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Journal

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PROMOTING ASTRONOMY IN CANADA

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Inside this issue:

Giving it a whirl

DISCOVER THE COSMOS

AT THE DAVID THOMPSON ASTRONOMICAL OBSERVATORY

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contents / table des matières

Feature Articles / Articles de fond

Columns / Rubriques

Departments / Départements

Steve Leonard shot the Whirlpool Galaxy (Messier 51) from his home in Markham, Ontario. He shot in LRGB with an Astro-Tech AT115EDT 4.5″ APO, using an ASI1600MM Pro, and Astrodon filters. Total integration was 6 hours under Bortle 8/9 skies.

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

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

As summer 2022 is upon us, and COVID is (kind-of) behind us, many RASC Centres and members look forward to the return of in-person outreach. Here at my home centre of Calgary, we've actually had two in-person events: the Calgary Outdoor Adventure and Travel Show where we had thousands of visitors to our booth; and a members-only orientation at the Rothney Astrophysical Observatory (RAO) where about 100 members, along with family and guests, had a tour of the facility and some casual observing. The RAO is home to monthly public nights where the Calgary Centre provides speakers and volunteers with telescopes for 300–500 guests and programming will resume there soon.

For those of you who are new to volunteering at public outreach events, there are three things you can do to ensure that you and the public have a memorable experience. Educate yourself, prepare your gear, and speak from the heart.

Since you are already passionate about astronomy, educating yourself is easy, and you likely know a lot already. Keep in mind that you don't need to be an expert. As our friend Jennifer Howse states, you don't need to know all there is to know: you can look it up, and doing that with the public live at an event engages them and allows them to contribute to the collective experience. As to your education, be sure to consider what's up in the sky the night of your event, pick a few targets so that you and your colleagues aren't all showing the same thing, and gather some interesting talking points about the object. That can be simple facts, such as M31, the Andromeda Galaxy, is roughly 2.5 million light-years away. That means that the light you see left the galaxy 2.5 million years ago! Until Edwin Hubble determined that this was a galaxy with his study of Cepheid variables in the 1920s, it was known as the Andromeda Nebula; there was only one known galaxy back then. As you will quickly realize, there are many paths a conversation with the public can take. Be sure to have fun with that.

Preparing your gear is something you likely do for yourself all the time, but public access to your equipment takes some special consideration. Number one for me is the eyepiece I use. I have a good selection of quality eyepieces, but my go-to for public viewing is my trusty Explore Scientific 70° 25mm 2″ eyepiece. It's currently listed at $50 USD, but I got it on sale a few years back for $25 USD. Something with a decent field of view, not too much magnification, an eyecup that allows for cell-phone images of the Moon, and isn't too expensive, is perfect. A bit of mascara or fingerprints on a $25 eyepiece is no big deal; on my 35mm Panoptic, that's a different story. Some of my friends have zoom eyepieces for public events to avoid keeping multiple eyepieces on hand in crowded venues, too. Another equipment consideration I have is access for little ones; I take along a small step ladder or a sturdy equipment box. I use both to let little ones climb up to the eyepiece. You'll be surprised, too, about how interested people are about your gear. While someone may be looking through your telescope, you can have a side conversation about such common topics as the mount, the optical design, the choice of eyepieces, and how to take pictures with a telescope. A final consideration about gear is the tools you can share with people; whether it's a star map, star-finder, Messier card, Moon map, or your favourite app, and showing people how they can use those tools to find their way around the sky. Everything we do allows for more and deeper engagement.

The final tip is an easy one. Astronomy and sharing the night sky is your passion, and if you let that come across, all else becomes secondary. Talk about your "Wow!" moments, and help your audience solidify their "Wow!" moments. For example, last weekend, a young teenager saw the Moon through my telescope, and she was amazed. I then showed her and her dad Mare Serenitatis on a map and they looked again and found that in the 'scope. We then looked at the Caucasus and Apennine mountains on the map and they found those in the telescope view. Finally, we picked out Theophilus near Mare Nectaris on the map, looked it up and found that it is 110 kilometres in diameter. Then, looking through the telescope, they not only found the object, but had scale applied to the whole view. What could have been "Wow!" and then move on, became a 15-minute exercise of discovery. Whether it's 2 people or 10 people hanging around your scope, you can share this kind of insight easily and everyone, including you, will come away with more.

