The Journal of The Royal Astronomical Society of Canada

Journal

Le Journal de la Société royale d'astronomie du Canada

PROMOTING ASTRONOMY IN CANADA

April/avril 2023
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Inside this issue:

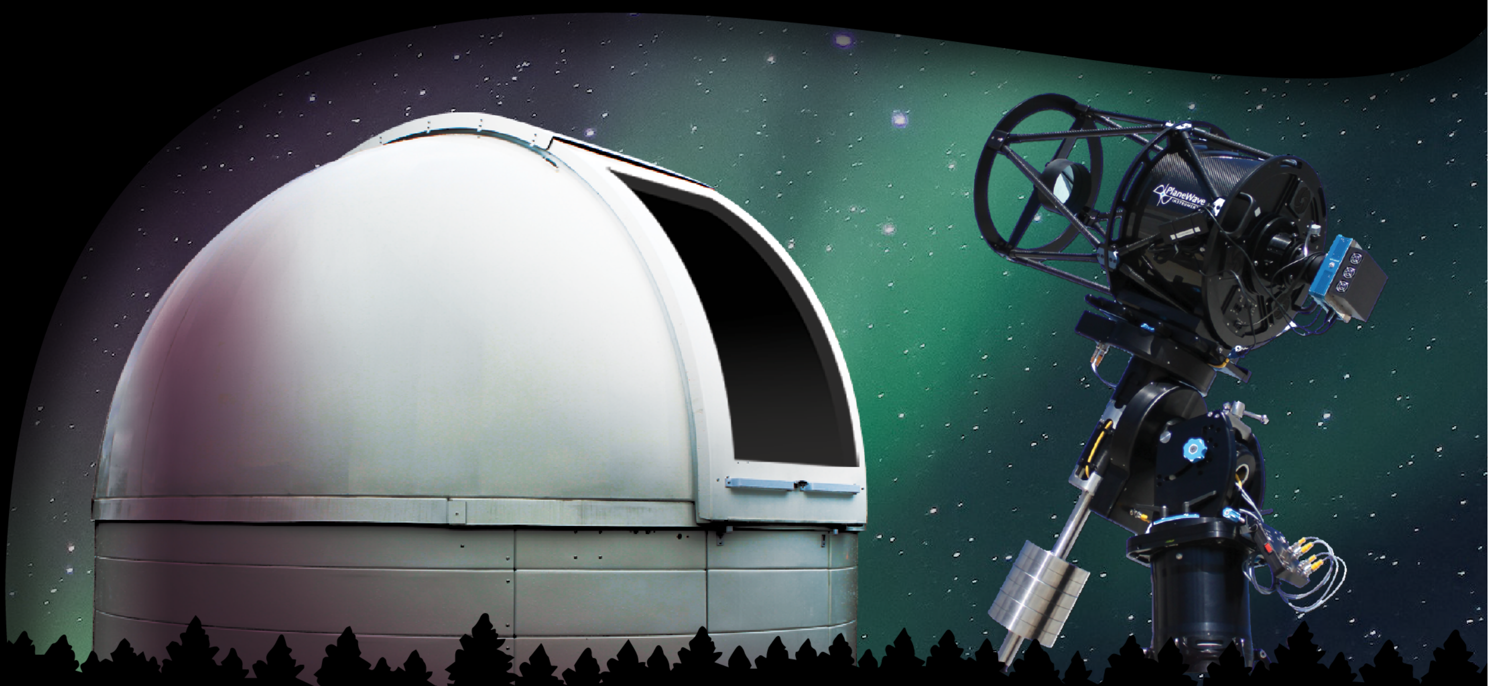
NGC 891 and Friends

David Thompson Astronomical Observatory

DTAO

Fort William Historical Park, Thunder Bay, Ontario

Embark on a celestial journey across Northern Ontario's night sky at the David Thompson Astronomical Observatory (DTAO) and Quetico Provincial Park. The DTAO, located at Fort William Historical Park, one of North America's largest living history sites, features a 20" Corrected Dall Kirkham (CDK) telescope and offers an array of enlightening experiences year-round. While you're in the region, continue your explorations of the cosmos at Quetico Provincial Park. Located just 2 hours west of Thunder Bay, Quetico is a designated International Dark Sky Park and is the perfect wilderness getaway for astronomy enthusiasts.



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Société Royale d'Astronomie du Canada

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Ron Brecher captured NGC 891 along with other dozens of other galaxies in this image from his SkyShed in Guelph over the nights of 2023 February 6–13, under a moonless sky. Ron says, "NGC 891 is an edge-on spiral galaxy located in the constellation Andromeda, about 30 million light-years away. It shows a prominent dust lane with lots of details, and some astronomers think that it looks similar to how our own galaxy would look seen edge-on from a distance. I put the galaxy up in the corner of this image to allow me to include the dozens of distant galaxies in the lower left of the image." Acquisition, focusing, and control of Paramount MX mount were with NINA, and TheSkyX*, unguided. All pre-processing and processing were done in* PixInsight*. Good transparency and seeing. He used a Sky-Watcher Esprit 150 ƒ/7 refractor and QHY600M camera with a* Optolong *UV/IR filter and a Takahashi FSQ-106 @ ƒ/5 (530-mm), QHY-367C Pro One-shot colour camera with an* Optolong *UV/IR filter. Total acquisition was 15 hours and 45 minutes.*

Journal

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

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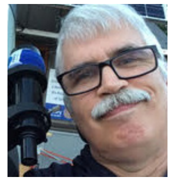
President's Corner

The Role and Value of Citizen Scientists



by Charles Ennis,
Sunshine Coast Centre
(cuhulain@telus.net)

On 2023 February 7, I was invited to appear before the House of Commons Standing Committee on Science and Research (SRSR) as part of a panel of witnesses. This committee was undertaking a study on the role and value of citizen scientists and to develop recommendations on how to encourage and expand the roles played by citizen scientists. The other panelists that appeared with me that day were Geofffrey S. LeBaron of the Audubon Society and Christopher Wood of EBird. Panelists who appeared in the previous session included Dr. Mona Nemer and Dr. Remi Quirion. Members of the committee and some panelists were especially interested in how to combat the dissemination of misinformation on social media. Dr. Nemer pointed out that citizen scientists were not just a source of helping hands but for ideas for science projects. I pointed out that breakthroughs in science required new perspectives and that citizen scientists from their various ethnic, educational, and social backgrounds were a good source of such perspectives. I explained how the bottleneck created by a large number of astrophysicists trying to get time on a small number of large telescopes was often alleviated by amateur astronomers who collected the light curves for variable stars and exoplanet hunters and spectroscopy from supernovae. It is amateur astronomers who search off the plane of our galaxy where there is no funding to hunt for comets, near-Earth objects, and supernovae. Amateur scientists monitor light-pollution levels. We help scientists find exoplanets and classify galaxies through our cooperation on projects such as Zooniverse. We track and find meteorites. Image data from the Juno Mission is largely processed by amateur astrophotographers. The RASC's World Asterisms Project is a citizen-science project. Citizen scientists go out into their communities and show people how to investigate their surroundings. We bring accurate information back to our communities and train the next generation of citizen scientists. ✶

News Notes / En manchette

Compiled by Jay Anderson

Microlensing reveals white-dwarf mass

An international team, led by the University of Cambridge, used data from the *Hubble Space Telescope* and *Gaia* astrometric telescope to measure the gravitational bending of light from a distant star by a white dwarf known as LAWD 37. This lensing caused the distant star to temporarily change its apparent position in the sky as the white dwarf passed in front. This is the first time this effect has been detected for a single, isolated star other than our Sun, and the first time the mass of such a star has been directly measured.

LAWD 37, the second-closest white dwarf, is at the end stage in the evolution of a star like our own. When a medium-weight star dies, it stops burning its fuel, its core collapses, and its outer atmosphere is expelled (forming a planetary nebula). Only the hot, dense core is visible, gradually cooling and crystallizing over an interval longer than the current age of the Universe, to become a so-called black dwarf. The core of the white dwarf is supported by electron degeneracy pressure, a quantum-mechanical effect that results in an extremely dense object in a small Earth-sized body. LAWD 37 is relatively close to us, about 15 light-years away, and is what remains of a star that died around 1.15 billion years ago.

"White dwarfs give us clues into how stars evolve—someday our own star will end up as a white dwarf," said lead author Dr. Peter McGill, who carried out the research while completing his Ph.D. at Cambridge's Institute of Astronomy. "Because this white dwarf is relatively close to us, we've got lots of data on it—we've got information about its spectrum of light, but the missing piece of the puzzle has been a measurement of its mass."

Mass is one of the most important factors in a star's evolution. For most stellar objects, astronomers infer mass indirectly, relying on strong, often untested modelling assumptions. In rare cases where mass can be directly inferred, the object must have a companion, such as a binary-star system. But for single objects, such as LAWD 37, other methods for determining mass are needed.

In his general theory of relativity, Einstein predicted that when a massive compact object passes in front of a distant star, the light from the star would bend around the foreground object due to its gravitational field, an effect known as gravitational microlensing. In 2017, astronomers detected this gravitational microlensing effect for another nearby white dwarf in a binary system, Stein 2051 b, which marked the first detection of this effect for a star other than our Sun. Now, the Cambridge-led team has detected the effect for LAWD 37, giving the first direct mass measurement for a single white dwarf.

Using positional measurements from the European Space Agency's *Gaia* satellite, astronomers were able to predict the movement of LAWD 37 and identify the time during which it would align close enough to a background star to detect the lensing signal. They then turned the *Hubble Space Telescope* (which has greater positional accuracy than *Gaia*) to LAWD 37 and watched the event transpire from May 2019 to September 2020.

Since the light from the background star was so faint, the main challenge for astronomers was extracting the lensing signal from the instrumental noise, a task that represented a significant modelling and statistical challenge. Once they had extracted the lensing signal, the researchers were able to measure the size of the astrometric deflection of

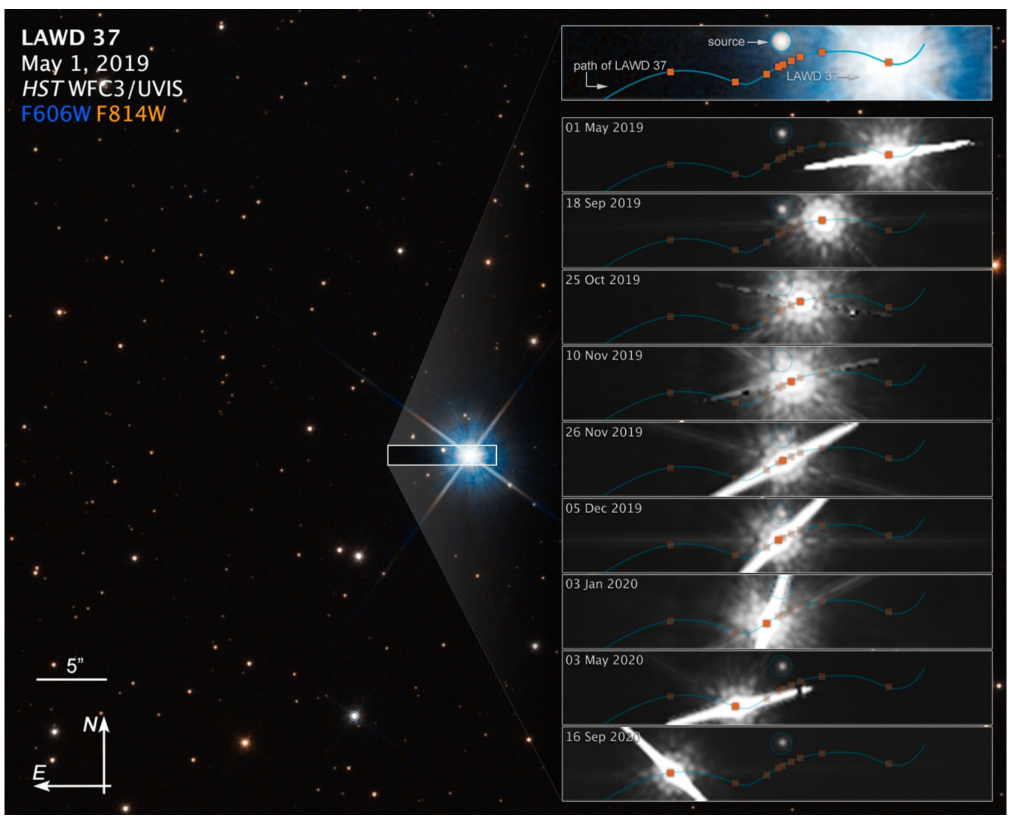


Figure 1 — An image displaying the field of the white dwarf star with insets showing the passage of LAWD 37 past the background star (circled in blue). The wavy blue line traces the LAWD 37's apparent motion across the sky; the sinusoidal path is caused by the motion of the Earth in its orbit. Credits: NASA, ESA, Peter McGill (UC Santa Cruz, IoA), Kailash Sahu (STScI); Image Processing: Joseph DePasquale (STScI).

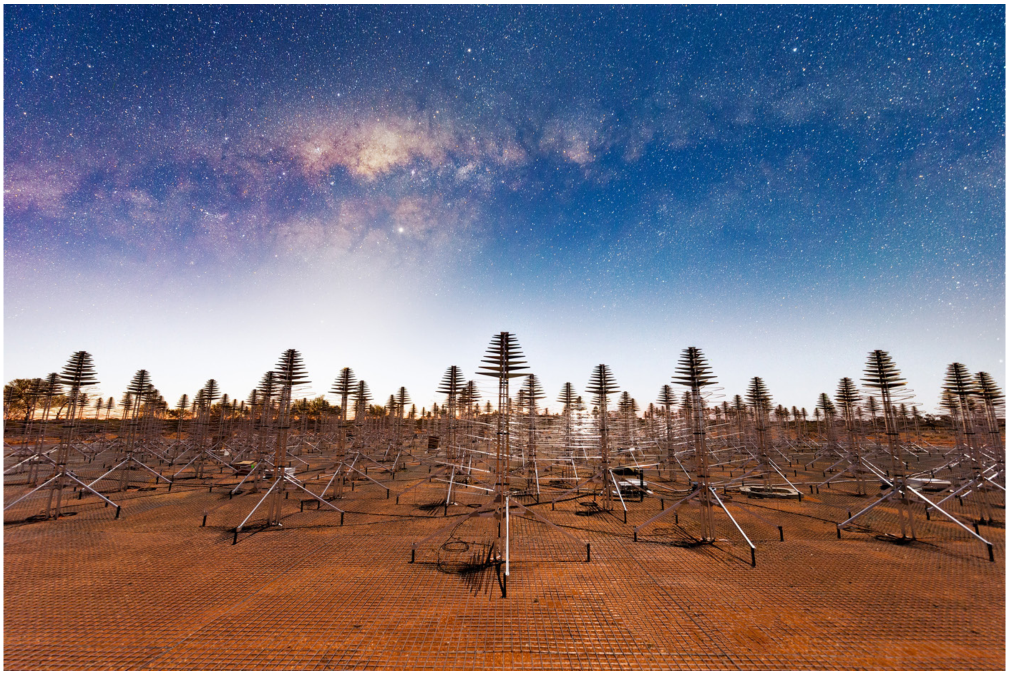


Figure 2 — A 20-second exposure showing the Milky Way overhead a test array of SKA-Low antennas. Image: Michael Goh and ICRAR/Curtin.

a variety of benefits for Canadian astronomers peering into the distant past of the Universe.

The Australian part of the project comprises 131,072 antennae built across 74 km in the Murchison region, on the traditional lands of the Wajarri Aboriginal people. The site has been named Inyarrimanha Ilgari Bundara, which means "sharing sky and stars" in the Wajarri language. Construction of the Australian part of the project began in December last year. In South Africa, the SKA currently consists of the 64-antenna MeerKAT array and a planned 350-antenna HERA (Hydrogen Epoch of Reionization Array) array. The whole of the SKA will not be ready for scientific observations until about 2027.

the background source using the position of 20 other, more-distant, calibration stars. Because the deflection scales with the mass of the white dwarf, the researchers were able to determine that the gravitational mass for LAWD 37 is 56 percent of the mass of our Sun. Because this measurement is independent of models of stellar evolution, it can be used to test the theoretical models.

"The precision of LAWD 37's mass measurement allows us to test the mass-radius relationship for white dwarfs," said McGill. "This means testing the properties of matter under the extreme conditions inside this dead star."

The researchers say their results open the door for future event predictions with *Gaia* data that can then be detected with space-based observatories such as JWST, the successor to Hubble.

Compiled in part with material provided by Cambridge University.

SKA gets a new partner

Canada has officially announced its intention to apply to join as a partner in the Square Kilometre Array Observatory (SKAO). The observatory is an international radio telescope project being built in Australia (low–frequency) and South Africa (mid–frequency), with headquarters at Jodrell Bank Observatory in the United Kingdom. Its location in the Southern Hemisphere, where radio interference is least, also gives it the best view of the Milky Way. The announcement formalizes Canada's long involvement in SKAO and provides

SKAO is the realization of a long-theorized project to study how the Universe evolved in its earliest days at the Cosmic Dawn and what that means for fundamental questions in astrophysics. In 2012, sites at locations in Australia and South Africa were selected, and a permanent headquarters was established in the United Kingdom. The SKA Observatory Convention was established in 2019, and construction activities started in 2021. Currently, 16 countries are involved in the project and another 8 are committed to future support.

The SKAO's announcement of the partnership said that the Herzberg Centre "has been identified to represent Canada in the governance of the SKAO and will work with domestic and international partners to deliver key observatory systems. This includes the digital correlator, the all-important 'brain' behind the SKA-Mid telescope in South Africa." The arrays will generate immense amounts of data, and as the data is "faint and buried in noise," it will take equally immense computing power to process. The correlator takes in wideband data from the antennae and produces the visibilities needed to make astronomical images, as well as the data processing used to search for very fast astronomical transients and pulses. It is estimated that the full array will generate an exabyte of data every day.

In return, Canada will be entitled to a six-percent use-share of the observatory, "access to a next-generation radio-astronomy facility" and support for "the establishment of a domestic regional centre. This centre will provide direct connections to data collected with the telescope as well as science support to enable ground-breaking discoveries."

In the announcement, Minister of Innovation, Science, and Industry François-Philippe Champagne said that the partnership will "solidify our scientific expertise and ensure Canada stays at the leading edge of astronomy and astrophysics," adding that "Canadian contributions to the SKAO could lead to new opportunities for Canadian businesses and, more so, for our scientists." NRC President Iain Stewart said that the SKAO will "enable transformational science about the Universe, the fundamental laws of physics and the prospects for life beyond our Solar System," and that Canada's membership will "maximize Canada's recognized capabilities in astronomy and scientific computing platforms."

"This is tremendously exciting news," says Bryan Gaensler, director of the University of Toronto's Dunlap Institute for Astronomy & Astrophysics in the Faculty of Arts & Science and former science director of the Canadian Square Kilometre Array, a global radio observatory. "Canadian membership in the SKAO was one of the marquee priorities in the Canadian Astronomy Long Range Plan for 2020–2030. Membership will open new opportunities for University of Toronto leadership at an international scale."

The announcement didn't go into details on next steps, however, only saying "the official signing ceremony and other steps necessary to complete the membership process are anticipated to take place in the coming months."

Diffuse galaxy sports a tail

A giant tidal tail has been discovered emanating from a dwarf galaxy in the nearby M81 Group. The galaxy, named F8D1, is remarkable on account of its low luminosity and large size and is now recognized to be one of the closest examples of an "ultra-diffuse" galaxy (UDG).

The origin of these enigmatic galaxies has puzzled astronomers for several decades—are they born this way or are their present-day properties the result of processes that have shaped them over their lifetimes? Using observations with Hyper Suprime-Cam (HSC) on the Subaru Telescope and the MegaCam imager on the Canada-France-Hawaii Telescope (CFHT), a team of researchers has mapped the tidal stream of stars from F8D1 over 1 degree on the sky, corresponding to 200,000 light-years at the distance of the galaxy. Revealing F8D1 to be a galaxy in an advanced state of tidal disruption has implications for both the dynamical evolution of the M81 Group and for the origin of galaxies that exhibit UDG properties.

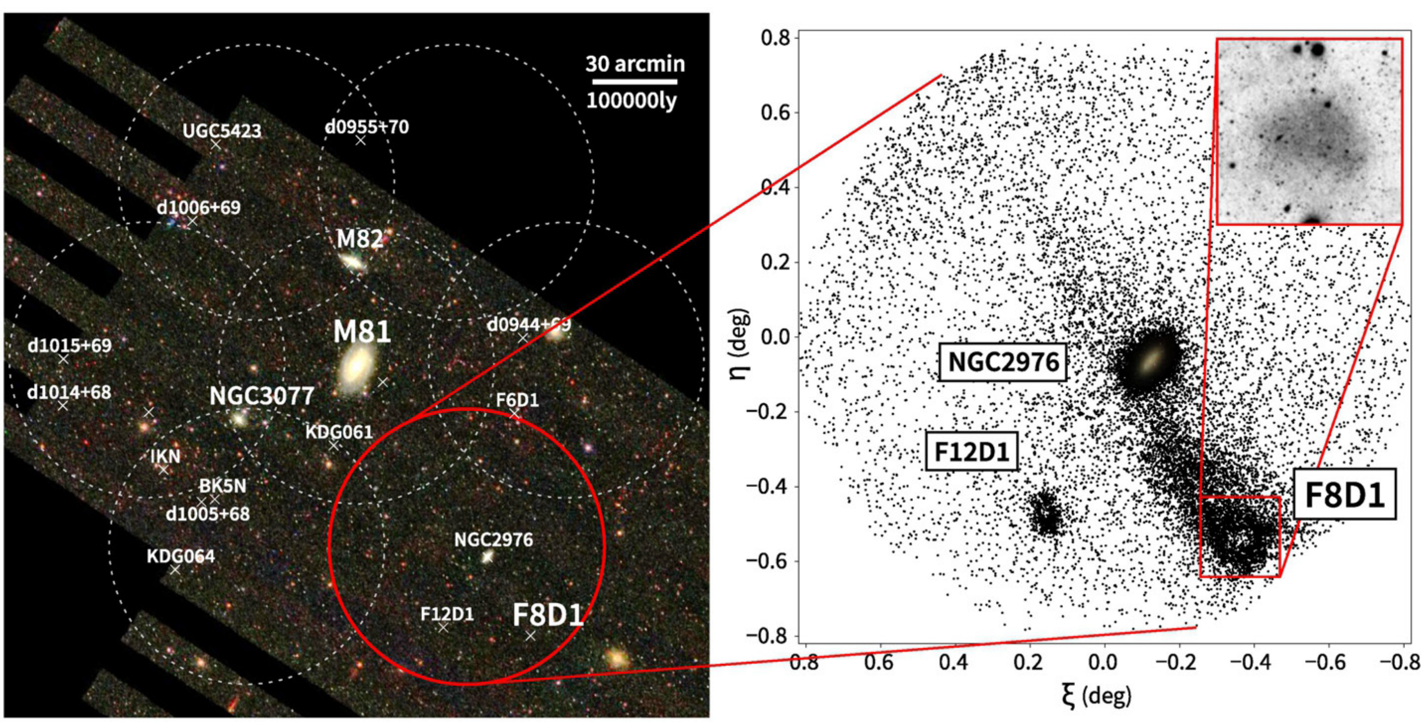


Figure 3 — (Left) M81 Group survey footprint (white and red circles) overlaid on a Sloan Digital Sky Survey image. (Right) The spatial distribution of red-giant-branch stars at the same distance as F8D1 in the field delineated by the red circle in the left panel. The upper-right image is a zoom-in on the main body of the F8D1 galaxy. Image: NAOJ.

