, only Lowell, Mauna Kea, and Perth were still active. (Martin et al. 1992, 62).

As had been the case in the pre-spacecraft era, the continuous surveillance of the planets, briefly, during the IPP's existence, the professionals' burden once more was resigned to amateurs. Minami, though not alone, was among the most eager to fill the gap. Over the years, he had, according to his friend Reiichi Konnai, "acquired the conviction that ground-based Mars observations should emphasize meteorological phenomena and reveal the entire picture of Martian phenomena, but since this was not easily accomplished through an isolated personal effort, he realized that his own observations should be correlated with those of other diligent observers spread around the world at appropriate intervals of longitude." This, of course, had been the IPP's program all along. Minami, moreover, who beneath a thoughtful and understated exterior was possessed of great self-confidence and a fiercely competitive nature, had long been critical of the quality of the IPP's photographs. In fact, Klaus Brasch, who has researched the IPP enterprise, confirms that the criticism was indeed justified (personal communication, 2020 February 3):

> In spite of the IPP's wide photographic overage of Mars and other major planets, image resolution was not really very good. In fact, E.C. Slipher's stacked images were far better but of course laborious efforts. The film IPP used was fast and very grainy and nowhere near what a skilled visual observer could record. Hence Minami and many others recorded more detail visually than could be photographed at the time.
>
> The major innovation of IPP data was the automatic cameras employed, round the globe coverage and the RGB UV filters employed. Hence large-scale changes like Martian dust storms (1971 and 1973), polar caps and clouds were thoroughly monitored, as well as UV markings in the Venusian cloud deck and that planet's retrograde rotation. Apart from Mars, Jupiter's cloud and red spot phenomena were fully documented for years as well. Although some Saturn and Mercury work was done, nothing spectacular was revealed. The best IPP Saturn work was done spectroscopically, and showed definitively that the rings are composed mainly of small particulate components.
>
> The sad thing is that just as IPP was ending, Kodak's ultra-high resolution Tech Pan film entered the scene along with early electronic

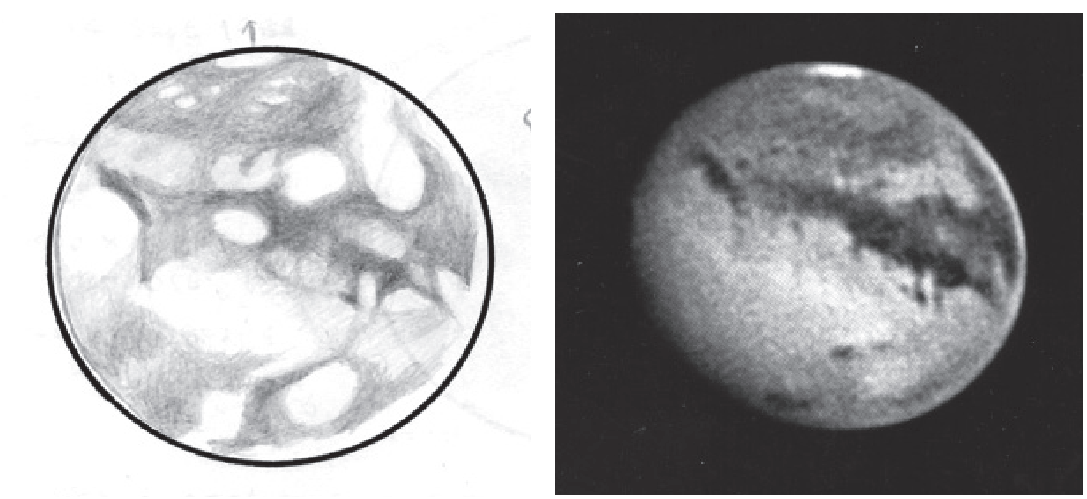


Figure 6 — (Left) Minami's drawing, 1988 September 14. (Right) Stephen Larson's CCD image 1988 September 9. Courtesy Stephen Larson and Lowell Observatory archives.

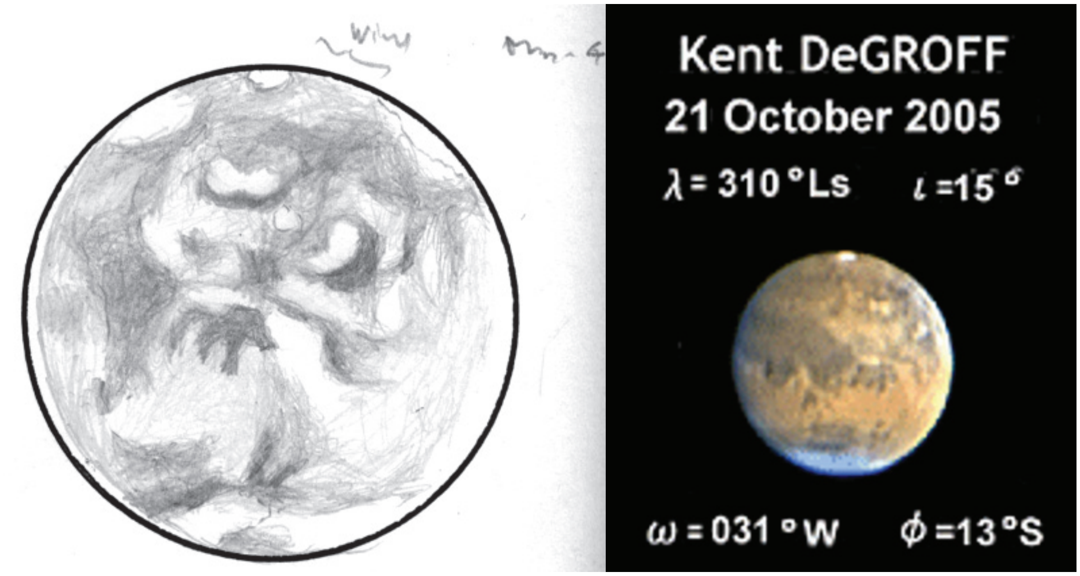


Figure 7 — Regional dust storm of 2005 getting underway. The drawing on the left by Minami was made on 2005 October 21 at 8:40 UT with the 91-cm refractor at Lick Observatory (stopped down to 50 cm), ×500. For comparison, a CCD image by CMO contributor Kent DeGrof of Scottsdale, Arizona. Courtesy: Lowell Observatory and Communications in Mars Observations.

> imaging efforts, meaning that nowhere near the attention the IPP data deserved was forthcoming, as Bob Millis told me when I was working on the S&T article [on the IPP].

Minami remained convinced that a trained visual observer could record more detail on Mars than could be recorded in any photograph, and later—even as planetary imaging moved into the CCD era (with the Mars opposition of 1988, when astronomers such as Stephen Larson at the University of Arizona and Jean Lecacheux at Pic du Midi stunned the astronomical world with the amount of detail they were able to record), he was one of few visual observers to avoid complete demoralization by the CCD. He was perhaps the last visual observer using the classical methods of sketching the planet to seriously challenge the supremacy of CCD—a kind of Gary Kasparov figure pitting his wits against Deep Blue.

Minami was also one of the last to aspire to the standards that the 19th-century astronomers set forth by Smyth, Trouvelot, and Green. He had enormously high standards in everything he did, and as a planetary artist, he achieved consummate mastery in setting down, quickly and economically but accurately, the position and proportions of the markings seen in the eyepiece, in pursuit of the meteorological phenomena that were present. He actually believed that he could recognize everything that a CCD could capture. His drawings have great beauty, but they were not conceived or executed for aesthetic purposes. First and foremost, they were meant to be scientific records.

He was far from being the only Mars observer, even in Japan, whose renderings of Mars are aesthetically pleasing. Going back to Mayeda, a number of Japanese observers of Mars attempted to follow Antoniadi's style, including, notably, Sadao Murayama (1924–2013) and Dr. Shiro Ebisawa using the 20-cm f/18 Nikon semi-apochromat refractor at the National Science Museum in Tokyo. (Ebisawa, a dentist by profession, was the only visual Mars observer of recent times to rival Minami in dedication, concentration, and skill. The two of them of them towered over everyone else.)

Murayama also taught Reiichi Konnai, one of the most skillful observers of recent years. He, too, followed Antoniadi's style. Minami shared the admiration of Japanese observers from Mayeda on for Antoniadi's brilliant work, but adopted a somewhat different approach, in which he prized high positional accuracy to aesthetic finish, and in the interests of economy was not seduced by the fine elusive detail that had snared so many observers. Instead, he concentrated on those details that were most germane to his project of monitoring the planet's meteorological phenomena. Thus he commented on Reiichi's drawings (personal communication R.Konnai to W. Sheehan, 2020 January 16), "Your drawings are natural and beautiful. But always keep in your mind that a drawing itself is no more than a supplement for ample, precise, meteorologically minded observational remarks. Analyzers/Recorders can extract nothing from a drawing of Mars with poor notes." His method was to rapidly sketch very lightly the main landmarks, and then proceed to more careful study in which smaller features were added. He took particular care in getting all the tonalities right.

Minami's own notes are always succinct and to the point, written in a rapid but legible cursive in English and—as Ben Jonson remarked of Shakespeare—he scarcely struck a line. It is hard to believe that these meticulous notes were composed, in real time, at the telescope—and yet they were. They supplement the drawings by calling attention to the specific phenomena of interest. Minami was not only a rapid (though still meticulous) worker; he was also, at least in his prime, tireless. No sooner had he completed one drawing (and added annotations), to which he never devoted more than 10 or 15 minutes in order to avoid distortions of the positions of the markings owing to rotation, but he would begin another. Sometimes, when Mars was favourably positioned and the seeing was good, he would turn out eight, ten, or even a dozen sketches of the planet on a given night. Apparently, as was once said of E.E. Barnard, he was a man who was never known to sleep.

Beautiful as they were, Minami's drawings were means to other ends, which were the elucidation of Martian meteorological phenomena—its clouds and dust storms. Nevertheless, the enchantment of his studies occasionally appears, as when he describes morning mists "haunting" regions such as Mare

Acidalium or Utopia from day to day, or orographic clouds "rolling over" Elysium or the Tharsis Montes. Possessed of a keen eye made even sharper by practice and infinite pains, he had the ability to spot even minor changes in surface markings and small atmospheric events—as, for instance, on 2001 June 24, when he and his Japanese colleagues Higa, Ishadoh, and Teruaki Kumamori were first to notice the small dust cloud over Hesperia that rapidly developed into the planet-encircling dust storm of that year. (Already on July 2, Minami and Nakajima rather poetically described the planet as "not simply a disk; it appeared to be a glossy globe in beautiful perspective.")

The comprehensive nature of his observations led him to make discoveries. He realized that, at least at ground-based resolution, the dust cores of major storms did not change during the Martian day—an important insight at the time. (Only in 2018 did high-resolution data qualify this result by showing detectable diurnal changes in at least some cases.) He also championed the idea that the famous Blue Clearing first described by Lowell Observatory astronomer Earl C. Slipher (1883–1964), was an effect belonging to the Martian surface not the atmosphere, and so there is no longer any mystery to this intriguing but no longer exotic phenomenon. An atmospheric effect Minami was first to describe as imaging techniques improved in the 1990s, was the so-called violet hole. These "holes" are darker patches or streaks visible in violet images where a local absence of water vapour produces a locally lower albedo, while the area is seen in integrated light as a much redder colour. Minami's own term for them was "wine red" areas. Some of these were observed in 2005 in association with the initial dust clouds that later developed into the southern regional storm of that apparition (which Minami observed from Lick Observatory), and they have been observed at every successive approach of the planet.

In controversies, which for some reason seemed to generate enormous vitriol among amateur astronomers, he was one to have on one's side, and did not suffer fools gladly. He liked to stir up controversy in the pages of the CMO, and he drew on a strongly developed if somewhat surprising sense of humour that was not always apparent beneath his studied reserve and politeness. He was fearless and not intimidated by anyone. Thus he once wrote an article about the two Patrick Moores (a reference to work published by the prolific but sometimes reckless British astronomer popularizer), one of whom had predicted a global dust storm in 1973 and the other (in a different publication) that there would be none. He took aim at a controversial member of the American Association of Lunar and Planetary Observers who mounted vicious *ad hominem* attacks against supporters of the work of the American astronomer John E. Mellish, who in November 1915 using the 1.02-m Yerkes refractor had suspected craters on Mars (Minami, 2011). He also tackled several Mars observers who were dogmatic climate-change skeptics, and who claimed on the basis of their analysis of polar-cap regression curves and cloud and dust storm frequency data that Mars was experiencing global warming in synchrony with the Earth. The cause of said warming on both planets was therefore said to lie with the Sun. Minami never accepted this. He was fully aware of the complex ways that albedo changes due to dust-storm activity would likely affect the climate and large-scale weather patterns on Mars, and was convinced that the anthropogenic increase in greenhouse gases explained the observed warming on Earth. At a time when matters were much less clear than they are now, he believed that the Sun should be exculpated of blame in both cases, and in this he has of course now proven to have been correct. (For Mars, see Fenton, Geissler, and Haberle, 2007; for Earth, see Fourth National Climate Assessment, Volume 1, Chapter 2).

After his breakthrough success at the 1984 opposition, Minami—at the July 1986 opposition, at which Mars was far south of the equator—took advantage of a sabbatical year to observe the planet from the more southerly latitudes of Taipai and Okinawa (latitudes 25° N and 26° N, respectively, compared to 36° N at Fukui City). In Okinawa, he often observed with fellow Japanese amateurs Yasunobu Higa and Hiroshi Ishadoh. That year he produced 998 drawings of Mars—stopping short of 1000 because, he claimed, "Over 1000 observations in an apparition by a single observer

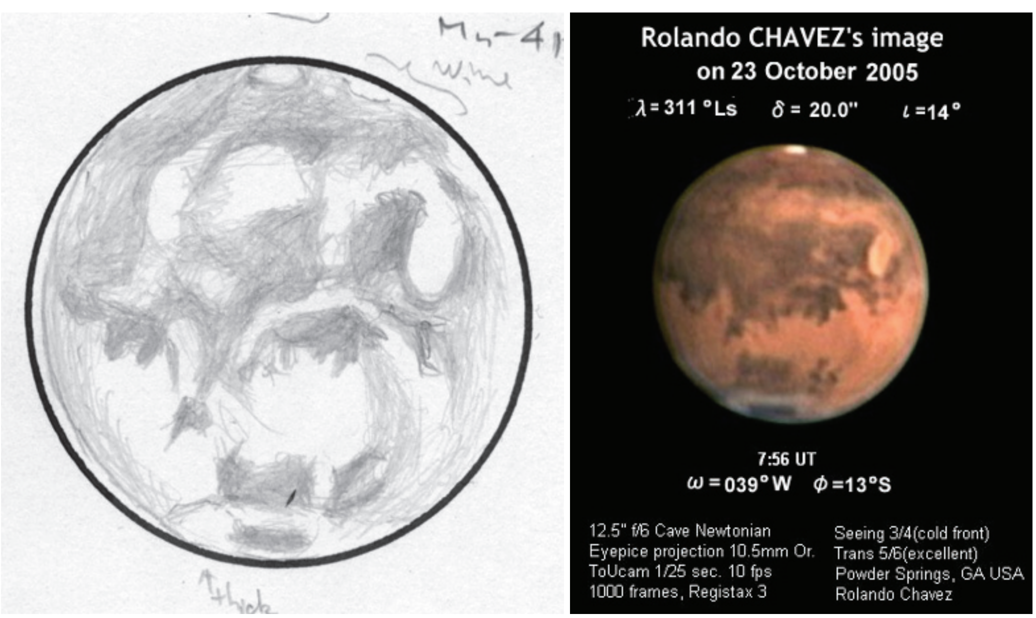


Figure 8 — (Left) Minami's drawing of the dust storm on 2005 October 23, 7:40 UT. Minami notes that the dust appeared brilliant, and one core has spread in linear fashion from the side of Margaritifer Sinus, where it fills the depressed areas of Ganges Chasma and Eos Chasma, west into Coprates Chasma. Solis Planum and Argyre Planitia are also covered in dust. Drawing with the 91-cm refractor at Lick Observatory (stopped down to 50 cm), ×500. (Right) A comparison CCD image by CMO contributor Rolando Chavez of Powder Springs, Georgia. Courtesy: Lowell Observatory and Communications in Mars Observations.

might be thought unsufferable" by other observers. (He was to become insufferable by bursting through the self-imposed barrier in 1997–98, as well as in 1999–2000–2001, 2002–03, and 2005–06–07.)

That same year he founded the *Communications in Mars Observations* (CMO), which was presented in both Japanese and English editions and appeared semi-monthly during opposition years and monthly in alternate years. It included predictions, observations, and analysis to Mars observers throughout the world, though Minami seldom published his own drawings, presumably because he felt the analysis was more important. A remarkable effort by a single individual, Minami wrote most of the articles and published the CMO for 32 years, at first in a paper edition sent postpaid to anyone interested in receiving it. In later years, because of the ever-increasing cost of postage, it appeared only in an electronic edition. In 2009, he was the driving force in establishing the International Society of Mars Observers, which that year co-sponsored an International Workshop on One Century of Mars Observations at Paris Observatory and Meudon (on the occasion of the centennial of E.M. Antoniadi's first night of observing Mars with the Grand Lunette at Meudon). One of the talks concerned the various artistic styles of representing Mars: "A Pretty Picture, Signor Schiaparelli, but you mustn't call it Mars." Minami at long last had realized his dream of an international team of dedicated observers keeping the planet under constant surveillance from longitudes all around the world. He continued to edit the CMO, which was henceforth published by ISMO. By then, though Minami and a few others continued to make visual observations, most observers had by then adopted CCD for their observing programs.

The End of an Era

Minami's activity as a Mars observer is almost unbelievable. Here I have listed the number of sketches in the logbooks he kept at each apparition between 1969 and 2014. (see table on p. 201)

After his retirement in 2002, just before the extremely favourable oppositions of 2003 and 2005, his productivity reached its greatest heights. During these years, he still had enormous energy and reasonably good health. However, when he hosted my visit to Japan in the spring of 2004, during which Minami, Tadashi Asada, and I followed Percival Lowell's 1889 route described in his book *Noto*, he was already suffering from atrial fibrillation, and had to be very careful not to overdo. (Minami's, Asada's, and my Noto adventure is described in Sheehan, 2005).

The View from Mount Hamilton

A highlight of the October 2005 opposition of Mars (which was very nearly a repeat of the 1926 opposition) was a visit to the United States. Minami joined Rem Stone, Laurie Hatch, Tony Misch, and the author on Mt. Hamilton, near San Jose, California, where he used the famed 91-cm refractor to make one of the most remarkable series of drawings of Mars ever made. Fortune shone on him, as his time at Mt. Hamilton happened to coincide with the onset of an impressive regional dust storm. In his Lick drawings he arguably came as close as anyone in the history of Mars observations in achieving Green's standard of "the highest accuracy with the highest art."

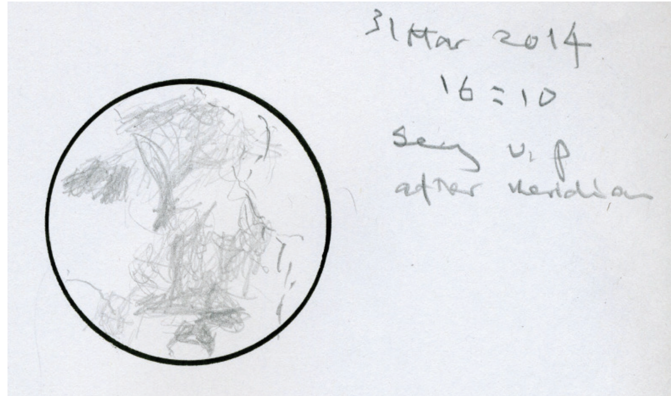


Figure 9 — Mars, 2014 March 31, sketched by Minami with his 20-cm f/8 reflector. Courtesy: Lowell Observatory.

After 2005, Minami became somewhat more secretive and less communicative of his Mars observations. As recalled by Richard McKim, the British Astronomical Association Mars Section Director, who shared Minami's keen interest in the development of Martian dust storms (personal communication, 2019 December 13): "He used to send me many Xerox copies, from 1986 up to 2003. And he would redraw for publication if asked to. So I do have some very fine pencil

Opposition date	Number of drawings
1969 May 31	82
1971 August 10	37
1973 October 25	—
1975 December 15	—
1978 January 21	85
1980 February 25	154
1982 March 31	346
1984 May 11	808
1986 July 10	998
1988 September 28	838
1990 November 27	992
1993 January 7	839
1995 February 12	781
1997 March 17	1001
1999 April 24	836
2001 June 13	1088
2003 August 28	1158
2005 November 7	1001
2007 December 8	408
2010 January 29	519
2012 March 3	192
2014 April 8	3

Table — Log of Minami's drawings of Mars, 1969–2014, in Putnam Collection Center, Lowell Observatory.

originals in my files. After that it was hard to get anything out of him and I do not think I managed to get any of his 2005 drawings." Part of the reason for this doubtless had to do with the increasing amount of his time required for preparation of the CMO. (In 2003 the publication actually collapsed for a time, as Minami was overwhelmed with submissions. There was then a big gap in the numbering of the issues before he finally started again. A year later he filled in some gaps, but many of the missed numbers were never reprinted.) He was also trying to write up his personal work with Nakajima at the observatory of the Fukui City Museum of Natural History, and published write-ups of the observations of 1994/95, 1996/97, and 1999. (Nakajima and Minami, 1995, 1999, and 2002). However, the observations at the extraordinarily favourable oppositions of 2001, 2003, and 2005 became so numerous that he gave up the plan to continue the series as hopeless.

He was also struggling against age and deteriorating health. His productivity fell off markedly in 2007–08, revived somewhat in 2009–10 when he felt strong enough both to resume work at the telescope, catch up on part of the CMO backlog, and travel to Paris. His revival continued into 2011–12, when he made over 100 drawings. However, by 2014, Parkinson's disease was taking its toll. During that aphelic opposition, he managed only three drawings on one night of trying, in a shaky hand. Despite an evident falling off, one can still discern in them the hand of the master.

The last issue of the CMO, no. 469 in the series, was co-authored with Masami Murakami; it appeared on 2018 May 25, and provided a summary of observations submitted in April 2018 as the Red Planet approached the sixth perihelic opposition since that of 1939, the year of his birth. It was obviously meant to be followed by additional numbers. However, Minami was no longer able to do the work. (Ironically, the 2018 opposition was to see one of the greatest Martian dust storms on record.)

On 2019 January 28, Masatsugu Minami, perhaps the last purely visual Martian observer, passed away. With him ended an era. Fortunately, arrangements were made to see to it that his logbooks were bequeathed to the Putnam Collection Center at Lowell Observatory, where they share shelf space with the observing logbooks of Percival Lowell and other great pioneers of the Red Planet. The author always dreamed of hosting Minami during a visit to Lowell Observatory. It was not to be. But Minami would no doubt be delighted that his work will be preserved near the dome that Camille Flammarion once referred to as a "temple to the planet Mars," and made available in perpetuity to all future researchers with an interest in the ever-fascinating red world. ✶

Acknowledgements

The author expresses deep appreciation to Mrs. Tomoko Minami for providing a great deal of personal information about Masatsugu Minami. Thanks also to Tadashi Asada, Reiichi Konnai, Masami Murakami, Takashi Nakajima, Akinori Nishita, and many other members of the OAA Mars Section and the ISMO for their assistance and friendship. Dr. Richard McKim of the Mars Section of the British Astronomical Association has provided many useful comments based on his long correspondence with Minami about Martian dust storms, and Stephen Larson of the University of Arizona's Lunar and Planetary Laboratory generously provided me with prints of his 1988 CCD images of Mars and allowed me to include them here. Lauren Amundson, the archivist at Lowell Observatory, has been helpful as always. Finally, I am indebted to Randall Rosenfeld for his friendship over many years and for his excellent paper on art in astronomy in the JRASC, which provided the initial impetus to the writing of this paper.

References

Fenton, L.K., Geissler, P.E., and Haberle, R.M. (2007). Global Warming and climate forcing by recent albedo changes on Mars. *Nature*, *446* (5 April), 646–649.