You will quickly find that showing people the beauty of the night sky with your telescope is a real privilege. You get to share their "first" time seeing that object through a telescope, whether it's the Moon, a planet, or a distant galaxy, and you'll be there for their "Wow!" moment. Re-experiencing that first "Wow!" ten times and even 100 times over is something that you will never forget. It's difficult to describe, but you'll know it when it happens for you.

Your passion for the night sky is contagious, and unlike COVID-19, this is a contagion we want to spread far and wide.

Clear Skies. ✶

News Notes / En manchette

Compiled by Jay Anderson

New family member for Elektra

Dedicated astrophotographers know the importance of digital processing to reveal details hidden in the noisy background of an image. Now a team of astronomers lead by Anthony Berdue of the National Astronomical Research Institute of Thailand has used a sophisticated processing algorithm to reveal the presence of a hitherto undetected third moon around the asteroid Elektra, thus identifying the first quadruple asteroid system.

Elektra is a large outer main-belt asteroid with a mean diameter of about 200 km. Thanks to a number of stellar occultations and light-curve measurements over the years, Elektra has been shown to have a peanut-shaped body, possibly due to the merger of two bodies in the early Solar System. Direct images from large telescopes have confirmed the overall shape. In 2003, using the Keck II telescope on Maunakea, Elektra was found to have a companion moonlet (S1), about 6 km in size, in a slightly eccentric orbit of 1300 km radius and a period of 5.3 days.

In December 2014, a second moonlet (S2) was found using the Very Large Telescope (VLT) in Chile. This body was assigned a diameter of 2 km by assuming that its albedo was

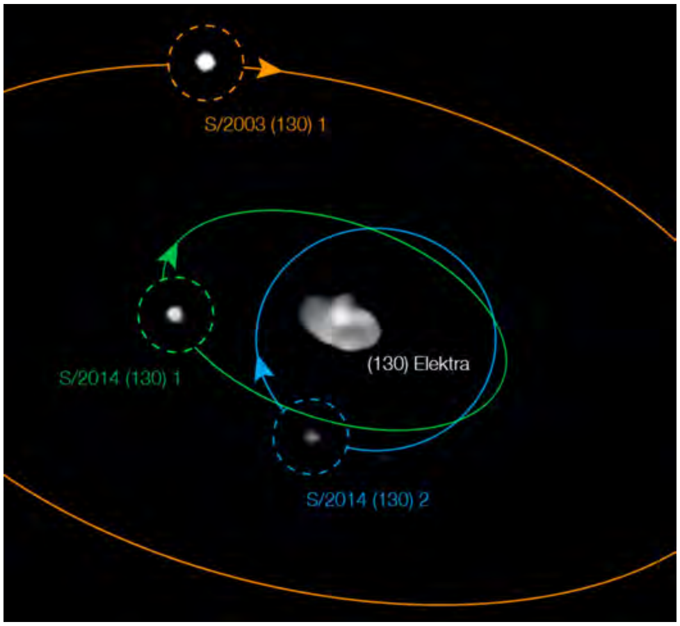

Figure 1 — A composite image of Elektra and its moonlets with orbits superimposed. The new moonlet, S/2014 (130) 2, and its orbit are labelled in blue. Image: ESO.

the same as Elektra. S2 travels in a near-circular orbit, 500 km from Elektra, with a period of 1.2 days.

In November last year, Berdue, with co-researchers Maud Langlois (Université de Lyon), and Frédéric Vachier (Sorbonne Université), re-analyzed the December 2014 images, revealing the fourth member of the quadruple system. This new moonlet (S3) is estimated to have a diameter of 1.6 km and a 16-hour orbital period at an average distance of nearly 350 km. The orbit is very eccentric and highly inclined with respect to the other two moonlets.

The researchers were able to separate the image of S3 from that of Elektra by modelling the glare produced in the image by the parent asteroid and the telescope and then subtracting that model from the original image. By removing a large part of the glare (even though it was imperfectly modelled), the presence of S3 became obvious. A set of two additional observations was then used to determine a preliminary orbit.