Since 2014, the science team has conducted a deep contiguous photometric survey of the M81 Group using HSC on the Subaru Telescope. Lying at 11.7 million light-years, the M81 Group is one of the nearest galaxy groups. Its proximity and resemblance to the Local Group have fuelled much astronomical research over several decades. It contains more than 40 member galaxies, including the large spiral galaxy M81, the peculiar galaxies M82 and NGC 3077, 9 late-type galaxies, at least 20 low-luminosity early-type dwarfs and a variety of stellar debris features, some of which are tidal dwarf-galaxy candidates. Strong tidal interactions between M81, M82, and NGC 3077 have been revealed through the neutral hydrogen gas studies.

The F8D1 stream was revealed through analyzing the spatial distribution of individual stars with properties that place them at the distance of the M81 Group. Since F8D1 lies at the edge of the survey footprint, only one tidal arm can be seen, extending to approximately 200,000 light-years to the northeast. The team has recently been awarded further observing time to search a counterpart stream to the southwest.

Rokas Žemaitis, a Ph.D. student at the University of Edinburgh who led the work, said that: "The discovery that F8D1 is tidally disrupting is very exciting and it will be important to establish how many other UDGs also show faint tidal tails."

To assist in the analysis of the main body of F8D1, the team utilized the Low Surface Brightness (LSB) observing technique unique to MegaCam, CFHT's one-degree by one-degree optical imaging camera. Originally optimized for surveys at CFHT, LSB mode observations of F8D1 illustrate the complex nature of the galaxy's structure amid galactic cirrus features (faint gas clouds between the Earth and F8D1). The presence of galactic cirrus previously obscured the view of F8D1's tidal tail from discovery. Effectively mapping the cirrus via MegaCam's observations complements the observations done with HSC.

"MegaCam's unique capabilities in LSB mode were essential to deriving the physical properties of F8D1's tidal tail," said Jean-Charles Cuillandre, a co-author on the F8D1 paper and prior papers using LSB mode at CFHT. "The collaboration between MegaCam on CFHT and HSC on Subaru opened an unparalleled window into the deep nearby Universe."

The finding of a huge tidal tail from F8D1 is compelling evidence that the galaxy's present-day properties have been strongly shaped by events that have occurred in the past billion years. The team estimates that more than one-third of F8D1's luminosity is contained in the tidal tail and they suggest that the source of the disruption has been a recent close passage to the massive spiral M81. While the images seem to show an interaction with NGC 2976, that galaxy lies in the foreground at a distance much larger than that to M81.

"The observations for the team were observed as a "snapshot" program at CFHT, a program that is observed during poorer seeing conditions on Maunakea," said Todd Burdullis, queued service observing operations specialist at CFHT. "This discovery is a testament to the power of MegaCam's LSB mode, collaboration with our neighbours at Subaru, and the incredible conditions on Maunakea."

Compiled with material provided by National Institute of Natural Sciences in Japan.

Webb studies rings around Chariklo

In an observational feat of high precision, scientists used a new technique with NASA's *James Webb Space Telescope* to capture the shadows of starlight cast by the thin rings of Chariklo, which is an icy, small asteroidal body, but the largest of the known Centaur population, located more than three billion kilometres away beyond the orbit of Saturn. Chariklo is only 250 kilometres in diameter, and its rings orbit at a distance of about 400 kilometres from the centre of the body. Here is the report of the observation team:

> In 2013, Felipe Braga-Ribas and collaborators, using ground-based telescopes, discovered that Chariklo hosts a system of two thin rings. Such rings had been expected only around large planets such as Jupiter and Neptune. The astronomers had been watching a star as Chariklo passed in front of it, blocking the starlight as they had predicted. Astronomers call this phenomenon an occultation. To their surprise, the star blinked off and on again twice before disappearing behind Chariklo, and double-blinked again after the star reemerged. The blinking was caused by two thin rings—the first rings ever detected around a small Solar System object.
>
> Pablo Santos-Sanz, from Instituto de Astrofísica de Andalucía in Granada, Spain, has an approved "Target of Opportunity" program to attempt an occultation observation as part of Webb's Solar System Guaranteed Time Observations (GTO) led by Heidi Hammel from the Association of Universities for Research in Astronomy. By remarkable good luck, we discovered that Chariklo was on track for just such an occultation event in October 2022. This was the first stellar occultation attempted with Webb. A lot of hard work went into identifying and refining the predictions for this unusual event.
>
> On October 18, we used Webb's Near-Infrared Camera (NIRCam) instrument to closely monitor the star *Gaia* DR3 6873519665992128512 and watch for the tell-tale dips in brightness indicating an occultation had taken place. The shadows produced by Chariklo's rings were clearly detected, demonstrating a new way of using Webb to explore Solar System objects. The star shadow due to Chariklo itself tracked just out of Webb's view. This appulse

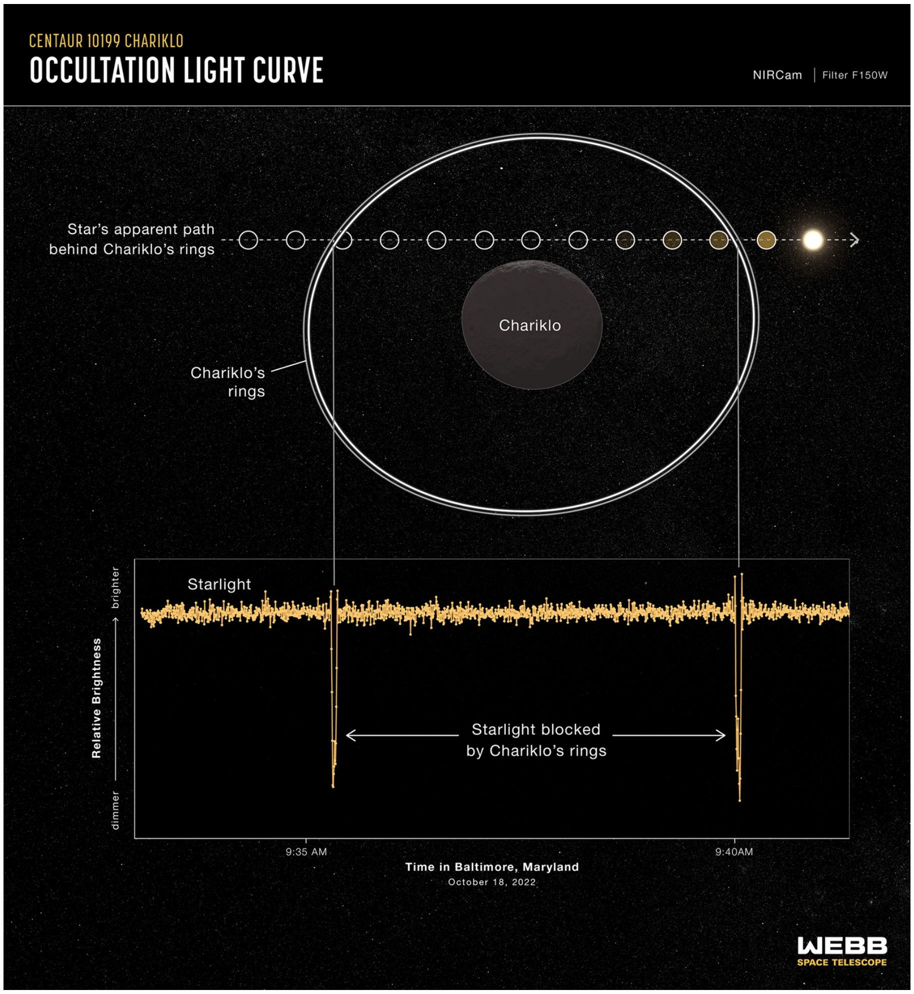


Figure 4 — An occultation light curve from Webb's Near-infrared Camera (NIRCam) Instrument at 1.5 microns wavelength shows the dips in brightness of a background star as Chariklo's rings passed in front of it on October 18. The star did not pass behind Chariklo from Webb's viewpoint, but it did pass behind the rings. Each dip actually corresponds to the shadows of two rings around Chariklo, which are ~6–7 kilometres and ~2–4 kilometres wide, and separated by a gap of 9 kilometres. The two individual rings are not fully resolved in each dip in this light curve. Image: NASA, ESA, CSA, Leah Hustak (STScI). Science: Pablo Santos-Sanz (IAA/CSIC), Nicolás Morales (IAA/CSIC), Bruno Morgado (UFRJ, ON/MCTI, LIneA)

(a close pass with no occultation) was exactly as had been predicted after the last Webb course trajectory maneuver.

The Webb occultation light curve revealed that the observations were successful! The rings were captured exactly as predicted. The occultation light curves will yield interesting new science for Chariklo's rings. Santos-Sanz explained: "As we delve deeper into the data, we will explore whether we cleanly resolve the two rings. From the shapes of rings' occultation light curves, we also will explore the rings' thickness, the sizes, and colours of the ring particles, and more. We hope to gain insight into why this small body even has rings at all, and perhaps detect new fainter rings.

The rings are probably composed of small particles of water ice mixed with dark material, debris from an icy body that collided with Chariklo in the past. Chariklo is too small and too far away for even JWST to directly image the rings separated from the main body, so occultations are the only tool to characterize the rings by themselves.

Shortly after the occultation, JWST targeted Chariklo again, this time to collect observations of the sunlight reflected by Chariklo and its rings. The spectrum of the system shows three absorption bands of water ice in the Chariklo system. Noemí Pinilla-Alonso, who led Webb's spectroscopic observations of Chariklo, explained: "Spectra from ground-based telescopes had hinted at this ice, but the exquisite quality of the Webb spectrum revealed the clear signature of crystalline ice for the first time." Dean Hines, the principal investigator of this second GTO program, added: "Because high-energy particles transform ice from crystalline into amorphous states, detection of crystalline ice indicates that the Chariklo system experiences continuous micro-collisions that either expose pristine material or trigger crystallization processes.

Most of the reflected light in the spectrum is from Chariklo itself: Models suggest the observed ring area as seen from JWST during these observations is likely one-fifth the area of the body itself. Webb's high sensitivity, in combination with detailed models, may permit us to tease out the signature of the ring material distinct from that of Chariklo. Pinilla-Alonso commented that "by observing Chariklo with Webb over several years as the viewing angle of the rings changes, we may be able to isolate the contribution from the rings themselves."

Our successful Webb occultation light curve and spectroscopic observations of Chariklo open the door to a new means of characterizing small objects in the distant Solar System in the coming years. With Webb's high sensitivity and infrared capability, scientists can use the unique science return offered by occultations, and enhance these measurements with near-contemporaneous spectra. Such tools will be tremendous assets to the scientists studying distant small bodies in our Solar System.

Compiled with material provided by NASA. ✶

Feature Articles / Articles de fond

Recognizing the *Stellarium* Training Team

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

On 2011 March 2, I delivered a custom-made, hands-on introductory course for using the *Stellarium* software. I did this as it was relatively easy for me, being a computer-software trainer by day, being familiar with and enthusiastic about the software, and noting that many RASCals seemed very interested in using the *Stellarium* application.

Figure 1 — Blake Nancarrow

At the time, I pitched it internally, to members of the Toronto Centre. Our partner, the Ontario Science Centre was gracious and provided me with presentation space. This first session was well received and the dozen participants were quite happy.

Nine months later, I did it again. I ran another in-person introductory course on the *Stellarium* application for microcomputers. It was clear, at this early stage, that there was a great deal of interest. Others wanted to take a future level 1 course and the graduates of the level 1, wanted advanced training. I promised to help.

And…life happened.

Fast-forward to 2020. In the middle of the pandemic, I observed that the Toronto Centre was struggling to satisfy its members. There was nothing happening other than virtual meetings. I felt people wanted something to do and it was apparent to me that it was the perfect time to learn new skills. Plus, we needed a distraction! My computer training home studio was ready and, with an old software course "in the can," I knew I could help.

Figure 2

On 2020 November 23, I offered a *Stellarium* informational webinar. Some goals were to generate interest, communicate my plans, and inform members of a program that they could sign up for. Some 39 people registered with 23 attending the software demo. I had enough people to run courses.

A week later, with fresh materials—an updated slide deck and revised Quick Reference Card—I delivered an on-line training session using the *Zoom* meeting software. It went very well. Rinsed and repeated on 2020 December 28. Now I had a gaggle of people ready for the next level!

On 2021 January 20, for the first time ever, I ran my new level 2, intermediate course, which included a topic on connecting to a telescope mount and driving it from the software. That worked a treat and I had still more happy members wanting to learn more about *Stellarium*.

Rolling back a bit, there was a participant in the November course, who stuck his hand up when I asked about training experience. By March, Ian Bain of the Toronto Centre was running his own introductory sessions, helping split the

Figure 3 — Ian Bain

workload. In an April session, Al McCue from Calgary offered to help. And a short time later, Kersti Meema of Toronto was onboard. I was ecstatic. With 4 trainers, we could support the increasing volume of people wanting level 1 and 2. We could cover all of Canada's time zones. It also relieved me of some duties so that I could expand the curriculum.

It occurred to me in the fall that running the courses for only one Centre didn't make any sense. So, we retooled and started offering the *Stellarium* training to all RASC members, coast to coast to coast. The fall also marked another webinar and the first run of the new level 3, advanced course.

It was an incredible year. We ran 22 sessions for various time zones. Again, we continued the basic primer course but also launched two new courses.

The 2022 January 26 course kicked off the new season hosted from the RASC national *Zoom* training account. It was an even better year with 25 sessions. And midway through the year, we introduced our latest course: *Stellarium Mobile*, helping people master the app on their Android or iOS device.

Figure 4 — Al McCue

At the time of writing, we have trained 230 people on level 1, 150 on the intermediate level, 34 on level 3, and 18 on mobile. With no hints of slowing down. I'm pleased as punch that so many have expressed interest in this high-quality educational program.

I owe a huge debt of gratitude to my fellow trainers. I'd like to introduce these fine humans to you.

Figure 5 — Kersti Meema

Ian Bain. Teaching since 1997, Ian is a Toronto public school teaching administrator. He has more than 32 years' experience as a cadet instructor. He works on the Macintosh and Windows platforms. He volunteers at the RASC DDO. He is also a do-it-yourselfer and built his own barn-door tracker for wide-field imaging. Ian teaches the introductory and intermediate *Stellarium* courses. He assists in curriculum development.

Al McCue. Joined RASC in 2019. Al is an engineer who works with oil and gas field operations software. He has been teaching at the Southern Alberta Institute of Technology, Mount Royal University, and the U of Calgary for over 40 years. He is primarily a Windows user, and he teaches introductory *Stellarium* courses.

Kersti Meema. She is a retired high-school science teacher who has been an active member of the RASC Toronto for 12+ years. Kersti is a presenter for the RASC NOVA series, at the DDO, and other outreach presentations, during which she often uses *Stellarium* to show the night sky. She is pursuing her passion for nature photography, including wide-field astrophotography. Kersti teaches the introductory *Stellarium* courses.

I thank Ian, Al, and Kersti for their volunteer support, passion for the training series we have built, and their excellent on-line classroom delivery.

Visit rasc.ca/stellarium-training to learn more about the *Stellarium* training courses. If you have any questions, message software-training@rasc.ca for more info.

Be seeing you in 2023. ✶

Blake Nancarrow joined RASC in 2007. He started using Stellarium *around 2008 and has used it for public education and outreach events, The Sky This Month presentations, and for astronomy event planning. In daylight, Blake is an instructor of information technology and business software. Blake uses Windows, Mac, and Linux computers and teaches all the* Stellarium *courses. He's actively developing the curriculum. Over the Christmas break, he also developed the new* Backyard EOS *level 1 introductory course and ran the first session in January.*

Teaching Astronomy in Québec's Schools: A Personal and Academic Journey

by Pierre Chastenay, Ph.D., Full Professor,
Université du Québec à Montréal

With a background in astrophysics, and after a 25-year career at the Planétarium de Montréal, I made a late return to graduate school and completed a Ph.D. in science education in 2013. I then began an academic career at Université du Québec à Montréal (UQAM). Given my initial training in astronomy, I was naturally drawn to astronomy education in elementary and secondary schools. Since 2006, Québec's school curriculum contains topics in astronomy that must be taught at the elementary and secondary levels, such as the diurnal cycle, the phases of the Moon, and the seasons. But how is astronomy taught in Québec school classrooms?

To answer this question, I surveyed over 600 elementary school teachers across Québec (Chastenay, 2014; 2018; Chastenay & Riopel, 2019). Results show that less than half of respondents teach astronomy in their classrooms; those who do address astronomical topics with their students do so mostly through textbooks and workbooks, thus turning the study of astronomy into a reading and writing activity.

I then analyzed the content of the dozen or so textbooks and workbooks most often used for science teaching in Québec elementary classrooms. I found that all the astronomy content targeted by the curriculum is indeed covered and that astronomy is therefore well represented in these textbooks. However, I found several factual errors in these texts; for example, one textbook states, "In space, there is no gravity; objects float in the air and do not fall. This is called weightlessness." (Bergeron, 2013, p. 33, free translation) Such a statement can only reinforce a common misconception among many students (and their teachers!) that Earth's gravity vanishes at the top of the atmosphere.

But the most problematic elements of these astronomy textbook pages remain the illustrations they contain. These are overwhelmingly two-dimensional, not to scale, static, implicitly depicted in perspective (but rarely explicitly described as such), and are overall extremely difficult for students to understand. A classic example is the perspective image depicting the mechanism of the seasons and suggesting that the Earth's orbit around the Sun is highly elliptical, which can only reinforce students' belief that it is the variation in the Earth-Sun distance that is responsible for Earth's seasons.

Lee (2010) noted that textbook images are increasingly seen as a likely source of confusion for students who, unlike experts, lack the basic conceptual knowledge to properly interpret them and understand the information they convey. Some, like Stern & Roseman (2004), even consider that many textbook illustrations are detrimental to learning. In the specific case of astronomical phenomena depicted in textbooks, several authors such as Åberg-Bengtsson, Karlsson, & Ottosson (2017), Calderon-Canales, Flores-Camacho, & Gallegos-Cazares (2013), Kikas (1998a; 1998b), and Michaels & Bruce (1989) find that astronomical illustrations are often the source of the most common misconceptions held by students, such as the shadow of the Earth being cast on the Moon to explain lunar phases.

In the survey I referred to above, I also asked teachers what were the main obstacles they faced when teaching astronomical concepts to their students. Most teachers mentioned their lack of confidence in their ability to teach astronomy and the lack of or poor quality of pre-service and in-service training to teach the subject. They also mentioned the fact that for them, astronomy remains a complex and abstract science that, unlike other school subjects, does not lend itself to a hands-on approach that allows students to manipulate concrete objects and "think with their hands."

The need for pre-service and in-service training in astronomy (and in science in general) for elementary and high-school teachers is still present, and it has been well documented in Québec (Conseil de la science et de la technologie, 2004; Conseil supérieur de l'éducation, 1982; 1990; 2013). I do not believe that the introductory astronomy courses offered in many Canadian universities (Astro 101) can meet these needs, since teachers must not only know the concepts to be taught, they must also master *how* to teach them. Therefore, I have created a course in astronomy teaching (DDD4321) at UQAM, which is primarily intended for pre-service elementary and high-school teachers. This course deals with the astronomical content to be taught, but it does so by using a pedagogical approach on which I have been working for several years and which results from an epistemological analysis of the way astronomers do astronomy.

Unlike physicists or chemists, astronomers cannot manipulate their objects of study (Giordan, 1999), with rare exceptions, such as Moon rocks, meteorites, and comet dust. All that we know about the Universe, we owe to observation, which informs us about the nature, origin, and evolution of astronomical objects. However, this does not make astronomy a less "concrete" science than the others, on the contrary, since systematic observation is a fundamental part of the process of scientific investigation. Would it be possible to make the study of astronomical phenomena in the classroom more "concrete" by proposing to students to "Do astronomy like astronomers do"?

Figure 1 illustrates what I call the Astronomy Knowledge-building Cycle. It is based on a historical and epistemological analysis of how astronomers construct new knowledge. The starting point of any scientific investigation is a problem,

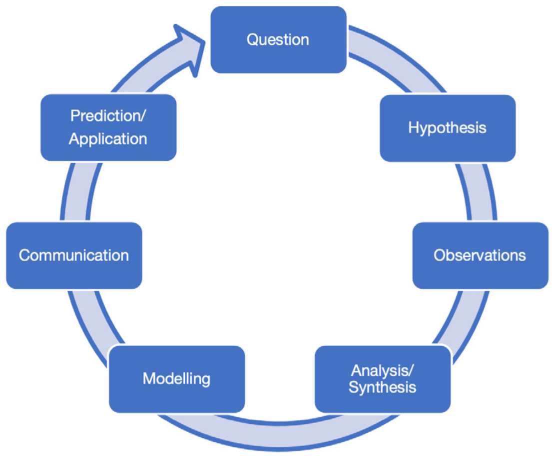


Figure 1

which leads to a question. As the philosopher of science Gaston Bachelard wrote, "for a scientific mind, all knowledge is an answer to a question. If there is no question, there can be no scientific knowledge" (1938, p. 14, free translation). But the question must be operationalized to make it a true research question. This process of operationalization involves the production of hypotheses, which are tentative explanations based on the current knowledge of the astronomical community, as well as on astronomers' intuitions, and which attempt to answer the research question. Next, astronomers choose the observation instruments that will facilitate the collection of data needed to sort out the various hypotheses.