Green, N.E. (1892–1893). How to Secure Accuracy in Astronomical Drawing and Sketching, *JBAA 3, 8*, 367–368

Lowell, P. (1905). Observations of the Planet Mars During the Oppositions of 1894, 1896, 1898, 1901 and 1903 Made at Flagstaff Arizona. *Annals of the Lowell Observatory*, Vol. III.

Martin, L.J., James, P.B., Dollfus, A., Iwasaki, K., and Beish, J.D., 1992. Telescopic Observations: Visual, Photographic, Polarimetric. In: *Mars*, H.H. Kieffer, B.M. Jakosky, C.W. Snyder, and M.S. Matthews (eds.). Tucson, University of Arizona Press.

Minami, M. (2009). A History of Mars Observations in Japan, IWCMO Conference at Paris/Meudon, 2009 September 19. www.kwasan.kyoto-u.ac.jp/~cmøcmomn5/2009Paris_Meudon_Talks_Mn1.htm

Minami, M. (2011). How Can One Deny How Revolutionary John Mellish Was? *Communications in Mars Observations, no. 386* (25 June), Ser. 3, No. 12, 137–142.

Nakajima, T. and Minami, M. (1995.) Mars Observations in 1994/95 at the Observatory of Fukui City Museum of Natural History. *Bulletin of the Fukui City Museum of Natural History*, *44*, 1–20.

Nakajima, T. and Minami, M. (1999). Mars Observations in 1996/97 at the Observatory of Fukui City Museum of Natural History. *Bulletin of the Fukui City Museum of Natural History*, *46*, 1–26.

Nakajima, T. and Minami, M. (2002). Mars Observations in 1999 at the Observatory of Fukui City Museum of Natural History. *Bulletin of the Fukui City Museum of Natural History*, *49*, 1–25.

Rosenfeld, R.A. (2019). Requirements for a Good Astronomical Drawing: An Evolving Landscape of Purpose? *JRASC*, *113, 6*, 252–256

Sheehan, W. and Misch, A. (2003). Two Weeks on Mars. http://mthamilton.ucolick.org/public/TwoWeeksOnMars/

Sheehan, W. (2005). To Mars by Way of Noto. *Sky & Telescope*, *110, 6*, 108–111.

Smyth, P. (1843). A Memoir on Astronomical Drawing. MNRAS, *5, 31*, 277–279

Webb, T.W., (1886). Planets of the Season: Mars, *Nature*, *34*, 213

The Biological Basis for the Canadian Guideline for Outdoor Lighting 2—Impact of the Brightness of Light

by Robert Dick, M.Eng., P.Eng., FRASC

Abstract

One of the most obvious attributes of light is brightness. This paper will address specific brightness thresholds that have been found to impact animal health and behaviour, including humans. However, the meaning of brightness is vague and must be further refined and quantified. This paper will introduce and define these terms and will discuss the sensitivity of wildlife biology and behaviour to levels of luminance and illuminance.

It may not be apparent from the common metrics used for "brightness" that a lamp will impact the ecosystem or human health. Our focus is on biology, which depends on the energy carried by the light, or its spectrum, and not strictly its apparent brightness. However, the subject of spectrum will be deferred to the third paper in this series.

Luminance

The luminance of a light source is a measure of how bright it looks—its "perceived brightness." The source can be a star, lamp, or light that reflects or scatters off a surface. A star or lamp emits light in all directions (4π steradians), which is called its luminous flux. But a surface cannot emit light in all directions, so it is more common to report its brightness as being somewhat directional.

Industry defines this angular flux density or "intensity" as the light directed out from a source (lamp or surface) within a solid angle of 1 steradian[1]. If it emits 1 lumen of photopic light in this angle, it is defined as 1-candela (cd). So an omni-directional light source (a light bulb) that emits 1-cd per 1-steradian emits a total of 12.57 lumens of light in all directions (1-lumen × 4π).

A quick review of spherical geometry reminds us that a steradian covers an area of 1 square metre at a distance of 1 metre. At a distance of 2 metres, the area increases by 4 times, which dilutes the light resulting in the inverse-square law $(r/r_o)^2$, but the angle remains the same, so the luminance does not change with distance.

It is important to put the magnitude of this metric into perspective. The planet Venus at magnitude –3.5 has a luminance of about 1 cd/m^2, which is also called a "nit," and the full Moon is about 4,500 cd/m^2. In a city, streetlights and traffic lights are about 1–4 million cd/m^2. Other comparisons are shown in Figure 2. This figure reveals the incredible dynamic range of light in our environment: from 1 mcd/m^2 (4th magnitude star) to the Sun at 1.6×10^9 cd/m^2 (Wikipedia)—a factor of 1.6 trillion:1. Our vision accommodates this with complex processes of light absorption and photochemistry in the retina (Lamb 2004), which render our vision decidedly non-linear.

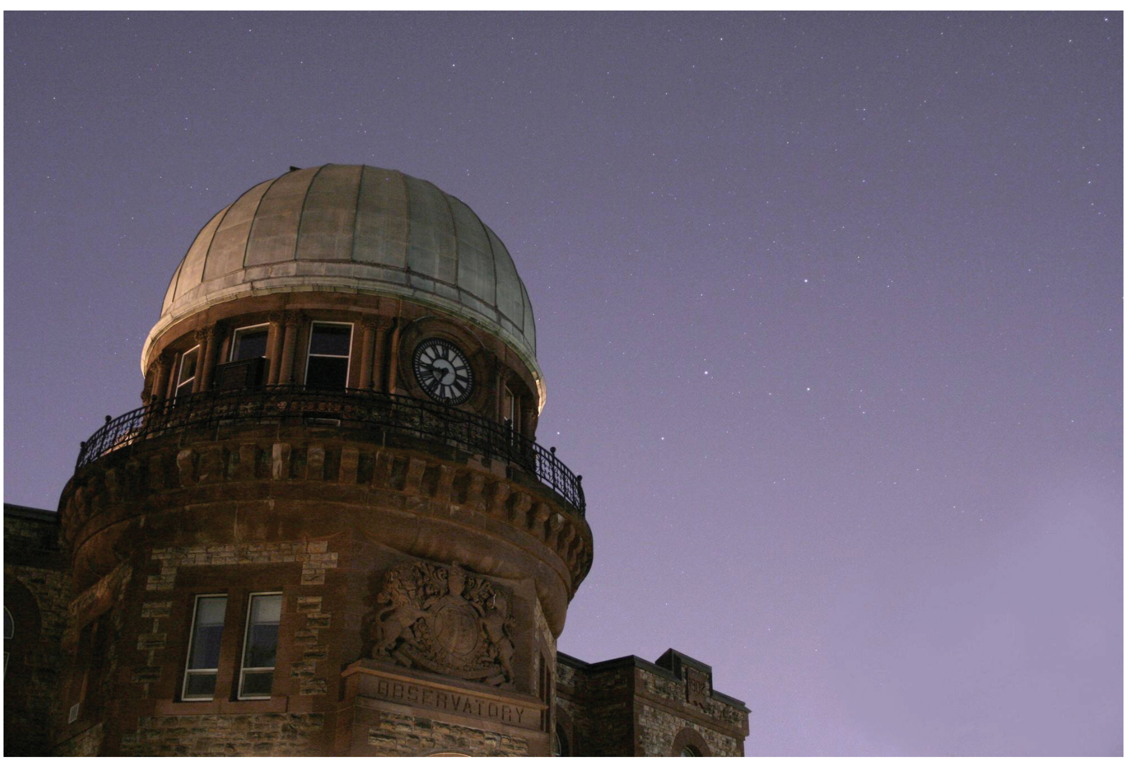


Figure 1 — The Dominion Observatory in Ottawa, beside the Central Experimental Farm. Streetlights, greenhouses, and soon a large regional hospital will illuminate buildings throughout the night. Although a heritage building, there is no policy to protect its scientific heritage. The constellation Cassiopeia is visible to the right of the dome suggesting a photographic limiting magnitude of mag. 5, but visually it was about mag. 2.5.

Rod Cells Only						Cone Cells Only
10^{-6} cd/m^2	10^{-3} cd/m^2	0.1 cd/m^2	1 cd/m^2	4,500 cd/m^2	1M cd/m^2	10^9 cd/m^2
Rod Limit **DIM**	Urban Star Limit	Rod Bleach	Venus Cone Limit	Full Moon	Traffic Light	Sun **BRIGHT**

Figure 2 — The range of luminance for typical natural and artificial light sources. The low rod limit is not practical for vision because there is insufficient information to form an image. A practical urban rod cell limit is a mag. 4 star, though some people can see to less than 1/10 this limit under dark skies. The difference between the luminance of Venus and the Moon is the concentration of the light. Venus appears as a near-point source, whereas the Moon is an extended source with the light spread out over many detector cells.

Rod Cells Only							Cone Cells Only
0.001 lux	0.01 lux	0.1 lux	1 lux	10 lux	100 lux	1000 lux	10K lux
Night Sky **DIM**	Crescent Moon	Moon Rods Only	Reading Limit (Mesopic)	Cone Cells Only	Home Room	Office	Cloudy Day **BRIGHT**

Figure 3 — The range of illuminance in the rural and urban environment extends beyond this figure from a dark sky at 0.1 mlux to a limit of 127,000 lux under a clear sunny day—a range of 1.3 billion:1.

Our practical photopic (daylight) cone limit extends from the luminance of Venus up to brighter than a traffic light but dimmer than a streetlight—since staring at the signal will not leave a blind spot, though looking at modern streetlights may leave a blind spot. Glancing at the Sun will leave a blind spot but staring at it will cause permanent blindness.

As astronomers, we understand our vision is made more complicated because the perceived brightness depends on the sensitivity of our eyes to different wavelengths. The apparent brightness of Cepheid variable stars changes primarily as its emission shifts from visible light into the infrared.

The metrics used by the lighting industry use the spectral response of our daytime photopic vision, so the metric of lumens is based on the action spectrum of our cone cells. The peak spectral sensitivity of our cones is 591 nm where one joule of energy is used to produce 685 lumens, or 685 $_{P}$Lumens/watt.

When night vision is used, we should use the unit of "scotopic lumens," which matches the spectral sensitivity of our rod cells. It peaks at about 508 nm with a sensitivity of 1700 $_{S}$Lumens/watt (Yao and Lin 2018). A rod cell detects 2.5× more lumens than our cone cells. However, the structure of neurons that connect the rod cells is different for the cone cells, and there are about 20× the number of rods than cones. So, our night vision is much more sensitive than our day vision by 100–1000×.

Generally, the photopic lumen is assumed if the scotopic lumen is not stated.

The ratio of the perceived brightness of the scotopic vision and photopic vision is the SP ratio convolved with the specific spectrum of the illumination that is being compared. Since scotopic lumens are rarely used in specifying outdoor lighting, this distinction is not critical to this paper. However, it is important in our discussion of the emitted light spectra in the next paper of this series.

Illuminance

When light falls on a surface, it "illuminates" that surface. This "illuminance" depends on the amount of light that shines on the surface and the area that is illuminated (lumens/m^2) and has the metric unit of "lux." However, most city officials continue to use the imperial (American) unit of foot-candles, which is 1 lumen/ft^2 (10.764 fc = 1 lux).

Surface Coating

We see a surface by the light that reflects toward our eyes, but if the surface is inherently dark, then the surface will absorb most of the incident light. To see the surface, we need more incident light than if it was covered with a more reflective material. For example, we will use less than 1/10 the light (and 1/10 the energy) by changing a pathway from asphalt to crushed stone, such as dolomite.

Most natural surfaces are not very reflective. Of particular interest here is grass. Visually, grass is only slightly more reflective than asphalt, but crushed stone stands out—even under starlight.

Street lighting can be specified by surface luminance or illuminance, but surface luminance is complicated by its colour and texture as well as the angle between the incident and reflected,

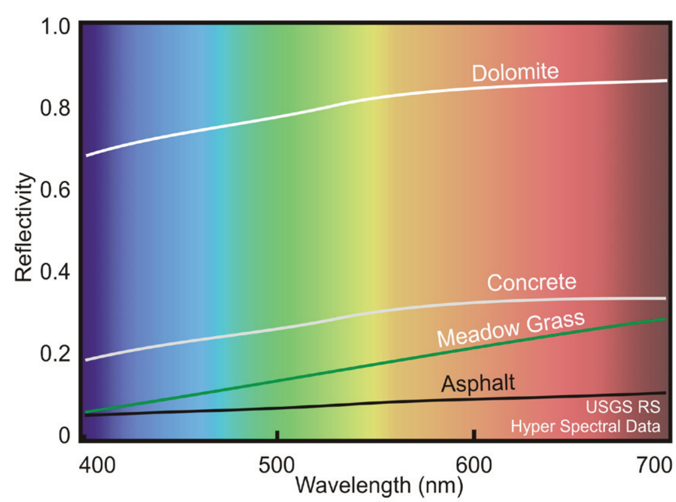


Figure 4 — Reflectance of various ground coverings. Although some ground coverings are quite visible and contrast well with the surroundings in daylight, at night we lose our colour sense and longer wavelength colours appear darker. If a pathway is covered with asphalt, it will not stand out from the grass to the side. However crushed stone cover, or a white paint or lime edging can be used to delineate the path. (USGS)

or scattered light. So, there is a complex relationship between the amount of light that illuminates a surface and its apparent luminance.

The surface spectral reflectivity is subject to change as surfaces age, if wet or dry, or degraded by dirt. Surface texture also affects the directional reflectivity of the surface. So, a lighting design based on a surface luminance is problematic.

In contrast, it is easy to design to a surface illuminance because it depends only on the spectrum, distance, and direction of the light source, which are relatively easily to engineer.

Brightness Limits For Wildlife Behaviour

There are two contributing features to ecology: animal behaviour and their biology. Animals can quickly adapt their behaviour to a change in the environment. However, biology is based on environmental cues and a bio-chemical response to those cues. These responses are encoded in the animal's DNA and require very long periods (100s–10,000s years to change). An environment that changes slowly encourages evolution. One that changes quickly causes extinction.

The luminance threshold for most species has not been determined. However, we can determine a limiting illuminance by monitoring animal activity in various natural settings and during different phases of the Moon. For example, studies indicate an aversion to foraging during a bright Moon (Daly 1992, CIP 2015, Benoit-Bird 2009). Periodic moonlight attracts the activity of predators that prefer the evening and periods of a bright Moon for hunting but has also moulded the foraging schedule of small animals that wish to remain anonymous.

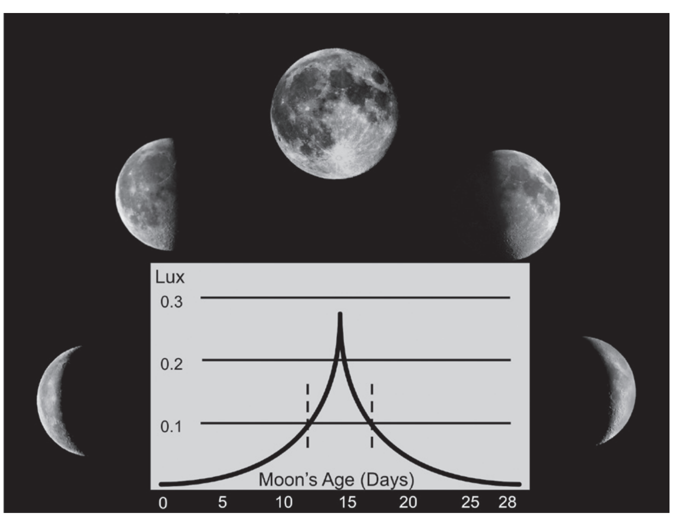


Figure 5 — Illumination from the moon over a lunar month. The Moon illuminates the countryside for about a week every month to a maximum possible illumination of 0.267 lux. The enhanced illumination at full Moon is due to the optical properties of the Moon. The maximum illumination assumes the Moon is at the zenith and clear air. The more typical illumination is about 0.1 lux.

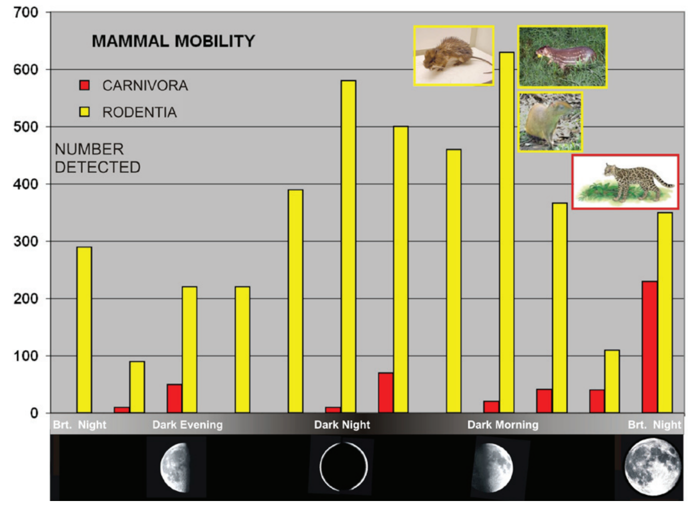


Figure 6 — Mobility of predator and prey animals with lunar phase. Predatory species are most mobile during the evening and especially with the illumination of the Moon. A foraging species (the prey) prefers the early morning and the anonymity of a dark Moon. (data from Yanachaga Chimillen National Park, Peru, July 2011–September 2013, TEAM Network)

Moonlight affects the landscape for roughly 1 week per lunar month centred on the full Moon and reaches a maximum brightness of almost 0.3 lux, but more typically 0.1 lux (Kyba 2017) due to atmospheric extinction and typically low incidence angles. From our general experience, this is sufficient for walking about, especially if the path surface is sandy soil, but it becomes more difficult when walking on grass or asphalt due to their low albedo.

If we assume there is a balanced ecology, then an impact on one species will change that balance and will affect, to some degree, the survival of all species in that ecosystem. Therefore, the sensitivity of foragers to the illumination by the Moon suggests an illumination threshold of less than the full Moon, and preferably a crescent Moon of roughly 0.02 lux.

This conclusion can be generalized to other habitats. Aquatic and marine zooplankton are near the base of the food chain and are vulnerable to predation by larger fish. They forage at night and seek anonymity in the cool dark depths during the day—a behaviour called Diel Vertical Migration (DVM). Not all zooplankton avoid the light. In some cases, remaining in the warm nutrient-rich surface water may be worth the risk of higher predation. However, records of DVM suggest the threshold illuminance is at about a half lunar phase, or roughly 0.02 lux (Benoit-Bird 2009).

There should be a luminance limit for birds since they use stars to navigate. A bright light source may confuse their use of stars. For example, the stars around the North Celestial Pole (Foster 2018) (roughly magnitude 2.5) have luminances of roughly 0.003 cd/m^2. However, the Moon has a luminance on the order of thousands. How can this sensitivity be reconciled with moonlight?

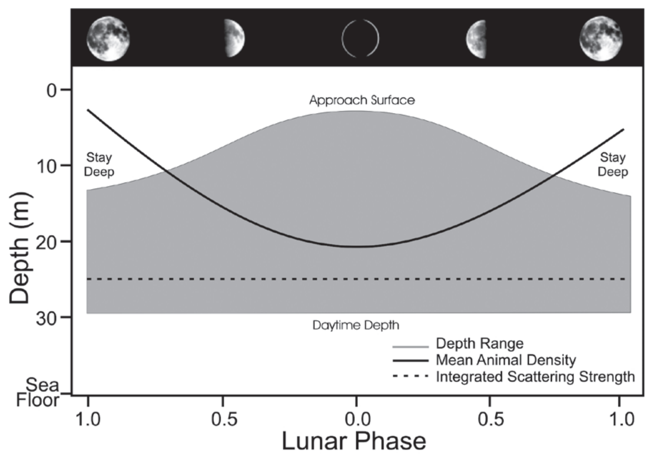


Figure 7 — Variation in zooplankton distribution over a lunation. Zooplankton avoid the surface during the bright lunar phase resulting in a compress (higher density) distribution (grey band). At new Moon, they approach the surface, which reduces the density (dark line). (from Benoit-Bird 2009)

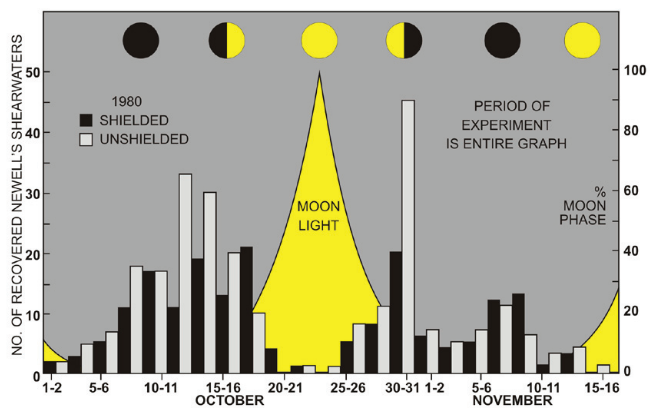


Figure 8 — Number of birds recovered during light shielding experiments. Most ALAN is ignored during the bright lunar phases, but is particularly distracting when they do not compete with moonlight. Even shielded lights cause a problem, but unshielded lights are particularly distracting. (Ref: Reed et.al. 1985)

There is no research on this point. However, the bright Moon could be differentiated from the fainter starlight. When low in the east and west it might be used in a similar fashion to the rising and setting Sun to identify the east and west. And, during migration in the early and late autumn the full Moon is roughly halfway up the sky in the south, leaving the lower altitude southern stars for navigation.

Artificial light at night (ALAN) is particularly distracting for birds during the Moon's partial phases (Reed 1985). Light sources on the ground and on towers distract birds from navigating by real stars—drawing them off course and wasting flight time. Even shielded lights are distracting but the intense luminosity of unshielded light appears to be more distracting.

The Audubon Society reports of declining songbird populations (Audubon). Numerous causes have been given that are generally referred to as habitat disruption. Absent from the list of obvious disruptions is light pollution. This is to be expected, as outdoor lighting has only recently been accepted to affect the behaviour of animals. But the evidence is increasing. For example, urban lighting is moving the foraging schedule of birds out of synch with insects on which they feed.

The ALAN simulates an early dawn. One study (Miller 2006) reports that compared to a century ago, birds are aroused an hour earlier in the morning. If their food supply is not also aroused, the birds will be out of synch with their food supply, which can result in about an hour of wasted foraging/hunting activity.

Insects play a critical role in the pollination of plants, which requires their maturation to be synchronized with plant development. The brightness and spectra of ALAN miscues the development of some plants.

The effect of day length on plants has been known for at least a century (Tincker 1924) and is used commercially to artificially prepare some plants for harvest at a time convenient for sales (Cathey 1975). Although the intention of some past research was to assess the benefit of greenhouses, the research reinforces the assertion that plants are profoundly sensitive to their photoperiod.

Plants "foretell" the coming season by the length of the night. The limit for photosynthesis in plants is roughly 1,000 lux (Leopold 1951). The threshold brightness that affects their biochemistry is on the order of 0.1 lux (Bunning 1969). (However, this published value assumed an erroneous maximum Moon illumination of 1 lux.)

Those plants that tolerate urban ALAN are called "long-day" or "day-neutral" plants. However, short-day plants are rarely found in cities, and give rural vegetation its unique character. Plant development is synchronized by the length of night. The ratio of two photo-molecules phytochrome-R (red sensitive) and phytochrome-FR (far-red sensitive) switches the plant between vegetative growth (leaves) and growth of their stalks. An artificially extended daylight is interpreted as summer, and can delay the preparation of seeds and preparations for winter.

There is no single threshold to the sensitivity of plants. But those that have been studied indicate a sensitivity less than 6.6 lux (Poulin 2014).

Brightness Limits For Wildlife Biology

The over-arching transspecies cue for development is the length of night. Although we have not yet found any definitive studies of celestial navigation by mammals, there is significant data that they use light at night in their hunting and foraging strategies. This in turn will be impacted by artificial light that illuminates the landscape—even from distant cities.