The discovery of the third moonlet demonstrates that improvements in processing and data analysis can bring new life to old images—a discovery that applies to past images collected by RASC members.

Compiled in part with material provided by the ESO.

The question of ORCs

ORCs (Odd Radio Circles) are mysterious rings of radio emission—rare, ghostly, millions of light-years in size, and totally unexpected before their discovery last year. Their appearance can best be compared to that of planetary nebulae, except that these orbs are the scale of galactic clusters. The first (ORC1) was detected in a sky survey by the Australian Square Kilometre Array Pathfinder (ASKAP) telescope; since then, four others have been added to the list. A new, high-resolution image captured by the South African Radio Astronomy Observatory's MeerKAT radio telescope is providing researchers with more information to help narrow down its identity. To date, ORCs have only been detected using radio telescopes, with no signs of them when researchers have looked for them using optical, infrared, or X-ray instruments.

Orcs were first thought to be galactic structures, but the distribution of the five known examples on the sky rules out their identification as a Milky Way structure and instead argues for a much more distant origin. There have been several suggestions as to their cause—a spherical shock wave from a central starburst galaxy, an end-on view of jets of energetic particles from an active galactic core, an interaction between colliding galaxies, and even the throat of a wormhole—but at the moment, there is no accepted description of their cause.

The latest image of ORC1 shows a circular, edge-brightened ring with diffuse emission inside and a number of indistinct arcs crossing the ring from side to side. A central galaxy, probably an elliptical, is clearly visible and is believed to be the host of ORC1. A number of knots of emission within the ring appear to be associated with other galaxies. The rings are enormous—about a million light-years across, which is 16-times bigger than our own galaxy. Despite this, odd radio circles are hard to see.

Polarization measurements of ORC1 reveal that the associated magnetic field is tangential to the ring (that is, it follows the shape of the ring) and reaches values as high as 30 percent at the edge of the ring. The same measurements suggest that the ORC resides within a dilute thermal plasma.

Dr. Jordan Collier of the Inter-University Institute for Data Intensive Astronomy, who compiled the image from MeerKAT data, said continuing to observe these odd radio circles will provide researchers with more clues. "People often want to explain their observations and show that it aligns with our best knowledge. To me, it's much more exciting to discover something new, that defies our current understanding," Dr. Collier said.

Figure 2 — Data from SARAO's MeerKAT radio telescope data (green) showing the odd radio circles, is overlaid on optical and near-infrared data from the Dark Energy Survey. ©Jayanne English, University of Manitoba.

"We know ORCs are rings of faint radio emissions surrounding a galaxy with a highly active black hole at its centre, but we don't yet know what causes them, or why they are so rare," commented Professor Ray Norris from Western Sydney University and CSIRO.

To really understand odd radio circles, scientists will need access to even more sensitive radio telescopes such as those of the SKA Observatory, which is supported by more than a dozen countries including the UK, Australia, South Africa, France, Canada, China, and India.

"No doubt the SKA telescopes, once built, will find many more ORCs and be able to tell us more about the lifecycle of galaxies," Professor Norris said. "Until the SKA becomes operational, ASKAP and MeerKAT are set to revolutionize our understanding of the Universe faster than ever before."

Compiled in part with material provided by the Australia Telescope National Facility.

Is Ryugu a CAT

Asteroids hold many clues about the formation and evolution of planets and their satellites. Understanding their history can, therefore, reveal much about our Solar System. While observations made from a distance using electromagnetic waves and telescopes are useful, analyzing samples retrieved from asteroids can yield much more detail about their characteristics and how they may have formed. An endeavour in this direction was the *Hayabusa* mission, which, in 2010, returned to Earth after 7 years with samples from the asteroid Itokawa.

The successor to this mission, called *Hayabusa2*, was completed near the end of 2020, bringing back material from Asteroid 162173 "Ryugu," along with a collection of images and data gathered remotely from close proximity. While the material samples are still being analyzed, the information obtained remotely has revealed three important features about Ryugu.