The raw observations collected by astronomers never directly answer their research question; the data must be analyzed to reveal correlations, cycles, systematicities, and invariants hidden in the observations. It is these synthetic elements resulting from the analysis, and not the raw data themselves, that will help astronomers to reveal the underlying mechanisms of the astronomical phenomenon under study.

The result of this analysis will then lead astronomers to create a model, whether it is a concrete physical model, a mathematical model or, as is often the case in modern astrophysics, a numerical model. Through the model, which is a functional and simplified representation of a class of objects or phenomena (Giordan & de Vecchi, 1987; Roy & Hasni, 2014), astronomers retain only certain elements of a complex reality to create a simpler and more easily manipulated representation. Since direct manipulation of celestial objects is impossible, the model is also the only tool that allows for controlling variables, testing a new hypothesis, making predictions, etc. The model in astronomy thus has a double epistemological status (Mathewson, 2005): it is used to reproduce observations (model validation phase), but also to make predictions about other aspects of the system studied (application phase). The model is for astronomers what the experimental setup is for physicists and chemists.

The results of this sequence of observation, analysis, and modelling will then be communicated to the research community, most often in the form of a scientific paper, to share new results and ideas, but also to submit them to critical peer review. Finally, the research findings will contain predictions and applications of the model that will raise new research questions and initiate a new cycle of observation, analysis, and modelling.

There are many historical examples to support this view of the work of astronomers. Consider Copernicus, who put forward the heliocentric hypothesis to answer the question of the configuration of the Solar System (see Crowe, 2001; Kuhn, 1957). Armed with more than 20 years of meticulous observations of the planet Mars compiled by Tycho Brahe, Kepler constructed the mathematical model that led to the three laws of planetary motion and predicted the transits of Mercury and Venus in 1631 and 1639 respectively (Athreya & Gingerich, 1996). Newton formalized these discoveries in his now-famous law of universal gravitation, initiating a vast research program that continues to this day.

In the context of my research in astronomy education, I have studied the effect of implementing this epistemological approach in various contexts of pre-service and in-service training of primary and high-school teachers, as well as their students, to address the teaching of two astronomical concepts in particular, the phases of the Moon (Chastenay, submitted; Chastenay & Guay-Fleurent, 2022; Chastenay & Riopel, 2020) and the seasons.

In the case of lunar phases, the teaching sequence I propose begins with a simple question: Why does the Moon change its appearance from day to day? This is followed by a brainstorming session where learners are invited to share everything they know about our satellite and its phases. This step allows students to take ownership of the research question and often leads them to realize that they themselves have personal ideas and theories about our satellite and that these ideas are sometimes different from those of their peers. Thus begins the revision of these ideas. Students are then asked to formulate a hypothesis in the form of "I think the Moon shows phases because…," which they will be asked to revise throughout the teaching sequence.

I recommend starting the study of lunar phases a few days before first quarter. This way, it will be easy for students to see the Moon in the afternoon, during recess, or after school, or early in the evening from home. This will provide them with a first-hand experience of observing the Moon and recording their observations. Observing and recording an astronomical phenomenon such as lunar phases in a systematic way, as astronomers do, is an important learning experience for students and facilitates their understanding of the phenomenon (Plummer, 2012). Ideally, students should take a few minutes each day for one month to record basic data about the

Lunar Phases Observation Log Name : ______________________ Group : ______________

Day Nr	Moonrise		Moonset		Phase (darken the invisible part)	Name of the phase	Illumination (%)	Elongation (degrees)	I notice something or I have a question
	Date	Time	Date	Time					
1									
2									

Figure 2

phases of the Moon on an observation sheet that will later help them model the phenomenon.

The figure above is an excerpt from the Lunar Phases Observation Log that I use in teacher training and with my university students. It is of course too elaborate to be used in primary school, where one will often simply draw the phase and record its name. But with adults or high-school students, this log does not pose any problem, even less if one introduces students to an astronomy freeware like *Stellarium*[1], which provides all the necessary information to complete the sheet daily.

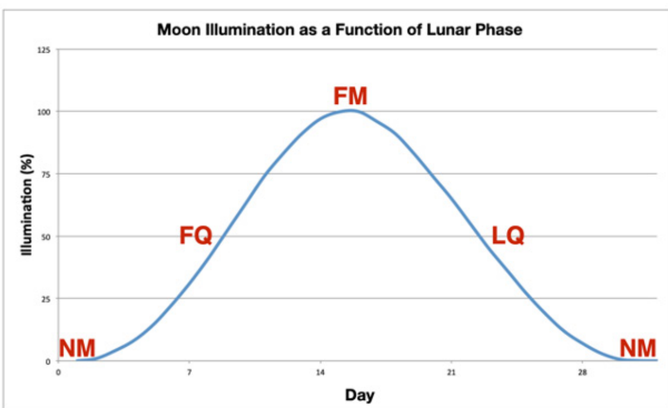


Figure 3

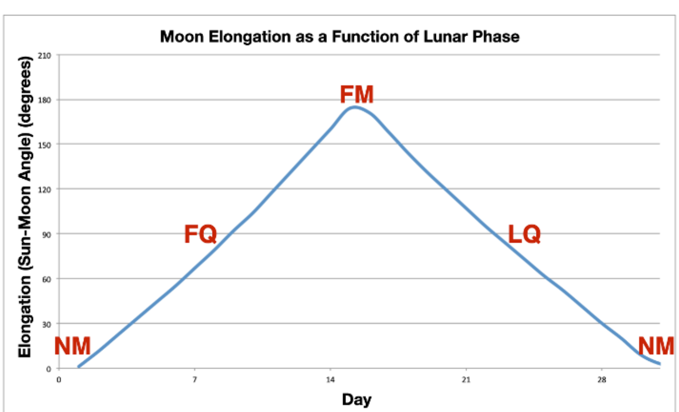


Figure 4

After a month of observations, the learners are invited to analyze their data with a document that helps them sort out their observations. This document takes the form of a series of questions whose answers can be found in the data collected. For example, they are asked to determine in what direction the terminator advances on the lunar disk from day to day. By plotting and studying graphs of the Moon's illumination and elongation as a function of time, learners can better appreciate the cyclical nature of lunar phases as well as the connection between the Moon's position in its orbit and its phase (figures below, left).

After completing the analysis, learners are asked to create a summary (a synthesis) of their observations. This summary, in the form of a table, becomes the basis for the modelling process. The modelling of the lunar phases by learners in a darkened room can simply use white Styrofoam balls representing the Moon, a bare light bulb for the Sun and the students' heads representing the Earth (figure below), or use more complex representations, such as a white ball stuck on a hula hoop held at eye level to represent the plane of the Moon's orbit. In all cases, the goal is to reproduce what the learners have observed.

As they model the lunar phases, participants are encouraged to discuss and present their findings to each other, allowing for further dialogue. Students are also encouraged to present their model to other classes, to their parents, or to create animations (e.g. with *Scratch*[2]) or videos. Peer–to–peer communication is very important to properly anchor the model in the learner's conceptual network. As Vygotsky once wrote, "the word is the

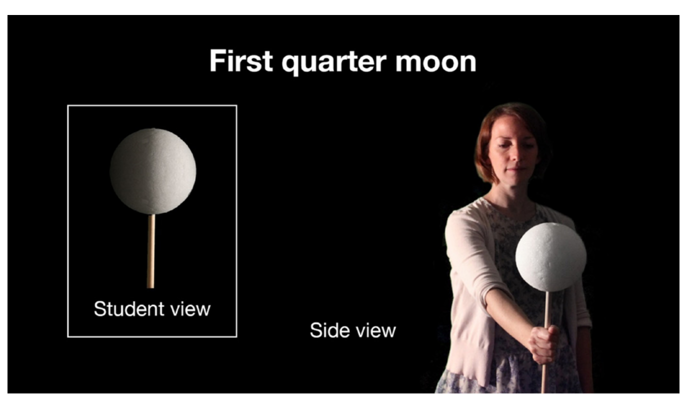


Figure 5 — Credit: NASA

direct tool of concept formation" (2014, p. 525, free translation).

The models constructed by the learners are used not only to replicate what they observed but also to predict future lunar phases, explain the variation in moonrise and moonset times as a function of its phase (by including the Earth's rotation in the model), explore the formation and frequency of lunar and solar eclipses (with the hula hoop model), etc. Emerging questions and new applications of the model can also be explored, such as the phases of the Earth as seen from the Moon, the phases of Mercury and Venus as seen from the Earth, the phases of the satellites of Mars and Jupiter, etc.

	A	B	C	D	E	F	G	H	I	J
1	Éphémérides du Soleil (2022)									
2	Les heures sont données en heure normale pour Montréal (73° 30' O, 45° 36' N)									
3										
4										
5	Date			Lever	Passage	Coucher	Durée	Altitude	Azimut	Azimut
6	aaaa	mm	jj	hh:mm	hh:mm	hh:mm	hh:mm	max.	lever	coucher
7										
8	2022	1	1	7:35	11:57	16:20	8:45	21	123	237
9	2022	1	2	7:35	11:58	16:21	8:46	22	123	237
10	2022	1	3	7:35	11:58	16:22	8:47	22	123	237
11	2022	1	4	7:34	11:59	16:23	8:49	22	123	238
12	2022	1	5	7:34	11:59	16:24	8:50	22	122	238
13	2022	1	6	7:34	11:59	16:25	8:51	22	122	238
14	2022	1	7	7:34	12:00	16:26	8:52	22	122	238
15	2022	1	8	7:34	12:01	16:28	8:54	22	122	238
16	2022	1	9	7:33	12:01	16:29	8:56	22	122	239
17	2022	1	10	7:33	12:01	16:30	8:57	22	121	239
18	2022	1	11	7:33	12:02	16:31	8:58	23	121	239
19	2022	1	12	7:32	12:02	16:32	9:00	23	121	239
20	2022	1	13	7:32	12:03	16:33	9:01	23	121	240
21	2022	1	14	7:31	12:03	16:35	9:04	23	120	240
22	2022	1	15	7:31	12:03	16:36	9:05	23	120	240
23	2022	1	16	7:30	12:04	16:37	9:07	24	120	240
24	2022	1	17	7:30	12:04	16:39	9:09	24	120	241
25	2022	1	18	7:29	12:04	16:40	9:11	24	119	241
26	2022	1	19	7:28	12:05	16:41	9:13	24	119	241
27	2022	1	20	7:28	12:05	16:43	9:15	24	119	242
28	2022	1	21	7:27	12:05	16:44	9:17	25	118	242
29	2022	1	22	7:26	12:05	16:45	9:19	25	118	242
30	2022	1	23	7:25	12:06	16:47	9:22	25	118	243
31	2022	1	24	7:24	12:06	16:48	9:24	25	117	243
32	2022	1	25	7:23	12:06	16:50	9:27	25	117	243
33	2022	1	26	7:22	12:06	16:51	9:29	26	116	244

Figure 6

	A	B	C	D	E	F	G	H	I	J
1	Éphémérides du Soleil (2022)									
2	Les heures sont données en heure normale pour Coihaique, Chili (73° 30' O, 45° 36' S)									
3										
4										
5	Date			Lever	Passage	Coucher	Durée	Altitude	Azimut	Azimut
6	aaaa	mm	jj	hh:mm	hh:mm	hh:mm	hh:mm	max.	lever	coucher
7										
8	2022	1	1	4:09	11:57	19:46	15:37	67	125	235
9	2022	1	2	4:10	11:58	19:46	15:36	67	125	235
10	2022	1	3	4:11	11:58	19:46	15:35	67	125	235
11	2022	1	4	4:12	11:59	19:46	15:34	67	125	236
12	2022	1	5	4:13	11:59	19:46	15:33	67	124	236
13	2022	1	6	4:14	11:59	19:45	15:31	67	124	236
14	2022	1	7	4:15	12:00	19:45	15:30	67	124	236
15	2022	1	8	4:16	12:01	19:45	15:29	67	124	236
16	2022	1	9	4:17	12:01	19:44	15:27	67	124	237
17	2022	1	10	4:18	12:01	19:44	15:26	66	123	237
18	2022	1	11	4:19	12:02	19:44	15:25	66	123	237
19	2022	1	12	4:21	12:02	19:43	15:22	66	123	237
20	2022	1	13	4:22	12:03	19:43	15:21	66	123	238
21	2022	1	14	4:23	12:03	19:42	15:19	66	122	238
22	2022	1	15	4:24	12:03	19:42	15:18	66	122	238
23	2022	1	16	4:26	12:04	19:41	15:15	65	122	238
24	2022	1	17	4:27	12:04	19:40	15:13	65	122	239
25	2022	1	18	4:28	12:04	19:40	15:12	65	121	239
26	2022	1	19	4:30	12:05	19:39	15:09	65	121	239
27	2022	1	20	4:31	12:05	19:38	15:07	65	121	240
28	2022	1	21	4:33	12:05	19:37	15:04	64	120	240
29	2022	1	22	4:34	12:05	19:36	15:02	64	120	240
30	2022	1	23	4:35	12:06	19:35	15:00	64	120	241
31	2022	1	24	4:37	12:06	19:34	14:57	64	119	241
32	2022	1	25	4:38	12:06	19:33	14:55	63	119	242
33	2022	1	26	4:40	12:06	19:32	14:52	63	118	242

Figure 7

Observing and recording the phases of the Moon every day for a month is a relatively easy project to do in an elementary or high-school classroom. Studying the seasons using a similar approach of observation, data analysis, and modelling faces a major difficulty: the seasons take place over a full year and the daily changes are too subtle to be easily noticed by students. A relatively simple solution to this problem is to provide students with all the data they will need to analyze the seasonal changes and draw conclusions that will then be modelled.

Personally, I use a powerful astronomy program called *Coelix*[3], developed by Jean Vallières, a Québec amateur astronomer, to produce daily ephemerides of the Sun for Montréal for an entire year, which I then export to an Excel spreadsheet (see Figures 6 and 7 above).

I use the same software to produce ephemerides for the city of Coihaique, Chile, located at approximately the same longitude and latitude as Montréal, but in the Southern Hemisphere (Excel table on the right above). Coihaique thus provides a "mirror image" of Montréal, as far as seasons are concerned. I provide this data to my university students along with a handout that details the very contrasting seasonal climate data for the two cities, which illustrates the fact that the seasons are reversed from one hemisphere to the other.

Using an analysis worksheet that I prepared for my students, they are asked to answer a series of questions that require them to graphically compare the annual variation in sunrise and sunset times between Montréal and Coihaique, as well as the length of daylight and the height of the Sun at noon. They must also draw the apparent path of the Sun above the horizon (south in Montréal and north in Chile) on solstice and equinox days (see figures below).

Such an exercise serves two purposes: First, it familiarizes students with the aspect of seasonal variations (apparent motion of the Sun in the sky) from a geocentric perspective (e.g. the view from Earth) in both hemispheres. As Plummer (2017) writes, "beginning with [student's] own Earth-based observations of celestial phenomena is an important foundation for their understanding of astronomy; they must first develop an understanding of astronomical phenomena before later learning how to explain those observations" (p. 189). The second goal is to convince students of the marked differences in the seasons from one hemisphere to the other, especially in the apparent motions of the Sun as seen from each hemisphere.

The modelling step can take many forms. In my classes, I use a large Earth globe tilted at 23.5 degrees and mounted on wheels to move around a bare light bulb in a dark room. Then I use my phone as a video camera: by sticking the phone on the globe at the positions of Montréal and Coihaique, I can project on a screen an image showing the difference in the height of the mid-day Sun as seen in both hemispheres. I also task my students to build their own model with a small flashlight and a ping pong ball as a diffuser (to represent the Sun) and a Styrofoam ball tilted 23.5 degrees to represent the Earth, on which two pins are stuck, one for Montréal and one for Coihaique (see figure 13).

Using this model, students working in pairs can explore the connections between the tilt of the Earth's rotational axis and the apparent movements of the Sun from both hemispheres from season to season. As with the lunar phases, using a concrete, manipulable model that offers an allocentric view (i.e. the view from space, see Chastenay, 2016) of the system under study helps students reconcile what is seen from the Earth's surface (geocentric view) with the positions of the astronomical objects in space.

Astronomy is indeed a "spatial" science, not only because astronomical objects exist and move in three-dimensional

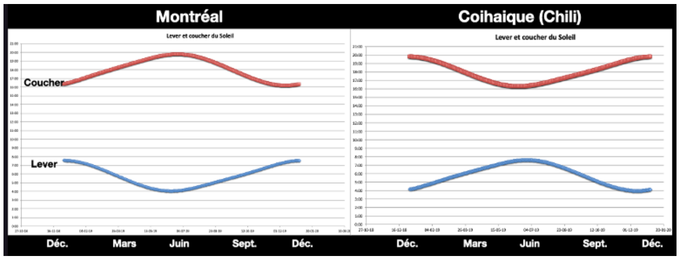


Figure 8

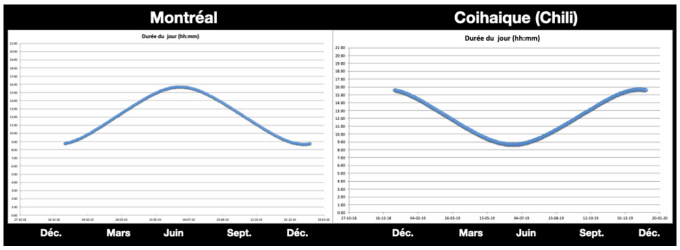


Figure 9

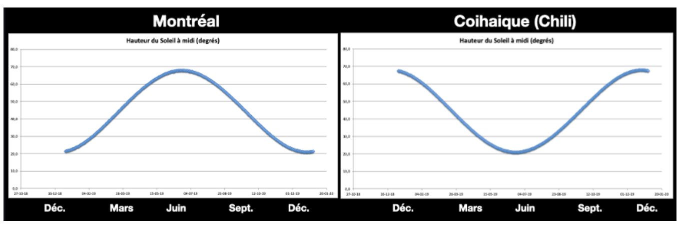


Figure 10

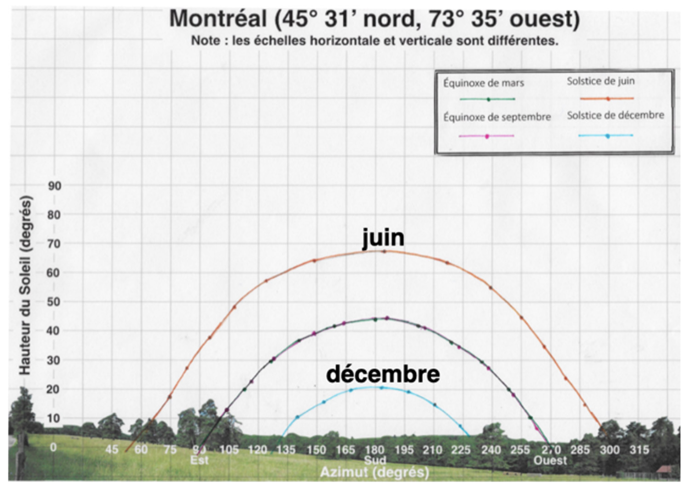


Figure 11

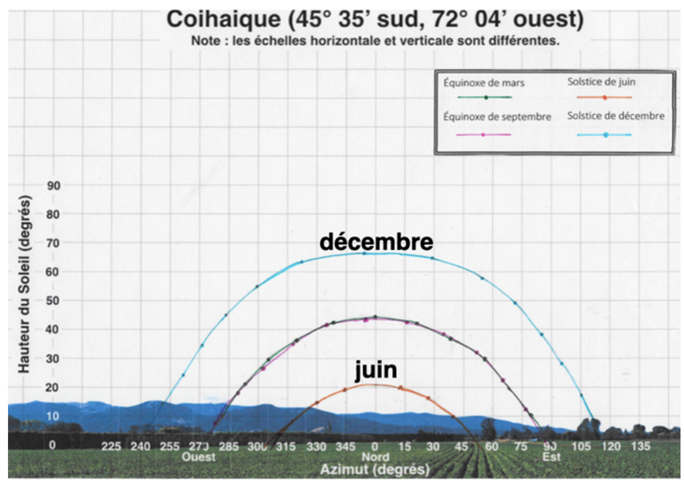


Figure 12

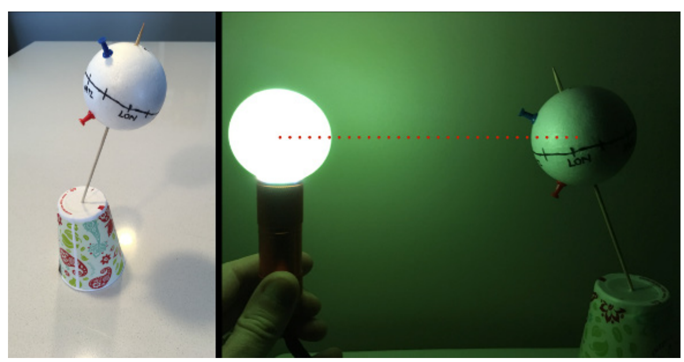


Figure 13

space, but also because understanding basic astronomical concepts, such as the diurnal cycle, phases of the Moon, eclipses, seasons, or the apparent motion of the planets in the sky, requires the ability to move from one frame of reference to another (Heywood, Parker, & Rowlands, 2013; Plummer & Maynard, 2014; Subramaniam & Padalkar, 2009), particularly from the geocentric viewpoint to the view from space. As pointed out by Sadler (1992), "without the ability to imagine what objects look like from different perspectives, students will find many astronomical concepts virtually impossible to learn" (p. 103).

Fortunately, spatial skills, including perspective-taking, can be learned (Plummer et al., 2022) and should in fact be specifically taught in school, as their importance in various STEM fields, like physics, architecture, engineering, chemistry, etc., has been frequently demonstrated (Newcombe, 2017). Astronomy education can certainly play a role in promoting spatial skills in students. On the other hand, since perspective-taking skills seem to predict a student's ability to explain astronomical phenomena, Plummer, Bower, and Liben (2016) recommend that "science educators foster this type of reasoning and provide children who have low perspective-taking skills with additional spatial aids, such as simulations showing the Earth-based perspective and physical models to support explanations" (p. 362).