All life has internal biological clocks that time and regulate biological processes in synch with its activity. These clocks do not run on a 24-hour period, so they are called circadian (approximate day) rhythms (CR). Although the average human CR is slightly longer than 24 hours, the period for other life forms can be from 18-30 hours. Resetting these clocks to the current 24-hour day is done with the fading light of twilight. There is a wide range of animals with CRs, from prokaryotes (Huang 1990) to higher life forms (Zhdanova 2006), which serve the same general purpose of regulating and synchronizing biology with the environment.

In humans, the intrinsically photosensitive Retinal Ganglion Cells (ipRGCs) detect the fall of twilight (twilight detectors). After twilight, they signal the suprachiasmatic nucleus in the hypothalamus at the base of the brain to release the hormone melatonin from the pineal gland. This process has profound consequences for human physical and mental health that are well documented in many review papers (Vetter 2019, Pauley 2004) and books (Koukkari and Sothern 2006).

Melatonin enables our sleep cycle and the ebb and flow of other hormones in mammals and other species. It is accumulated during the day and the pineal gland releases it when twilight fades below the blue light threshold for our ipRGCs. The hormone enables the release of a suite of other hormones that lower the metabolism in preparation for sleep and initiate tissue repair, the fight against infection, disease, and even purge incipient cancer cells. These hormones help rejuvenate the body prior to the next day's fight for survival.

Not all creatures are diurnal but even nocturnal animals are sensitive to the length of night. Their biochemistry has evolved to exploit the length of night to maximize their survival. For example, some animals have an immune response enhanced when nights are long (winter), which is believed to be an energy conservation mechanism (Walton 2019).

It should be mentioned, however, that there are other synchronizing parameters (zeitgebers) that may take precedence where imposed by the habitat (Wagner 2007). These include temperature, food supply, and others, but for many species, the photoperiod is the dominant zeitgeber.

Brightness And Human Health

As daytime creatures, humans require a minimum of light for vigorous activity. A thick overcast of cloud can reduce the Sun's illumination from 120 kLux down to less than 10 kLux. In the evening this can be lower than 1 kLux. Coincidentally, office illumination is recommended to be about 500–1000 lux (IESNA 2004). Our cone cells start to saturate at a luminance of about 500 cd/m^2. These are practical limits for luminance and illuminance for our day (photopic) vision.

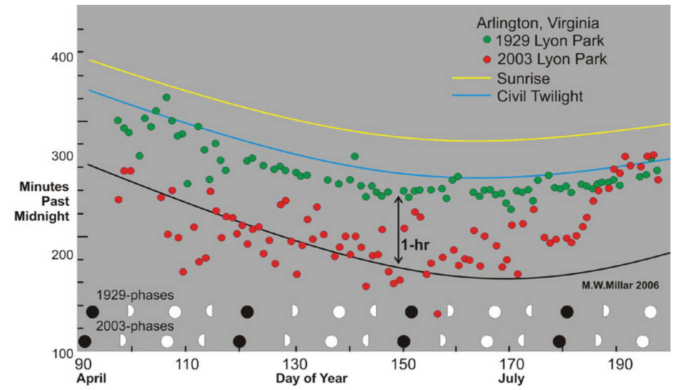


Figure 9 — Initiation of morning birdsong in 1929 and 2003. Between 1929 and 2003 the onset of birdsong has become roughly 1 hour earlier. The main difference cited is the increase of urban lighting. (from Miller 2006)

Reading is a technology we developed in our recent past. It cannot be achieved without ALAN because the high visual acuity required is only provided by our photopic vision. The luminance threshold for reading a typical page of text is about 1 cd/m^2 and the constriction of our iris also begins at the same luminance (Watson and Yellott 2012). The contrast of the print against paper and its size must be increased if we are to use our scotopic vision for reading.

The sensitivity of human biology to ALAN is revealed by studies in biological rhythms (Koukkari, Sothern 2006) and some cancer research. They are based on experiments with mice that have been bred to simulate human biology. Light at night of only 0.2 lux was sufficient to reduce melatonin by 60% of normal (dark night) levels and that cut the effectiveness of a tumour medication (Dauchy 2010, Dauchy 2014). Providing melatonin supplement renewed its effectiveness.

The effect of this melatonin suppression by light is amplified as we grow older. Following early adulthood, our peak night-melatonin concentration decreases with age to 1/2 at about 50 years and 1/4 at 80 years of age (Reiter 1995). Therefore any "artificial" reduction in melatonin will exacerbate the effects of aging.

Summary

The biological priorities of daytime creatures are different at night. Human biological limits to ALAN are similar to those supported by wildlife studies, which should not be surprising since all wildlife evolved to tolerate and even exploit the same natural environments. Generally, the sensitivity threshold of a lit environment for all species is that which is experienced in the wild. Engineering an environment does not change our biological predilections.

Light sources can confuse and disorient animals that use the stars to navigate. The illuminance limits for birds, plants, and some aquatic life, to name a few, is approximately 0.02 lux—

the illuminance produced by the crescent Moon. This is well into our scotopic vision but does not provide sufficient light for most human activity (reading) at night.

Our modern behaviour imposes higher limits on luminance and illuminance than our biology and that of wildlife. A luminance limit of about 1 cd/m^2 may seem reasonable given this is the luminance of the brightest planets. However, the apparent direction of isolated artificial sources will change unexpectedly for migrating birds as they fly past the source. Thus ALAN of even natural level brightness may adversely impact wildlife.

We must therefore look for other strategies to reduce its impact. These problems will be addressed in the next paper in this series that focuses on shielding. ✶

Endnotes

1 steradian is the spherical angle of 180/p degrees. It appears as the extent of a 1-metre diameter circle on a sphere with a 1-metre radius. Its two-dimensional version is called a radian.

References

Audubon, www.audubon.org/news/north-america-has-lost-more-1-4-birds-last-50-years-new-study-says, accessed 2020 February 7

Benoit-Bird, K., Au, W., and Wisdom, D. (2009) Nocturnal Light and Lunar Cycle Effects on Diel Migration of Micronekton, *Limnology and Oceanography, 54(5)*, 1789–1800 2009

Bunning, E. and Moser, I., (1969) Interference of Moonlight with the Photoperiodic Measurement of Time by Plants, and their Adaptive Reaction, *Botany, Vol.62*, 1969

Cathey, H. and Campbell, L., (1975) Security Lighting and its Impact on the Landscape, *Journal of Arboriculture, October 1975, Vol.1, No. 10*

CIP (2015) [Conservation International Program], Tropical Ecology Assessment and Monitoring Network (www.teamnetwork.org) Accessed January 2015

Daly, M., et.al., (1992), Behavioural modulation of predation risk: moonlight avoidance and crepuscular compensation in a nocturnal desert rodent, Dipodomys merriami, *Animal Behavior, 1992, 44*, 14

Dauchy, R., et.al., (2010) Dark-Phase Light Contamination Disrupts Circadian Rhythms in Plasma Measures of Endocrine Physiology and Metabolism in Rats, *Comparative Medicine, Vol. 60, No 5*, October 2010 Pages 348–356

Dauchy, R., et.al., (2014) Circadian and Melatonin Disruption by Exposure to Light at Night Drives Intrinsic Resistance to Tamoxifen Therapy in Breast Cancer, *Cancer Research; 74(15)* 2014 August 1, DOI: 10.1158/0008-5472.CAN-13-3156

Dick, R. (2020a) The Biological Basis for the Canadian Guideline for Outdoor Lighting: General Scotobiology, JRASC, *Vol. 114, 3*, pp. 122-126

Federal Highway Association (FHWA 2014), *Guidelines for the Implementation of Reduced Lighting on Roadways*, Publication No. FHWA-HRT-14-050, June 2014

Foster, J., et.al. (2018), How Animals Follow the Stars, *Proceedings of the Royal Society B, 285*: 20172322.

Huang, T., et.al., (1990) Circadian Rhythm of the Prokaryote Synechococcus sp. RF-1, *Plant Physiol. 92*, 531–533

IESNA (2004), (Illumination Engineering Society of North America), RP-1, Industrial Area.

Koukkari, W. and Sothern, R., (2006) *Introducing Biological Rhythms*, Springer Science, 2006

Kyba, C., Mohar, A., and Posch, T., (2017) How Bright is Moonlight? *A&G Astronomy and Geophysics, 58, 1*, pp. 1.31—1.32. DOI: http://doi.org/10.1093/astrogeo/atx025

Lamb, T. and Pugh, E. (2004) Dark Adaptation and the Retinoid Cycle of Vision, *Progress in Retinal and Eye Research, Vol. 23*, 307–380

Leopold, A. (1951) Photo Periodism in Plants, *The Quarterly Review of Biology, Vol. 26, No. 3*, Sept. 1951

Miller, M. (2006) Apparent Effects of Lighting Pollution on Singing Behavior of American Robins, *The Condor 108*:130–139# The Cooper Ornithological Society, 2006

Pauley, S., (2004) Lighting for the Human Circadian Clock: Recent Research Indicates that Lighting has Become a Public Health Issue, *Medical Hypotheses 63*, 588–596

Poulin, C., et.al., (2003) The Impact of Light Pollution on Diel changes in the Photo Physiology of Microcystis aeruginosa, *Journal of Plankton Research, 36(1)*, 286–291

Reed, J., Sincock, J., and Hailman, J. (1985) Light Attraction in Endangered Procellariform Birds: Reduction by Shielding Upward Radiation, *The Auk 102*, 377–383. April 1985

Reiter, R., (1995) The Pineal Gland and Melatonin in Relation to Aging: A summary of the Theories and of the Data, *Experimental Gerontology, Vol. 30, Nos. 3/4*, pp. 199–212, 1995

Tincker, M.A.H. (1924) Effect of Length of Day on Flowering and Growth, *Nature, Vol.114, No. 2862*

Vetter, C., et.al., (2019) Light Me up? Why, When, and How Much Light We Need, *Journal of Biological Rhythms, Vol. XX No. X*, Month 2019 1 –3 DOI: 10.1177/0748730419892111

Wagner, H., et.al., (2007) Rhythms at the bottom of the Deep Sea: Cyclic Current Flow Changes and Melatonin Patterns in Two Species of Demersal Fish, *Deep-Sea Research I, 54*, 1944–1956

Walton, J., Weil, Z., and Nelson, R., (2010) Influence of Photo Period on Hormones, Behavior, and Immune Function, *Frontiers in Neuroendocrinology*, (2019 Dec. 8), doi:10.1016/j.yfrne.2010.12.003

Watson, A. and Yellott, J. (2012), A unified formula for light-adapted pupil size, Figure13, *Journal of Vision 2012;12*, 1–16.

Wikipedia, https://en.wikipedia.org/wiki/Luminance, retrieved 2020 January 30

Yao, Q. and Lin, Y. (2018) R_{SP} Ratio Approach for Evaluation of Scotopic/Photopic Ratios of Light Source Performance at Varying CCTs, *Journal of the Optical Society of America, Vol.35, No.10*, October 2018

Zhdanova, I. and Reebs, S. (2006) Circadian Rhythms in Fish, *Behaviour and Physiology of Fish, Chapter 6, Vol.24*, DOI:10.1016/S1546-5098(05)24006-2

Observing

Comet NEOWISE

by Chris Beckett, National Member
cabeckett@gmail.com

Nothing embodies amateur astronomy like a bright naked-eye comet hanging delicately over a dark countryside. Add in Saturn and Jupiter while both are near opposition when the Milky Way flows overhead on a warm summer night and you have the quintessential visual observing experience.

Comet NEOWISE F3 was discovered on 2020 March 27 by the Near Earth Object Wide-field Infrared Survey Explorer (NEOWISE), and not since Hale-Bopp in 1997 have we had such a bright, easily observable comet grace our skies. During the intervening years, many comets since were predicted to be the next bright one, yet they either fizzled out, only just reached naked-eye visibility for a brief few nights, or were bright but rather awkwardly placed out of northern skies or over the horizon. In fact, it looked as though NEOWISE would follow this pattern and was predicted to perhaps break up during its close approach to the Sun on July 3 and would hug the northern horizon during the predicted peak of brightness. Fortunately, the observers on the RASC Astro-Sketchers list were ready with their pencils and paper!

Centuries ago when superstition reigned, comets were seen as harbingers of doom, prompting writers, such as Bede, who penned in his ~703 CE *On the Nature of Things* "Comets are stars with flames like hair. They are born suddenly, portending a change of royal power or plague or wars or winds and heat."

We now know that comets, like NEOWISE, come from the frozen outer reaches of our Solar System and are heated by their close approach to the Sun to form bright coma and tails. However, as I observed NEOWISE in my social isolation of the COVID-19 pandemic, I felt a certain connection to those skywatchers long ago. Fortunately for us, the comet was a happy, exciting observing opportunity and a welcome distraction for many non-observers during these uncertain times.

Alan Whitman's July 6 observing report of the comet among noctilucent clouds motivated me to grab my 7×35 binoculars on the next clear morning and head out. He reported good detail with both 7×50 and 15×75 binoculars as well as a bright coma and a 1.5-degree tail, noting, "The dust tail was faintly visible with the unaided eye. The comet was about magnitude 1.5, low in the bright sky (possibly brighter)." So, I was surprised to see a much longer tail when it cleared a few mornings later but happy to see that my observation of a 4-degree tail matched Alan's report from the same morning, when he noted it was also now the best comet since 2007's Comet McNaught.

Figure 1 — July 5: Silvia Graca Comet NEOWISE and Noctilucent Clouds Unaided Eye from Trout Lake, Ontario.

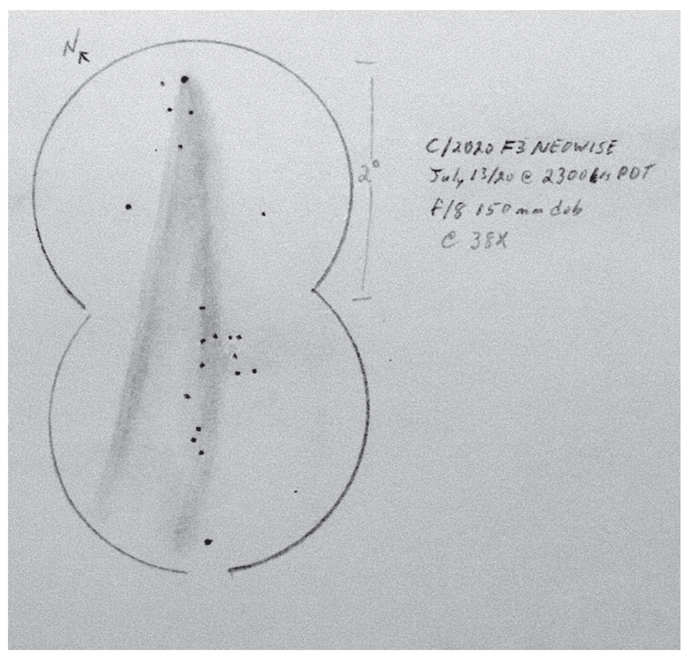


Figure 2 — July 13: Bill Weir observing with a 150-mm f/8 Dobsonian at 38× near Metchosin, B.C.

On July 18, I had the opportunity to observe NEOWISE from the Grasslands National Park under pristine, dark skies. I noted the comet's tail had grown to almost 20 degrees with the unaided eye and filled two fields of my 9-degree binocu-

Figure 3a — July 18: Jeremy Perez 15×70 binocular observation and sketch of Comet NEOWISE from Robinson Crater, Arizona.

Figure 3b — July 18: Jeremy Perez unaided-eye sketch of Comet NEOWISE from Robinson Crater, Arizona. See www.beltofvenus.net for more details.

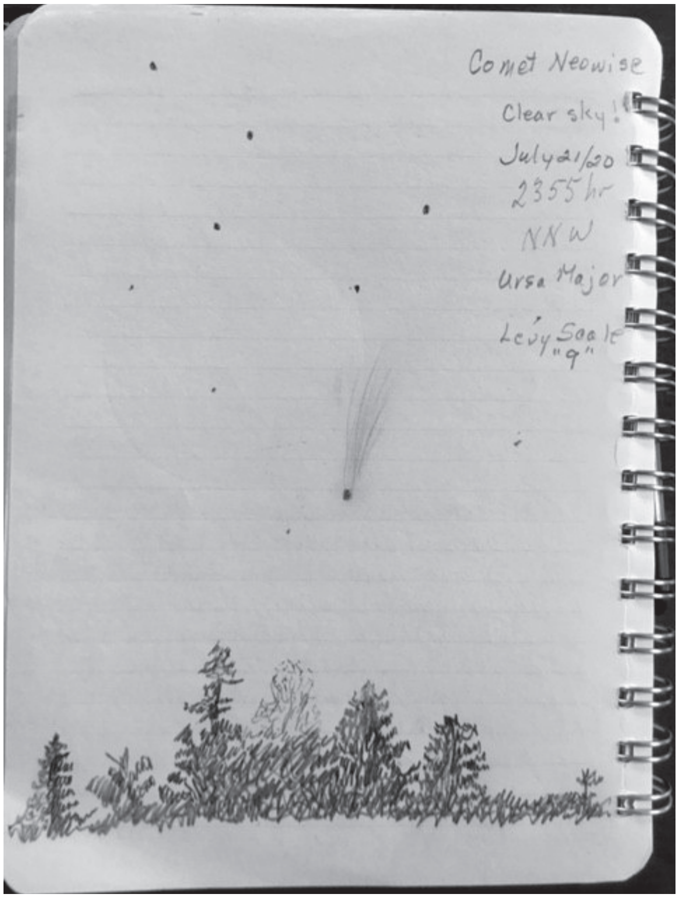


Figure 4 — July 21: Melody Hamilton observing from the shores of the Bay of Fundy in Nova Scotia.

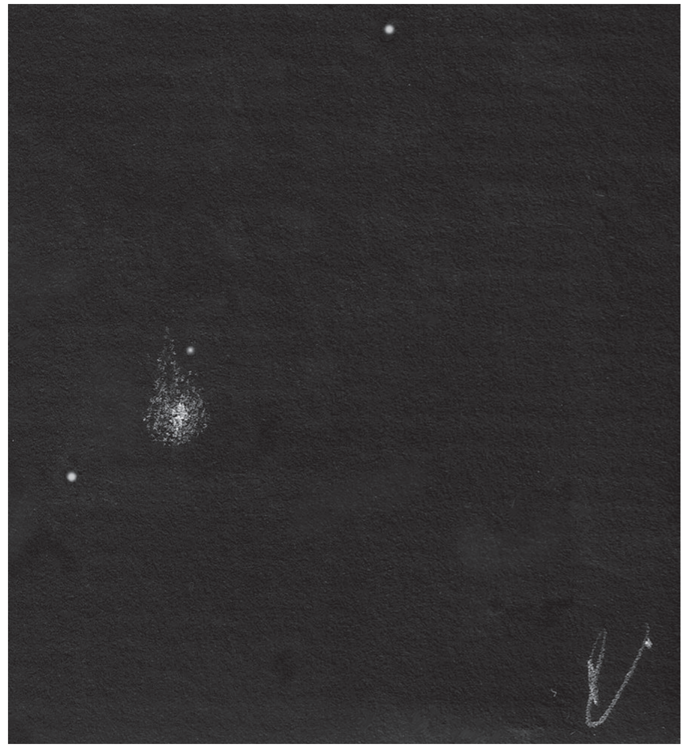


Figure 5 — Randall Rosenfeld C/2020 F3 (NEOWISE) 2020 July 24 ca. 3:15 UTC from downtown light-polluted Toronto! Stellarvue 80-mm Nighthawk, 25-mm orthoscopic, Baader Moon & Skyglow filter.

lars, while my 100 mm at 60× revealed the arrow-straight ion tail. The same night, fellow sketcher Jeremy Perez made unaided eye and 15×70 binocular sketches, noting the ion tail was scarcely visible without optics but clearly defined through the binoculars, appearing as "a fainter extension of the dust tail fanned away from the coma about 70 degrees to the main dust tail." Alan Whitman's observations the following evening put the nucleus at magnitude 4.5, identical to 26 Ursa Majoris, adding "the dust tail reached 13 degrees with the unaided eye near Upsilon UMa. With 7×50 binoculars the tail was 16 degrees long, to the vicinity of 23 UMa, but it is very wide at its far end, so I had to sweep back and forth with the 7×50s to discern this very faint extension."

Jeremy is a very generous observer and a well-known and highly regarded astronomical sketcher. He kindly provides some further details for observers looking to try their hand at sketching or, if you are like me, and can use a little more guidance. Jeremy states that "the field sketches were made on pre-printed star charts of the sky so I could focus on the comet. Those sketches were fairly rough isophote drawings, outlining areas of brightness, including written notes. Afterward, the star fields were traced onto Strathmore drawing paper and then a blending stump used to carefully shade in the comet. For the naked-eye view, an artist's chamois was used to apply broad swaths of graphite to show sky glow near the horizon. The comet was shaded atop that, and a kneaded eraser used to remove graphite between the tails to indicate the illusion of the darker wedge that helped identify the ion tail. Foreground trees in the naked-eye view were erased into the sky glow based on a photo reference from that night. So, all observational efforts were applied to the comet and/or sky glow, but not the stars or horizon silhouette. I can confirm though that the stars did appear through the diffuse dust tail and were beautiful to see in that state. After completion of the graphite sketch, it was scanned and then inverted and cleaned up in Photoshop. I used dodge, burn, and clone tools to clean up any rough areas that might indicate structure in the comet that was not actually observed."

By July 26, the comet had faded. While the core was visible in small binoculars and telescopes near Regina, it had now paled with a tail scarcely a few degrees long through my 100-mm telescope. No one knows when the next bright comet will appear in our skies, but when it does, our pencils and paper will be ready to record what our eyes see.

Acknowledgements

The author sincerely thanks all the observers who permitted their sketches, observations and notes to illustrate this article.✶

Pen & Pixel

Figure 1 — This image of the aurora and Comet NEOWISE was taken by Garry Stone on July 13 at 12:45 a.m. 100 km south of Saskatoon. Garry used a Canon EOS Rebel Xs, with a 5-mm *f*/1.8 lens at ISO 1600 for this 8-second exposure.

Figure 2 — (July 14 by Klaus Brasch) from my backyard as it is visible low in the northwest around 8:30 p.m. some distance below the Big Dipper. This image was shot with a modified Canon 6D and 135 mm lens, 10 seconds at ISO 1600 unguided.

Figure 3 — Mark Kaye was able to capture the green coma of Comet NEOWISE from his observatory on Loughborough Lake, Ontario. He took a 30-second exposure using a Canon EOS 7D Mark I, at ISO 6400 with a 1016-mm ƒ/8 Astrophysics refractor, tracked but unguided.

Notanee Bourassa captured a celestial trio: Comet NEOWISE, the aurora, and STEVE, 17 km north of Kisbey, Saskatchewan, in the late evening of July 13.

Skyward

Reflections of a Comet and Reasons to Join Your Local Astronomy Club

by David H. Levy

A few months ago, I wrote in this space about Comet Atlas (C/2019 Y4), a comet that at the time showed signs of becoming a bright comet visible without a telescope or binoculars with just one's eyes. I also repeated my maxim that "Comets are like cats; they both have tails, and they both do precisely what they want." This comet indeed did not live up to its billing, and neither did the next one, comet Swan (C/2020 F8).

The third comet, however, did! Comet NEOWISE (C/2020 F3) put on a beautiful performance in the morning sky at the start of the summer of 2020 (Figure 1). It was a shining cosmic beacon amidst the terrible time we are all having this year. Over the course of July, this comet faded slightly as it moved into the evening sky, but it moved so far north that for a time it was visible in the night sky all night long.

When I look at a comet, my thoughts often dwell on the role that comets have played in the origins of life, and in particular why and how I am here looking up at the sky to ask. For a long time, we have suspected that when a comet strikes a planet, it leaves behind four of its substances—carbon, hydrogen, oxygen, and nitrogen—CHON particles, the simple alphabet of life. For impacts in the oceans, long-lasting hydrothermal vents might have helped form prebiotic molecules that began to replicate themselves before evolving into proteins, amino acids, then RNA, and finally DNA.