Firstly, Ryugu is a rubble-pile asteroid composed of small pieces of rock and solid material clumped together by gravity rather than a single, monolithic boulder. Current scientific explanations propose that the rubble-pile character was formed by the accretion of debris after a catastrophic collision between larger asteroids

Secondly, Ryugu is shaped like a spinning top, likely caused by deformation induced by quick rotation. That spin period for deformation is estimated to be 3.5 hours, at which point centrifugal forces balance the gravitational forces along the equatorial plane.

Third, Ryugu has a remarkably high organic matter content. Calculations based on the difference in albedo between the surface and the sub-surface materials determined after the touchdown of the *Hayabusa2* spacecraft infer that the surface layer of Ryugu contains about 60-percent organic matter by area, if the surface materials have optical properties similar to carbonaceous chondrite meteorites.

Figure 3 — Image from the MASCOT camera on one of the rovers carried by the Hayabusa2 *spacecraft to Ryugu. The camera identified two types of rock on Ryugu: Type 1 are dark, irregularly shaped boulders with crumpled, cauliflower-like surfaces, type 2 are slightly brighter, with sharp edges, and smooth, fractured surfaces. Image Credit: MASCOT/DLR/JAXA.*

Of these, the third feature raises a question regarding the origin of Ryugu. If the asteroid is high in organic content (which will be confirmed once the analyses of the returned samples are complete), then its formation from a collision is suspect. Asteroid-belt objects are not noted for their organic content, in contrast to comets, which are known to be rich in carbon compounds.

In a recent effort to answer this question, a research team led by Associate Professor Hitoshi Miura of Nagoya City University, Japan, proposed an alternative explanation backed up by a relatively simple physical model. The researchers suggest that Ryugu, as well as similar rubble-pile asteroids, could be remnants of extinct comets. This study was carried out in collaboration with Professor Eizo Nakamura and Associate Professor Tak Kunihiro from Okayama University, Japan.

Comets are small bodies that form on the outer, colder regions of the Solar System. They are mainly composed of water ice, with some rocky components (debris) mixed in. If a comet enters the inner Solar System—the space delimited by the asteroid belt "before" Jupiter—heat from the solar radiation causes the ice to sublimate and escape, leaving behind rocky debris that compacts due to gravity and forms a rubble-pile asteroid.

To test their hypothesis, the research team conducted numerical simulations using a simple physical model to calculate the time it would take for the ice to sublimate and the resulting increase in the asteroid's rotational speed. Beginning with a homogeneous cometary nucleus composed of centimetre-sized rocky debris and water ice, the model allowed the ice to gradually sublimate, leaving behind a porous, dusty mantle to clothe the evolving asteroid. As the ice continues to sublimate, the nucleus shrinks, eventually becoming a rubble-pile asteroid with an organic character, once all of the water-ice is gone.

The results of their analysis suggested that Ryugu has likely spent a few tens of thousands of years as an active comet before moving into the inner asteroid belt, where the high temperatures vapourized its ice and turned it into a rubble-pile asteroid. In their original assumptions, it took about 8 years for the comet nucleus to build a metre-thick regolith, 640 years to reach a depth of 10 metres, and 51 Ky for all of the ice to sublimate.

This process fits all the observed features of Ryugu, as Dr. Miura explains, "Ice sublimation causes the nucleus of the comet to lose mass and shrink, which increases its speed of rotation. As a result of this spin-up, the cometary nucleus may acquire the rotational speed required for the formation of a spinning-top shape. Additionally, the icy components of comets are thought to contain organic matter generated in the interstellar medium. These organic materials would be deposited on the rocky debris left behind as the ice sublimates."

Overall, this study indicates that spinning-top-shaped, rubble-pile objects with high organic content, such as Ryugu and Bennu (the target of the *OSIRIS-Rex* mission) are comet–asteroid transition objects (CATs). "CATs are small objects that were once active comets but have become extinct and apparently indistinguishable from asteroids," explains Dr. Miura. "Due to their similarities with both comets and asteroids, CATs could provide new insights into our Solar System."

Further compositional analyses of the samples from both Ryugu and Bennu will shed more light on these issues.

Composed in part with material provided by Nagoya City University.

Cloudy and warm with a chance of rubies

MIT astronomers have obtained the clearest view yet of the perpetual dark side of an exoplanet that is "tidally locked" to its star. Their observations, combined with measurements of the planet's permanent day side, provide the first detailed view of an exoplanet's global atmosphere.