My research to date shows that the observational and modelling approach that I detailed above is superior to the use of textbooks for learning basic astronomical concepts. With pre-service and in-service teachers, this approach also has a large positive effect on their own perceived self-efficacy in understanding astronomical topics and teaching them to their students. Much work remains to be done to refine and validate the approach I advocate in this text for teaching astronomy. But "Doing astronomy like astronomers do" seems to be a good way to get teachers out of the textbooks and to make student learning of astronomy more concrete, more interesting, and more like the work that scientists themselves do on a daily basis. ✶

Endnotes

1 www.stellarium.org
2 www.scratch.mit.edu
3 www.ngc7000.com/en/coelix/index.htm

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Blast From the Past

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

Due to the age of the articles, which are converted with OCR software, there are bound to be minor errors. These articles don't follow the current Style Guide. The main thing, though, is the content from a previous era.

Memories of the Plaskett Era of the Dominion Astrophysical Observatory, 1931-1934

By Helen Sawyer Hogg
David Dunlap Observatory, University of Toronto

Originally published 1988 September 8

Abstract

The author describes the Dominion Astrophysical Observatory during the years when J.S. Plaskett was Director. She makes special reference to the work on galactic rotation by Plaskett and J. A. Pearce and to her own early work on variable stars in globular clusters.

On a late August afternoon in 1931, my husband Frank and I chugged up the hill of the Dominion Astrophysical Observatory about ten miles north of the centre of Victoria, B.C. We went way to the top of the hill in our Model A Ford Coupe named "Wishbone" (Harper, 1932). The namesake bone, which dangled just above the windshield, came from the first chicken I had cooked after we were married. In "Wishbone" we had just finished driving from the Atlantic to the Pacific over stretches of the Trans-Continental Highway not yet completed, in mountain passes where workmen told us just to drive across pastures, trying to avoid as many boulders as possible till we connected with the road again.

At the top of the Observatory Hill we received a warm welcome from Dr. J.S. Plaskett and his wife Rebecca Hope Hemley, whom he called Reba. In the first of a long series of abundant hospitalities which they showered on us throughout our years at the Observatory, Mrs. Plaskett immediately invited us to return for dinner with them a couple of hours later. The Plasketts' home was beautifully furnished and meticulously kept with the help of a live-in maid, Barbara, who put in long hours as was customary for domestic help in those days. We had many visits with them, both at the Director's residence and at their seaside home for retirement in Esquimalt. Frequently the Plasketts' son Stuart would join us.

I think we did not quite realize at the time that our years with Dr. Plaskett at the Dominion Astrophysical Observatory were at the very summit of his career. An inspection of the invaluable bibliography of Plaskett papers, published soon after his death by C.S. Beals, R.M. Petrie and K.O. Wright (1941) as a supplement to his obituary (Beals 1941), shows a miscellany of papers on radial velocities, spectroscopic binaries and astronomical equipment, until 1928. In that year the accumulated radial velocities were beginning to bring widespread results on the rotation of the Galaxy. From then through 1934 with one more in 1938, 16 papers appeared related to this subject. In about half of these, J.A. Pearce collaborated.

The paper which seems to have alerted the astronomical world to the important work going on at Victoria was that by Plaskett (1928). In this, "The Rotation of the Galaxy", Plaskett seized on recent work by B. Lindblad (1927) on a theory of the rotation of the galactic system which explained the observed stream and other radial velocities in that system. Plaskett noted that the theory of galactic rotation had been placed on a firmer basis by J.H. Oort (1927) with radial velocities of distant stars and by J. Schilt (1927) using proper motions. He then proceeded to apply Oort's method to velocities of fainter O- and B-type stars under investigation by Pearce and himself, brighter than visual magnitude 7.5 and north of declination ~21°. Final velocities were then available for 250 stars, and probable velocities for 140 more. Plaskett concludes that "The probability of galactic rotation seems to be materially increased by the analysis of the fainter B- and O-type stars".

By 1930 the velocities for most of the stars under investigation had become final, and the importance of the interstellar H and K lines of calcium with their confirmation of galactic rotation, had come into the picture, as discussed by Plaskett (1930a) in his presentation to the American Philosophical Society, by Plaskett and Pearce (1930) and again by Plaskett (1930b) in his George Darwin lecture. The whole massive work with a preface and four papers by J.S. Plaskett and J.A. Pearce (1935) is gathered together in one volume, No. 5, of the Publications of the Dominion Astrophysical Observatory.

It is not surprising that the name of J.A. Pearce appeared on many of the galactic-rotation papers. He joined the staff in 1924 and received his doctorate from the University of California in 1930. He was a most indefatigable observer, full of enthusiasm and imagination for a project. In 1940 he became the third Director of the Dominion Astrophysical Observatory, and in 1949 the second, and last to date, astronomer to be President of the Royal Society of Canada. Still full of reminiscences of those days, he lived at Glengarry Hospital in Victoria, with his wife Betty, until a few days after these reminiscences were completed.

Other staff members then were W.E. Harper, who became the second Director, C.S. Beals, who became the Dominion Astronomer, S.N. Hill, Tom Hutchinson, the Night-Assistant, and Miss Lora Blake, the pleasant Secretary-Librarian.

Frank had had considerable experience in photography with telescopes, including spectrographic work in the yard of Harvard College Observatory in Cambridge, Massachusetts, and observations with the large 18-inch refractor at Amherst College. His experience with a big reflecting telescope came in the summer of 1930, just before we were married, when he used the 60-inch at the Mount Wilson Observatory to determine the distribution of light in six globular clusters. (Hogg 1932a). In addition to routine velocity work at D.A.O., Frank had a research problem on Z Andromedae, which had been suggested to him by Professor H.H. Plaskett at Harvard, the son of Dr. J.S., and which proved to be a very difficult one, really beyond the state of the art at the time. The recent excellent book *The Symbiotic Stars* by S.J. Kenyon (1986) of the Harvard-Smithsonian Center for Astrophysics refers to two papers Frank published about this star (Hogg, 1932b, 1934). Frank's work is also mentioned in the comprehensive review of Kenyon's book by George Wallerstein (1988) of the University of Washington.

My doctoral thesis at the Harvard College Observatory in 1931 was based on plates already in the Harvard collection. My own telescope experience had been largely limited to the use of the superb 8-inch Alvan Clark refractor at Mount Holyoke College. Photography with an instrument the size of the 72-inch was a totally new experience for me. It had been many years since this telescope had been used briefly at the Newtonian focus to take some direct photographs of a few objects for show purposes. Several weeks were necessary to get the instrument prepared for Newtonian work when the next moon dark came. Both Tom Hutchinson and Frank were on hand to help when I took my first globular cluster plates on September 22, 1931 (Sawyer Hogg, 1973). A routine soon developed whereby I stayed all night at the top of the dome and after each exposure, let the plate holder down in an old leather handbag to the observers on the floor below, who swiftly in the darkroom replaced the exposed plate with a fresh one, and I hauled the bag up again.

Figure 1 – (1865–1941) J.S. Plaskett played a pivotal role in the establishment of astrophysical research in Canada and helped to confirm the rotation rate of the Milky Way. He was an active member of the Ottawa Centre between 1907 and 1918, acted as an Associate Editor of the Journal for 28 years, and Society President (1914–15).

The globular clusters I was working on conveniently disappeared from reach of the telescope after October. I use the word "conveniently" because I would have found observing at the top of the dome in the very long winter nights extremely difficult. That first year I did go to the Observatory with Frank on the nights he was observing throughout the winter, but I could retreat into the warm room with bed on the first floor for rest periods.

I was the first woman to be given the use of the 72-inch telescope (Sawyer Hogg, 1980). Strangely, it was only a few years ago, when I first read the fascinating autobiography of Cecilia Payne-Gaposchkin edited by her daughter, Katharine Haramundanis (1984) that I learned from the historical introduction by Peggy A. Kidwell of the story behind the scenes here.

In 1924 Plaskett wrote to Henry Norris Russell asking for a recommendation for an open position at D.A.O. Russell noted that "Quite the best of the young folks" in astrophysics was Cecilia Payne. Plaskett responded that "there would be difficulty about the observing end of it with a woman in this isolated place and 1 think we can hardly consider her". Not till I read this statement did I realize that my superb observing privileges with the 72-inch reflector had been made possible by the automatic presence of a built-in chaperone, my husband.

In June, 1932 a second woman came to use the big telescope. Miss A. Vibert Douglas of McGill University, later of Queen's

University, came with Dr. J. Stuart Foster for a study of the Stark effect (Harper, 1932), remaining for a month. I was away from night observing because of the birth of our daughter Sally on June 20, 1932, but resumed it on July 27. As I was nursing her, this meant that she had to come to the dome with us for the night, which resulted in some world-wide publicity because the Astronomer Royal of England, Sir Frank Dyson, paid a visit to the dome. A jovial individual and traveller and a great story teller, Dyson loved to tell how, as he mounted the stairs to the observing floor of the dome, he heard a whimpering and exclaimed "What's that?" and Dr. Plaskett calmly replied, "Oh, that's the Hoggs' baby in its basket on the platform by the pier". The story has come back to me in various forms, including one in which I was said to let the baby in her basket down on a rope from the Newtonian platform.

Of course during my first year at D.A.O. I had not secured enough plates there for any completed research. In one paper in my doctoral thesis at Harvard, (Sawyer, 1932a) I had found a strange distribution of periods of Cepheids in the globular cluster NGC 362, in the optical region of the Small Magellanic Cloud. This anomaly was worth pursuing, and before I left the east I had measured more of the 14-inch by 17-inch Bruce plates from the southern hemisphere on the outskirts of the Cloud, between it and the cluster. So in my first year at D.A.O. I worked up the periods of the variables in this region and found an abundance of very short- period Cepheids (Sawyer, 1932b).

By the autumn of 1932 I did have enough plates to start hunting for variables by comparing positive and negative plates. And to start determining periods in the globular cluster Messier 2 in Aquarius, in which a bright variable discovered by the French astronomer Chèvremont, (1898) had a curiously long period that baffled everyone, including the eager Cecilia Payne. Though from the beginning of our work in Victoria I knew that Dr. Plaskett could offer me no money because of a Government of Canada restriction that husband and wife could not both be employed in the depression years, he did find a way to pay me a little. He had received a research grant of $200 from the Gould Fund of the National Academy of Sciences, Washington, D.C., and this, he said, he was free to turn over to me for a year's work. (I then had a doctorate and one-and-a-half year's experience teaching at the college level.) I was pleased to accept the money because it just nicely paid for a full-time, live-in maid Lily, a lovely 17-year old, who took excellent care of the baby and the house.

Before we left Victoria, I had taken several hundred plates of globular clusters. In those days we were using slow Seed photographic emulsions, and exposure times of 30 minutes or more for my clusters averaged at least twice as long as they did a few years later. The periods of the variables in Messier 2 (Sawyer, 1935) and the discovery of 132 new variable stars in five globular clusters (Sawyer, 1938) appeared in the Observatory Publications.

An extracurricular activity of two staff members in 1933, which Harper apparently considered unworthy of mention in his regular Observatory Notes, stands out in my mind. The mountains near the coast of both Canada and the United States have always had great appeal for residents of the Victoria region. These mountains include both the coast ranges and the isolated volcanic peaks. The most distant of the peaks, Mount Rainier, 140 miles away in the state of Washington, is visible only occasionally. In the spring of 1933, Frank and C.S. Beals developed a project to try to photograph Mount Rainier from the Observatory, using a Zeiss lens of 39-inches focal length, newly acquired for one of the Observatory's spectrographs, with a deep-red filter and a panchromatic plate. Their efforts met with success on July 14, 1933 with probably the first picture ever taken of Mount Rainier from Victoria. The front page of the Victoria newspaper, the Daily Colonist for Wednesday, August 2, 1933 carried the picture with an 8-line caption. The photograph was also published in the London Sunday Times.

In the spring of 1934 Frank received an invitation from Dr. C.A. Chant, Chairman of the Department of Astronomy at the University of Toronto, to return to that University in 1935 as a staff member of the Department. Chant was augmenting the staff in preparation for the opening of the David Dunlap Observatory that year, with a reflecting telescope similar in design to that of the 72-inch, and two inches larger in aperture, making it the largest telescope in Canada and the second largest in the world. Frank had some weeks to make the decision and it was a painful one, as had been his decision three years earlier to decline an appointment to the staff of Harvard University in favour of one at the Dominion Astrophysical Observatory. Frank accepted Chant's invitation and we prepared to make 1934 our last year in the west.

One of the most memorable events of that year was the forest fire which threatened the Observatory for some hours in August, 1934. An account of the fire was given by W.E. Harper, (1935) the Assistant Director, in his regular feature Notes from the Dominion Astrophysical Observatory:

> During the few days from the 22nd to the 26th of August the weather was quite hot for Victoria, with the result that the fire hazard increased greatly. From an unknown cause a fire broke out on the main road passing the observatory property on the afternoon of August 24 and in a few minutes spread rapidly over the observatory property. The few of the staff who were present managed to protect the buildings until help arrived. A call was put in to the officer commanding the Work Point barracks, ten miles away, and General Ashton rushed a couple of hundred men out and in a few hours the fire was surrounded and under control. A ghastly-looking western slope of some 40 or 50 acres is the final outcome and doubtless seeing conditions will suffer in consequence.
>
> Recognizing the inadequacy of the present fire protection, the Public Works Department is spending considerable money in

> bringing the city water from its present terminus, a couple of miles distant, and erecting a large reservoir on the top of the hill by which it is hoped to avoid a recurrence of August last. The contract has also been let for clearing off the burned-over area and a number of other improvements are under way as well.

Harper's account does not fully convey the frantic efforts of the few members of the Observatory staff as they struggled to fight back the flames swirling up the mountainside and crackling in the tops of the great Douglas fir trees. Nor does it mention the panic of these firefighters when they discovered that most of the available fire hoses did not fit the sockets of the fire hydrants. There was a mighty struggle to pull hoses over the mountain-top to try to find a hydrant which fitted. Hastily called for the crisis, the military arrived both in civilian dress and in uniforms. My husband Frank spotted an individual standing seemingly aloof from the turmoil and tugging, and shouted to him, "Hey, you! Don't just stand there! Give us a hand with this hose!!" Frank was slightly taken aback when he learned that the person he had thus addressed was the Commander of the Unit, General Ashton. As Harper indicated, a result of the fire was that fire protection on the mountain top was enormously improved, and, I will add, the fire hoses then fitted the hydrants.

In the same compilation of Notes in which he described the fire, Harper also told of the departure of the Hogg family for Toronto, and of the retirement of Dr. J.S. Plaskett;

> Dr. Frank S. Hogg of our staff resigned to accept a lectureship in the University of Toronto, and with Mrs. Hogg and "Sally" left for his new field of labour on December 16. The staff took note of his leaving by presenting him with a beautiful drawing set. The local centre of the Astronomical Society also tendered a complimentary dinner to Dr. and Mrs. Hogg a few evenings before their departure. Our loss is Toronto's gain.
>
> Dr. I.S. Plaskett, who has been the director of the observatory since its beginning in 1917, made application to the Department in September to be granted retirement, effective January 31, 1935*. He plans to spend six months in England and with Mrs. Plaskett and Stuart leaves on January 19, going by way of the Panama canal. Dr. Plaskett's name appeared in the New Year's list of honours, being made a C.B.E. (Commander of the British Empire). The Canadian Club of the city tendered him a complimentary dinner on January 11, at which he spoke briefly of his recent researches. The staff also took occasion to tender its best wishes for a pleasant future and presented him with a beautiful desk set. A fuller notice of his work will appear later.

Frank and I said goodbye to Dr. and Mrs. Plaskett in the privacy of their home on the hill, after another of the cozy dinners there. It was a sad parting, with Dr. Plaskett's kindliness and concern for us most apparent. The four of us realized fully that we had come to the end of an era. Dr. Plaskett died on October 17, 1941. And, as told by F.S. Hogg (1943) Mrs. Plaskett used the gold from his medals to provide beautiful stained glass windows in his memory in their church, St. John's, Victoria, where Dr. Plaskett had played a prominent part in the Church of England (see p. 326).

Epilogue. Frank began his work at the University of Toronto on January 2, 1935 and I began my volunteer work there a month later, having been occupied in January with establishing a home in the east after the Trans-Continental move. On January 1, 1951 Frank died suddenly, having completed exactly five years as Director of the David Dunlap Observatory and Chairman of the Department of Astronomy of the University. (Chant, 1951). His heart had been damaged by rheumatic fever in childhood.

More than two decades elapsed before my first return to Victoria, in August, 1956, for the National Science Foundation conference on binary stars. This was organized by the Director, Dr. R.M. Petrie (1957) and sponsored by the Foundation, Washington, D.C., while I was its second Program Director for Astronomy, on leave of absence from the University where I had been on its staff from 1936. I have returned many times since then to the warm and friendly atmosphere and beautiful scenery which first greeted me. Now, at 83, 54 years later, I am Professor Emeritus and still working at the David Dunlap Observatory part-time.

And Sally is a grandmother now. ✶

Acknowledgments

I am grateful to Dr. F. Marguerite Hill of Women's College Hospital, Toronto, whose medical skill has enabled me in recent years to continue my soul-satisfying astronomical work. And I am especially pleased to have an article in the last issue of this JOURNAL to be edited by our remarkably able and perspective Alan Batten.

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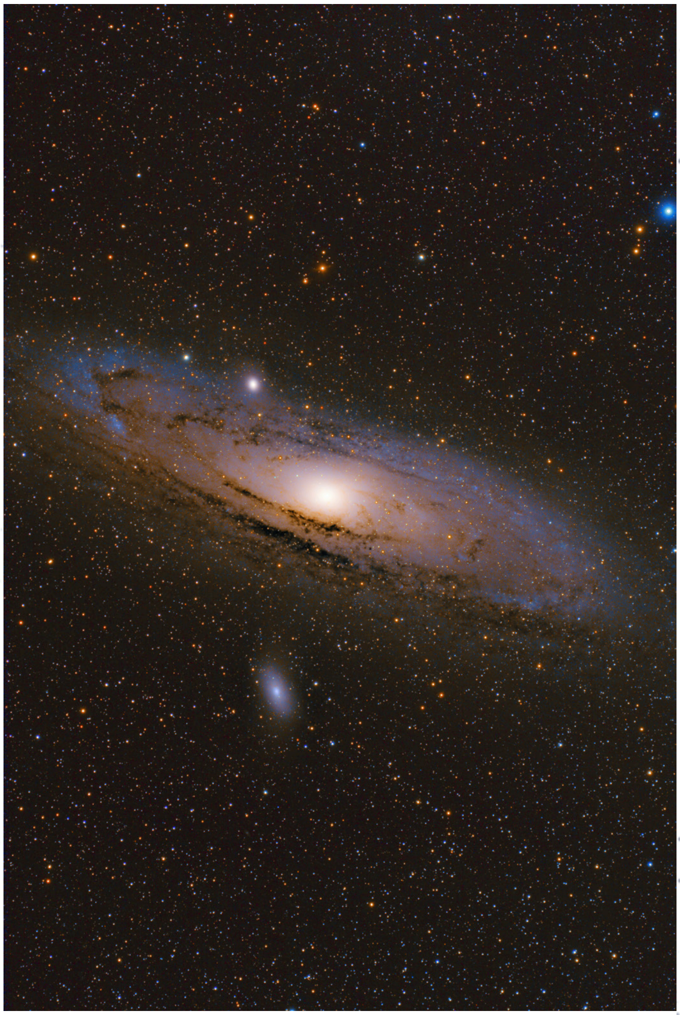

Figure 1 — Andromeda (M31), our nearest spiral galaxy, is seen here in an image by Tammy Foley. She captured it from Norfolk County, Ontario, near the shores of Lake Erie under Bortle 5 skies.

Tammy says, "M31 was one of the first deep-space objects I fell in love with when my astrophotography journey began just a few years ago, using just a DSLR and a tripod." She used a ZWO Redcat 51 (250mm fl), ZWO ASI183MC Pro, an L-pro filter, mounted on a EQ6-Pro. Capturing software was a combination of ASIAIR Pro & NINA/PHD2. It is a combination of 30-second and 120-second exposures, for a total of approximately 10 hours. All processing was done in PixInsight.

Figure 2 — The Rosette Nebula is a favourite of many astrophotographers, and Katelyn Beecroft did an amazing job capturing its magnificence in a false SHO palette. She used an Askar FRA400 and ASI533MC camera on A Sky-Watcher HEQ5 mount. She used the L-Extreme filter for most of the exposure (8h 5min) with an additional hour using the Astronomik L3 filter to get the RGB stars in the image. She also used an ZWO 30-mm guidescope and ASI1 20-mm camera, along with the ZWO Electronic Automatic Focuser, and the ASI Air Plus. The final image was processed using PixInsight. *Of the final image, she says, "I really love the depth you can see in the Rosette along with all of the Bok Globules that will one day coalesce into stars."*

Figure 3 — Steve Leonard says that one of his favourite regions in the sky is the core of the Heart Nebula, which includes Melotte 15. "Some dark features … remind me of the dementors from the Harry Potter movies," he says. His image of the region was taken with 3-nm SHO filters from Markham, Ontario, (Bortle 8/9) and was processed as a composite of SHO and Forax palettes. Steve used an AstroTech AT115EDT 4.5″ triplet refractor at ƒ/5.6 on an HEQ5 mount using NINA, an ASI 1600MM Pro camera, and Chroma 3-nm Hα-OIII-SII filters. The final image was processed in PixInsight, *for a total of 8 hrs Hα, 1.5 hrs OIII, 2 hrs SII.*

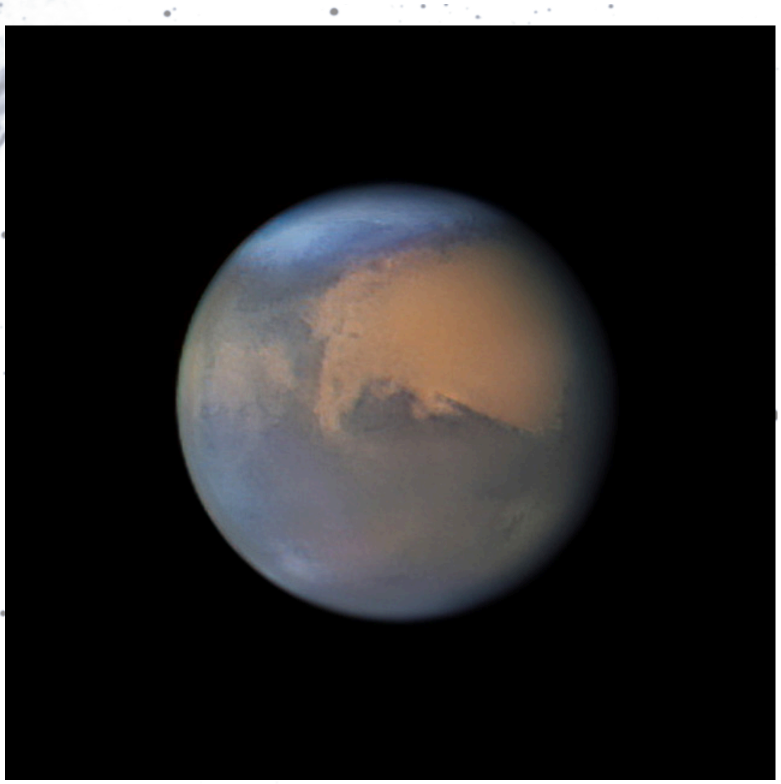

Figure 4 — This magnificent image of Mars, the god of war, was taken by Shakeel Anwar a week before closest approach in 2022. He used a Celestron 11-inch SCT, a ZWO ASI224MC camera and 2.5× Powermate. Four images were derotated in Winjupos *and processed in* Photoshop *to produce the final image. Shakeel says, "Multiple surface details are visible including the white polar cap, wispy water-ice clouds in the southern hemisphere, Terra Meridiani in the centre of the planet, and Hellas Basin setting in the lower right."*

Goodbye to an Astronomical Giant: Terence Dickinson (1943–2023)

by Alan Dyer, Calgary Centre
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Terence Dickinson, founding editor of *SkyNews* and author of numerous popular books on astronomy, passed away February 1, 2023, at age 79 after a long battle with Parkinson's.