Gene Shoemaker, the famous geologist, loved to say that "we are the progeny of comets." Comet NEOWISE itself had nothing to do with it. This comet was formed when the Solar System was very young, and trillions of other comets formed at the same time. Some of these other comets might have, too. Certainly at least one of them did collide with Earth well over three billion years ago. If the impact were in an ocean, it could have led to the start of one of those hydrothermal vents at the ocean bottom. So much time has elapsed, and we are still here somehow. We also have the opportunity to look at the sky and witness a cosmic cousin of the comet that did collide, that cousin being Comet NEOWISE. In all its magnificence, this comet is visiting, to tell us its story, and ours.

Join Your Local Astronomy Club

By a long shot, the best way to get into and enjoy astronomy is to become affiliated with your local astronomy club. Not only do you get access to a ton of knowledge about how to find constellations, and to choose and use your first telescope, but also you get a firsthand look at what is happening in the sky from the people who love it the most.

When I was a young teenager, one had to be 16 years of age to join the Society in Montreal. (Thank goodness, that rule no longer applies.) But younger people could indeed attend most of the meetings, and on 1960 October 8, I attended my first meeting. Isabel K. Williamson was in charge, and she gave me my first assignment, to create a map of the Moon based on my own observations. Even though I couldn't be a member yet, I embarked on a project that took me three years to complete. (The map is pictured in Figure 2.) In Canada, most of the astronomy clubs are under the single banner of The Royal Astronomical Society of Canada. There are "Centres" within most major Canadian cities. In the United States, the local clubs are independent, and I have been a member of the Tucson Amateur Astronomy

Figure 1 — Comet NEOWISE just after dawn, 2020 July 9

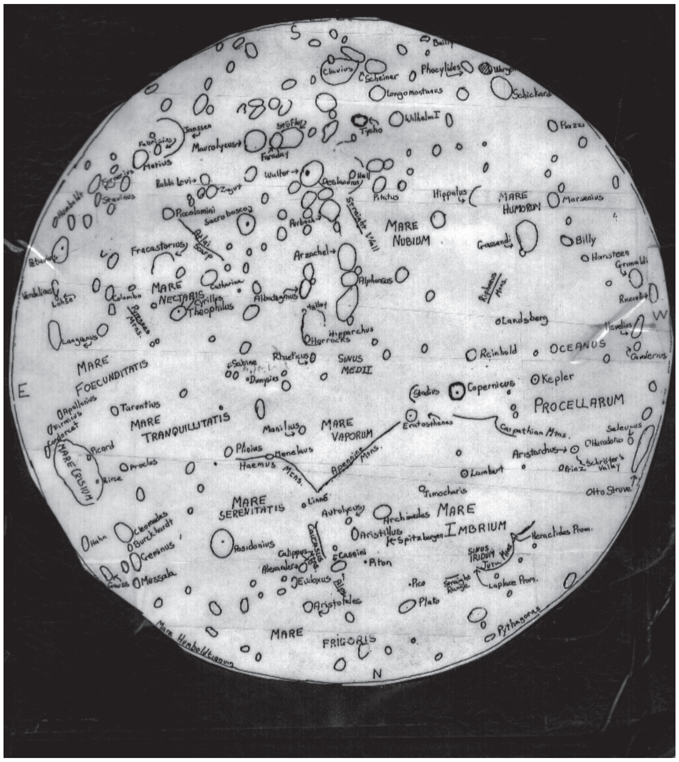


Figure 2 — This is a drawing of the Moon that I did between 1960 and the summer of 1964. It is based on my own observations of the Moon using my first telescope, Echo, at that time.

Figure 3 — The Montreal Centre of The Royal Astronomical Society of Canada used to meet in this observatory. I took this photo of my friend Carl Jorgensen, and his daughter Christine, standing in front of it.

Association (TAAA) since 1979 and served as its President from 1980 to 1983.

The observatory that Wendee and I operate from our home is called Jarnac Observatory. Unlike almost everything NASA does, Jarnac is not an acronym. But if it were, Jarnac could be short for Join A Really Neat Astronomy Club.

In recent months, astronomy clubs have stopped having in-person meetings because of the COVID-19 pandemic. But that hasn't stopped them from indulging in online events. Using platforms like Zoom, Cisco Webex, or Facebook, online meetings have had an explosion in popularity. I've been attending one meeting or another almost every night this week. They have been so successful that when the pandemic is over, they may continue in some manner.

The most important thing you can get out of an astronomy club is friends. Almost all of my friends are members of one astronomy club or another. They enrich my life and increase my own enjoyment of the night sky a millionfold. I cherish their always-welcome insights. In fact, Tim Hunter, one of my closest friends, recently made an independent discovery of a supernova, or exploding star, in the faraway galaxy labelled UGC 10509, which is hundreds of millions of light-years away from us. He may not have been the first to spot it, but his observation has added important new information about the Universe. That star blew up a very long time ago. Its light travelled across space and time until it landed as a speck on one of his pictures, and it is now called Supernova 2020 LQL. This is one of the best things about astronomy. It is an area of study where amateur astronomers can add to our understanding of how the Universe works. Nice work, my friend.

When you next go outside to look at the night sky, enjoy your eyeful of stars. The time after that, try it with your local astronomy club. You couldn't give yourself a better gift. ✶

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 the 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

Claude Mellan's Moon in Pierre Gassendi's Printed Letters: Clues to Changes in Perceptions of Accuracy?

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

Abstract

The surviving lunar engravings by Claude Mellan from the mapping effort led by Nicolas-Claude Fabri de Peiresc and Pierre Gassendi are justly acclaimed monuments in modern accounts of selenography. The Mellan images were highlighted during a recent *SkyNews* and RASC Speakers Series webinar exploring evolving concepts of accurate eyepiece depictions of celestial objects (https://tinyurl.com/yaydqv69). These images are instrumental in illustrating seemingly puzzling disjunctions between early modern and modern perceptions of what constitutes an accurate representation of a celestial object or phenomenon. To provide contemporary context during the webinar, some passages from Pierre Gassendi's published letters (1658) about the lunar images were read. As these have not been widely available in English translation, annotated working translations of the relevant passages are offered here.

The Peiresc–Gassendi–Mellan images, and perceptions of truth at the eyepiece

From 1634 to 1637 the Provençal jurist, parliamentarian, and polymath Nicolas-Claude Fabri de Peiresc (1580–1637, Figure 1) joined with the priest, astronomer, and epicurean philosopher Pierre Gassendi (1592–1655, Figure 2) in a lunar mapping project with the goal of finding the longitude (Gassendi 1657, 124–125; Turner & Gomez 1992, 144–146; Miller 2000). The optical means for the venture was a telescope supplied by Galileo himself (see the 1636 letter below), a most compelling sign that the Grand Duke's philosopher thought the project worthwhile, and Peiresc and Gassendi worth cultivating. Not everyone was successful in prying a telescope from Galileo's hands by direct appeal; neither prominence as a mathematician (*e.g.* Johannes Kepler, Rudolph II's Imperial Mathematician), nor the possession of an elevated title (*e.g.* Marie de'Medici, Queen of France), could guarantee the favour (Galluzzi 2017, 24; Heilbron 2010, 160).

During the life of the project, several artists were employed with varying degrees of success, till Peiresc engaged Claude Mellan (1598–1688), who enjoyed a considerable reputation even in the 1630s (see the letters of 1636 and 1644 below). With the death of its patron, Peiresc, the project withered on the vine. The final lunar map to aid in finding the longitude was never produced, and neither the artists' working sketches nor the astronomers' logbooks (in whatever form they took) have been reported as extant.

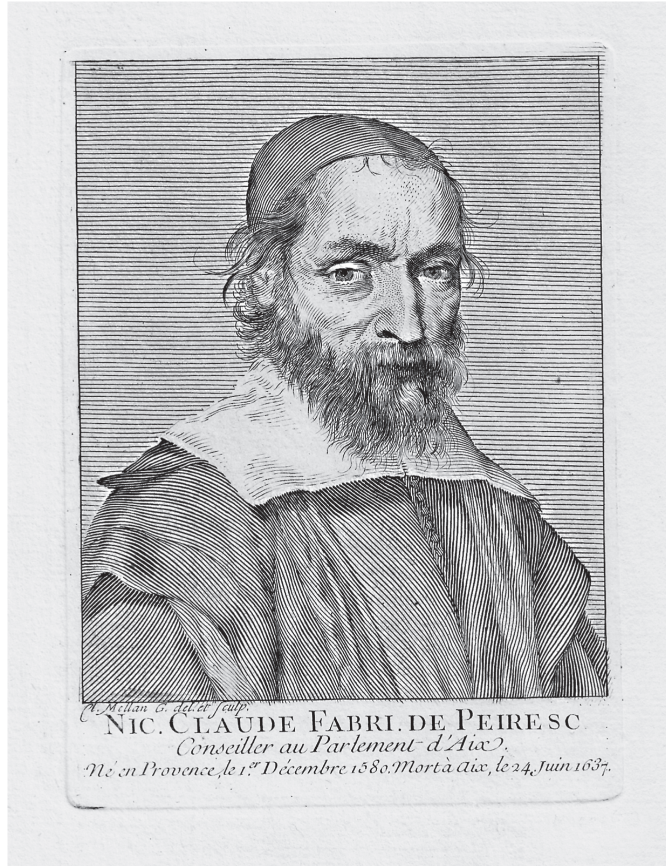


Figure 1 — Nicolas-Claude Fabri de Peiresc (1580–1637), engraved portrait by Claude Mellan (1598–1688), 4th state ca. 1786. Reproduced courtesy of the Specula astronomica minima.

Three surviving lunar engravings by Mellan are the sole traces of the graphic production from the project, but they are enough to attest to the potential of the endeavour (www.metmuseum.org/art/collection/search/393278; www.metmuseum.org/art/collection/search/393543; www.metmuseum.org/art/collection/search/359769).

Ewen Whitaker stated that:

> One does not have to be a lunar expert to see that these images are infinitely more detailed, accurate, and aesthetically pleasing than any of their successors. For anyone who has looked at the Moon through binoculars or a small telescope, the usual remark on seeing these images is that they "really look just like the Moon" (Whitaker 1999, 33).

Horst Bredekamp's opinion is similar: "Claude Mellan, who created three matchless pictures of the moon on commission from Peiresc..." (Bredekamp 2019, 7-8). And Irene Kampa wrote of the engravings that:

> The first map of the Moon worthy of the name in its modern sense came from the pen of Claude Mellan.... In 1637 he made for Pierre Gassendi...and Nicolas de Peiresc...three nearly photorealistic depictions of the Moon.... (Kampa 2018, 100).

Or, to paraphrase what was said during the webinar, if anyone unfamiliar with the Mellan lunar engravings saw them flash by on a computer screen, they could easily be mistaken for Lewis Morris Rutherfurd's albumen silver plates of the Moon from the 1860s. To modern lunar observers, Mellan's images appear centuries ahead of their time.

We have no licence to assume that what we see as prescient modernity in the images was also naturally perceived that way by viewers of the 17th or 18th centuries. Visual vocabularies, ways of seeing, and modes of representation shift as cultures change. It is thought that the Mellan images were not widely circulated (and few survive to the present), but some astronomers of significance did see them in the 1630s and 1640s, before their limited circulation ceased, and they dropped from sight and memory for about 80 years (Le Monnier 1746, 121, footnote). Gassendi's letter of 1636 (below) expresses the intention to send the engravings to Galileo: "If the project is successful, no one will be entitled to a sample ahead of you." The gesture was fitting, both because Galileo enjoyed public priority for revealing the face of the telescopic Moon, and because he was the source of the optics for Peiresc's and Gassendi's project. As revealed in a letter to his ally Fr. Benedetto Castelli, the great man's reaction catches us off guard:

> The...printed designs [of Mellan] are truly clumsy beyond measure, and are drawn by someone who has never seen the face of the Moon, but who rather relies on the account of some very uninformed person (Galilei 1906, 204 [no. 3583]; but see Bredekamp 2019, 287-288 for a dissenting view).

Appraisals of accuracy, and perceptions of modernity aside, Galileo's judgement is equally insulting to the artistic skill and reputation of Mellan, and the astronomical ability of Gassendi. It is now difficult to determine whether Galileo's words stem from impaired vision, jealousy, well-honed grumpiness, or a culturally different way of perceiving the telescopic Moon. It may have been a combination of all these factors, with deteriorating vision in the lead.[1] The possibility of a different perspective from ours, however, is the most intriguing.

Another astronomer to receive a gift of the engravings was Johannes Hevelius, according to Gassendi's letter of 1644, and his reaction as inferred from his *Selenographia* of 1647 is every bit as surprising to a modern sensibility as Galileo's.[2] To judge from the plates in Hevelius's *Selenographia*, Mellan's graphic approach to portraying the Moon exercised hardly an iota of influence on Hevelius's lunar images.

There could be even more perceptual surprises, depending on how one reads Gassendi's statements. In the letter to Hevelius, Gassendi praises and encourages the former's selenographic project with the flattering "...to the extent that it is possible, the *Selenographia* I aspired to, you ought to complete," before making the offer of a gift of the Mellan engravings: "for I send you two images.... You will acknowledge in both the hand of that outstanding painter and engraver, Claude Mellan...you will have the most pleasing ones." If read literally, without any consideration of the role of flattery in 17th-century epistolary style, Gassendi seems to be saying that Hevelius's particular constellation of abilities should enable him to accomplish in selenography what he could not. In light of the eventual result, the only sense in which this seems true to a modern onlooker is that Hevelius completed and published his project, whereas Gassendi had to abandon his. One can't help but wonder if Gassendi still thought that Hevelius fulfilled the selenography he had to abandon when he saw the final result. Did Gassendi notice the huge disparities in accuracy of depiction between Mellan's and Hevelius's images that we perceive? We may never know. Mellan's images seemed to have no influence on Hevelius's style of lunar depiction.

At least one respected professional astronomer from the following century, Pierre-Charles le Monnier (1715-1799), seems to have shared our modern perceptions of these contrasting images:

> Of all the representations [*figures*] of the Moon which have been published up to the present, it can be said that those which were engraved in 1635 by the famous Cl. *Mellan* by order of *Peiresc*[, based] on the observations of Gassendi (& which comprise three phases[,] of which one represents the Full Moon[,] & the two others the First Quarter[,][3] & the Waning [phase])[,] without contradiction have been held to be the best and [possess] the greatest resemblance [to the Moon]. Although it has not been more than twenty years since they became known, these same [depictions of lunar] phases are nevertheless the most ancient, since they preceded those of Hevelius and Riccioli, which are the most imitated[,] and which astronomers endeavour to use up to the present (Le Monnier 1746, 141, footnote).

Le Monnier's words are of interest for another reason. In the modern literature it is often assumed that Cassini's "small" lunar map (1692) became the professional standard for astronomy upon its publication (*e.g.* Haddad 2019, 55, caption to Figure 16; for reproductions of the map see Van de Vyver 1971, 80, Figures 29–30; Whitaker 1999, 78–81). It undoubtedly came to wield extraordinary influence, though not immediately. Le Monnier included a version of the "small" Cassini map in his textbook (1746, pl. II, after p. 140), but when he identifies the dominant lunar maps in contemporary astronomical circles, the Cassini maps don't even merit mention! Clearly more work is needed to track the chronology of the "small" Cassini map's rise to dominance.[4] Le Monnier's words can even be read as implying that Mellan's maps of the

1630s were better likenesses of the Moon than Cassini's maps from the 1670s, and 1692.

The limited data presented here—one opinion from the 1630s, one account from the 1640s, an instance of inaction from the 1640s, and an evaluation from the 1740s—suggest a change in perception of lunar representation, toward a more modern view of the relative merits of Mellan's images compared to what went before, and what immediately came after. It can only be a suggestion, because four data points is very little to span a century. Much more evidence would be needed to verify that this actually took place as that reading would have it.

The chief and most valuable lesson of this material comes in the nature of a caution: we ought not to assume that our criteria for accuracy, and modernity in astronomical images hold across time. And it is of value to ask why that may be the case, and to reflect on how our best images made according to our canons of accuracy and "modernity" might fare down the ages.

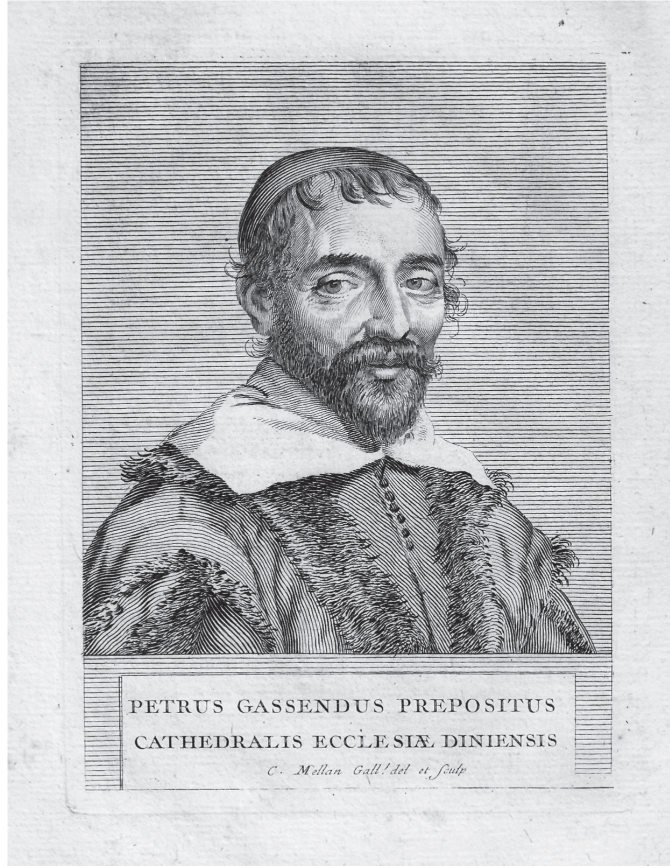


Figure 2 — Fr. Pierre Gassendi (1592–1655), engraved portrait (post-1655) by Claude Mellan (1598–1688), 2nd state post-1750. Reproduced courtesy of the Specula astronomica minima.

The translations

The texts presented below are translated from the Latin edition of Gassendi's letters in the sixth volume of his collected works published in 1658. In the 17th and 18th centuries, members of the learned classes wrote their letters with an eye to eventual, if not immediate, publication. Gassendi was involved with the selection of letters for the volume, although his last patron and the astronomer's associates saw the collected works into their final form, and through the press after his death; "From the outset, the *Opera* [*omnia*] was designed as a show-piece, a posthumous celebration of Gassendi's fame and the munificence of his patrons" (Hatch 2008, 524). The shaping of an epistolary legacy was an act of self-fashioning, a type of autobiography, as it were. Gassendi judged his selenographic project as a significant enough part of his life to be represented in the letters, as he considered it significant enough to feature in his life of Peiresc (Gassendi 1657, 124–125).

This translation attempts to adhere as closely to Gassendi's meaning as possible, while still aiming for an English idiom that isn't too alien. This is not a trivial task, not only because of the general differences between the languages, but specifically because of Gassendi's Latin style. One scholar who has spent decades tracking down the extant manuscripts of his letters, and mapping out the extent of his epistolary network, has remarked on "Gassendi's infamously difficult Baroque Latin. Correct but convoluted, Gassendi's Latin can make Kepler's look lithe and lively" (Hatch 2008, 523). A historian of philosophy in a review of a colleague's monograph on Gassendi was moved to write of "...Gassendi's notoriously clotted Latin..." (Kroll 1990, 297). His most prolific French translator, after arguing for a "Ciceronian"(!) quality to his Latin, admits that "Gassendi's style is very characteristic, in that he multiplies subordinate clauses, reflecting the nuance of his thinking...." (Taussig 2004 b, ix).[5] The referents of those clauses are not at first sight always clear. Another historian of philosophy notes:

> …secrecy as a guiding stylistic force can be seen in aspects of Gassendi's writing and rhetorical style, as he frequently makes allusions likely to be understood only by his friends or the equally erudite, constantly draws on expressions from ancient sources to make his own points, and offers a variety of quasi-coded rhetorical elements, most notably his hesitating and greatly qualified endorsement of the Copernican model (Fisher 2005, xvi).

It is hoped that this translation will not add to the above barriers to comprehension.

Additions to aid comprehension, and bridge comprehension, are enclosed in square brackets.

Finally, due to COVID-19 lockdown restrictions, I could not gain access to Humbert 1931, Préaud & Brejon de Lavergnée 1988, or Ashworth 1994. Additionally, while I had full access to Taussig 2004 a, I had no access to her volume of published notes, and only limited access to her volume of translations (Taussig 2004 b) after my translations were done.

The 1636 letter to Galileo in translation[6]

Pierre Gassendi, priest, to Galileo Galilei, a man who can never be praised enough, the principal mathematician and outstanding philosopher of the Grand Duke of Etruria [=Tuscany].[7]

Do you (O best of men, O most distinguished Galileo) think I ought not to take advantage of that noble man passing through, not to have entrusted to paper greetings that he might convey them to you? I cannot sensibly do so, nor ought I to. So much time has now elapsed since I have sent you any letters; as your memory ever flourishes in my grateful heart, although I fear you would not sufficiently credit, that we have preserved to the fullest extent possible your delightful discourse with that one [Peiresc], or that I may ascribe to such blessedness, whenever I hear of someone who spoke in your presence. So God help me, I wish you in good health, so that I myself may also finally be able to enjoy your most desired presence. For this reason, when the fates were very favourable to me, before last year finally faded from memory, when it became fixed, settled, and established that I would not be returning to Paris, I would approach you first; and I would honour your fortunate venerable age with my embraces. I decided to publish nothing from the trifling trash of my writings about the philosophy of Epicurus, until I returned from visiting you: if only you yourself were to be left standing in triumph, if finally that fruit would see the light.[8]

The illustrious man [Galileo] will recall what transpired while I laboured here; namely with that exceptional telescope, which you deigned to enrich me, I took care to have the Moon imaged with its features, and colours; the painter of the work has now been employed for more than two years through very many lunar cycles. As I have fallen to this same work more passionately, so has our Fabri [his patron, Peiresc]. That man without compare has retained here Claude Mellan, the painter, and most famous engraver, whom you knew at Rome (assuredly so, for he himself recalled many things about you to me), so that he might serve with dedicated pencil, and graver.[9] If the project is successful, no one will be entitled to a sample ahead of you.

It seems to me that I have observed in Venus—which yet has appeared crescent shaped, and will in a short while enter the dichotomic [διχότομος] phase—I know not what disparity between the innermost and outermost boundaries. If, when it passes through its biconvex [ἀμφίχυρτος] phase, cloudier in the middle (as it is perceived on the limb), will we see if it is borne out, that its appearance is consistent with the "face phenomenon" [τό φωνόμευον πρόσωπον], similar to the Moon.[10]

Farewell, O best of men, ever to be esteemed by me, who will always be most respectful towards you. The distinguished Fabri sends abundant greetings to you, by whom you are much admired, and esteemed, as you especially know. Written at Aix-en-Provence in my chambers, the 14th kalends of December [=November 18], in the year of salvation 1636.

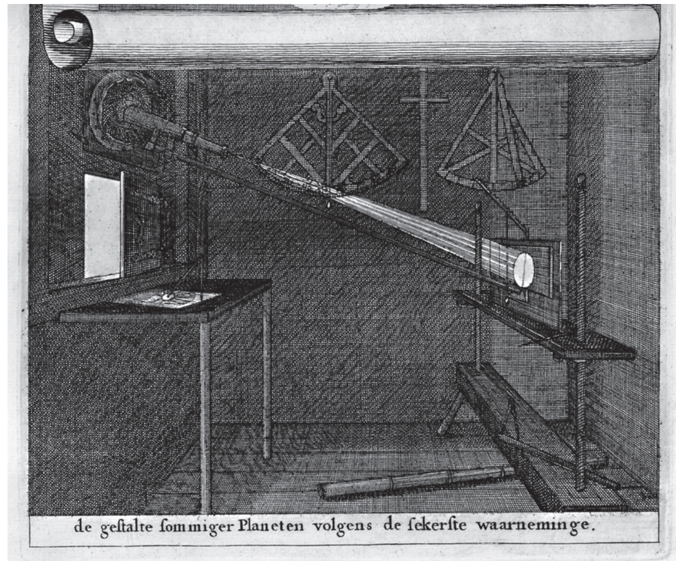


Figure 3 — One configuration of Johannes Hevelius's solar apparatus, engraving by Jan Luyken after Hevelius 1647, in Goeree, W. (1690) Vor-bereidselen tot de Bybelsche wysheid... Amsterdam: Willem Goeree. Reproduced courtesy of the Specula astronomica minima.

The 1644 letter to Hevelius in partial translation[11]

Father Pierre Gassendi to that most celebrated and learned man, Johannes Hevelius, magistrate of the venerable[?] city of the Republic of Dantzig…
I ought next to turn to the outstanding figure of the Sun in its immensity, in which you have added some spots, and faculae. I rejoice that you have obtained such an outstanding telescope, and use such a method [Figure 3], which seems easier by far than that of Scheiner, and that it is effective for one with sharp sight (a power certainly possessed by a lynx!), and a refined hand, as nothing can be depicted more accurately.[12] It is certainly effective—not only do I concur, but to the extent that it is possible, the Selenographia I aspired to, you ought to complete. For my part, I am ignorant of painting, and must employ other hands for such work; while you are capable of turning your own hand to painting with uncommon success, and, what's more, can engrave in copper. You will be in a position to acknowledge how far I was able to prosecute my project, for I send you two images, one of the full Moon, the other of dichotomy, or the later quadrature [i.e. third quarter], which are the only ones I had engraved, and printed.[13] The remaining images are well-advanced, but are neither engraved, nor, I predict, ever will be.[14] You will acknowledge in both the hand of that outstanding painter and engraver, Claude Mellan. He did forget to

depict a very slight spot, which is on the left limb, near another somewhat greater feature which is frequently rendered inconspicuous—neither he with his pen, nor I have reckoned well.[15] Nothing disturbs the appearance, which is derived from the image of the full Moon; since nothing conspicuous is observed on that part. In the other engraving it is somewhat indistinct near dichotomy [i.e. the terminator]: but you will recognize it as a fault of the engraver.[16] I will try to send more correct versions, if they are to hand; but, in short, others are non-existent, beyond an image of the full moon, in a more imperfect state.[17] Despite their state, I will send them, since I am not retaining them—rather you will have the most pleasing ones. That will suffice, since what I imagined of the various uses of the *Selenography* in the *Life of Peiresc*, you have read; there is nothing more that I can add here.[18] …Farewell. Dated Paris, the 7th kalends of April [=March 26], 1644.

All translations are by the author, unless otherwise noted.

Acknowledgements

This research has made use of NASA's Astrophysics Data System. ✶

References

Manuscripts, Books, and Articles

Ashworth, W.B. (1994). The Map of the Moon of Gassendi, Peiresc and Mellan. *Quadricenténaire de la naisance de Pierre Gassendi 1592–1992*, Actes du Colloque International Pierre Gassendi, Digne-les-Bains, 18–21 mai 1992, II (pp. 341–352). Digne-les-Bains: Société Scientifique et Littéraire des Alpes de Haute-Provence

Bredekamp, H. (2019). (Tr.) Mitch Cohen, *Galileo's Thinking Hand: Mannerism, Anti-Mannerism, and the Virtue of Drawing in the Foundation of Early Modern Science*, Galileo's 0 IV. Berlin–Boston: Walter De Gruyter

Fabbri, N. (2012). The Moon as Another Earth: What Galileo Owes to Plutarch. *Galilæana 9*, 103–135

Fisher, S. (2005). *Pierre Gassendi's Philosophy and Science: Atomism for Empiricists*, Brill's Studies in Intellectual History 131. Leiden: Brill

Freedberg, D. (2002). *Eye of the Lynx: Galileo, His Friends, and the Beginnings of Modern Natural History*. Chicago: University of Chicago Press;

Galilei, G. (1906). (Ed.) A. Favaro, *Le opere di Galileo Galilei*, XVII. Florence: Tipografia Barbèra

Galluzzi, P. (2017). (Tr.) P. Mason, *The Lynx and the Telescope: The Parallel Worlds of Cesi and Galileo*, (Ed.) M. Feingold, Scientific and Learned Cultures and Their Institutions 21. Leiden–Boston: Brill

Galilei, G. & Scheiner, C. (2010). (Tr.) E. Reeves & A. Van Helden, *On Sunspots*. Chicago: University of Chicago Press

Gassendi, P. (1657). (Tr.) W. Rand, *The Mirrour of True Nobility and Gentility Being the Life of the Renowned Nicolaus Claudius Fabricius, Lord of Pieresk, Senator of the Parliament at Aix*. London: J. Streater for Humphrey Moseley

Gassendi, P. (1658). *Petri Gassendi Diniensis ecclesiae praepositi… Epistolae…*, Opera omnia 6. Lyons: Laurent Anisson & Jean Baptiste Devenet

Gislén, L., Launay, F., et al. (2018). Cassini's 1679 Map of the Moon and French Jesuit Observations of the Lunar Eclipse of 11 December 1685, *Journal of Astronomical History and Heritage 21, 2 & 3*, 211–225

Haddad, T.A.S. (2019). *Maps of the Moon: Lunar Cartography from the Seventeenth Century to the Space Age*. Leiden–Boston: Brill

Hevelius, J. (1647). *Selenographia, sive, lunae descriptio…* Danzig: the author

Hevelius, J. (1673). *Machinae coelestis pars prior…* Danzig: the author

Hatch, R.A. (2008). The Correspondence of Pierre Gassendi: *Lettres Latines*, *Opera omnia*, and the "Primal Archive", *Journal for the History of Astronomy* 39, 4, 518–528

Heilbron, J.L. (2010). *Galileo*. Oxford–New York: Oxford University Press

Humbert, P. (1931). La première carte de la lune. *Revue des questions scientifique, 4th ser., XX, 1*, 194–204

Kampa, I. (2018). *Die astronomischen Instrumente von Johannes Hevelius*, Nuncius Hamburgensis—Beiträge zur Geschichte der Naturwissenschaften, Bd. 47. Hamburg: tredition

Kroll, R.W.F. (1990). Gassendi the Atomist: Advocate of History in an Age of Science. *Journal of the History of Philosophy 28, 2*, 297–299

Le Monnier, P.C. (1741). *Institutions astronomiques…* Paris: H.-L. Guerin & J. Guerin, 1746

Miller, P.N. (2000). *Peiresc's Europe: Learning and Virtue in the Seventeenth Century*. New Haven: Yale University Press

Plutarch (1957). Concerning the Face Which Appears in the Orb of the Moon. In (Tr.) H. Cherniss & W.C Helmbold, *Plutarch's Moralia. XII 920 A–999 B* (pp. 2–233). Cambridge MA London: William Heinemann

Plutarch (2013). (Ed.) A. Lernould, *Le visage qui apparait dans le disque de la lune: De facie quae in orbe lunae apparet*. Villeneuve d'Ascq: Presses universitaires du Septentrion

Préaud, M. & Brejon de Lavergnée, B. (1988). *L'œil d'or Claude Mellan, 1598–1688 : Bibliothèque nationale, Galerie Mazarine, 26 mai–21 août 1988*. Paris: Bibliothèque nationale

Sheiner, C. (1630). *Rosa ursina sive sol ex admirando facularum & macularum suarum phaenomeno varius…* Bracciano: Andrea Fei

Taussig, S. (2004 a). *Pierre Gassendi (1592–1655). Introduction à la vie savante*, Monothéismes et Philosophie, 5. Turnhout: Brepols Publishers

Taussig, S. (2004 b). *Pierre Gassendi (1592–1655). Lettres latines*, I, Monothéismes et Philosophie, 5. Turnhout: Brepols Publishers

Turner, A. & N. Gomez (1992). *Pierre Gassendi: explorateur des sciences: catalogue de l'exposition*. Digne-les-Bains: Musée de Digne

Watson, P.G. (2009). "The Enigma of Galileo's Eyesight…", *Survey of Ophthalmology 54, 5* (Sept.–Oct.), 630–640

Whitaker, E.A. (1999). *Mapping and Naming the Moon: a History of Lunar Cartography and Nomenclature*. Cambridge: Cambridge University Press

Websites

The Moon in its First Quarter/Full Moon/The Moon in its Final Quarter, Claude Mellan, 1635, The MET 150

www.metmuseum.org/art/collection/search/393278

www.metmuseum.org/art/collection/search/393543

www.metmuseum.org/art/collection/search/359769

(consulted 2020 February 16)

Endnotes

1 "Between the middle of 1636 and the end of 1637, when Galileo Galilei was 72 years old, his vision deteriorated from being able to observe minute changes in the position of the moon to blindness;" Watson 2009. 630.

2 Hevelius 1647, 207. And, to add a note of pleasing irony,… Hevelius in his turn said dismissive things about Galileo's published lunar images: "...[Hevelius] wonders that what he considers to be the appallingly low quality of the Moon drawings in the Sidereus Nuncius can only be explained if Galileo was either a careless observer, was unskilled in drafts-manship, or had a very bad telescope (Hevelius 1647, 205);" Haddad 2019, 35. The rough and tumble of the selenographic section of the Republic of Letters can be amusing—from the safety of four centuries distance!

3 Le Monnier is mistaken; the engraving depicts the 3rd quarter.

4 Gislén *et al.* 2018 is a start of sorts.

5 "Le style de Gassendi est assez caracteristique en ce qu'il multiplie les subordonnees circonstancielles, traduisant la nuance de sa pensee…" Taussig 2004 b, ix.

6 The Latin text of the letter can be found in Gassendi 1658, 92.

7 Ferdinando II de' Medici (1610–1670), reigned 1621–1670.

8 Some of this may have eventually born fruit as his *De vita et moribus Epicuri libri octo*. Lyons: Guillaume Barbier, 1647; *Syntagma philosophiae Epicuri cum refutationibus dogmatum quae contra fidem christianam ab eo asserta sunt*. Lyon: Guillaume Barbier, 1649; and *Animadversiones in decimum librum Diogenis Laertii: qui est De vita, moribus, placitisque Epicuri…* Lyon: Guillaume Barbier, 1649.

9 Mellan was in Rome from 1624 to 1633(?).

10 This is a reference to Plutarch's "On the Face of the Moon," from his *Moralia*; Plutarch 1957; 2013. On the role of this ancient text in the learned astronomical culture in the early 17th century see Fabbri 2012.

11 The Latin text of the letter can be found in Gassendi 1658, 182–184. Omitted from this translation are reports of observa-tions unrelated to selenographic concerns; positions of the Medicean moons, the face of the Sun and sunspots, long lists of observations of solar and lunar eclipses, an occultation of Saturn, and the transit of Mercury. Sharing observations with a correspondent was part of the economy of gift exchange within the Republic of Letters.

12 On Christoph Scheiner, SJ, (1573–1650), see Galilei & Scheiner 2010, 37–57. Scheiner, in his *Rosa ursina* (1630), gave the fullest early description of telescopic apparatus (*machina helioscopica*) for observing the Sun, and useful woodcuts of the equipment; Scheiner 1630, 76–77, 104–106, 137–140, 150. The apparatus Gassendi praises is shown in Hevelius 1647, 98–103, figures L & M(?), and, decades later, in Hevelius 1673, figures V & W. The reference to the lynx is also a reference to the very exclusive club of *lincei* (so named for the reason succinctly given in Gassendi's letter), an academy of those with an interest in natural history, medicine, and astronomy, and according to some, the first of the modern scientific societies; Freedberg 2002, & Galluzzi 2017. Neither Hevelius nor Gassendi were actually *lincei*; Gassendi meant it as a compliment to Hevelius.

13 This is curious, because there are three engravings of different phases extant. As only two phases are described in this letter, which agrees with the number stated therein, this is unlikely to be either a printing or editing error.

14 Beyond the three surviving engravings known to Le Monnier in 1746, and to us today, no others have yet been identified. They may not have survived.

15 I have been unable to positively identify the two features to which Gassendi refers, if the passage is to be read literally. They could be any pair of contiguous features near the limb, such as the craters now known as Cardanus and Kraft, or Struve and Eddington, or several others. Alternatively, Gassendi could be employing *deminutio* here, a rhetorical technique to emphasize the accuracy of his observations and oversight combined with Mellan's artistic skill, for only a "a very slight spot…on the left limb" was missed, and that near a "somewhat greater feature which is frequently rendered inconspicuous" by other less careful selenographers!

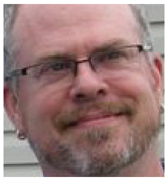
16 This seems ungracious.

17 This engraving does not seem to have survived.

18 Gassendi 1657, 124–125.

Binary Universe

Losing the Night



by Blake Nancarrow, Toronto Centre
(blaken@computer-ease.com)

Upgrading my smartphone has enabled the testing of new and more modern apps that use higher levels of the Android operating system or require a compass.

For a long time, I have wanted to try the *Loss of the Night* (*Verlust der Nacht*) app as I am terribly concerned about light pollution. I am sure you are too. This app allows you to assess progressively fainter stars and report on their visibility for your location.

I downloaded and installed Android version 2.1.7 from the Google Play Store.

https://play.google.com/store/apps/details?id=com.cosalux.welovestars&hl=en

The Loss of the Night (LON) main menu (see Figure 1) shows upon launching the application and you can retrieve it at any time by tapping the "hamburger" icon (Android) or arrow (iOS). From here you can access a variety of commands.

Understanding Light Pollution

The Project Information option helps one learn about the Loss of the Night project and the Globe at Night partner website. The information on light pollution (Figure 2) is quite extraordinary and good for people new to all this. I thought the Tips for Stargazers information particularly well written, reminding observers to be safe, have fun, and get properly dark adapted.

The News menu command (Figure 3) shows a list of article headings. Tapping on an entry takes us to the LON blog site and to the specific article. Of course, you can access their blog site directly. http://lossofthenight.blogspot.com/

A handy, quick tutorial illustrates how to use the app (Figure 4). They explain that you will need to hold your phone at arm's length and follow the arrow to reach the token star. You will be asked if you can see the star or not. Pretty simple—or so it seems.

I was glad to find an extremely detailed set of instructions on the blog site. Without it I would have been surprised using the app. For example, the assessment process requires a minimum of eight stars. They reinforce that the phone must be held perpendicular to "your body" (meaning your head).

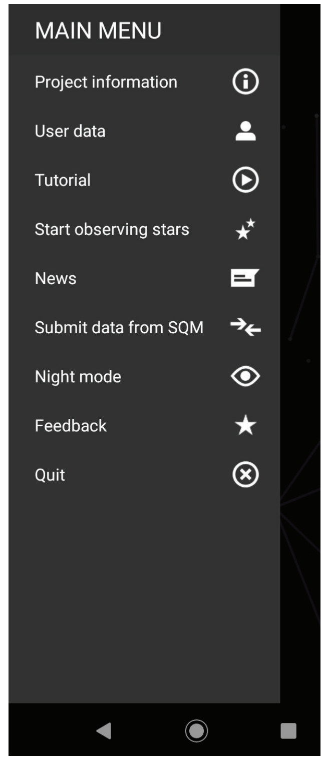


Figure 1 — The main menu in the Loss of the Night app on Android.

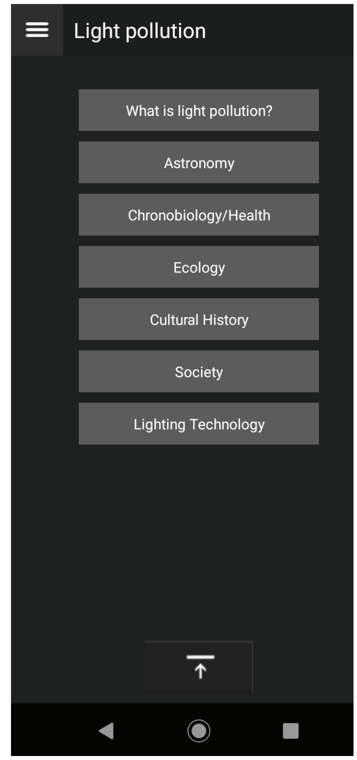


Figure 2 — The light pollution information screens in LON.

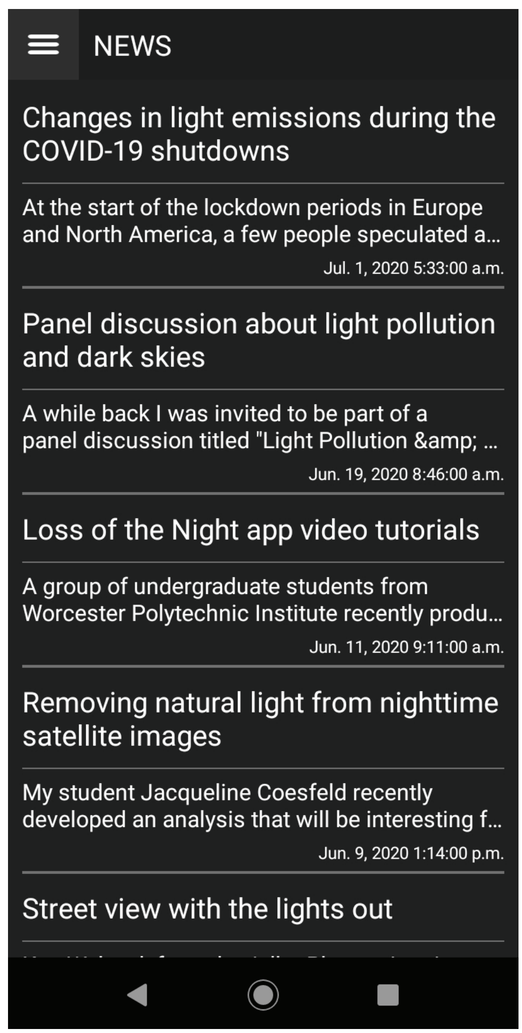


Figure 3 — The News screen with links to full articles on the companion blog.

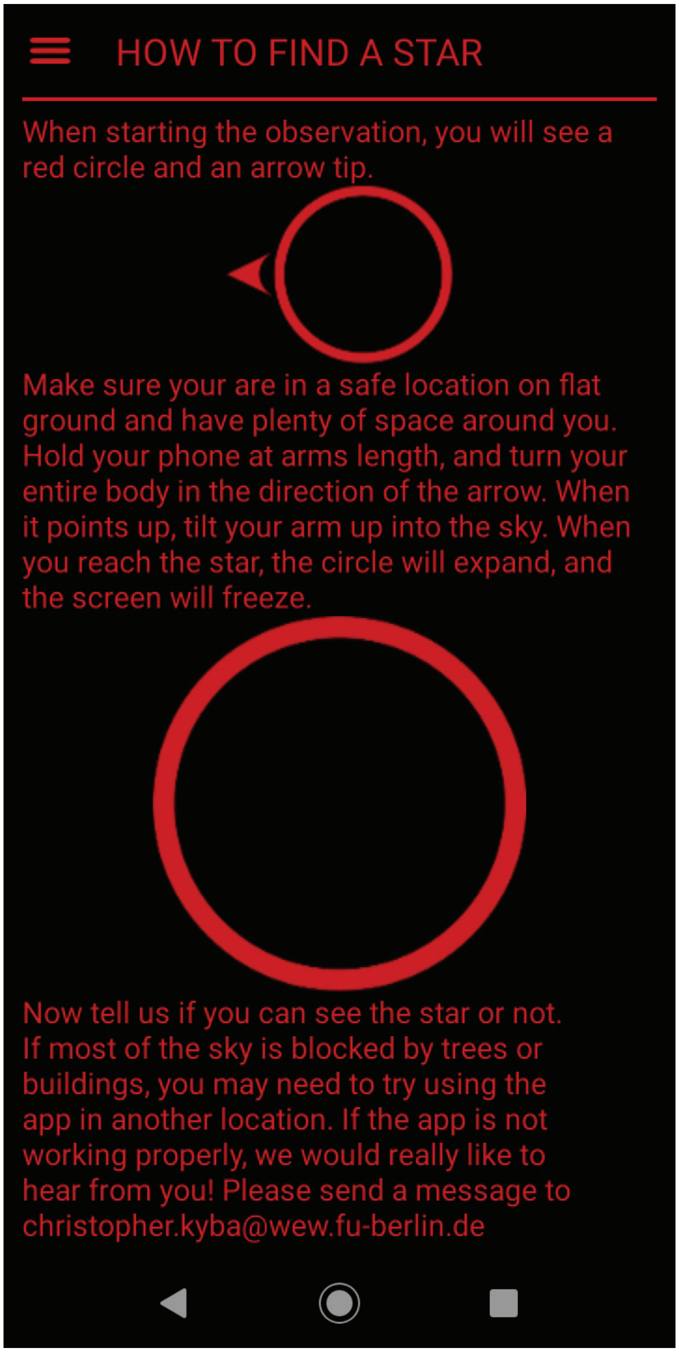


Figure 4 — The integrated quick tutorial on an Android phone in red-light mode.

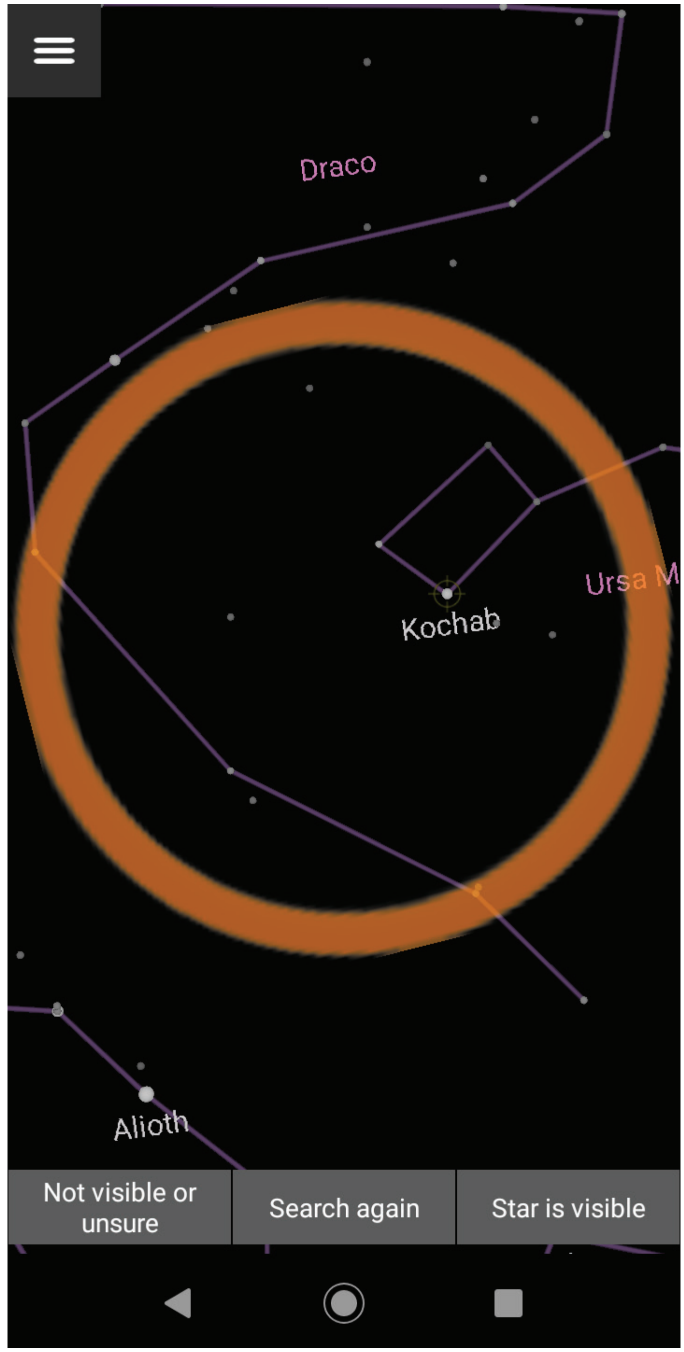


Figure 5 — The target star is in our sights (on an Android phone). Ready to assess Kochab.

Measuring the Night

When you're ready as a citizen scientist to assess your local light pollution, you can switch the app into red Night mode and then choose the Start Observing Stars command.