In the early 1990s, he took over the writing of a small publication called *SkyNews* from then editor Mary Grey. *SkyNews* was a newsletter being put out by the National Museum of Science and Technology in Ottawa. In 1995, Terry expanded the publication into a glossy and commercial magazine, which continued to be published by the museum until 1999. That year he and business partner Greg Keilty took over ownership of the magazine and published it until 2016.

Terry knew his condition would deteriorate to the point he would not be able to carry on the work of publishing the magazine. So, in 2016, he and Greg sold it to The Royal Astronomical Society of Canada, under the editorship of Gary Seronik. Terry continued to contribute guest columns to *SkyNews* until that, too, became impossible.

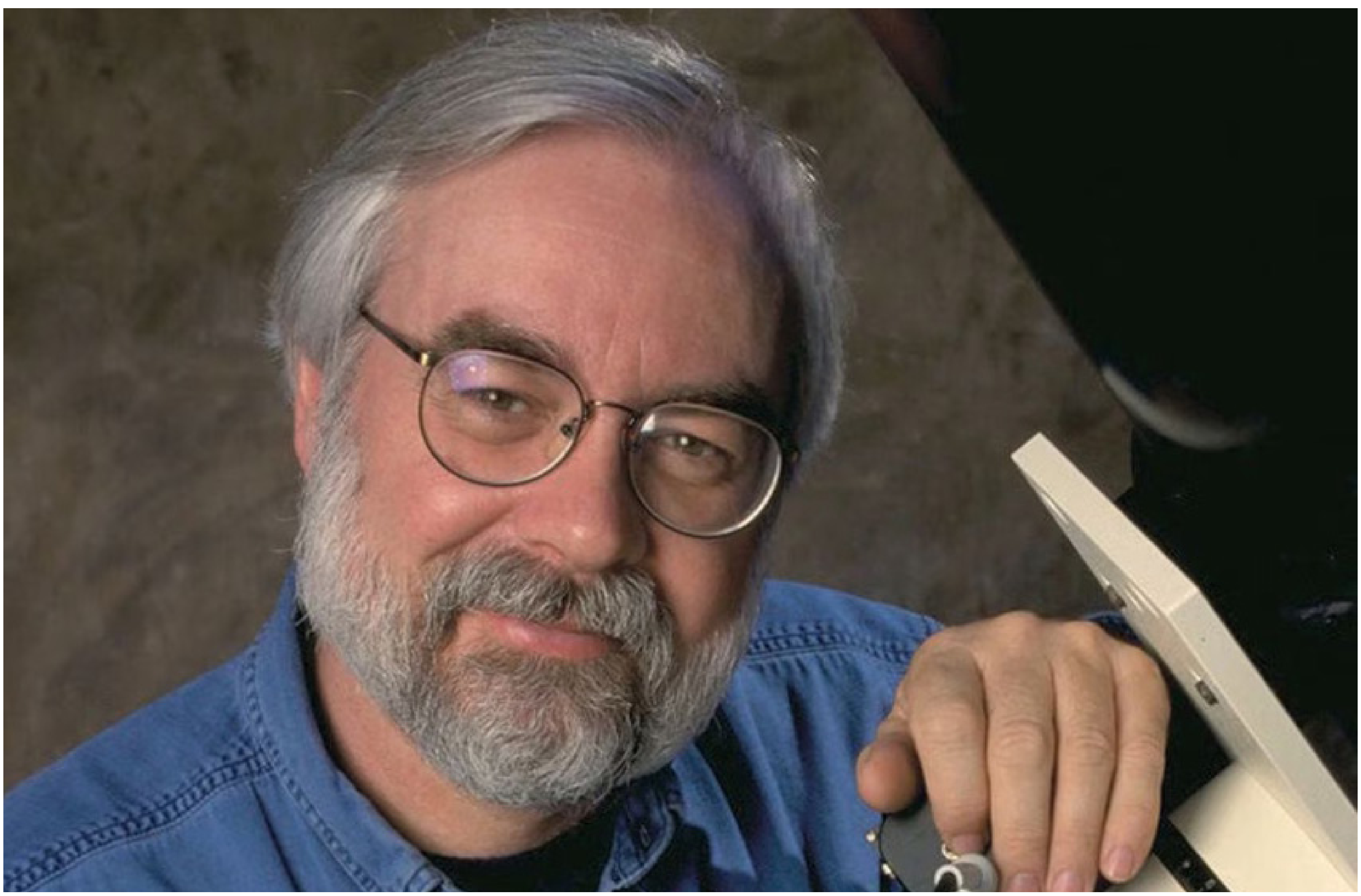
Terry is perhaps best known in the amateur astronomy world as the author of *NightWatch: A Practical Guide to Viewing the Universe*, a book that has helped tens of thousands of people get started in the hobby of amateur astronomy. It has been in print through several editions for forty years.

Terry also authored many other popular books, including *The Universe and Beyond*, *Hubble's Universe*, and *The Backyard Astronomer's Guide*, co-authored with Alan Dyer.

Terry's interest in astronomy began when he was only five years old, when he saw a meteor streak across the sky. His professional career began in 1968 when he became a staff astronomer and teacher at Toronto's McLaughlin Planetarium of the Royal Ontario Museum. In 1970, he became assistant director of the trendsetting Strasenburgh Planetarium in Rochester, New York.

He then served as the executive editor of the then new *Astronomy* magazine in 1974 and 1975, a publication celebrating its 50th anniversary this year.

Those in southern Ontario will remember that from 1981 until the mid–2000s, Terry wrote a weekly astronomy column for *The Toronto Star* newspaper, taking over the popular "With the Stars" column from author and legendary Canadian astronomer, Helen Sawyer Hogg, who wrote the column for 30 years until 1981.



Another of Terry's regular platforms for promoting astronomy was television, through his frequent appearances in the late 1990s and early 2000s on Canada's Discovery Channel.

For his work at popularizing astronomy in Canada and around the world, Terry received many awards and accolades. Among them are the New York Academy of Sciences' Children's Book of the Year (1988), the Royal Canadian Institute's Sandford Fleming Medal (1992), Industry Canada's Michael Smith Award for Public Promotion of Science (1993), and the Astronomical Society of the Pacific's Klumpke-Roberts Award (1996). He was the recipient of honorary degrees from Trent University and Queen's University. In 1995, he was invested as a Member of the Order of Canada for his contributions to public understanding of astronomy.

In 1994, asteroid #5272 was officially named Dickinson in his honour by the International Astronomical Union.

Terence Dickinson's ability to explain the Universe and simplify astronomical concepts in ways easily understood by the average reader has gained him a huge international audience. Thousands of people have developed an interest in astronomy and the wonders of the Universe because of his work. RASC members will surely remember his inspiring talks to the public and delegates at RASC General Assemblies and at star parties, such as Starfest, where he was a regular speaker for many years. An example recorded at the 1990 RASC GA, entitled "Naturalists of the Night," one of Terry's trademark phrases, is archived at the RASC's YouTube channel at

youtu.be/DE-UX-sKvaE.

His love for astronomy was infectious, as anyone who attended one of his wonderful lectures will attest. He once said, "I want to do what I'm doing for as long as I can. There's just so much more to know and see, and I'm still excited as a kid about new discoveries. I'll never run out of things to write about—I'll just run out of time."

His wife Susan, who served as Terry's business partner in many book and magazine projects, has written: "He loved getting up each morning because every day, he lived and breathed his passion. So captivated was he by the cosmos that he made it his mission to endeavour, through his writings, his astrophotography, and his lectures, to impart some of his awe and appreciation of the universe to others.

"Although he was physically tethered to this planet, his mind soared among the stars, and the time he spent gazing skyward from a dark country site brought him peace and serenity. Now he's at one with the universe that enchanted him for a lifetime."

There was no memorial service. His ashes were to be spread under the dark skies he loved so much. Condolences to the family can be left at the Wartman Funeral Home website at www.wartmanfuneralhomes.com/memorials/reginald-dickinson/5131548/index.php ✶

Skyward

Back to the Moon and Comets

by David Levy, Kingston & Montréal Centre

I shouldn't have been surprised by the complete success of the *Artemis* mission last fall. NASA's A-team of engineers really know what they are doing. The mission was fun to watch, particularly the brilliant light when the main engines lit up. It also provided some hope that we may actually return to the Moon someday soon.

But somehow, it isn't the same. Something is missing.

For those of us who were alive and young in 1961, do you remember President Kennedy's poignant speech to Congress on 1961 May 25, when he asked the nation to commit itself to landing a person on the Moon? Only three days after my 13th birthday, this was a call I heard distinctly. I did miss the fact that this was the second of three speeches. The first call was during his inaugural address: "Let both sides seek to invoke the wonders of science, instead of its terrors. Together let us explore the stars…" And at Rice University he gave his third: "We choose to go to the Moon."

On August 25 of the summer of 1961, I observed a 99.2-percent partial eclipse of the Moon in which the shadow of the Earth covered almost all of the Moon. I remember, a few years later, setting up my first telescope, Echo, across the street to time the Moon passing in front of a star, and explaining to a priest who was passing by that what I was doing might actually assist the Moon mission planning. Or not.

I have already written about where I was on 1969 July 20, during that emotional moonwalk. I listened attentively as the astronauts on *Apollo 13* somehow managed to return safely home after a near disaster. And I watched the interminable countdown hold when, on 1972 December 6, the countdown was stopped just 30 seconds before launch. About two hours later the launch was completely successful, and the program's only geologist, Jack Schmidt, conducted a field excursion 386,000 kilometres from Earth, in the Taurus–Littrow valley of the Moon's southern highlands.

"I was enormously pleased and proud of Jack," recalled his teacher Gene Shoemaker, "but I was also wistful. There but for a failed adrenal gland, went I." Because of Addison's disease, Shoemaker never made it to the Moon, at least not in life. After he died in 1997, some of his ashes landed on the Moon aboard Lunar Prospector.

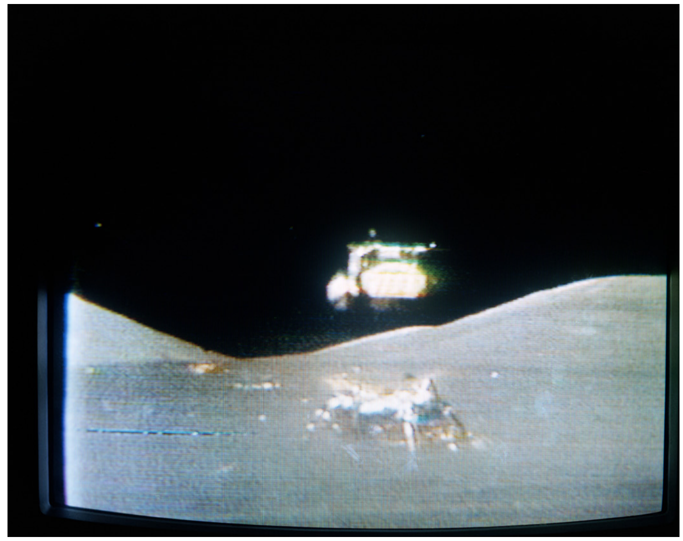


Figure 1 — The liftoff of Apollo 17 *from the Moon on 1972 December 7. (NASA)*

In the 1960s, I used the Apollo project to intensify my own passion for observing the Moon through telescopes and binoculars. In 1961, Kennedy set the goal. Eight years later, humans walked the lunar surface in one of the high points of human civilization. That passion I carry to this day. I still enjoy watching the Moon, looking at its well-known craters and mountain ranges. The Moon is not just a thing in the sky. It is a place. Twelve people have walked across its surface, and with luck, more people will someday stroll across its surface.

I will never walk on the Moon. But through my telescope, I shall continue to view the Moon from southern Arizona. And when my eye touches the eyepiece of my telescope, I will be as close to the Moon as I ever hope to get.

Of comets, more comets, and Fritz Zwicky

Since October 1965, when I spotted my first comet—Comet Ikeya-Seki—I have seen 227 different comets. Near the dawn of my passion for the night sky, watching that mighty comet rise, almost right out of the St. Lawrence River, was a sight I shall never forget. The two most recent comets I have seen share the same name: they are both called Comet ZTF for Zwicky Transient Facility. This project uses a new camera that offers a very wide field of view. The camera is attached to the large 48-inch Samuel Oschin Schmidt camera at Palomar.

This project has a rich history. It is loosely named for astronomer Fritz Zwicky, one of the founding astronomers at Palomar, and one of the foremost scientists of the last century. He developed not the big Schmidt but the original smaller 18-inch Schmidt camera, the very first telescope atop that mountain. Since this project is named after Zwicky, why are its comets called "ZTF" instead of just Zwicky? It is because the comets are named for the project, not the man.

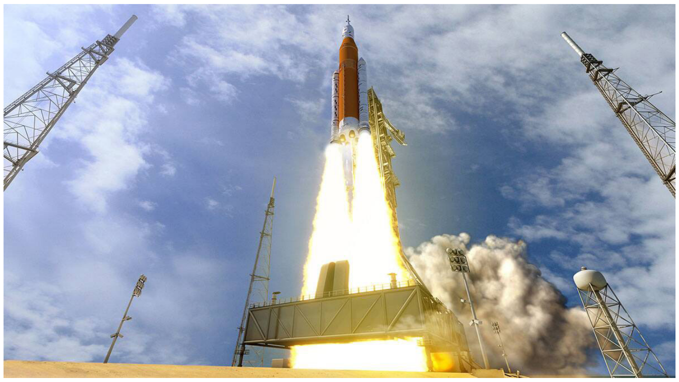


Figure 2 — The launch of Artemis 1 *on 2022 November 16. (NASA)*

The historical Zwicky actually had little interest in comets. His career leaned toward the big questions of cosmology, the study of the large-scale issues of the Universe. But he was the first regular user of Palomar's 18-inch Schmidt camera, the telescope Gene and Carolyn Shoemaker and I used to discover our comets, including the one that collided with Jupiter in 1994. That in itself was a tribute to Zwicky, for it offered insights into how comet impacts contributed to the origin of life on different worlds. Zwicky was not into comets, but he was deeply concerned with the distant explosions of massive stars that he and colleague Walter Baade called supernovae. When he began using the 18-inch, there were 12 known supernovae. He discovered 121 supernovae with the telescope, 120 by himself and one with Paul Wild.

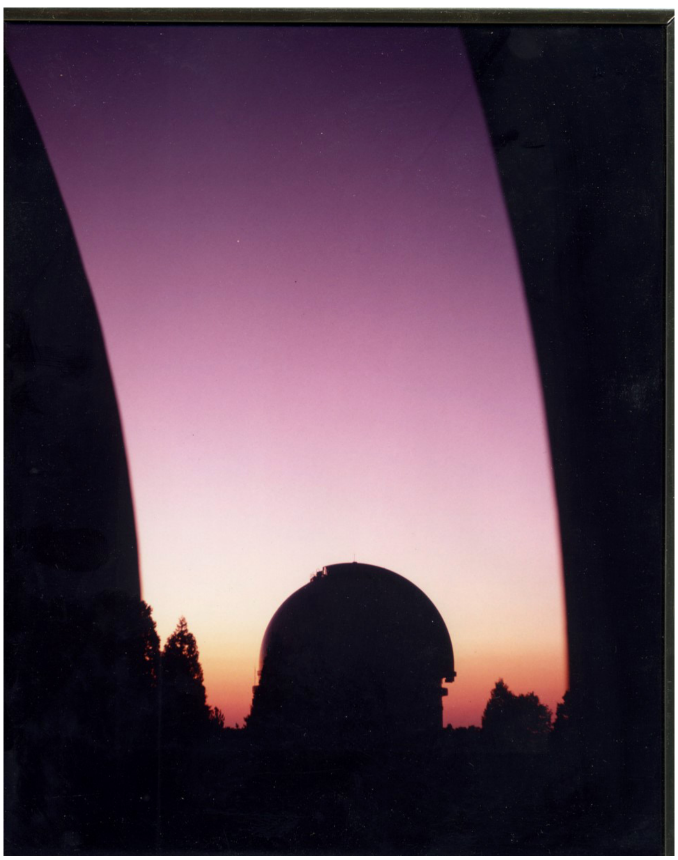


Figure 3 — The 200-inch dome at Palomar at sunset, taken from the opened dome of the 18-inch, from where Zwicky (and later the Shoemakers and the author) observed.

Even though I never met Zwicky, I can share three aspects of him, not including the most famous one in which he called anyone he did not like a "spherical bastard." The expression was intended to mean that no matter from which angle you look, that person is (or was) a bastard. One story I heard from Walter Haas, founder of the Association of Lunar and Planetary Observers, who said that when Zwicky was having a quiet chat in a corridor at Caltech with another astronomer, one could hear him two blocks away. The other involved Zwicky's observing coat, which he left in a closet at the 18-inch observatory building. One night, when I was about to observe alone there, as Gene Shoemaker left the building he said, "If you get too cold, you can wear Zwicky's coat!" The thought of that coat haunted me all night. Third, my friend David Rossetter named his large 25-inch diameter reflector Fritz, after Zwicky's first name. It is a wonderful telescope named for a brilliant man.

In January, the ion or gas tail of Comet ZTF showed a sort of disconnection in which the part of the tail closest to the comet was a thin line that suddenly broadened to a larger fan further out. This "disconnection event" was closely tied to a sudden increase in sunspot activity. This ZTF comet teaches us how comets interact with the solar wind.

As this article goes to press, there is not one ZTF comet, but two. David Rossetter and I saw the other one at our club's dark observing site. The second one is much fainter, visible as an amorphous smudge of small, slowly moving haze. As I looked at this second comet, I tried to understand and appreciate the seminal role that Zwicky played in his time. And in our time, that role has expanded to explore in still greater detail the night sky that he loved. ✶

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

CFHT Chronicles

Bad Seeing? No Problem!

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

In this column we will dive a little into our observing process, program ratings, and now how often "bad seeing" observations are incredibly productive.

Every semester, CFHT issues a call for proposals. Astronomers submit their proposal request to their agency: Canada, France, the University of Hawai'i, Taiwan, or China. The proposals include a science justification, instrument and configuration requested, hours needed, targets, etc.

CFHT resident astronomers review the proposals for technical feasibility. Can we observe the target or is it a little too far south? Is the time estimate for the observations reasonable based on instrument capabilities? Those kinds of instrument/facility-specific parameters. The proposals are then evaluated by time allocation committees (TACs), that evaluate the scientific merits of each proposal and set the priorities for the program's execution. For each instrument, proposals are given a grade (A, B, C), and a number (1, 2, etc..) that indicate the priority of the program. For example, a Canadian A1 program on MegaCam is our highest priority on the instrument from Canada. The TAC also sets the number of hours allocated for each accepted proposal.

All observations at CFHT are taken in Queue Service Observing mode and have been for two decades on MegaCam. In queue, the principal investigators (PIs) never set foot at CFHT. They do not go to the summit and operate the instruments themselves. Once a PI receives their ranking and time allocation, they use PH2, a detailed online form designed and managed by CFHT, to detail their observations. Within PH2, the PI creates observing groups (OGs) and selects all the necessary information to complete their program effectively; the image quality range (IQ), sky background, photometric vs non-photometric conditions, etc. They can also schedule time-sensitive observations and leave comments for the Queued Service Observations (QSO) team to consider when observing or scheduling. All information for all programs is stored within a custom database.

From this database, the QSO team creates queues or plans for every night. CFHT astronomers and queue specialists take turns creating the queues in the role of queue coordinator (QC). A typical QC shift lasts 5–10 nights. Each queue is made up of OGs created by the PIs. The length of an OG varies from <5 min to a maximum of two hours. Queues tend to be based around image quality, but the biggest defining quality of an OG is its program ranking. This is the beauty of the queue system; we can discriminate based on weather and sky conditions.

The number of queues per night varies based on the instrument. MegaCam tends to have the most queues; the number of programs combined with the vast difference in IQ requests leads to 5–6 queues per night. The QC always creates a queue for sub-optimal conditions, those other 65 nights a year, containing programs that do not need sub-arcsecond seeing or can tolerate thin cirrus.

And this is where the "snapshot program" gets introduced. Snapshot programs request the worst sky conditions (>1.2″ and often non-photometric conditions). Ideally, they are simple to execute; broadband filters, no time constraints, and short observations. The key is they must be scientifically useful, even if only a fraction of the observations are executed.

Those familiar with the CFHT calendar or Hawaiian Starlight images by former CFHT resident astronomer (and still very close collaborator) Jean-Charles Cuillandre and Giovanni Anselmi of Coelum are familiar with the most famous snapshot program—our calendar. The images taken for the calendar are typically done in poor seeing or as a filler in RA gaps in the queue.