A smart feature is the time monitor. I tried to take a measurement in daytime, and it discouraged me. I like how it tells me when I should next take a reading considering the Moon's phase.

First, you'll need to indicate your weather conditions. It is curious they don't ask the qualified astronomer for an assessment of seeing or transparency. I guess that's implied via the weather. Perhaps the back-end database does not accommodate for this data.

Then you'll begin the observation proper, indicating the visibility of the first of 8 stars. A small purple circle (Android) means you're off-target. When you reach your target (Figure 5), the panning starfield will freeze, the indicator circle will grow to full size, and your specific target star will be shown via a very small crosshair.

Once you indicate that you can see the star, the app asks if it is clearly visible, barely visible, or requires averted vision.

Rinse and repeat. After logging eight stars, which only takes a couple of minutes, you have the option of adding more (up to 20, I believe) for greater accuracy.

They recognise that some backyard scientists might have a Unihedron device. Choosing the menu command to Submit Data from SQM allows you to record the value captured by your Sky Quality Meter. I did not see a prompt for the serial number of the SQM device. Globe at Night requests that datum.

Sharing Your Assessment

When you declare the observation complete, you may submit the results. If you are remote and have a data plan, the observation will go to the cloud immediately. If you don't have a signal or have disabled your mobile data feed, the results will be transferred the next time you have a wireless connection. This is a key feature for me. I believe this app offers good utility in allowing you to work remotely without WiFi or mobile data active.

Your data can be posted anonymously on the LON and Globe at Night websites. LON asks you indicate the age of the observer, their visual acuity, and observational experience. This data is likely used in a weighting system with assessments submitted from experienced observers given more credibility.

If you want to provide details about yourself, you can update the User Information screen (Figure 6). And you can provide

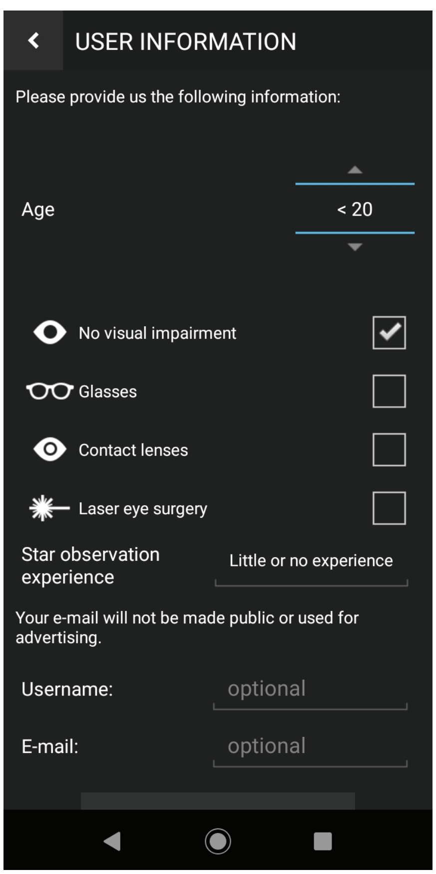


Figure 6 — Details about the user may be supplied with sky observations.

a username and email address, but this is optional. We are assured that this data is not for public use and will not be used in advertising.

You can view data collected by participants via the My Sky at Night website.

www.myskyatnight.com/

Intriguingly, you can control the sources used in the website, whether from LON (Loss of the Night app, Android or iOS), SQM (taken with Unihedron), DSM (Dark Sky Meter, iOS only), and GAN (Globe at Night). You may recall I reviewed Dark Sky Meter for iPhone about a year ago.

Specifications

To use *Loss of the Night*, you must have a phone with a compass and GPS capabilities. The Android version requires at least Android 2.1, but 4 or higher is recommended. Airplane mode must not be active. The Apple version requires iOS 7.0 or later. It works on iPhones and iPads with WiFi and cellular. Your phone case must not have a magnetic clasp.

The LON team encourages users to give feedback on the app. Developer Christopher Kyba shares his email address inside the app. There's a Feedback selection in the main menu. The Android user community seems pleased and this is reflected in the rating 4.1 out of 5 after over 760 reviews. The Apple App Store shows a rating of 4.4 based on eight reviews. The program has not been updated since December 2016. An emailed query went unanswered.

LON is sponsored and financially supported, keeping it free for the user. The app is available in 15 languages.

I was pleased to finally use the app Loss of the Night on my Android device. I particularly like that I can postpone uploading observations until convenient. And I think it quite useful that I can submit results to the Globe at Night initiative.

Try out Loss of the Night, make lots of observations, and together we can fight the loss of our dark skies.

Bits and Bytes

The ISS Detector app for Android (reviewed April 2016) now lists *Starlink* satellites. ✶

Blake's interest in astronomy waxed and waned for a number of years but joining the RASC in 2007 changed all that. He helps with volunteer coordination in the RASC Toronto Centre and is a member of the national observing committee. In daylight, Blake works in the IT industry.

John Percy's Universe

Young Stellar Objects and their Variability

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

Readers of this column will know that my students and I usually study the variability and properties of red-giant and supergiant stars—the final phases in the lives of stars. But occasionally, we dabble in the other end of the stellar life cycle—variable *young stellar objects* (YSOs).

This topic is a few years younger than I am. In 1945, Alfred H. Joy identified a small number of stars that were distinguished by large, irregular variability, Sun-like spectra but with strong emission lines of hydrogen and calcium, and associated with bright and dark nebulae (and therefore sometimes called *nebular variables*). They were YSOs. He chose T Tauri as the variable star prototype. T Tauri stars were sub-classified spectroscopically as classical (CTTS) and weak-lined (WTTS) according to their emission-line strength. In the last few decades, understanding of YSOs has grown by leaps and bounds, spurred on by new instrumentation and observations, and new models for their nature and behaviour.

For more detail about YSOs and their variability, see the excellent review and update by Herbst (2012, 2018), which are freely available online. Bill Herbst is a Professor of Astronomy at Wesleyan University in Connecticut, and an expert on YSOs; we are fellow Ph.D. graduates from the University of Toronto.

Star Formation

Stars form by the thousands in dense, cold clouds of interstellar gas and dust called *giant molecular clouds*. The clouds are called this as the gas is primarily in the form of molecules such as hydrogen. We may see these clouds visually as dark or bright nebulae, but they are best observed at radio wavelengths. The most famous is the Orion Nebula.

When a small part of the cloud becomes dense and cool enough—perhaps compressed by cloud collisions, or by a nearby star's powerful wind, or a local supernova, or simply by turbulence—it begins to contract under its own gravitation. Whatever small random rotation it had is amplified by the *conservation of angular momentum*, and it spins faster. I call this process the "figure-skater effect," because it's how the figure skater goes into a fast spin at the end of their routine; they pull their arms and legs closer to their axis of rotation. The rotation also causes further accreting material to spin into a disk around the contracting star by what is inaccurately called centrifugal force. In some cases, the contracting star may split into two and form a close binary system.

The gravitational energy released by the infalling matter goes partly into heating the star, and partly into the radiation—visible or infrared—by which we see the star. Eventually, the core of the star becomes hot enough for nuclear fusion of hydrogen to begin. A star is born. This overall process, acting on the whole cloud, results in a cluster of stars with a range of masses called the *initial mass function*—many low-mass stars, and very few massive ones. Star masses range from 0.08 to 150 solar masses.

In the disks around the stars, dust snowballs into larger chunks that aggregate, through their gravity, into planets and their moons, and leftovers such as Kuiper Belt objects. This process takes millions of years. At the centre is the rapidly rotating YSO. Decades ago, this theory of star formation implied that planets around other stars should be common. Now, we know of thousands of these *exoplanets.* See (1) for images of a variety of YSOs and their protoplanetary disks.

The star's rotation also helps to generate a strong magnetic field, as it does on the Sun. The magnetic field produces *starspots* and other types of stellar activity. Accreting gas follows the magnetic field lines, as it impacts the stellar surface. Winds, like the solar wind, can flow outward along these same field lines.

The Variability of YSOs

The photometric variability of YSOs is very diverse, and astronomers love to classify things. On the basis of decades of study, Herbst (2012, 2018) and others have classified variable YSOs as follows:

> Type I. Rotating variables with starspots, like sunspots, which modulate the brightness of the star as it rotates. The period is the rotation period, which is a few days, and is highly stable. The amplitude is small—a few percent—and often cyclically variable over a long timescale, like the sunspot cycle. By observing the rotational variability of hundreds of Sun-like stars, astronomers have confirmed that young stars rotate rapidly, but slow down with age (as we all do) as the stars' magnetic fields and winds couple to the surroundings, acting as a brakes. The Sun, a middle-aged star, rotates relatively slowly. The level of stellar "activity," including starspots, also declines with age.

The December *Journal* deadline for submissions is 2020 October 1.

See the published schedule at www.rasc.ca/sites/default/files/jrascschedule2020.pdf

Type II. Irregular variables with "hot spots" caused by energy release from the variable accretion of matter onto the star. The time scales can be days to months. This is the classical T Tauri star behaviour. The amplitude of variability can be two magnitudes or more.

Type III. Also known as UXors (after UX Ori) or "dippers." These are variable due to variable obscuration by the accretion disk. The variability may be periodic if there is an orbiting clump of gas and dust in the disk.

FU Orionis variables, or FUors. These brighten by several magnitudes for several months or years due to enhanced accretion onto the star, then slowly decline. FU Ori was once thought to be a unique object, but time has shown otherwise.

EX Lupi variables, or EXors. These show small-scale eruptions and are not well understood.

KH 15D (582 Mon) stars: Large-amplitude, strictly periodic variables; apparently stars in which one star is periodically obscured by material in a warped, precessing circumbinary disk (remember that, in some cases, star formation results in the formation of a close binary system). A special kind of Type III variable.

Visual Observation of YSO Variability

Percy and Palaniappan (2006) recount the story of one aspect of AAVSO (American Association of Variable Star Observers) visual observation of YSOs. YSOs tend to be concentrated in star-forming regions such as the Orion Nebula. They are therefore relatively easy to observe and measure in large numbers—like "shooting fish in a barrel," as they say. And the AAVSO provides awards to observers who make the highest number of observations each year! Certain Canadian observers—who shall remain nameless—thus garnered these awards in the late 1970s by making thousands of visual observations of YSOs each year. Alarmed, AAVSO Director Janet Mattei decided to discount observations of YSOs by a factor of ten. She was also concerned about the quality of the observations, including the possibility that they were negatively affected by the nebulosity around the stars. It was not clear that they had any scientific value. They unfortunately languished, unvalidated (quality-controlled) and unavailable and unused.

By the mid-2000s, I was able to convince AAVSO staff to validate some of the visual observations, and to make them available to me and my students—including Rohan Palaniappan, one of dozens of outstanding senior high school students that I supervised through the University of Toronto's prestigious Mentorship Program. Percy and Palaniappan (2006) were able to use these visual observations and time-series analysis to study 11 YSOs. We could detect periods of rotational variability in some of them, with

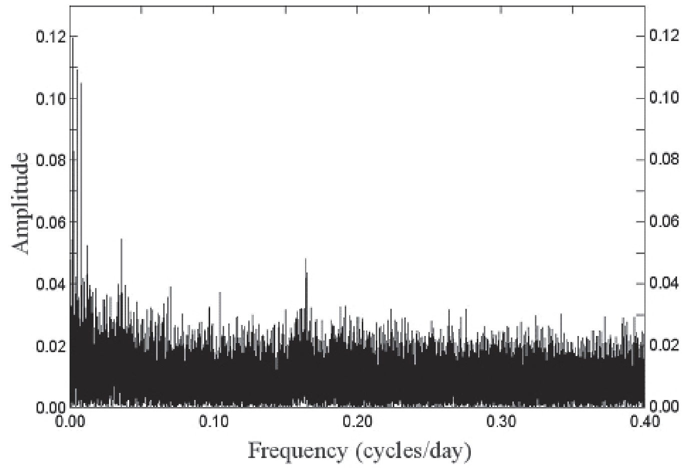


Figure 1 — The Fourier spectrum of AAVSO visual measurements of the T Tauri star S CrA. The Fourier spectrum measures the amount of variability as a function of frequency or period. In this star, there is a peak at a frequency of 0.16 cycle/day, or a period of 6.0 days—the rotation period of the star. The amplitude is only 0.04 magnitude. The variability is caused by the rotation of a star with one or more spots. Source: Percy and Palaniappan (2006).

amplitudes as small as a few hundredths of a magnitude! For all of them, we could create a "variability profile"—the relation between amount of variability and the time scale. Figure 1 shows the Fourier spectrum of the YSO S CrA, with a 6.0-day period of rotational variability, and an amplitude of only 0.04 magnitude. This was determined from visual observations having a precision of only 0.2 magnitude, through the power of numbers (of observations) and the "magic" of time-series analysis!

New Data Available for Analysis

In the last decade, the AAVSO has launched a very active YSO observing section. The Section Leader, and driving force, is Michael Poxon, a skilled and passionate amateur astronomer in the UK. The section Scientific Advisor is Bill Herbst. The YSO website (2) includes a comprehensive list of stars to be observed, lots of information about YSOs, and a link to a free monthly newsletter. Thanks to this initiative, there are large numbers of CCD observations of YSOs that you can access through the AAVSO International Database (3), or through the VSTAR time-series analysis package (4), which you can use to analyze the data.

Another source of data is the All-Sky Automated Survey for Supernovae (ASAS-SN, Percy 2020). The ASAS-SN variable-star catalogue of over 500,000 variable stars includes thousands of stars that the catalogue classifies as YSOs. My initial experience is that these data are not well-suited for studying the small rotational variability but are definitely suitable for studying the larger-amplitude Type II and Type III variables. I'm particularly intrigued by the number of stars with largish amplitudes, periods too long to be rotation periods, and a relatively high degree of regularity. There must be dozens of such variables in the ASAS-SN database, waiting to be studied.

So, there is much that you can do as an observer or analyzer. Herbst (2018) suggests three useful observational projects: (i) multi-colour CCD observations of Type III variables; (ii) visual or preferably CCD observation of known T Tauri variables, to see if any have changed their properties or variability; and (iii) in particular, watching for the rare FU Ori-type behaviour in YSOs. ✶

Endnotes

1 www.almaobservatory.org/wp-contentuploads/2018/12/20181212-Andrews-et-al-All-disks.jpg

2 www.aavso.org/aavso-young-stellar-objects-section

3 www.aavso.org/main-data

4 www.aavso.org/vstar

References

Herbst, W. (2012). The variability of young stellar objects, *Journal of the American Association of Variable Star Observers, 40,* 448.

Herbst, W. (2018). The variability of young stellar objects: an update, *Journal of the American Association of Variable Star Observers, 46,* 83.

Percy, J.R. and Palaniappan, R. (2006). Analysis of AAVSO visual measurements of T Tauri variable stars, *Journal of the American Association of Variable Star Observers, 35*, 290.

Percy, J.R. (2020). Assassin: the survey, *JRASC, 114,* 89.

John Percy FRASC is Professor Emeritus, Astronomy & Astrophysics and Science Education, University of Toronto, and a former President (1978–1980) and Honorary President (2013–2018) of the RASC.

Dish on the Cosmos

Neutron Star Sleuthing

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

In 1987, astronomers observing the Large Magellanic Cloud (LMC) noticed the sudden appearance of a new bright source, which was quickly identified as a supernova explosion called SN 1987A. The supernova explosion is the only such supernova explosion that has occurred near the Earth in the modern astronomical era. Even though it was in a satellite galaxy, it remains the nearest and best-observed object showing us a supernova explosion in progress. It has been 33 years since the light from the explosion arrived at the Earth, and in that time, astronomers have watched the young supernova remnant evolve with the corpse of the now-dead star hurtling outward from the site of the explosion. Analyzing the data from this event has been essential for establishing the detailed understanding of how stars die, but there has long been a missing piece in our model. The supernova explosion should have left behind a neutron star, an exotic stellar remnant that is formed in the supernova explosion. The neutron star has proven to be elusive, with no evidence for its existence. Recent observations of this site with the Atacama Large Millimetre/submillimetre Array (ALMA) now suggest that the neutron star is buried under a shroud of dust and is only visible through a telltale heating of the dust in one small part of the nebula. Paired with advanced modelling of how young neutron stars cool off, the final pieces of the puzzle seem to be coming together.

Supernova explosions are the last stage in the lives of high-mass stars. Stars with initial masses between 8 and 25 solar masses end their lives in supernovae. These explosions happen when a star runs out of the fuel required for the relatively ordinary process of nuclear fusion. Without the energy output from fusion, the star can no longer provide the thermal pressure required to keep the star supported against the force of gravity and it starts to collapse. For stars in this mass range, a key change happens in the stellar core: the increasing density of the core presses the protons and electrons together close enough that they form into neutrons. Neutrons under these nuclear conditions are extremely resistant to collapse and provide a source of pressure support that can halt the collapse of the star. The infalling material from the outer layers bounces off the proto-neutron star now found in the centre of the star.

Combining protons and electrons into neutrons in the formation of the proto-neutron star also creates a burst of neutrinos as a consequence of the laws of nuclear physics reactions. These neutrinos are very-low-mass particles that move near the speed of light. While neutrinos ordinarily pass through regular matter with ease, in the collapsing core, the density of the material is so high that the burst of neutrinos pushes out on the stellar envelope, driving a supernova explosion.

Observations of SN 1987A have played a central role in framing the description spelled out above. The light of the explosion was one of the first signs that the explosion was occurring. Soon after the light from the explosion arrived, particle detectors on Earth also detected a burst of neutrinos, implying the formation of a neutron star as part of the supernova. Later observations by several different observatories revealed an expanding cloud of gas consisting of the outer layers of the now-dead star plus gas that was near the star before it exploded.

Figure 1 shows the current images of SN 1987A from several different telescopes. The main image is a combination of data from three different observatories, each of which shows something different. The dust emission from ALMA reveals the gas ejecta from the explosion. The ring in the optical emission shows where the rapidly expanding shock wave has collided with surrounding gas, lighting up small clouds of gas. The X-ray emission shows the outer extent of the shock wave.

There is one thing conspicuously absent from the observations: any sign of the neutron star that formed at the start of the supernova. A neutron star should be extremely hot, with a surface temperature greater than 1,000,000 K. Such a hot object should emit X-rays that we can see with our satellite observatories. We see such a hot neutron star in the Cassiopeia supernova remnant, which evolved from the explosion of a nearby star over 300 years ago, but there is no sign of X-ray emission from the neutron star that should have been created in SN 1987A (see Figure 1, bottom right where there is no bright emission at the centre of the shell).

There are a few possibilities why we see no X-ray emission. If some gas fell back onto the neutron star during the supernova, it may have increased the mass of the neutron star past the point of support and it would then collapse into a black hole. Some theories predict that the neutron star can actually destroy itself, leaving behind no remnant at all. Finally, the neutron star could remain hidden behind a veil of material from the explosion. The neutron star should be hard to distinguish in the early days after the explosion since all the material is hot and also emitting X-rays. However, as the expanding material cools, the neutron star's emission should become visible relative to the other gas.

Even so, new observations with ALMA are driving an emerging consensus that the neutron star is indeed there but hidden behind a wall of dust. This possibility has gained traction since it has become clear that dust grains can form relatively quickly after a supernova explosion. New ALMA observations of SN 1987A show significant emission from dust grains toward the site of the explosion, showing that the dust has condensed in just the 30 years since the explosion. There is also significant emission from molecules. The presence of molecules and dust mean, that the exploding material has been able to cool efficiently, since both are excellent refrigerants. As the material has cooled, there is a small region that appears hotter than the surrounding material and has a reduced fraction of molecules (in Figure 1, bottom left, this is the small bright spot near the centre). This tiny hotspot has only become visible through high-resolution observations of the dust at the centre of the SN1987A region. The difference in temperature is relatively modest, but new calculations show that the extra heating associated with this small feature is exactly consistent with a new cooling neutron star. While the evidence is only circumstantial, the pieces of the puzzle finally look like they are fitting together.

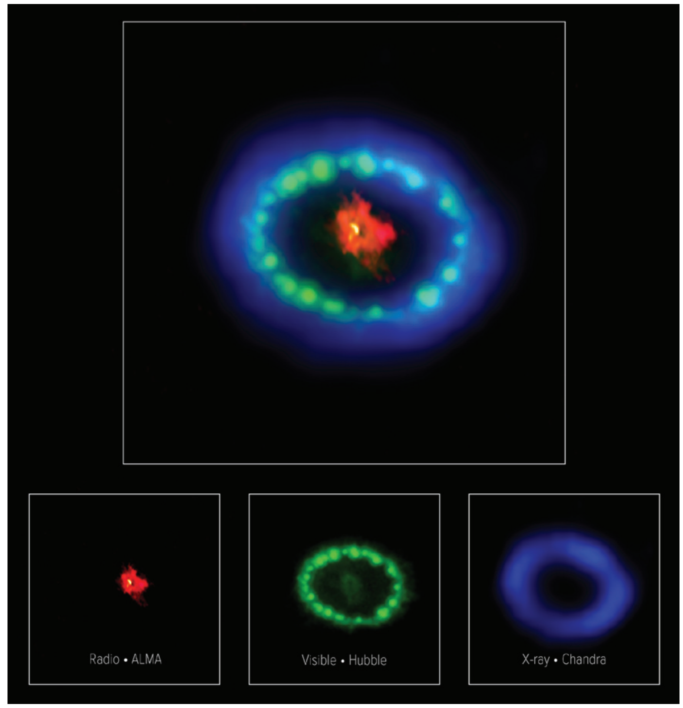


Figure 1 — Multi-wavelength observations of SN1987A. The image at the top combines data from three observatories, which are shown individually at the bottom. The ALMA data (bottom left) shows the dust and gas associated with the exploding star. The Hubble Space Telescope *data (bottom middle) shows the effects of the shock wave hitting the surrounding gas, causing it to emit light. The* Chandra Observatory *X-ray image (bottom right) shows the shock wave itself. There is no emission from a neutron star seen in the centre of the X-ray emission, raising questions as to whether a young neutron star actually exists in this remnant.*

The most exciting thing about these observations is that the remnant of SN1987A is evolving relatively quickly. Most astronomical phenomena take megayears to play out. Here, a few years' time will yield new insights through continued observations of a supernova explosion and a neutron star in its childhood. These new observations will reveal how neutron stars cool down over time, which is a unique opportunity to probe the exotic neutronium material from which they are made. ✶

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.

Celestial Review

Draconids, Orionids, Leonids, and Mars

by David Garner, Kitchener-Waterloo Centre
(jusloe1@wightman.ca)

October and November are going to be busy months, astronomically speaking, that is. The Draconids peak in the early morning of October 8 with a waning gibbous Moon. Radiating from the constellation Draco, the parent body is the periodic comet 21P/Giacobini-Zinner, first observed by Michael Giacobini in 1900.

The Orionids are the second meteor shower of October, which is expected to begin on October 21, this time with a waxing crescent Moon. The Orionids meteor shower, whose parent is the well-known Halley's Comet, is usually a good show that can last several days with rates of 50 to 70 sightings per hour.

You will have to wait until November 17 to see the Leonids. The Moon will be a thin waxing crescent just two days after a new Moon. The Leonids, whose parent is 55P/ Tempel-Tuttle, have been well recorded in history as far back as ancient times. Since the Leonids are known to produce bright meteors, and have occasionally produced several thousand per hour, it should be worth staying up late for this show.

This year Mars reaches opposition on October 13 in the constellation Pisces with a waning crescent Moon, and only 0.42 AU from Earth. Its disk will have a diameter of 22.3″ and should be very bright, with an estimated magnitude of –2.6. Have a look at Figure 1, then on the evening of October 13 set your sights for RA 1 h 23 min and Dec +5° 30′. You will not see Mars at opposition again until December 2022.

Just another detail, in the *Observer's Handbook* section The Sky Month by Month for the month of September, it states that Mars is "stationary" beginning the September 9. In other sources (Jean Meeus) this is sometimes stated as Station 1. Station 1 refers to a planet that appears to stop and possibly move westward (retrograde) among the stars. As we all know, the Sun, Moon, and planets all move eastward (prograde). This retrograde motion of Mars is just an illusion due to the relative position of Earth and Mars.

Later, for November 15, the *Observer's Handbook* states that Mars is "stationary" once more. Again, in other sources, this is sometimes referred to as Station 2, which occurs when the planet appears to resume its eastward (prograde) motion. Mars is not the only planet that does this; other planets also appear stationary, but it is quite noticeable with Mars.

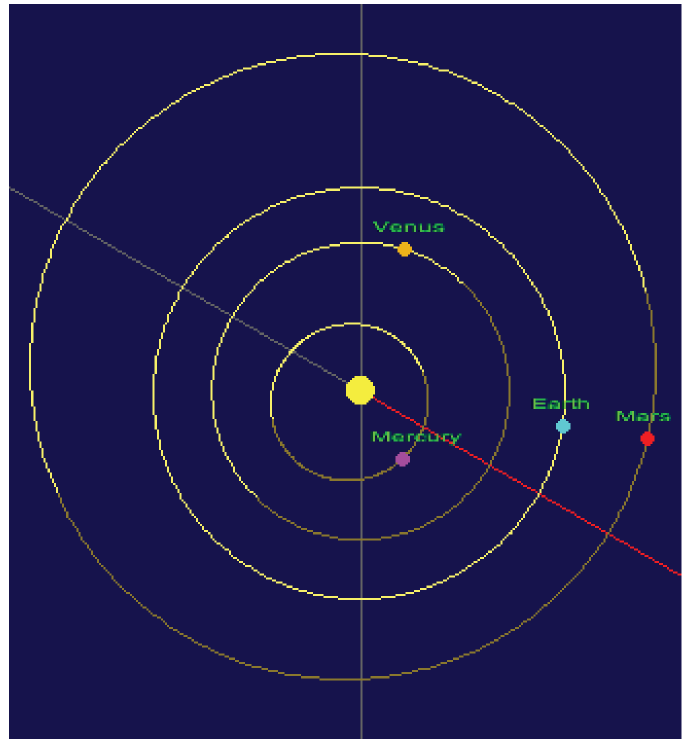


Figure 1 — October 13, Mars lies opposite the Sun in the sky. The Sun, Earth, and Mars are lined up with the Earth in the middle, between the Sun and Mars.

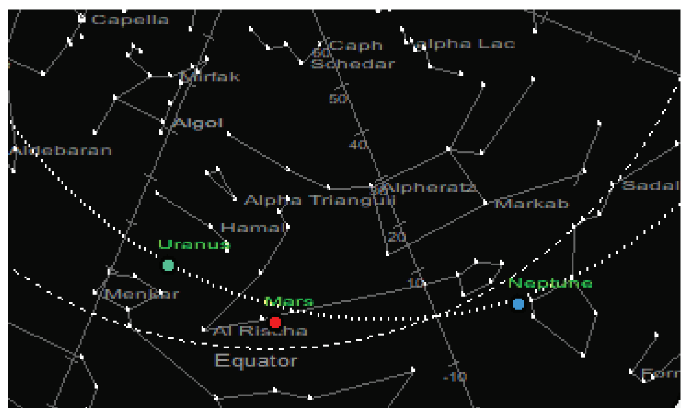


Figure 2 — Mars is "stationary" in the constellation Pisces throughout most of September, October, and November.

As a result of this "stationary" motion, Mars will appear to remain in the constellation of Pisces (see Figure 2), staying close along the ecliptic during this time. Depending on clear skies, of course, you should be able to witness "stationary" Mars throughout the evenings of September, October, and November. ✶

Dave Garner is a retired teacher who now enjoys observing both deep-sky and Solar System objects, especially trying to understand their inner workings.

Imager's Corner

Equipment Review—Optolong L-eNhance Filter Review

by Blair Macdonald
(b.macdonald@ns.sympatico.ca)

I recently purchased an Optolong L-eNhance Filter to do some narrower band imaging over the summer and some urban work under city lights as an experiment. My intention was to add a little narrow band detail to some of my RGB imaging and to test it as a possible light pollution filter for urban imaging. In the interests of full disclosure, I am definitely biased when it comes to light pollution filters. Generally speaking I'm not a fan of these filters for urban imaging. I have found that using proper masked processing you can get results as good as using a filter and I've always hated the colour casts caused by many of the products on the market. I'm happy to report that the L-eNhance solves one of those two problems, producing a very pleasing colour in emission nebulae.

The L-eNhance comes nicely packaged as either a 2 inch or 1.25-inch screw in filter with a standard 44 mm thread pitch to fit most filter wheels.

Figure 1 — L-eNhance filter as shipped

In my testing I simply screwed the filter in the filter cavity of the field flattener for my Esprit 120. The filter provides enough clear aperture to provide an unvignetted field for an APS-C DSLR, and my test images were evenly illuminated to the corners of my Canon 60Da. The filter covers the $H\alpha$, $H\beta$, and OIII bands, with the $H\alpha$ passband being 10 ηm and 24 ηm for the $H\beta$ and OIII bands as shown below.

For my testing I chose the Crescent Nebula, NGC6888, because I had an unfiltered shot taken under almost the same conditions from last year. My test site was my urban driveway, which has lots of light pollution, with my skies usually straddling the border between Bortle 6 and 7.

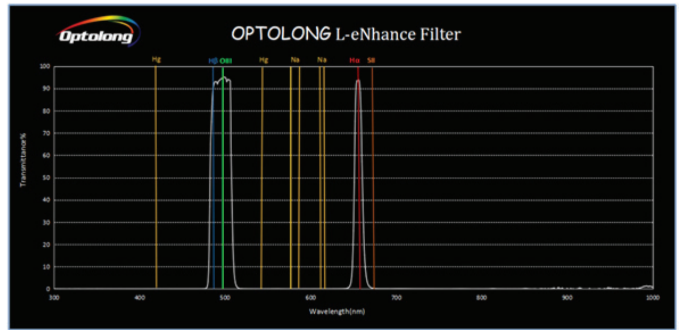


Figure 2 — L-eNhance bandpass characteristics

Figure 3 — My driveway is on the far right in this image, taken at 11 p.m. in mid-September on a cloudy night with no Moon in the sky. The red at the horizon is a function of the enhanced red sensitivity of my 60Da.

Figure 3 shows the level of light pollution I have to deal with for my urban imaging. After a quick two-minute test exposure to determine the correct sub-exposure time, I settled on five minutes, placing the peak of the camera histogram about 1/8th of the way up from the left side ensuring that the data was out of the camera noise floor. I had intended to shoot for an hour as that was the total exposure of my reference unfiltered image, but the clouds rolled in cutting my exposure short at 25 minutes, so I had to add in some data taken a night or two later. The next step was to create images from the filtered and unfiltered data with the same stretch applied. For this I used the arcsinh stretch function in Images Plus. Now I would never stretch the unfiltered view this way in processing, but since I want to measure background noise, my usual approach of starless masked stretches would render the two images incomparable.

Using levels to line up the sky background and neutralizing the background colour of both data sets, we get the following two images.

One of the first things you notice is that the filter has suppressed the stars substantially. This makes the image much easier to process and saves needing to use masks during the initial stretches. Measuring the signal-to-noise ratio (SNR) of the background in each version before stretching was applied we get the following data.

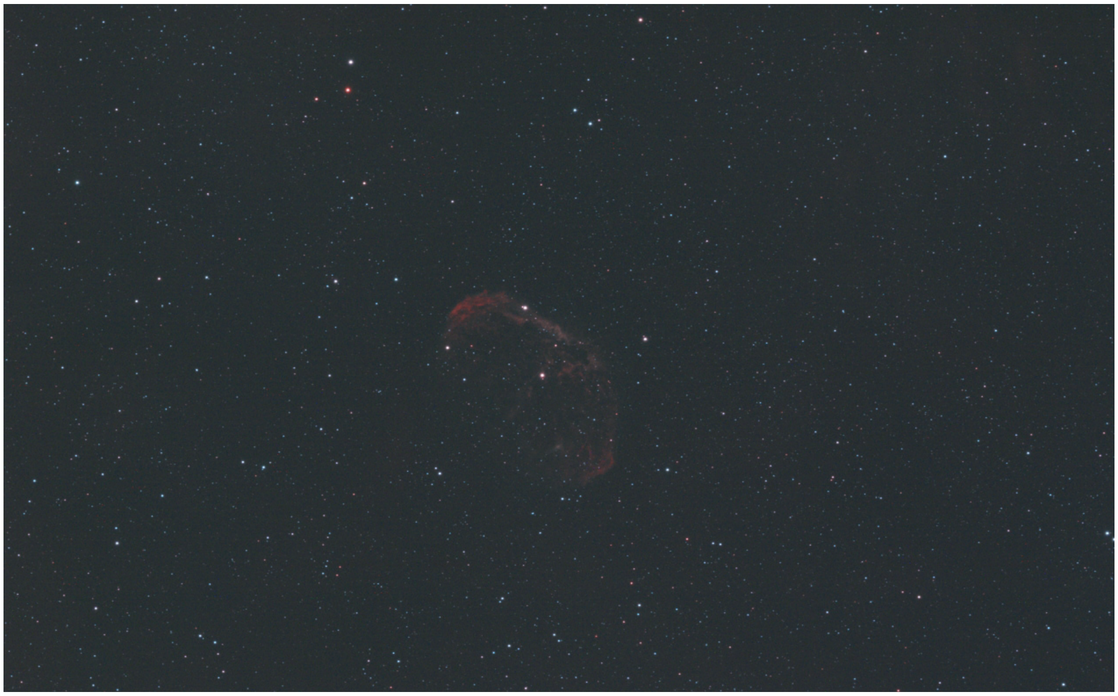


Figure 4 — Simple arcsinh stretch applied to the filtered version

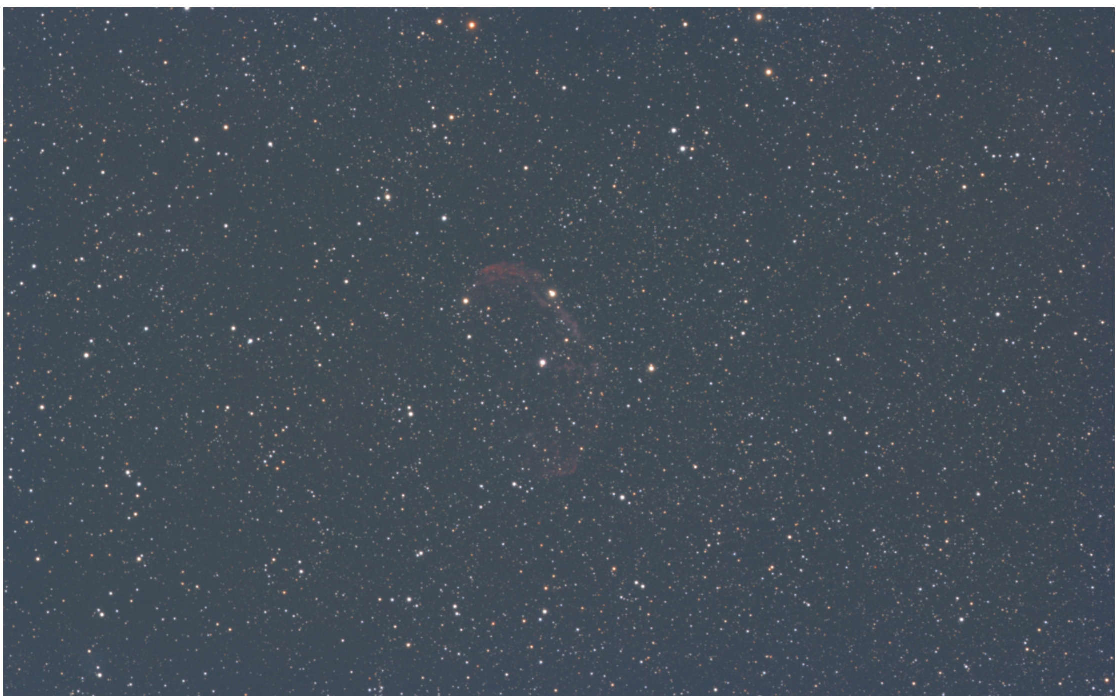


Figure 5 — Simple arcsinh stretch applied to the unfiltered version

Unfiltered Background SNR	20	26.0 dB
Filtered Background SNR	70	36.9 dB

The filtered version shows an improved SNR in the background. Remember that increasing the sky brightness adds photon noise to the target object, but this is more difficult to measure as the brightness of the target varies across its surface, making standard deviation measurements problematic.

After finishing the processing of both images, there really isn't a great difference between the two data sets, which is what I usually find when comparing filtered to unfiltered data. Light-pollution filters are not going to make it possible to get an image you could not get without the filter, despite what manufacturers claim. And proper processing can virtually eliminate the effects of light pollution.

Now I know that some will be saying that my skies are not bright enough to show the difference and I can assure you that this is not the case. My skies typically are a low Bortle 7 and definitely buried in a red zone. Sky brightness varies between 17 and 18 mag/arcsecond^2 and the Milky Way is not visible even overhead in the summer.

But in this case the final image only tells half the story. The filtered data was much easier to process as it starts off with the stars suppressed and it is easier to keep the detail as you stretch the image. Normally I use starless masks for all my initial stretches. The mask helps to suppress the stars and controls the background so I end up with an image that is very similar to the filtered version. For images taken under light-polluted skies, these masks are tedious to make and usually require several iterations to make the nebula stand out well from the background. With the L-eNhance filter, the mask was not necessary, and the nebula was much easier to pull

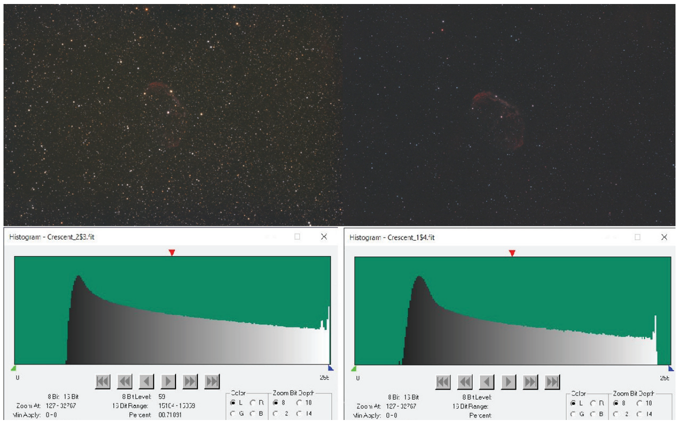


Figure 6 — Filtered and unfiltered images after stretching and background neutralization, filtered is on the right.

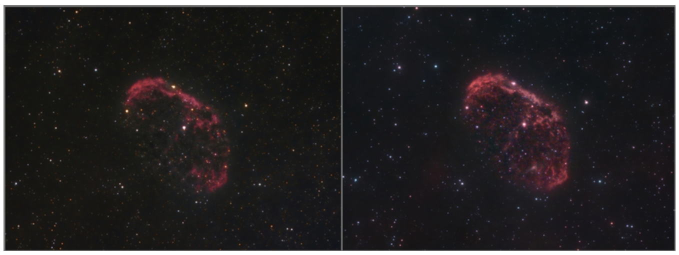


Figure 7 — Filtered and unfiltered, processed images, filtered on the right.

out of the background crud. The colour balance was much better than I'm used to when using light pollution filters and although I wouldn't say that the star colour was perfect, there were lots of reds and blues in the stars and the image remained well balanced throughout.

Zooming in on the filtered version to reveal some detail in the nebula shows that the L eNhance filter did a great job at pulling the Hα component out of the sky background and I really like the more natural colour balance provided by passing everything between the Hβ and OIII bands.

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

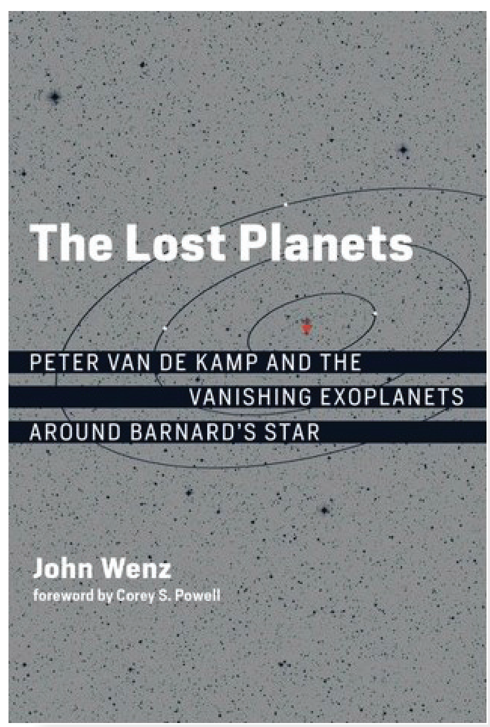
Blair MacDonald is an electrical technologist running a research group at an Atlantic Canadian company specializing in digital signal processing and electrical design. He's been an RASC member for 20 years, and has been interested in astrophotography and image processing for about 15 years.

Reviews / Critiques

The Lost Planets: Peter van de Kamp and the Vanishing Exoplanets around Barnard's Star, by John Wenz, pages 171 + xxvi; 14 cm × 21 cm, The MIT Press, Cambridge, MA, 2019. Price US$24.95 hardcover (ISBN 978-0-262-04286-4).

With the explosive growth that has taken place in recent decades in the discovery of exoplanets, namely planets orbiting other stars, it seems appropriate to review what has happened in the field and recall its tentative beginnings a half century ago. In essence, that is the intent of *Lost Planets* by John Wenz, as outlined by Cory Powell in his lengthy Foreword. As the subtitle suggests, the history of exoplanet detections essentially began with the work of Peter van de Kamp in the 1960s, based upon measurements made from photographic plates in the collection of Sproul Observatory on the campus of Swarthmore College, a Quaker-based institute of learning in the western suburbs of Philadelphia.

By chance, the December 2019 issue of *Physics Today* contains two items that relate directly to the exoplanet story. The first is an article entitled "Half of Nobel Prize in Physics Honors Exoplanet Trailblazers" by Andrew Grant describing the discovery by Didier Queloz and Michel Mayor of France of short-period, low-amplitude, radial-velocity variations in the star 51 Pegasi with their highly stable spectrograph ELODIE, a discovery that led to the identification of the star's companion as an exoplanet. The second is an editorial by Charles Day entitled "The Margins of Reproducibility," which discusses science reproducibility, or more correctly



irreproducibility, as a growing crisis in many fields. Astronomy and astrophysics rank highly in that category, with Peter van de Kamp's published measurements for Barnard's Star being a good example. Later measurements of the star from astrometric plates taken at other observatories failed to detect the periodic displacements recorded by van de Kamp using Sproul plates ("An Unsuccessful Search for a Planetary Companion of Barnard's Star (BD+4°3561)," Gatewood & Eichhorn, *Astronomical Journal, **78**,* 769, 1973; "The Barnard's Star Perturbation," Fredrick & Ianna, *Bulletin of the American Astronomical Society, **17**,* 551, 1985; "A Study of the Astrometric Motion of Barnard's Star," Gatewood, *Astrophysics and Space Science, **223**,* 91, 1995).

I have a personal interest in *Lost Planets* given that my birth sign is Ophiuchus, where Barnard's Star is located, and my M.Sc. supervisor at the University of Western Ontario for 1968–70 was David Gray, who completed his U.S. military service measuring plates at Sproul Observatory, giving rise to two papers on trigonometric parallaxes: "Parallax and Mass Ratio of BD+77°361 from Plates taken with the Sproul 24-Inch Refractor," *Astronomical Journal, **70**,* 304, 1965; "Parallax and Proper Motion of the White Dwarf CC 398 from Plates Taken with the Sproul 24-Inch Refractor," *Astronomical Journal, **70**,* 414, 1965. Gray even refers to systematic trends in the residuals for CC 398 that might suggest the presence of an unseen companion, but notes that the data are not definitive. It was from similar trends in measurements of Sproul plates that Peter van de Kamp detected evidence for planetary companions to Barnard's Star in 1963, as noted in *Lost Planets*. The work was originally an offshoot of separate studies that detected stellar, or possible sub-stellar, companions to stars like 61 Cygni and 60 Ophiuchi.

It is important to realize that long-focal-length refracting telescopes like that at Sproul, Allegheny, Leander McCormick, Van Vleck, and other astrometric observatories were very important in Peter van de Kamp's era for establishing precise proper motions and trigonometric parallaxes for nearby stars, such data being useful for establishing distances to such stars, or even for groups of stars of similar type (statistical parallaxes). His article on "Astrometry with Long-Focus Telescopes" in the reference volume *Astronomical Techniques* of the *Stars and Stellar Systems* series of the 1960s and 1970s was one of several important references for graduate education in that era. Peter van de Kamp even provided an illustrated example in *Astronomical Techniques* of the well-studied astrometric binary 61 Cygni. It was from smaller periodic deviations in their proper motions that Peter van de Kamp measured for other stars, including Barnard's Star, that he suspected the presence of low-mass companions in such systems. The questions raised at the time were exactly how small the masses were—borderline sub-stellar, such as brown dwarfs, or planetary—and were the temporal offsets in the proper motion of the stars caused by the regular gravitational attraction of planets on the system barycentre or by periodic distortions in the telescope optics?

Basically, that is the direction taken by Wenz in *Lost Planets*, where the sub-title *Peter van de Kamp and the Vanishing Exoplanets around Barnard's Star* summarizes the entire story line as Wenz saw it, namely van de Kamp's dubious discovery of a planetary system orbiting Barnard's Star and the subsequent work by astronomers using photographic images of the field obtained with other refracting telescopes demonstrating that the observational evidence for such planetary perturbations was not confirmed. But Wenz also summarizes the other techniques used to detect the presence of planetary companions to stars, namely the very small periodic gravitational shifts in radial velocity of stars like the Sun created by orbital motion of the star about the system barycentre or the miniscule brightness decreases lasting a few hours arising when a companion planet periodically eclipses the parent star. He also identifies all the various programs of exoplanet searches that have developed in the last decade, with all of their acronyms. Sadly, the descriptions of the discovery techniques in *Lost Planets* are rather sloppy and poorly presented, indicating a lack of fundamental knowledge of the subject by the author. The dust jacket identifies Wenz as digital producer at *Knowable Magazine* and a contributor to such periodicals as *Scientific American*, *Discover*, and *New Scientist*. Yet the blunders evident in *Lost Planets* are those commonly made by someone who has not been exposed to the knowledge normally transmitted in an introductory course in astronomy.

If truth be told, there is no justifiable reason why *Lost Planets* was ever published. A much better, more literate, and concise review of the early history of exoplanet searches was published by Gordon Walker in 2012 ("The First High-Precision Radial Velocity Search for Extra-Solar Planets," *New Astronomy Reviews, **56***, 9), as cited by Cory Powell in his Foreward to *Lost Planets*. Sadly, neither Powell nor Wenz seem to have fully read Walker's review, otherwise they would not have referred to Walker's research colleague Bruce Campbell as Walker's *graduate student* in their writing. Bruce was Gordon's *postdoctoral fellow* after completing his postgraduate degrees at the University of Toronto in the late '70s. That rather dulls the one high point I found in *Lost Planets*, namely that the work of Canadian researchers Walker and Campbell (and Stephenson Yang) is actually cited for its novel development of innovative techniques in precision radial-velocity measurement of stars. Normally the efforts of Campbell and Walker are far too frequently overlooked by the later developments of Queloz and Mayor, Geoff Marcy, and others.

Lost Planets discusses those individuals only peripherally. Instead, Wenz focuses his attention on Peter van de Kamp, the Sproul Observatory astrometrist best known for the publicity surrounding his discovery of planets orbiting nearby

Barnard's Star. Although given a lot of press attention at the time, the planets supposedly orbiting Barnard's Star defied all subsequent attempts to confirm their existence by astrometric observations at other observatories, Allegheny in particular. It turns out that the displacements found by van de Kamp in the otherwise smooth proper motion of Barnard's Star across the sky could be attributed to positional offsets in the measurements arising from colour differences in the reference stars used, as in 1941, or to effects attributable to the old aluminum mounting cell for the objective doublet lens prior to 1949, when it was replaced by a less thermal dependent cast-iron cell (van de Kamp, "Astrometric Study of Barnard's Star from Plates Taken with the Sproul 61-cm Refractor," *Astronomical Journal,* ***80****,* 658, 1975). The problem is not explained very clearly by Wenz. In Chapter 7, for example, he describes how "in 1987 the *mirrors* of the telescope had to be recoated because of environmental degradation, showing some of the encroaching creep of Philadelphia's urban pollution." Wenz seems unaware of the fact that refracting telescopes like that at Sproul use doublet lenses, not mirrors, to form images.