Another snapshot example is the Pristine survey. Their snapshot program uses poor seeing, but photometric skies in their search for ultra-low metallicity stars. Our Universe is roughly comprised of 74 percent hydrogen, 24 percent helium, and 2 percent metals, i.e. everything else on the periodic table and all compounds. The metallicity of the Sun is roughly 2 percent. The Pristine team is looking for stars with much lower metallicity, almost devoid of any heavy elements with concentrations 10,000 to 100,000 times lower than our Sun.

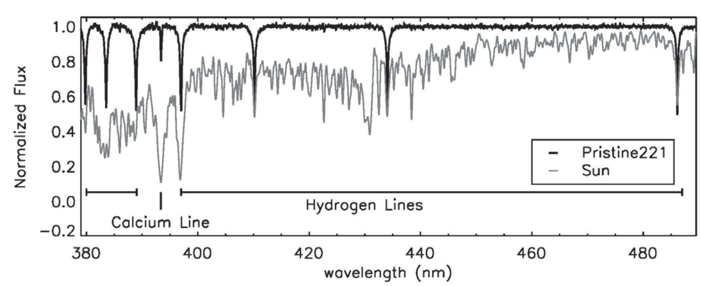


Figure 1 — The spectrum observed with the William Herschel Telescope on La Palma for Pristine_221.8781+9.7844, compared to the spectrum of the Sun. As can be seen, the spectrum of Pristine_221.8781+9.7844 contains far fewer features. Only hydrogen (the large dips) and a small amount of calcium (the small dip) can be seen in the spectrum of Pristine_221.8781+9.7844. This tells us that the star is ultra metal poor, it has an unusual lack of heavy elements in its atmosphere, which means that it belongs to an early generation of stars formed in the galaxy. Credits: E. Starkenburg and the Pristine collaboration.

Pristine uses poor seeing, but photometric conditions to take images in a specific filter. Typically, metallicity surveys take spectra of individual stars, but Pristine strategy of combining MegaCam's large field of view with this filter has mapped more than 6,000 square degrees. As of this writing (and the most recent update of the Pristine website), the team has published over 30 papers and five Ph.D. theses. All in "bad seeing."

A recent news release from CFHT came from snapshot data. The remainder of the column pulls from that release—another perfect example of the science that can be done by snapshot programs.

In late 2022, a team of astronomers announced the discovery of a giant tidal tail emanating from a dwarf galaxy in the nearby M81 Group. The galaxy, named F8D1, is remarkable on account of its low luminosity and large size, and is now recognized to be one of the closest examples of an "ultra-diffuse" galaxy (UDG). The origin of these enigmatic galaxies has puzzled astronomers for several decades: Are they born this way or are their present-day properties the result of processes that have shaped them over their lifetimes? Using observations with Hyper Suprime-Cam (HSC) on the Subaru Telescope and the MegaCam imager on the Canada-France-Hawaii Telescope, a team of researchers has mapped the tidal stream of stars from F8D1 over 1 degree on the sky, corresponding to 200,000 light-years at the distance of the galaxy. Revealing F8D1 to be a galaxy in an advanced state of tidal disruption has implications for both the dynamical evolution of the M81 Group and for the origin of galaxies that exhibit UDG properties.

Since 2014, the science team has conducted a deep contiguous photometric survey of the M81 Group using HSC on the Subaru Telescope (see Figure 2 left panel). Lying at 11.7 million light-years, the M81 Group is one of the nearest galaxy groups. Its proximity and resemblance to the Local Group have fueled much astronomical research over several decades. It contains more than 40 member galaxies, including the large spiral galaxy M81, the peculiar galaxies M82 and NGC 3077, 9 late-type galaxies, at least 20 low-luminosity early-type dwarfs and a variety of stellar debris features, some of which are tidal dwarf galaxy candidates. Strong tidal interactions between M81, M82, and NGC 3077 had been revealed through the neutral hydrogen gas studies. In 2015, the same science team showed, for the first time, that the signatures of these interactions are also present in the low surface brightness stellar distribution (subarutelescope.org/en/results/2015/08/04/2272.html).

The F8D1 stream was revealed through analyzing the spatial distribution of individual stars with properties which place them at the distance of the M81 Group. Since F8D1 lies at the edge of the survey footprint (see Figure 2 right panel), only one tidal arm can be seen, extending to approximately 200,000 light-years to the northeast. The team have recently been awarded further observing time to search a counterpart stream to the southwest.

Rokas Žemaitis, a Ph.D. student at the University of Edinburgh who led the work, said, "The discovery that F8D1 is tidally disrupting is very exciting and it will be important to establish how many other UDGs also show faint tidal tails."

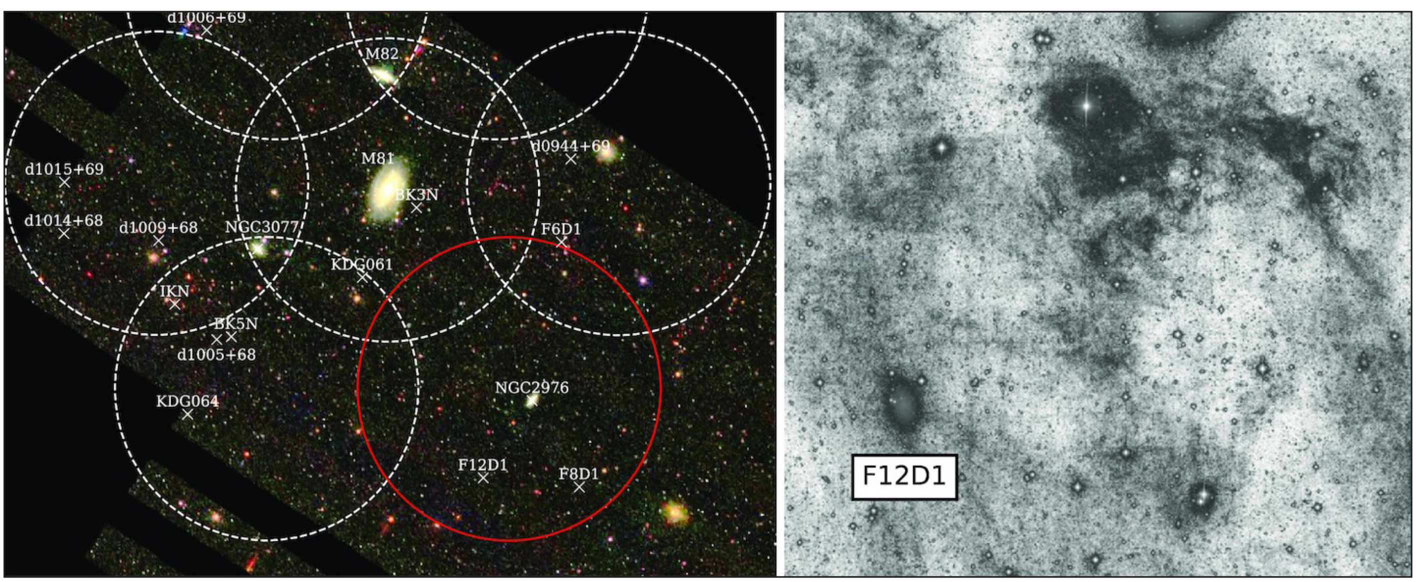


Figure 2 — Left: The team's M81 Group Survey footprint (seven HSC pointings) overlaid on an SDSS image. Each HSC pointing has a diameter of 1.5 degree and the known galaxies within this area are marked. The red circle indicates the pointing containing F8D1, which is the focus of this paper. Right: A portion of a deep i-band image taken with CFHT/MegaCam that shows a zoom-in on the central region of the red-circled HSC pointing. Highly structured cirrus is present throughout this region of the sky, which greatly complicates integrated light studies of the low surface brightness emission of F8D1 and its neighbours.

Figure 3 — Colour rendering of F8D1 with MegaCam LSB mode. Credit: Cuillandre

To assist in the analysis of the main body of F8D1, the team utilized the Low Surface Brightness (LSB) observing technique unique to MegaCam, CFHT's 1-degree × 1-degree optical imaging camera. Originally optimized for surveys at CFHT, LSB mode observations of F8D1 illustrate the complex nature of the galaxy's structure amid galactic cirrus features, faint gas clouds between the Earth and F8D1. The presence of galactic cirrus previously obscured the view of F8D1's tidal tail from discovery. Effectively mapping the cirrus via MegaCam's observations complements the observations done with HSC.

"MegaCam's unique capabilities in LSB mode were essential to confirming F8D1's tidal tail," said Jean-Charles Cuillandre, a co-author on the F8D1 paper and prior papers using LSB mode at CFHT. "The collaboration between MegaCam on CFHT and HSC on Subaru opened an unparalleled window in the deep nearby Universe."

The finding of a huge tidal tail from F8D1 is compelling evidence that the galaxy's present-day properties have been strongly shaped by events that have occurred in the past billion years. The team estimate that more than one-third of F8D1's luminosity is contained in the tidal tail, and they suggest that the source of the disruption has been a recent close passage to the massive spiral M81.

"The observations for the team were observed as a 'snapshot' program at CFHT, a program that is observed during poorer seeing conditions on Maunakea," said Todd Burdullis, queued service observing operations specialist at CFHT. "This discovery is a testament to the power of MegaCam's LSB mode, collaboration with our neighbors at Subaru, and the incredible conditions on Maunakea."

These results appeared as Žemaitis et al. "A tale of a tail: a tidally disrupting ultra-diffuse galaxy in the M81 group" in the Monthly Notices of the Royal Astronomical Society on 2020 November 2. https://arxiv.org/abs/2209.09713 ✶

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

The June 2023 *Journal* deadline
for submissions is 2023 April 1.

See the published schedule at

rasc.ca/sites/default/files/jrascschedule2023.pdf

Imager’s Corner

Layering Techniques

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

This edition’s column continues our look at some layer techniques. In this edition, we will look at a layer-based noise reduction method. Some are good at preserving detail and edges, while others are good at really taking down background noise, this one does a reasonable job of both.

Many image processors hide some of the details of these approaches by allowing the user to specify a blend mode for a blur and add a mask to the adjustment layer, but some force you to use a full layer combine to accomplish the task. Either way the result is the same, a targeted approach that can focus on one type of noise. Add in a mask any you get great control over the whole process.

This method works with a masked layer combine to preserve much of the detail in the brighter areas of the image. It works best if you remove the stars from the image first. This helps to limit the blur applied to them, keeping the stars sharp in the final image. For this column I used an image I took earlier this year of M101. The shot was taken from Bortle 6/7 urban skies, so it has lots of fine noise throughout the background and the galaxy.

Here is a look at a 100% crop of the upper left corner of the shot. It gives a better idea of the noise that permeates the entire shot.

Figure 1 — Urban M101 with arcsinh stretch

Figure 2 — Noise in the upper left corner

The first step is to remove the stars. Here I used the Feature Mask tool in Images Plus. You don’t have to be too picky here so leave the larger halos in the image. For those who don’t use Images Plus, it is available free at www.mlunsold.com and you can also use *Starnet++* or other tools to do the same job. I also made a star-only image and tucked it away on my hard drive for later merging back into the final image.

Next a mask is needed to protect some of the brighter areas of the image. Use a simple luminance mask of the starless image, invert it then add a contrast boost using a levels tool. The idea here is to make the areas of the mask that contain detail as dark as possible to protect them from the noise reduction while making the background bright.

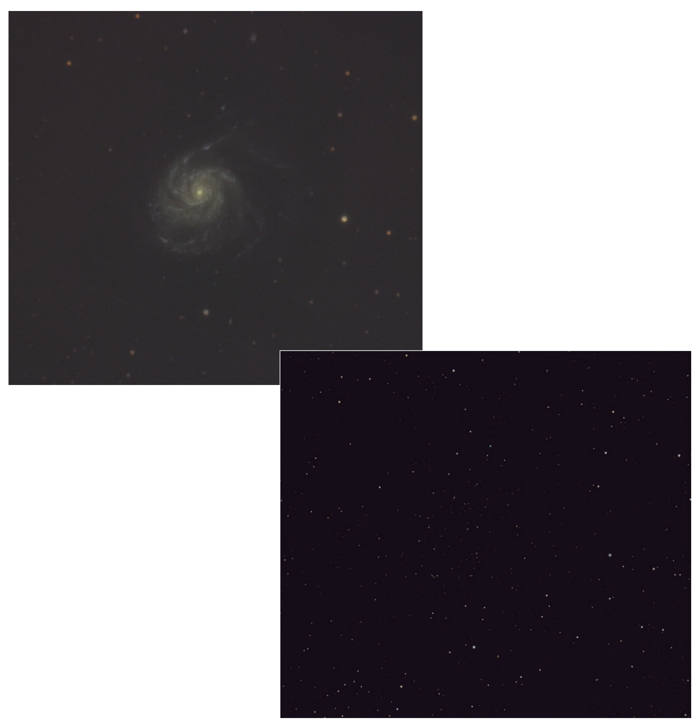


Figure 3 — Starless and star only images

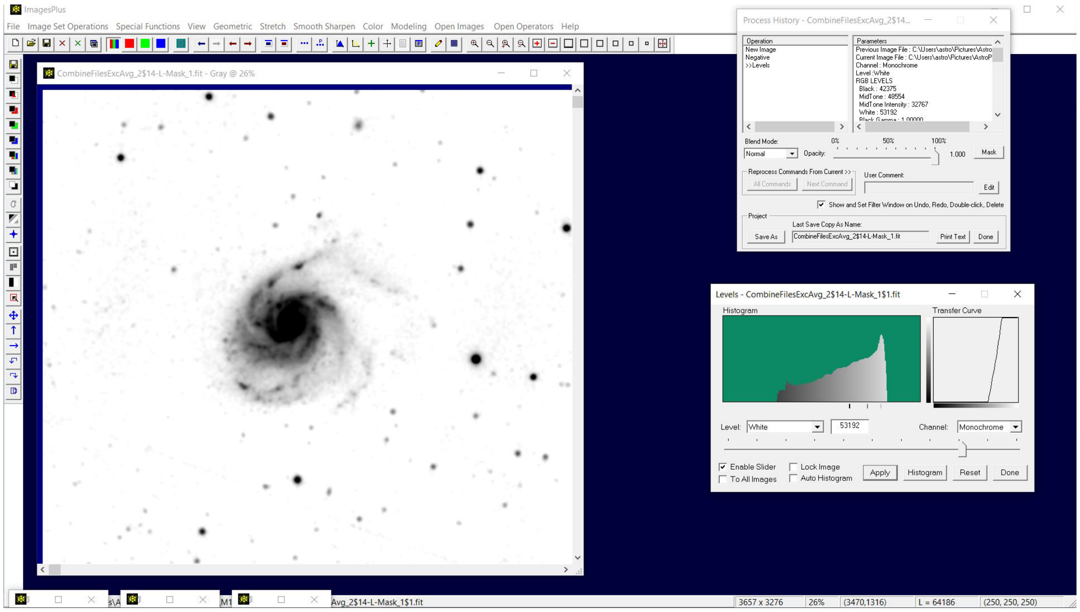


Figure 4 — Making the mask

The next step is to blur the starless image enough to remove all the noise in the background. Use your favourite blur tool and don't push it any further than what is required to tame the background noise. This will be more of a blur than most are accustomed to as shown in Figure 5.

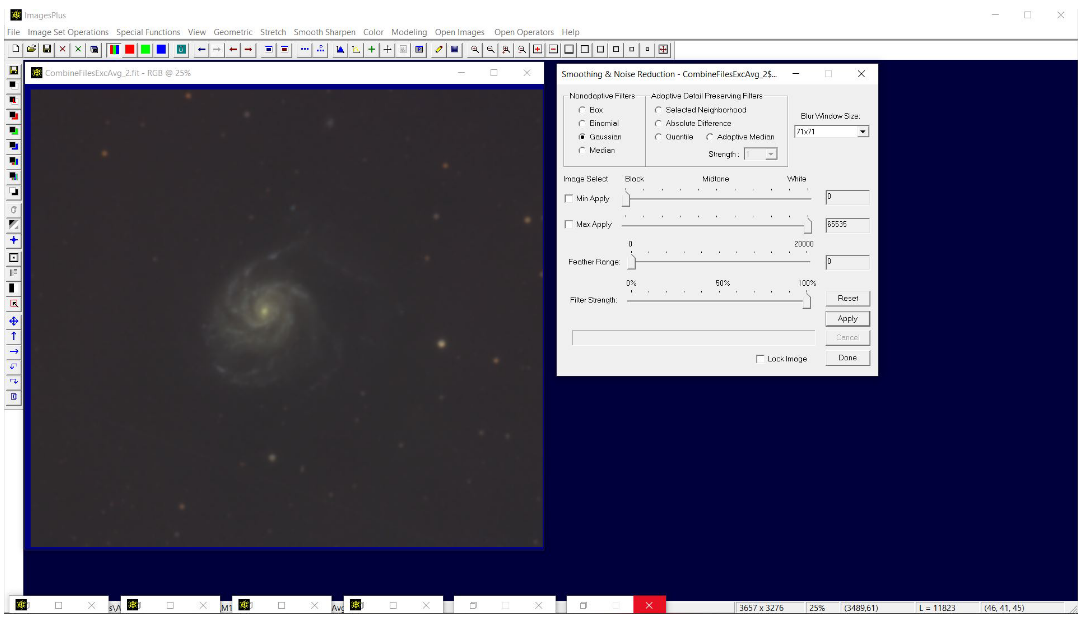


Figure 5 — Blurred starless image

Apply the mask to the blur to maintain the core detail.

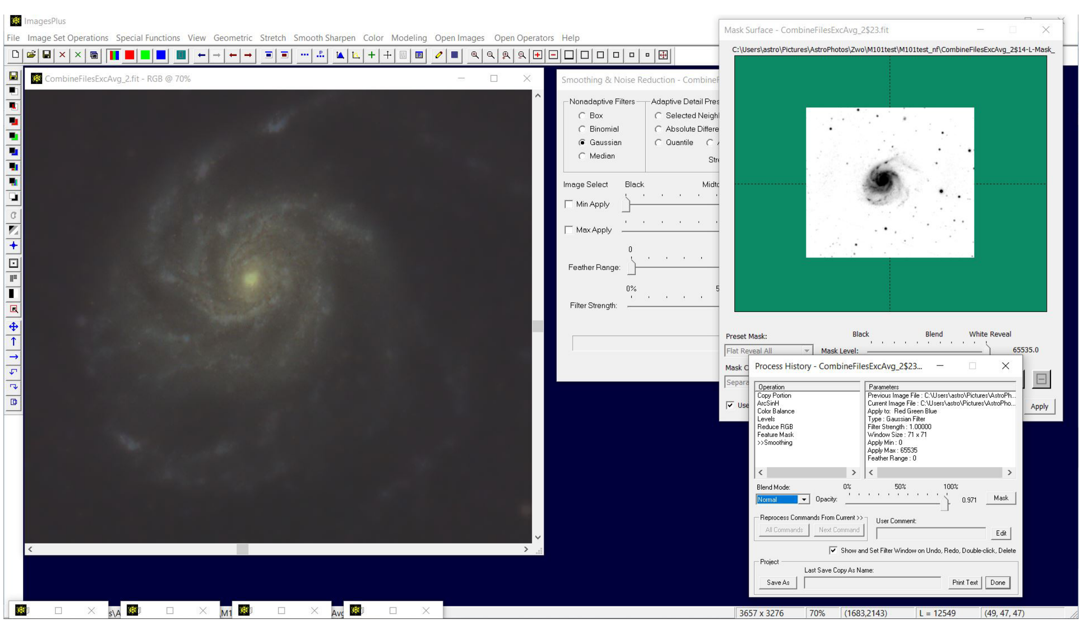


Figure 6 — Blurred image with mask applied

The mask does a great job in protecting the core, but as it gets lighter toward the outer arms, they blur a bit more than desired. To avoid this, switch the combine mode to lighten instead of normal. The result is a blend that better preserves the detail at the cost of a slight contrast loss. The layered approach here is to use a lightened blend mode to combine the blurred image with the original.

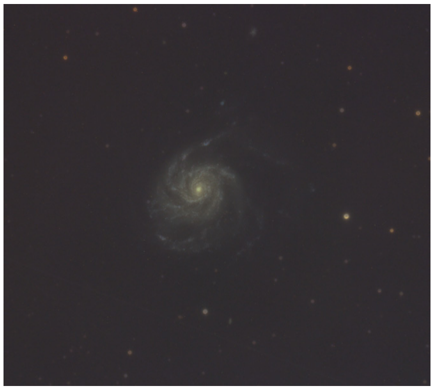


Figure 7 — Masked lighten blended image

Next add a little sharpening to the core area and recombine the star layer. Images Plus has a dedicated blend mode for this called merge split. Once the result of the blend is flattened then flatten the background to remove the colour cast. Most astro-image processors have a tool for this, *Images Plus* uses the multipoint flatten background tool.

Figure 8 — Combined noise reduced image

Finally apply a slight curve to set the final image contrast to taste. This produces an image that is ready for the final colour tweaks to remove the greenish red cast from my local light pollution.

Figure 9 — Noise reduced image, ready for the final colour tweaks.

Let's compare the upper left of both the original stretched image with the same corner of the processed version to see the difference in the image noise.

Figure 10 — Noise reduced (left) versus the simple stretched version of the image. Note that both versions have the same faint stars visible although the right-hand version has more background noise.

The nice part about this layered technique is that the combination of the mask and a lighten combine allows you to hold on to the core detail in the galaxy while greatly reducing the noise in the background and spiral arms.

Figure 11 — Galactic core detail

Not too shabby for a two-hour exposure taken from light polluted urban skies.

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

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

Binary Universe

Dealing with the Uneven

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

I struggle with gradients.

In many of my LRGB images, I note gradients, mild to strong, caused by moonlight, the edge of the observatory dome, or infernal light pollution. At first, I didn't know how to deal with this. But left uncorrected, I would invariably find the final result—the assembled full-colour image—of poor quality with distracting swashes of colour in the corners and edges. As I gain more experience—and train my eye—it is increasingly perturbing when I can't eliminate gradients.

The purpose-built astronomical image editing software tools have features to help deal with vignetting and uneven illumination. For example, *PixInsight* offers Dynamic Background Extraction. I don't have PI.

There exist plug-ins for *Photoshop*. A popular option within the Astronomy Tools Action Set is Gradient Xterminator. I don't own any astronomy action sets. I've written a few of my own action scripts over the years, but they don't always work.

From Scott Ireland, author of *Photoshop Astronomy*, I learned a couple of techniques to deal with uneven fields, including making synthetic gradients. Using these different techniques helped to make some final images look much better. Other times, I could not seem to correct the problem no matter what I did.