The extent of the author's poor knowledge of what he is writing about is evident from countless blunders sprinkled throughout the book, almost one a page. He manages to attribute the work of Vera Rubin to Margaret Burbidge, for example, and denotes radial-velocity Doppler shifts as red and blue spectra [sic] shifts. They are actually a stretching of spectra towards longer wavelengths or a shrinking toward shorter wavelengths, respectively. Stars from the Bonner Durchmusterung Catalogue (Bonn Star Survey) are cited incorrectly, a common flaw that applies to most newspaper writers as well, and word usage is confusing at best—the word "volley" is used instead of "valley" on page 64 in describing the rift between van de Kamp and the wider astronomical community. Yet both terms could have been used, although with somewhat different meanings. The section raises the spectre of friction in 1975 between Sproul colleagues over the issue of funding from the National Science Foundation, one of many meanings for NSF.

The writing itself is also very poor, sprinkled with all of the common grammatical errors committed regularly in today's scientific journals, sadly, plus a few other blunders that I had previously imagined to be too outrageous to commit. Contractions are used far too frequently in *Lost Planets*, which abounds in them, ten or more per page in some places. Many pages are also plagued by extremely awkward phraseology, missing words, poor terminology, and improperly cited stars, journals, or attributes, to name but a few. The writing could have and should have been done with greater care. I question if the manuscript was ever subject to copyediting, or if M.I.T. Press simply gave up at the enormity of the task.

It takes very little time for the average reader to realize that the author cannot write (I came to that conclusion in the first paragraph of the acknowledgments on p. xix), and has little basic knowledge of the subject matter of which he writes. What is more bothersome is how M.I.T. Press could have promoted the project in the first place, or how the readers identified on the dust jacket could have been so glowing in their praise! M.I.T. Press also seems unable to cite the book's particulars properly; it is listed as having 200 pages, for example. The logic behind the chapter headers is also mystifying; they consist of all-black pages with a tiny series of white dots running diagonally across and a circled number in a sequence running from 1 to 9. No title is given to warn, er, indicate to readers what subject will be mangled next. My impression of the standards of the Press has sunk to an all-time low.

The book is not without some good points. It does describe some of the events surrounding Peter van de Kamp's discovery, such as his 1966 interview with Don Herbert, a.k.a. Mr. Wizard, and Peter's penchant for classical music and Charlie Chaplin movies. Wenz also presents a variety of historical information about other observers at Sproul: Sarah Lee Lippincott, Wulff Heintz, and John Hershey. There is also a brief description of Sarah Lee's late-in-life marriage to Dave Garroway, former anchor of the Today show when I was a kid, and its sad ending with Dave's suicide. The subsequent events at Sproul related to Heintz and Hershey are also noted briefly, with Heintz's death from lung cancer being the inevitable result of a lifetime of cigarette smoking, and Hershey's career after Sproul being left as a bit mysterious. *Lost Planets* also goes into some detail about Bruce Campbell's troubles in trying to secure long-term funding for his postdoctoral research with Gordon Walker, and its distressing ending with his decision to leave astronomy research for a career in computing. It was a common problem for young astronomy postdocs of that era, as I well know.

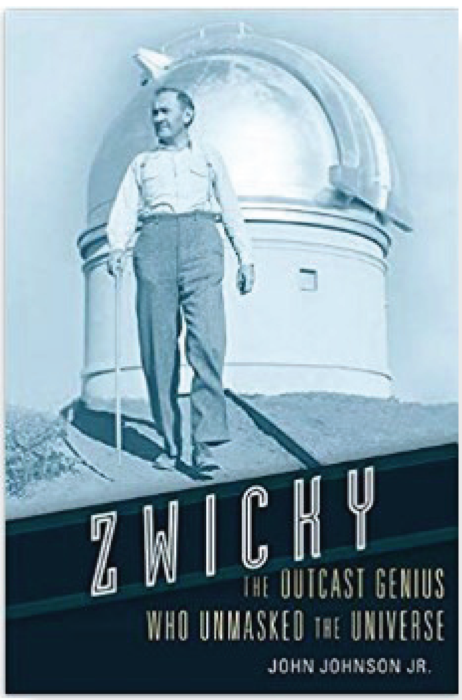
If you wish to read a good introduction to the history of exoplanet discoveries, *Lost Planets* is not a good choice. I was employed in astronomy during the entire era described in *Lost Planets*, and have made observations (photometry, spectroscopy) and reduced data (eclipse photometry and radial-velocity measurements) directly related to much of what is described, and I still found myself confused by what Wenz had written. In marked contrast, Gordon Walker's conference paper cited above is an excellent summary of the early years of the field, indicating the dangers inherent in trying to discern signals in old photographic plates relative to sizeable uncertainties in measurement, and that paper is available online.

Although Peter van de Kamp was aware of the difficulties and otherwise took special care in his work, it was only in his later years that he realized the problems inherent to the measurement of older plates in the Sproul series, the same ones that led him to deduce the existence of a periodic displacement in the position of Barnard's Star unrelated to its dominant proper motion. There is no need to have an entire book devoted to the details of that history, however interesting they may be. A different focus and a *very* heavy hand on copy editing might turn *Lost Planets* into something of interest to historians.

– David Turner

David Turner is a retired astronomer at Saint Mary's University in Halifax, former editor of the Journal *of The Royal Astronomical Society of Canada (JRASC), a member of several scientific editorial boards, and an avid observer of variable stars and open clusters that can be used as calibrators for the extragalactic distance scale.*

Zwicky: The Outcast Genius Who Unmasked the Universe, by John Johnson, Jr, pages 352 + viii; 16 cm × 24 cm, Harvard University Press, Cambridge, MA, 2019. Price US$35 hardcover (ISBN 978-0-674-97967-3).



When we glance back at the diorama of 20th century astrophysics, Fritz Zwicky's (1898-1974) figure stands out. He could be the type specimen for the quality of *sui generis* ("an entity unlike any other"). Colourful, capable, difficult, innovative, mercurial, presciently right, and irascibly wrong could all be used to describe aspects of his personality. According to friends and enemies alike, he was not a figure to whom one could be indifferent.

Allan Sandage, Hubble's heir, found himself counted among the "spherical bastards." In the year of Zwicky's death, he remarked[1] that:

> He did not have the self-discipline himself to plug all the holes. It's terribly easy to talk and terribly difficult to get something right, and I think he just would not work hard enough to plug all of the different routes that he'd opened up…Now he said almost everything about everything, so some of the things had to be correct…I think if you were to put Tycho on a modern stage, he would be like Zwicky in his demeanor and his feeling toward other people. Actually[,] there was a very successful man [i.e. Tycho]. Now maybe Zwicky was successful also…

Another giant of the time, Cecilia Payne-Gaposchkin, memorialized Zwicky in the chief periodical directed to North American amateurs[2]:

> Fritz Zwicky was one of the last of the scientific individualists, a breed that is dying out in an age of team work. Aggressively original, outspoken to the point of abrasion, he seemed to his contemporaries stubbornly opinionated. His ideas were so fertile and his projects so vast that he could have employed all the facilities of a great observatory. Looking back on his rugged determination and his slightly Renaissance flavor, one is reminded of Tycho Brahe: brilliant, opinionated, combative, a superb observer, and a very human person. For Zwicky was one of the kindest of men, with a deep concern for humanity.... The man who gave us so much of what is known about supernovae, galaxies, and clusters of galaxies has placed the world in his debt. Astronomy will never be the same again, and these permanent legacies will be remembered when the superseded theories and battles for priority are long forgotten.

And, nearly two decades after his death, his friend Gerard De Vaucouleurs recalled[3] that:

> …[he] knew so many things that he didn't feel he had to spend time[,] you know[,] convincing others, and that led to endless fights with Hubble and Sandage. He was really a great man. Of the astronomers of the 20th century he is perhaps one of the very few, if not the only one, to which the word "genius" can apply. This one was a genius, and he was very impatient with those not quite up to his measure…and he had of course these crazy ideas about building jet propelled subterranean tanks and all sorts of things. Some of his ideas were crazy, but he was really a genius and a great man…Always full of ideas and things. In fact so many he could not really pursue them and develop them and convince everybody.

There is truth in all of these assessments, of course (they could even be combined for a "morphological" gauging of Zwicky à la Zwicky!).

Among his accomplishments were his work theorizing on, discovering, and classifying supernovae, and connecting them to the origin of neutron stars (pursued at first with Walter Baade and afterwards independently), the multi-volume *Catalogue of Galaxies and of Clusters of Galaxies*[4] (also done with collaborators), his pioneering work in "composite" wavelength astrophotography[5], and in proving the potential of the Schmidt camera for survey work, would have ensured sufficient claim on posterity's attention. His speculation on missing matter only acquired cumulative significance in the decades after his death, but it is the informed hunch for which he is now best known[6]. Others of his speculations and *idées fixes* have fared less well, such as his take on red shifts (one of the sources of friction between Zwicky, and Hubble and Sandage).

Among some amateur astronomers—invariably males, and of a certain age—I have encountered a cult following around an imagined construct of Zwicky, conjured of equal parts extreme libertarian, anti-establishment rebel, and shock radio host. The makers of that cardboard cut-out Zwicky have compounded their figure out of Zwicky's fabled facility with coining memorable insults to fit the occasion, and his challenging attitude to any authority that was not his own. Despite its kernel of truth, it omits the Zwicky who belonged to many charitable organizations, and who spent untold time and energy rebuilding decimated scientific libraries in Europe, and on other worthy humanitarian causes.

There already exists a recent biography of Zwicky in English, translated from the German of Stöckli and Müller (2011), and itself based on the much fuller standard biography by Müller (1986)[7]. New, unexploited sources arise from time to time, novel interests reshape the discipline, and canonical theories and material are always subject to reassessment. In short, given Zwicky's achievements, his colourful character, and the inherent interest in his times and acquaintances, no justification for a new biography in English is needed. It is greatly to Johnson's credit that he has undertaken to write such a work.

Johnson has opted for a largely chronological treatment of Zwicky's life, which is a very sensible way to structure a biography. The narrative follows its hero from birth in Bulgaria, and youth there and in Glarus, Switzerland, to his formation at the ETH with a doctoral thesis on crystallography, his arrival at Caltech were he spent nearly the entirety of his career, his turn to astrophysics, his collaborations and then schisms with other researchers, his lasting discoveries, prescient predictions, innovations, and intellectual bizarreries, his rocketing aerospace career, and his not entirely successful attempts to metamorphize at will into a sort of philosopher. (Helge Kragh in a review of this same book considers Zwicky's "morphology," in which he set such stock, as a variant of empiricism[8]. Whatever it is, it strikes me as empirically unworkable. Nevertheless, it has a limited following—just not in astrophysics.)

Johnson's book is not without flaws, some of them quite serious. I most readily noted mishandlings of the materials of the history of astronomy. There are rather a lot of them for a book of this size. A few of them will have to suffice by way of illustration.

At the very start of his book Johnson states that in the late 19th century "In one area, however, the United States remained decidedly provincial: the physical sciences" (p. 1). Unfortunately, the picture he paints seems little informed by the historical record. C.A. Young (eclipse spectroscopy), Henry Rowland (design and production of precision gratings), Samuel Pierpont Langley (invention of the bolometer, and its use in measuring total energy flux), Albert Michelson (aether drift measurements), and even Simon Newcomb (some of his work on determining constants had direct astrophysical applications, such as the speed of light), made notable contributions to astrophysics that were recognized in Europe, and others of their colleagues could be cited as well. The book is not off to an auspicious start.

According to Johnson, "[William] Herschel was a very fine oboist, who counted Mozart and Beethoven among his fans" (p. 57). Would that it were true. Unfortunately, neither Mozart nor Beethoven are recorded as ever having heard Herschel play oboe. It is perhaps indicative of things that Johnson doesn't even attempt to provide a citation for this touch of fiction. Nor does he provide any for his contention that "…his [William Herschel's] ideas about how the universe was arranged were understandably limited, given that the telescopes he built to study the heavens used metal discs of tin and copper for mirrors" (p. 57). It would seem that Johnson has actually had no real experience with Enlightenment era instruments powered by speculum mirrors, or the serious literature about them. A major fact-based evaluation of the optics of Hershel's reflectors by Roger Ceragioli appeared a full year before Johnson's book, in which one can read that "… it is undeniable that many of Herschel's smaller Newtonians gave excellent images, even by modern standards[9]." Johnson's error is even more egregious than blindly repeating a hoary urban myth about the inadequacy of an old technology. He has not considered the context of what came before, and after, Herschel. Herschel's theories on the "construction of the heavens" based on his star counts were a considerable advance on the way to our modern conceptions, and they were achieved through novel survey techniques, steady application, and instruments fully suited to the task[10]. Herschel's "ideas about how the universe was arranged" are only limited if one takes an ahistorical and presentist view. But anyone who does that has no business writing a biography of an astrophysicist of any century.

A propensity for fiction also seems to have crept into Johnson's account of the "Great Debate." His chief reference appears to be Virginia Trimble's 1995 discussion, but his retelling has little in common with her thoughtful and fully referenced paper[11]. And he somehow seems to have overlooked Robert Smith's well-known book on the subject[12].

Much is rightly made of the 18-inch Schmidt as an engine of discovery, with Zwicky as the first in the line of formidable observers at its controls. Johnson refers in a note to its circumstances of manufacture (the sole source for which is "an exhibit at Palomar today"!; pp. 321–322, note 26), but nowhere does he inform his readers that Russell W. Porter was the designer of the instrument (the opportunity to do so is again missed at p. 186).

It is hard to connect the claim that "Over the next few decades, the 200-inch telescope would…cut a sure path through the underbrush to the ultimate discovery of the Big Bang…." (p. 193) with the serendipitous discovery of the cosmic microwave background by Penzias and Wilson in 1964, using a horn antenna. Perhaps I lack the necessary imagination to see the Hale Telescope as a pathfinder to the Holmdel Horn Antenna.

The source deficiencies in this biography are as troubling as the handling of the history of astronomy in its pages. Roland Müller's 1986 biography of Zwicky, the most complete to date (roughly twice the size of the work under review), is not mentioned, or cited by Johnson anywhere in his book. He does, however, cite the much smaller work by Stöckli and Müller derived from it.

Major astrophysicists, such as Gérard de Vaucouleurs, who collaborated with Zwicky, respected him, and left interesting accounts of working with him, do not figure in Johnson's biography. And some readily accessible sources by those who do appear in Johnson's narrative seem not to have been utilized, such as the AIP interviews with Sandage and de Vaucouleurs from which the quotes at the beginning of this review were taken.

Finally, on a matter of form and style, the text is punctuated by a handful of narrative interruptions in the form of present-day accounts of visits to sites or projects associated one way or the other with Zwicky's legacy, headed "On the Trail of Zwicky's Ghost." It is not a bad strategy, but they have a flat quality about them, and rather than effectively making a meaningful connection between then and now, seem only to impede the narrative. But this, unlike the book's historical errors, is a matter of individual judgement.

If Johnson had had more time, and a more rigorous review process, I am sure many of the problems could have been addressed. As it is, I am sorry this book is not the biography of Fritz Zwicky it could have been.

I will end on a RASC note. It is revealing that Zwicky is not so much as mentioned in the manuscript biography of Clarence Augustus Chant, an older contemporary who attended some of the same conferences and knew some of the same people. Given what is known of Chant's conformist character, he may have been unsettled by Zwicky. Zwicky's one-time colleague in creating the modern era of research into supernovae, Walter Baade, was made an honorary member of the RASC in 1954. Zwicky never was. And, as far as I can tell, no notice of his death ever appeared in JRASC. That too I regret[13].

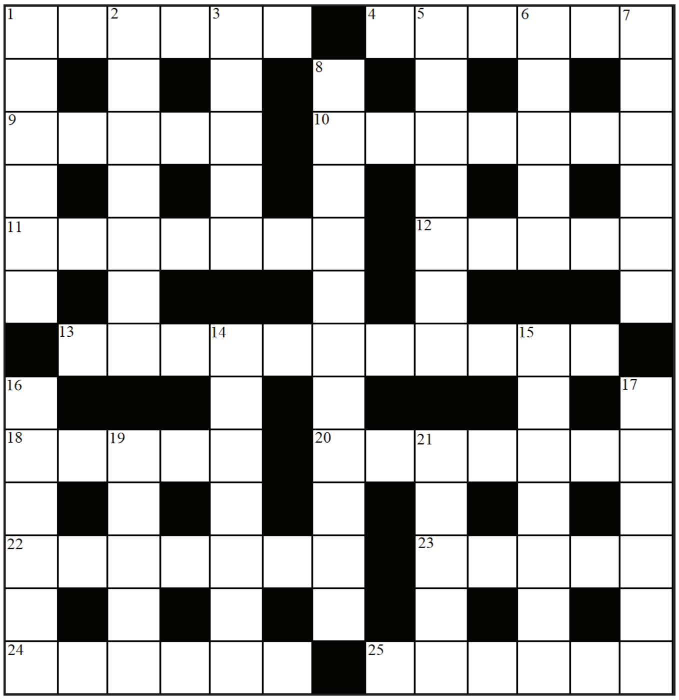
1 Allan Sandage, AIP interview 1974 May 16 (www.aip.org/history-programs/niels-bohr-library/oral-histories/32874).
2 *Sky & Telescope 47*, 5 (1974 May), 311–313, at p. 313.
3 Gerard De Vaucouleurs, AIP interview 1991 November 23 (www.aip.org/history-programs/niels-bohr-library/oral-histories/31929-2).
4 F. Zwicky, with the collaboration of Maria Karpowicz and C.T. Kowal, *Catalogue of Galaxies and of Clusters of Galaxies* (Pasadena: California Institute of Technology, 1961–68), 6 vols.
5 Gérard de Vaucouleurs, *Astronomical Photography: From the Daguerreotype to the Electron Camera*, tr. R. Wright (New York: The MacMillan Company, 1961), p. 77. Fehrenbach, Daudin, and Gum also pioneered these techniques.
6 Cecilia Payne-Gaposchkin hardly alluded to it in her *Sky & Telescope* assessment of him, and J.D. North's well-respected *The Measure of the Universe: A History of Modern Cosmology* (Oxford: Clarendon Press, 1965), only makes mention of Zwicky's 1933 dark matter "discovery" paper in a footnote to someone else's theory (incidentally that reason for citing Zwicky has subsided into crepuscular obscurity; 51, note 90). Neither the Tartu Observatory group nor the Princeton group mention Zwicky's paper; Jaan Einasto, Ants Kaasik, & Enn Saar, "Dynamic Evidence on Massive Coronas of Galaxies," *Nature* 250 (1974 July 26), 309–310; J.P. Ostriker, P.J.E. Peebles, & A. Yahil, "The Size and Mass of Galaxies, and the Mass of the Universe," *AJ* 193, (1974 October 1), L1-4; J. G. de Swart, G. Bertone, & J. van Dongen, "How Dark Matter Came to Matter," *Nature Astronomy, 1*, 59 (2017 March 2), 1–7. Nonetheless, Ostriker is generous to Zwicky in the *AJ* Centennial issue (525, 1999, 297–298).
7 Alfred Stöckli & Roland Müller, *Fritz Zwicky: An Extraordinary Astrophysicist*, tr. I. Gordon (Cottenham: Cambridge Scientific Publishers, 2011); Roland Müller, *Fritz Zwicky: Leben und Werk des grossen Schweizer Astrophysikers, Raketenforschers und Morphologen* (Glarus: Verlag Baeschlin, 1986).
8 Helge Kragh, "Astrophysicist's personality outshines his scientific legacy," *Physics Today 73*, 2 (2020), 52–53.
9 Roger Ceragioli, "William Herschel and the "Front-View" Telescopes," in *The Scientific Legacy of William Herschel*, ed. Clifford J. Cunningham (Cham: Springer International Publishing, 2018), pp. 97–238, at 100.
10 Michael Hoskin, David Dewhirst, & Wolfgang Steinicke, *The Construction of the Heavens: William Herschel's Cosmology* (Cambridge: Cambridge University Press, 2012).
11 Virginia Trimble, "The 1920 Shapley-Curtis Discussion: Background, Issues, and Aftermath," *Publications of the Astronomical Society of the Pacific* 107 (1995 December), 1133–1144.
12 Robert W. Smith, *The Expanding Universe: Astronomy's "Great Debate," 1900–1931* (Cambridge New York: Cambridge University Press, 1982).
13 For a more positive review of this book, see Freeman Dyson, "The Power of Morphological Thinking," *The New York Review of Books* 2020 January 16 (www.nybooks.com/articles/2020/01/16/zwicky-power-morphological-thinking/). This is one of the last pieces Dyson wrote before he died.

– Randall Rosenfeld

Randall A. Rosenfeld is the Society's Archivist.

Astrocryptic

by Curt Nason



ACROSS

1. Common complaint of the zodiac (6)
4. A big gun in stellar classification (6)
9. Astronomy popularizer once played Romeo (5)
10. Yon disc spins to a relative orbital period (7)
11. Giggle about who started a RASC media account (7)
12. Leitner Family Observatory student in Sunday Alien marathon (5)
13. Coordinate Alnilam's position from the equator (11)
18. Revolutionary periods of club listeners (5)
20. A thousand in one quiet stage of the Sun (7)
22. The source of solar power is strangely unclear (7)
23. Stave off collision with an asteroid (5)
24. Ancient observing log format found in RASC roller shelves (6)
25. Why Ceres rotational time cannot be told (6)

DOWN

1. You might find me in small beds looking for them (6)
2. One odd owlish person was a summer highlight (7)
3. Not an odd time to seek the horizon (5)
5. Twist any tail you find in Scorpius (7)
6. Machholz backed into Nagler at the orbital line (5)
7. A significant chunk of ataxite will cost more than this (6)
8. We count on more stars rotating (11)
14. Scottish and mostly French girls discovered Triton (7)
15. RAS home for a source of molecule detection in comets (2,5)
16. Young lion prey fly in the Milky Way (6)
17. I am near agreement on lunar crater formation (6)
19. Rider seen in central Corner Brook (5)
21. Cataclysmic variables seen at back-flowing river east of Stratford (5)

Answers to August's puzzle

ACROSS: **1** APOPHIS (a pop+his)); **5** HOMAM (hom+am); **8** TRACE (2 def); **9** ULYSSES (hid); **10** OLIVINE (anag+e); **11** ERRAI (anag+i); **12** HAYDEN (hay+den); **14** ISOBAR (2 def); **17** SONIC (anag); **19** ALGENIB (2 def); **21** CASSINI (hid); **22** TEIDE (anag+e); **23** LYRAE (anag); **24** ENRIGHT (2 def)

DOWN: **1** ASTROPHYSICAL (anag); **2** OPACITY (op+a+city); **3** HAEDI (anag); **4** SAUCER (anag); **5** HUYGENS (2 def); **6** MASER (anag); **7** MESSIER OBJECT (anag); **13** EUCRITE (anag+rev); **15** BINDING (2 def); **16** HALITE (hid); **18** NASIR (anag); **20** GATOR (astrogator)

The Royal Astronomical Society of Canada

Vision

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

Mission

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

Values

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

Great Images

by Tenho Tuomi

Tenho Tuomi imaged NEOWISE from Lucky Lake, Saskatchewan, on July 15 using a Canon T5i camera and a ƒ/1.8 55-mm Super-Takumar lens from a film camera stopped down to ƒ/2. This is a 10-second exposure at ISO 6400.

Journal

This beautiful close-up of NEOWISE was taken on July 14 by Debra Ceravolo using the Ceravolo 300-mm telescope (2700 mm focal length) with an SBIG Aluma 694 camera. Total of 16 minutes of RGB data.