When I spot significant gradients in my FITS files, I know I should follow the additional steps in my notes. This makes for a longer and more involved workflow, which seems to butt against my want for instant gratification. It is a deep-seated issue for me, going back to my yearbook photographer days 40 years ago: I don't want to process! And I am very reluctant to lay down a lot of cash for image processing software and additional plug-ins. I'm cheap!

While a computer guy, I am strangely anxious about climbing a new software's steep learning curve. I should probably just collaborate. But I digress.

Removing Gradients for Free

So, I was rather intrigued when I noted a conversation on gradient removal in the amazing, useful, and informative Cloudy Nights forums in the spring of 2022. People were talking about a new, free software tool called *GraXpert* ("gracks-pert"), and it sounded very promising. I set the handy tag to follow the Cloudy Nights conversation, and messages started rolling in beginning the 1st of May.

In August, while attempting to process the LRGB data for the Hamburger Galaxy, I had a go at using *GraXpert*. I used it on the TIFF files output from FITS Liberator and the result was a bit better. But a day later, I tried processing the RASC Finest NGC 3628 again, this time flattening the original FITS files. I saw a dramatic improvement in the final result while enjoying a simplified workflow. Then, on another set of galaxy data from the Burke-Gaffney Observatory—The Whale this time—I tried a different technique, the Kriging interpolation method, and was even more satisfied. It is safe to say that *GraXpert* is a tool I rely on and regularly use now.

Download and Run

Visit the website graxpert.com to learn about the standalone application, watch informative demonstration videos, access the brief English or German PDF user guide, and download the relevant file. *GraXpert* runs on Windows, Mac, and Linux. I have used the Windows version many times and tested the Linux edition. At the time of writing the current version was (release candidate) Dione v1.0.4.

The downloaded file does not need to be formally installed; it is a self-contained executable. After a User Access Control prompt, I was quickly up and running on my 64-bit Windows 10 and 11 computers. I ran into a snag on Linux, but a fellow user on Discord rapidly came to my rescue and advised me how to reconfigure the file download to run on my Ubuntu 22 laptop. I understand Mac users need to white-list the program.

The *GraXpert* Workflow

On launching the program, you will see a control panel on the left edge of the screen with numbering delineating sections. Literally, you follow the number sequence. If additional help is required, the orange Help tab on the right side can be tapped to reveal some hints and suggestions.

The status bar at the bottom of the screen shows the mouse point position and the overall dimensions.

If a loaded image is too dark (Figure 1), a screen stretch may be applied. Four percentage levels are available in the Stretch Options and the highest is recommended to clearly emphasize the gradient in your image. Zooming and panning an image are supported and easily managed with a mouse. Images with bad edges can be dealt with when the Crop Mode in enabled (Figure 2).

The Sample Selection section allows the user to place sample points within the image. Points can be placed rapidly using the Create Grid button. The density of points is governed by the Points per row slider. The Grid Tolerance can be adjusted if

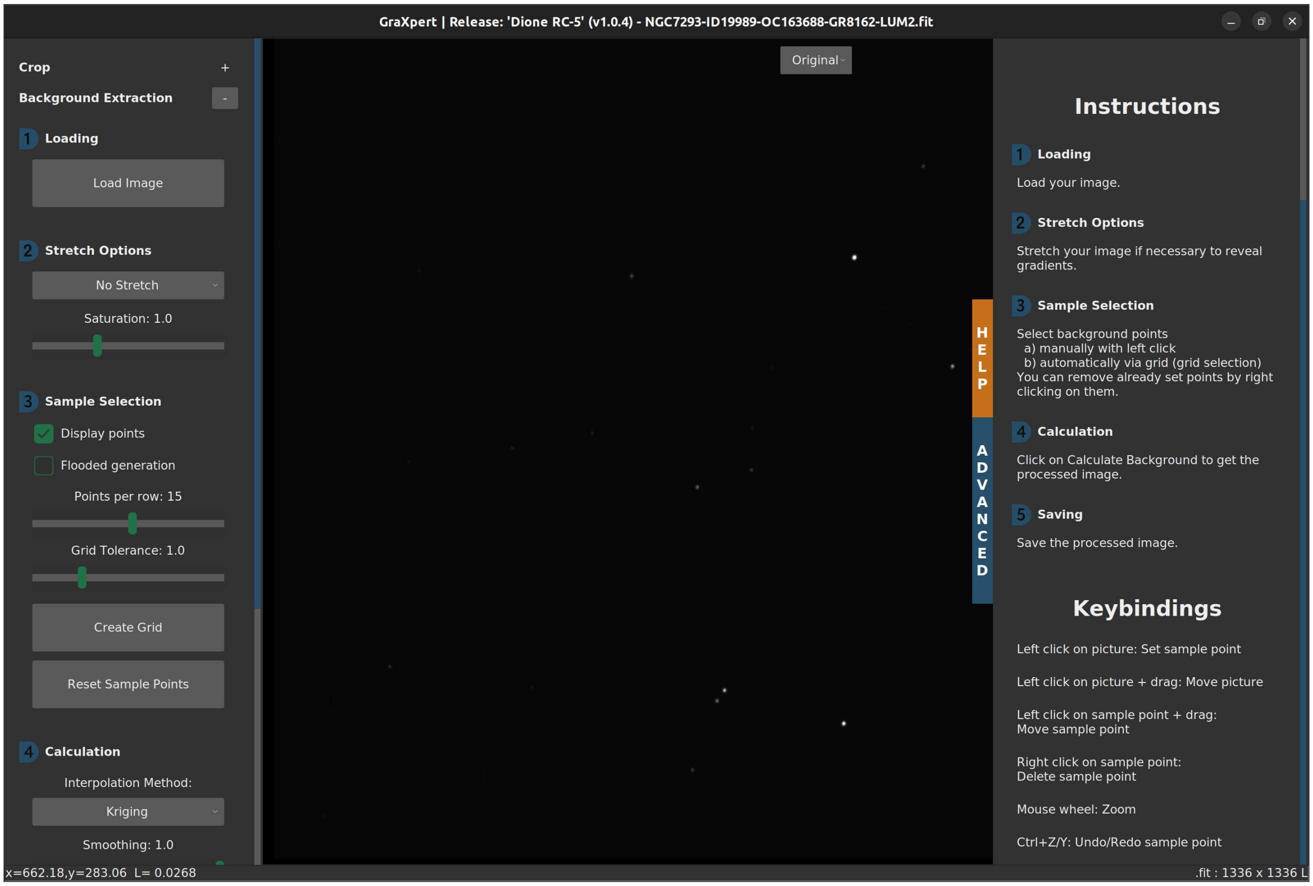


Figure 1 — An unstretched luminance image loaded into GraXpert *with the Help panel showing.*

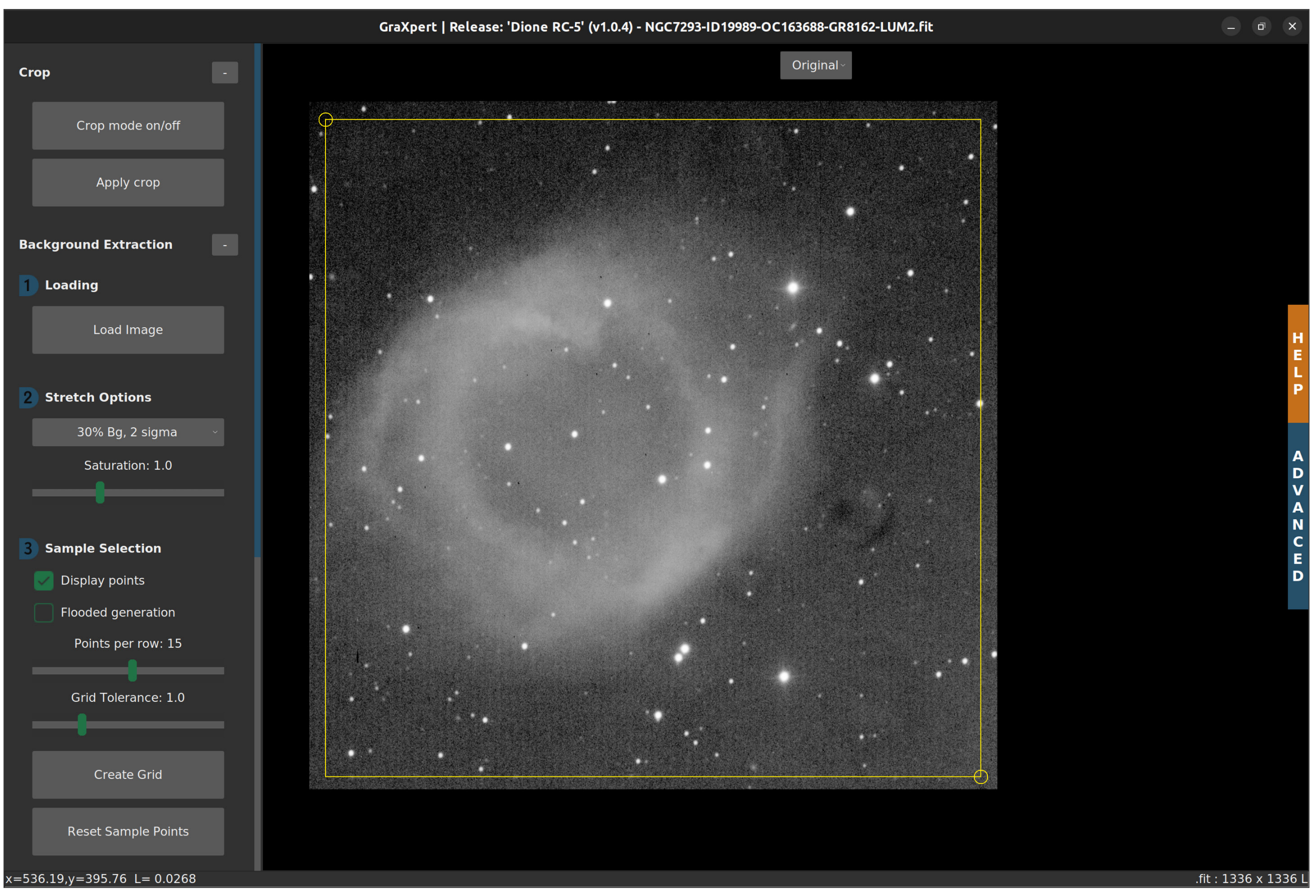


Figure 2 — Uneven image stretched, zoomed out slightly, cropping enabled.

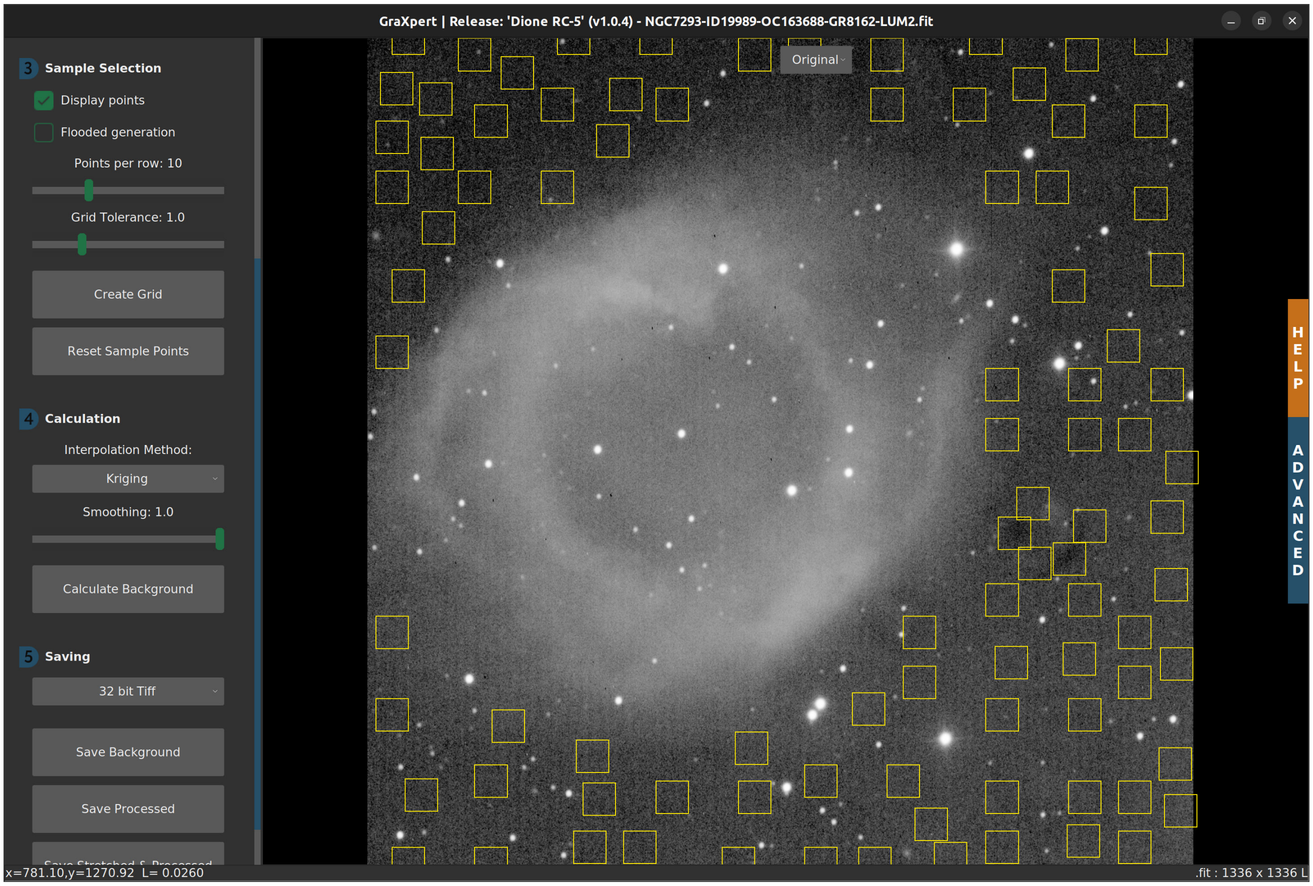


Figure 3 — Sample points in the background added automatically then adjusted manually.

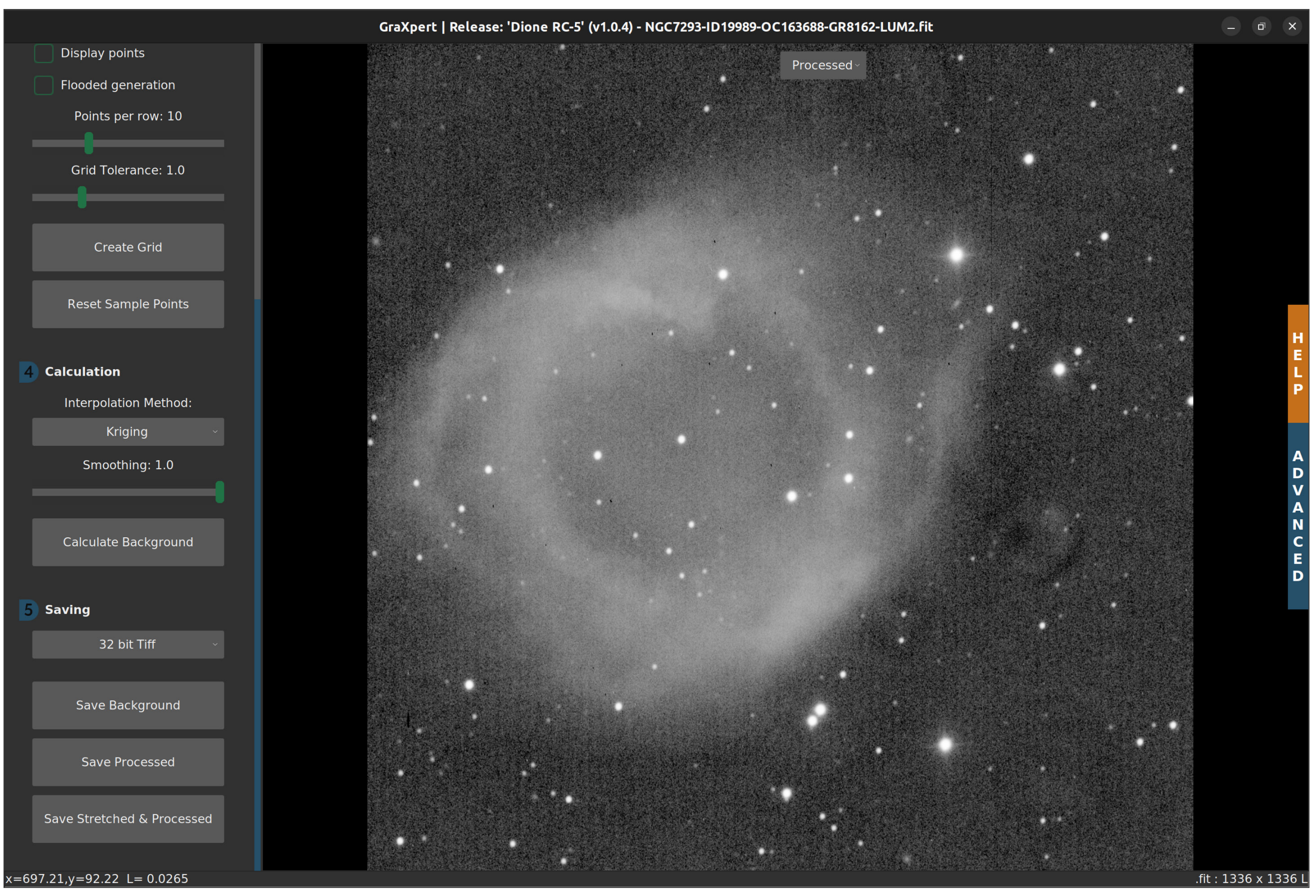


Figure 4 — Uneven field corrected in the processed image, display points turned off.

too much of a nebula or galaxy is incorporated into the sample grid pattern. Individual squares may be added by clicking anywhere in the image; moved by dragging an existing point; and deleted by right-clicking. The Flooded Generation option will create multiple points when adding. The classic Undo keyboard shortcut may be used if you make a mistake. Or you reset and start again.

Sample points on or in nebula and stars should be avoided (Figure 3).

If you load another image without closing *GraXpert*, the same grid pattern will be used. I found this very convenient.

Three different interpolation calculation methods are offered by *GraXpert*. RBF (radial basis function) is the default, and the developers say it delivers very good results while operating reasonably fast. Splines on the other hand is the fastest method and works well with simple gradients. Finally, the Kriging option provides the best results but is computationally intense. I never experienced long wait times for my images.

A Smoothing option is available to control how soft or hard the transition between sample points, not unlike a Gaussian blur filter.

The Advanced panel allows one to control the sample size and colour and tune the RBF and Spline calculations.

When the sample areas are set, *GraXpert* can be ordered to proceed with the Calculate Background button. When the processing is complete, the adjusted image will be shown. You can flip or blink between the Original and Processed image using the menu at the top-centre of the screen. Hiding the sample squares unclutters the screen and helps one assess the result (Figure 4).

A starless Background image is also generated should you wish to manually subtract the gradient in a subsequent processing step outside of *GraXpert*.

If you're not happy, adjust the sample points and mash the Calculate Background button again.

The *Saving* section marks the last step. An image may be output as a TIFF, FITS, or XISF file, in 16- or 32-bit format. The final processed image may be saved, the background only, or the processed image with the applied screen stretch.

The output file is appended with a tag for easy identification,

e.g. NGC7293-ID19989-OC163688-GR8162-LUM2_GraXpert.tiff

Summary

GraXpert is described as "a fast and easy way to remove gradients," and I would have to agree. While more steps in my overall workflow, it is a necessary evil to deal with uneven field illumination. It's helping me make better looking LRGB images.

The editor tool seems to be receiving favourable reviews in Cloudy Nights and there seem to be a good number of enthusiastic and supportive users. One CN user reported, "I've found it to be superior to DBE in some cases!" I even noted that the excellent imager Malcolm Park uses it beside *PixInsight*.

You certainly can't beat the price!

If you're staring down nasty gradients in your images, consider adding *GraXpert* to your toolbox.

Bits and Bytes

Until relatively recently, it was improper to say that *Stellarium* was free on ***all*** platforms. Now, it is! *Stellarium* on computers has always been free. There was and remains a free edition for Android. But now there's a free version (limited like Android) for Apple iOS. Now *Stellarium* can be had completely free. ✶

Blake's interest in astronomy waxed and waned for a number of years but joining the RASC in 2007 changed all that. He is a member of the national observing committee. In daylight, Blake works in the Information Technology industry.

John Percy's Universe

The R Coronae Borealis Stars: Beyond Bizarre

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

In my February 2023 column, I described Tycho Brahe's discovery of a "new" star that suddenly and unpredictably brightened by many magnitudes, then slowly faded away. It turned out to be a supernova: "Tycho's Supernova." It helped to usher in the Copernican revolution. But there's a very small group of variable stars that behave in the opposite way. They suddenly and unpredictably *fade*, over days to weeks, by up to eight or more magnitudes. Then, over weeks to months, or even years, they return to normal maximum brightness. They are the R Coronae Borealis (RCB) stars. See Clayton (2012) for an excellent and freely available review. Jim Fox (2022) has provided a brief introduction to RCB stars for readers of this *Journal*, and provided a deep finder chart.

RCB Stars

The variability of R CrB was discovered by Edward Pigott (1753–1825) in 1795. Though classified as an amateur astronomer, he was the son of professional astronomer Nathaniel Pigott, so he was presumably well informed about astronomy. Edward Pigott is also known for his friendship with amateur astronomer John Goodricke who, despite his disabilities, made several important discoveries in variable star astronomy before his untimely death at the age of 21. R CrB has been described (by Margaret Mayall) as "a jewel worthy of a place in any crown."

Figure 1 shows a visual light curve for R CrB, based on AAVSO (American Association of Variable Star Observers [1]) observations. Several fadings are seen, including a recent one that lasted for several years. When at maximum, the brightness is approximately constant at V = 5.8. Photometric observations show, however, that R CrB varies semi-regularly due to pulsation, with a period of about 40 days, and a V amplitude of a few times 0.1 mag. Figure 2 shows these short-period variations in the light curve during a recent recovery, based on AAVSO photometric V observations. For southern observers, RY Sgr has very similar properties to those of R CrB: V magnitude 6.5 at maximum, and a pulsation period of about 38 days. Careful observations show that the majority of RCB stars vary on a time scale of a few tens of days, due to pulsation (Lawson et al. 1990, Percy et al. 2004).

RCB stars are mostly low-mass yellow supergiants, with surface temperatures of 5000–7000 K, and luminosities of a few thousand Suns. There are thousands of stars in our Milky Way Galaxy with these properties; the Sun will become one in five billion years. Why don't they all become RCB stars? Why are RCB stars so rare? Here's where things become really bizarre.

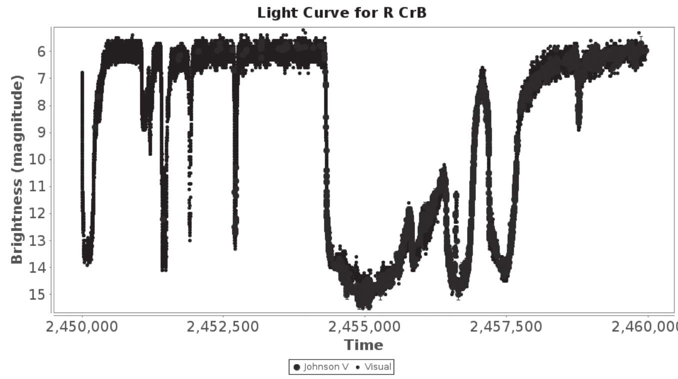


Figure 1 — A long-term light curve—visual magnitude versus Julian Date—for R CrB, based on visual observations from the AAVSO International Database. It shows the deep, random fadings of the star, including a recent one that lasted for several years. Source: AAVSO.

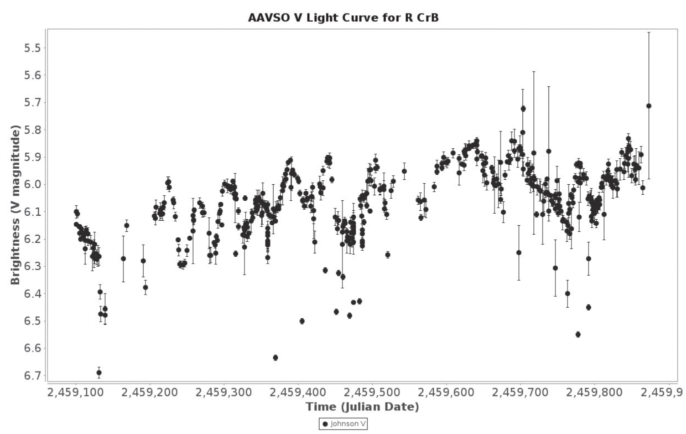


Figure 2 — A 1000-day light curve for R CrB, based on photometric V observations from the AAVSO International Database. Note the small-amplitude, semi-regular 40-day variations that are due to pulsation. Source: AAVSO.

RCB Chemical Composition

Most stars in our galaxy, including the Sun, are made up of about 3/4 hydrogen, 1/4 helium, and about 2 percent everything else by mass. They are born from clouds with this composition. RCB stars are about 9/10 helium, and less than 1 percent hydrogen by mass. Most of the other 10 percent is carbon. This unusual composition—produced during their thermonuclear evolution—is the key to explaining the strange behaviour of these stars.

The Fadings of RCB Stars

The fadings occur when the star randomly ejects clouds of gas and dust, in random directions. These clouds move away from the star. The dust cools and, being carbon-rich, condenses to produce solid grains of carbon—soot. If the cloud lies between us and the star, it blocks the star's light, and the star fades. The dust cloud, having absorbed starlight, is warm and is therefore detectable at infrared wavelengths. As the dust cloud disperses, the star gradually reappears.

But why should the star eject a cloud, rather than a shell? Aren't stars spherical? Perhaps to first approximation they are. But processes such as convection, rotation, magnetic fields, and binarity make them non-spherical. The non-spherical shapes of planetary nebulae are another sign that their progenitor stars are not perfect spheres.

And what causes the cloud to be ejected, and pushed away from the star? Perhaps the pulsation and shock waves that the pulsation produces. Pulsation is well known for helping to drive mass loss in other stars, such as red giants.

Relatives of RCB Stars

There are four hot RCB stars, which have compositions and variability similar to those of the cooler majority, and presumably for the same reason. There is also a small group of stars, DY Per being the prototype, that resemble RCB stars, but have much slower fadings. We are not sure why, but the fadings of DY Per are semi-regular in time, with a period of 793 days, so binarity may be involved.

The Origin of RCB Stars

How do stars develop such bizarre compositions, enabling them to become RCB stars? There are two leading theories: (1) the merger of two white-dwarf stars, a helium white dwarf, and a carbon-oxygen white dwarf, or (2) a final helium-shell flash in a star that has just passed through the end of the red-giant stage of evolution and is on its way to the white-dwarf state. In astronomers' jargon, these are the double-degenerate (DD) theory, and the final-flash (FF) theory.

White dwarfs are the inert cores left behind at the end of the evolution of stars like the Sun. They will be mostly helium, or mostly carbon-oxygen, depending on the mass and previous evolution of the original star. Enough white-dwarf binaries exist in our galaxy to produce RCB stars if and when they merge.

A helium-shell flash is an instability in the helium fusion process in a red giant. Several such flashes are expected during the lifetime of a red giant. If one of them occurs as the red giant is undergoing its final transition to a planetary nebula, then the star will swell into an RCB-like supergiant.

Which theory is more likely? Clayton (2012), in his Table 3, lists the evidence for and against each one. Neither is completely satisfactory. Clayton leans toward the DD theory and, since he is the expert, I will lean that way also.

What's New

One of my current research projects is to study the pulsation of RCB stars using data from ASAS–SN, the All-Sky Automated Survey for Supernovae [2]. There are 93 RCB stars in the ASAS–SN variable-star catalogue, but many of them do not show fadings in the ASAS-SN data, so I restricted myself to 26 RCB stars in the *General Catalogue of Variable Stars*, one of the "bibles" of variable star astronomy. Some of these 26 stars were entering or leaving a fading, making small-amplitude pulsation difficult to detect. Others were too bright or faint for study. For seven stars in my study, there was small-amplitude variability, but no evidence for regular variations in the light curve or Fourier spectrum. The other 16 showed evidence of semi-regular pulsation, with an amplitude of a few times 0.1 mag. The periods tended to be 30–50 days, consistent with R CrB and RY Sgr. This is significantly shorter than the periods of "normal" low-mass pulsating yellow supergiants such as RV Tauri stars. This is likely because RCB stars have vastly different composition, structure, and evolution, and therefore pulsate differently, compared with normal stars. It is also possible that the RCB stars are pulsating in higher overtone modes.

By the way: if you like looking at and playing with photometric data on variable stars, I do recommend the ASAS-SN freely available data. One warning, though: the classifications and periods in the ASAS-SN catalogue are not always reliable, simply because of the complexity of some variable stars, and the fact that the ASAS-SN catalogue assumes that variable stars can be adequately described by a single period, with constant amplitude (Percy and Fenaux, 2019). Also: ASAS-SN data are not dependable for stars brighter than magnitude 10.

What You Can Do

R CrB is normally visual magnitude 5.8 so, if you have dark skies and good eyes, you could possibly look to see whether it is visible to your unaided eye. Binoculars or a small telescope will obviously help. Figure 3 shows a simple R CrB finder

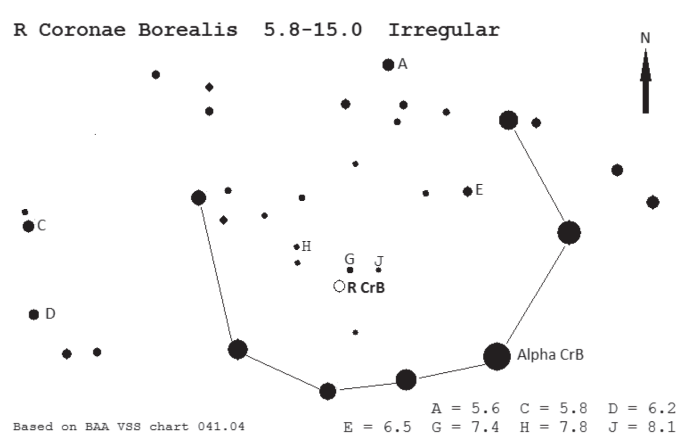


Figure 3 — Finder chart for R CrB. The magnitudes of some comparison stars are given. Source: British Astronomical Association.

chart for this purpose, and there's a deeper one in this *Journal* (Fox 2022). If you are really keen, you can join the ranks of the "citizen scientists" and monitor the variability of R CrB or other RCB stars in a systematic way, and submit your observations to the AAVSO. Thousands of other skilled amateur astronomers do! And we professional astronomers are very grateful! ✶

Endnotes

1 American Association of Variable Star Observers (AAVSO): aavso.org

2 All-Sky Automated Search for Supernovae (ASAS-SN): asas-sn.osu.edu

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Clayton, G.C. (2012), "What are the R Coronae Borealis stars?", *J. Amer. Assoc. Var. Star Obs.*, 40, 539.

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John Percy FRASC is Professor Emeritus, Astronomy & Astrophysics and Science Education, University of Toronto, and a former President (1978–1980) and Honorary President (2013–2017) of the RASC.

Dish on the Cosmos

PAHs get into the Gas Game

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

In this month's column, I am going to go a little out of my lane and describe some new results from research inspired by the James Webb Space Telescope (JWST). These are exciting new results, but the full picture of these results returns to this column's mainstay: radio and submillimetre astronomy. In the first several months of operations, JWST has inspired and revitalized several new and exciting paths toward discovery. From new studies of exoplanets to finding the most distant galaxies forming in the early Universe, JWST has over-delivered on expectations across astrophysics. These impressive results include my own areas of study in galaxy evolution and the matter cycle in galaxies. While my collaborators and I had great expectations for JWST improving our science, we never anticipated how good the telescope would be at providing images of the gas in galaxies. Such imaging is normally the province of the radio and submillimetre telescopes that feature in this column, but in some ways JWST is beating radio telescopes at their own game.

The key to this innovation comes from a special type of molecule called a polycyclic aromatic hydrocarbon (PAH). As a chemist can tell you, PAHs are large molecules featuring several rings of carbon atoms (benzene rings) adorned with hydrogen atoms at loose bond ends. These molecules can contain hundreds of atoms and are some of the largest molecules uniquely detected in space. PAHs are one of the building blocks of interstellar dust, which fills the space between the stars and blocks out starlight. Compared to dust, PAHs have a unique feature: when a PAH is hit by starlight, it re-radiates that light in the infrared part of the spectrum, right where JWST can observe. This infrared light corresponds to specific sets of energy transitions in the PAH molecule, similar to but less well-defined than the spectral lines from the quantum transitions of individual atoms and molecules.

These PAHs are well mixed in with the atomic and molecular hydrogen gas in galaxies. This gas plays a vital role in the galactic ecosystem: the gas is the place where new generations of stars form. When this gas forms into stars, it gives rise to stars of all different masses from the low-mass, long-lived red dwarfs, to the high-mass, hot and luminous blue stars that end their lives in just a few million years. These high-mass stars give off vast amounts of radiation, stellar winds, and they end their lives in supernova explosions. These winds, radiation, and shock waves from supernovae push energy and momentum back into the gas of the galaxy, carving out vast cavities. The action of these stellar winds and radiation is blandly called "stellar feedback."

Stellar feedback plays a vital role in how galaxies self-regulate over their lifetimes. If stars were not injecting feedback, the gas in a galaxy would all collapse and form stars in a single burst. Instead, the feedback keeps the gas stirred up and rations out the galaxy's gas reservoir by preventing all the stars from forming at once. This leads to a self-regulation of a galaxy: if the gas disk is not stirred up enough, more gas will collapse to form stars and the resulting high-mass stars will generate more feedback. This feedback will stir up the gas and slow down star formation. This leads to a nice picture of self-regulation, but the details of feedback leave a lot of open questions: how efficiently does the feedback connect to the gas in the host galaxy? Do stars that form in clusters lead to more effective feedback than if the same number of stars formed while spread out? Our models for galaxy evolution depend on these answers, but we really only have some educated guesses and simple models.

The best way to study the effects of feedback is to see the gas that the stellar feedback is sculpting. If we can study the bubbles blown around the young stars and supernovae, we gain a lot of insight into the nature of feedback. The challenge often lies in seeing the bubbles: the walls of the bubbles are a mix of hydrogen gas in atomic and molecular forms. Each phase of this gas can be observed by different forms of radio telescopes, but these radio waves have comparatively long wavelengths with respect to the infrared light observed by JWST. For JWST and the radio telescopes, the main limitation for the sharpness of their images comes from the interference between

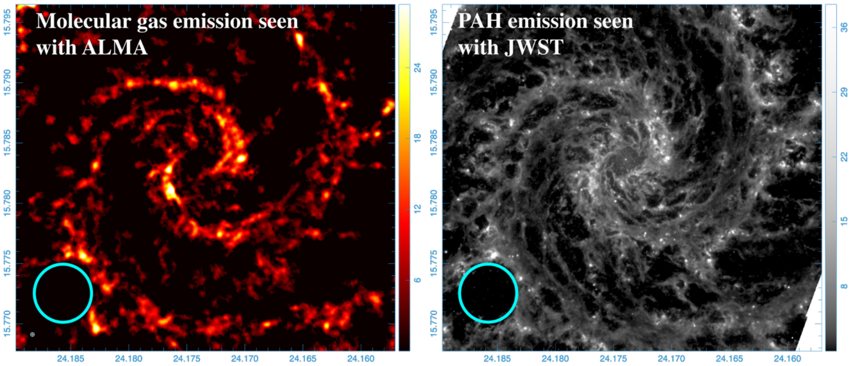


Figure 1 — Comparison of molecular gas emission from ALMA (left) and PAH emission from JWST (right) from the centre of the Phantom Galaxy (M74). The circle in the lower left indicates the location of a massive bubble that becomes obvious in the PAH emission. The PAH emission traces the walls of over 1000 bubbles in this galaxy.

the waves moving through the optics of the telescopes. Longer wavelength radiation leads to more blurring of emission, so radio telescopes have a major disadvantage in resolution compared to JWST.

Figure 1 shows the advantage that JWST affords in studying feedback bubbles. The figure compares the best available image of molecular gas from the Atacama Large Millimetre/submillimetre Array (ALMA) to an image of PAH emission from JWST from the nearby Phantom Galaxy, M74. The new images show the vast improvement in resolution and contrast from studying the galaxy in PAHs compared to the molecular gas image. The difference in quality is even more stark when comparing the JWST to maps of the atomic gas, where the resolution is 5 times worse that the molecular gas image.

The light blue circle in the lower-left corner of the image traces the interior of a massive bubble. If we were to only study the galaxy in the molecular gas image, we would not see the full wall of the bubble across all the phases. If ALMA provided the only view on the bubble, it would be challenging to definitively state that this is a feedback bubble at all. Instead, by using PAH emission, the complete boundary of the bubble is visible, and we can clearly see the full circular shape of the cavity, which presents a much more convincing case that this is the result of feedback. Where the molecular-gas image appears as a fragmented, clumpy view of the gas in the galaxy, the PAH emission reveals a churning engine of star-formation-driven feedback. There are over 1000 feedback bubbles identified in this image alone.

Two other unique features of the JWST images of PAHs reveal even more about feedback in galaxies. In Figure 2, we show the PAH emission from a different galaxy: M61. Like the Phantom Galaxy, this image shows a host of bubbles. In looking at both of the PAH images, we see that star-forming regions and massive stars are not found in the middle of the bubbles but are frequently found at the edge. These star-forming regions appear in the PAH images as bright points of light. Thus, bubbles tend to be blown out from sources in just one asymmetric direction. The other thing we note is that there are several features that are not associated with bubbles. Instead, they are long, extended filaments that are gas without high-mass stars. These filaments are instead shaped by the dynamic motions of the galaxy as a whole. There is thus more going on to create structure of gas in galaxies than just the feedback.

Despite these beautiful images and new perspectives on gas in galaxies from JWST, we are not giving up on radio telescopes. The images of atomic and molecular gas still have several advantages. Chief among these is the ability to measure the velocities of the gas motion from the Doppler effect. Since the emission from the molecular and atomic gas comes from specific quantum transitions, we can use our knowledge of this transition to measure how fast gas is moving toward and away from us. Indeed, when we look at the molecular gas inside the large bubble highlighted in Figure 1, we see that the gas is expanding, and we can measure how fast the bubble is expanding. Connecting this speed measurement with the near-perfect tracing of the walls from JWST has enabled us to measure how much energy is in these bubbles and how long they take to form. Radio telescopes and JWST are thus highly complementary.

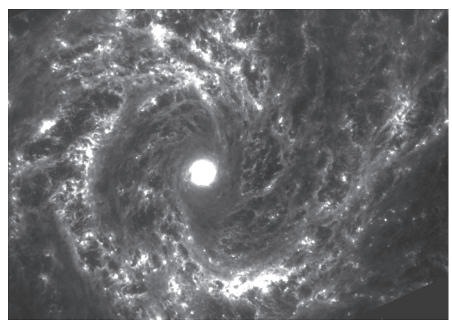


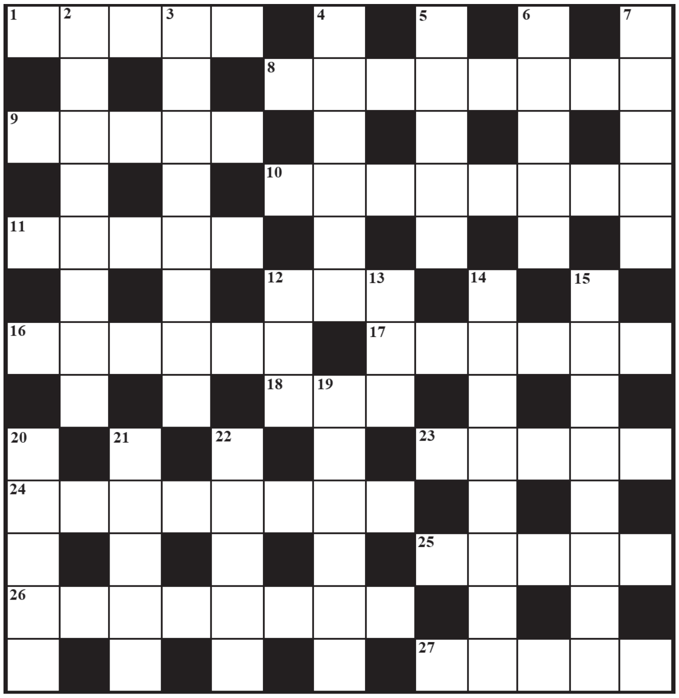
Figure 2 — PAH emission from JWST observations of M61. The image reveals a wealth of feedback-driven bubbles like those seen in M74 (Figure 1, right). The image also shows the long filamentary structures of gas shaped by the motions of material in orbits through the galaxy.

We are at the dawn of the JWST era and new radio telescopes are being built. Canada has recently indicated its interest in formally joining the Square Kilometre Array, a next generation radio telescope. The SKA promises to bring atomic gas studies into a similar quality as the images from ALMA and JWST. With the combination of all these observatories, we will have a complete view of feedback and the individual details of how the internal workings of galaxies drive their evolution. ✶

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.

Astrocryptic

by Curt Nason



ACROSS

1. Great comet co-discoverer worked first year in big furniture store (5)
8. Disorderly queue of 50 leads us to a foal (8)
9. Eratosthenes's unit got the dates wrong (5)
10. Feral fowl clustered in the sky (4,4)
11. Parks take turns with a chamber for cosmic ray detection (5)
12. Abbreviated giraffe makes a popular return with cheese (3)
16. Many love his OH galactic names (6)
17. Blaise danced around her at the Montréal Centre (6)
18. Fishes briefly have the Sun in spring (3)
23. Short wave H series in a manly sort of way (5)
24. Oddly ride on one's butt down the river (8)
25. The Beatles rejected ET for this famous old rascal (5)
26. Southern company wrecked Prius on a giant killer (8)
27. Yerkes astronomer heard to resemble another in a pod observatory? (5)

DOWN

2. Eartha had a sound glance at a domed area of AZ (4.4)
3. Eccentric Roy Pride doubles as a western snake holder (3,5)
4. Ganymede abductor was not a quail (6)
5. Bay at the Moon's tidal extremes (5)
6. Half of Betelgeuse seen in rotation by SDSS program (5)
7. You audibly ask about a former Japanese X-ray observatory (5)
12. Sky King briefly gets periodic error correction back up (3)
13. Instrumental constellation shortened for audio equipment (3)
14. Many edge around a Jovian satellite (8)
15. Much laboured Greek uplifted nominally as a Roman (8)
19. Make a cut in the total to shield from above (6)
20. Table of names being changed (5)
21. Part of three constellations with brief number in a space station (5)
22. A hips-swiveling star of the winter stage

Answers to previous puzzle

Across: **1** COLUMBA (col(anag)a); **5** GUSEV (Gus+eV); **8** NIGER (anag-o); **9** THEATER (anag); **10** TUCANAE (anag); **11** TERRA (rev); **12** LAPIRI (anag+i); **14** GRAVEL (g(r)avel); **17** ATOMS (anag); **19** PEGASUS (anag); **21** ION TAIL (anag); **22** OMEGA (O+anag); **23** NIXON (Nix+on); **24** ORPHEUS (2 def)

Down: **1** CONSTELLATION (anag); **2** LOGIC (log+IC); **3** MARINER (2 def); **4** AITKEN (anag); **5** GUEST (homonym); **6** SATURN V (2 def); **7** VARIABLE STARS (anag); **13** PHOENIX (2 def); **15** REGROUP (re group); **16** APOLLO (a poll+o); **18** SWAIN (hid); **20** STERE (hid)

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

Great Images

by Peter McNamee

While some people may take our closest neighbour for granted, Peter McNamee certainly doesn't. In Peter's words, "Our Moon is so close and is simply beautiful." He photographed the Moon on 2023 January 11, from urban Vancouver, using a Nikon Z6II, Sigma 150–600 F5–6.3 telephoto, taken at 600 mm, f/10, 1/200s, at ISO 250. He then processed it lightly through Adobe Photoshop.

Journal

Comet C/2022 E3 ZTF delighted astrophotographers in early 2023. Andrea Girones managed to capture the fleeting visitor (it won't be back for another 50,000 years, if ever) using a C11 SCT telescope and the Hyperstar lens. The final image—which was 2 hours of 90s exposures—was a result of stacking using the comet alignment tool in PixInsight.