"We're now moving beyond taking isolated snapshots of specific regions of exoplanet atmospheres, to study them as the 3-D systems they truly are," says Thomas Mikal-Evans, who led the study as a postdoc in MIT's Kavli Institute for Astrophysics and Space Research.

The planet at the centre of the new study is WASP-121b, a massive gas giant nearly twice the size of Jupiter. The planet is an ultrahot Jupiter and was discovered in 2015 orbiting a star about 850 light-years from Earth. WASP-121b has one of the shortest orbits detected to date, circling its star in just 30 hours. It is also tidally locked, such that its star-facing day side is permanently roasting, while its night side is turned forever toward space.

"Hot Jupiters are famous for having very bright day sides, but the night side is a different beast. WASP-121b's night side is about 10 times fainter than its day side," says Tansu Daylan, a TESS postdoc at MIT who co-authored the study.

Astronomers had previously detected water vapour and studied how the atmospheric temperature changes with altitude on the planet's day side.

The new study captures a much more detailed picture. The researchers were able to map the dramatic temperature changes from the day to the night side, and to see how these temperatures change with altitude. They also tracked the presence of water through the atmosphere to show, for the first time, how water circulates between a planet's day and night sides.

While on Earth, water cycles by first evaporating, then condensing into clouds, then raining out. On WASP-121b, the water cycle is far more intense: On the day side, the atoms that make up water are ripped apart at temperatures over 3000 K. These atoms are blown around to the night side, where colder temperatures allow hydrogen and oxygen atoms to recombine into water molecules, which then blow back to the day side, where the cycle starts again.

The August 2022 *Journal* deadline for submissions is 2022 June 1.

See the published schedule at

rasc.ca/sites/default/files/jrascschedule2022.pdf

The team calculates that the planet's water cycle is sustained by winds that whip the atoms around the planet at speeds of up to 5 kilometres per second.

It also appears that water isn't alone in circulating around the planet. The astronomers found that the night side is cold enough to host exotic clouds of iron and corundum—a mineral that makes up rubies and sapphires. These clouds, like water vapour, may whip around to the day side, where high temperatures vapourize the metals into gas form. On the way, exotic rain might be produced, such as liquid gems from the corundum clouds.

"With this observation, we're really getting a global view of an exoplanet's meteorology," says Mikal-Evans. Co-authors included collaborators from MIT, Johns Hopkins University, Caltech, and other institutions.

The team observed WASP-121b using a spectroscopic camera aboard NASA's *Hubble Space Telescope*. Spectroscopic studies allow scientists to observe atmospheric details on the day sides of many exoplanets. But doing the same for the night side is far trickier, as it requires watching for tiny changes in the planet's entire spectrum as it circles its star.

For the new study, the team observed WASP-121b throughout two full orbits—one in 2018, and the other in 2019. For both observations, the researchers looked through the data for a specific spectral line that indicated the presence of water vapour.

"We saw this water feature and mapped how it changed at different parts of the planet's orbit," Mikal-Evans says. "That encodes information about what the temperature of the planet's atmosphere is doing as a function of altitude."

The changing water feature helped the team map the temperature profile of both the day and night side. They found the day side ranges from 2500 K at its deepest observable layer, to 3500 K in its topmost layers. The night side ranged from 1800 K at its deepest layer, to 1500 K in its upper atmosphere. Interestingly, temperature profiles appeared to flip-flop, rising with altitude on the day side—a "thermal inversion" in meteorological terms—and dropping with altitude on the night side.

The researchers then passed the temperature maps through various models to identify chemicals that are likely to exist in the planet's atmosphere, given specific altitudes and temperatures. This modelling revealed the potential for metal clouds, such as iron, corundum, and titanium on the night side.

From their temperature mapping, the team also observed that the planet's hottest region is shifted to the east of the "substellar" region directly below the star. They deduced that this shift is due to extreme winds. From the size of the shift, the team estimates that the wind speeds clock in at around 5 kilometres per second.

"The gas gets heated up at the substellar point but is getting blown eastward before it can reradiate to space," Mikal-Evans explains.

"These winds are much faster than our jet stream and can probably move clouds across the entire planet in about 20 hours," says Daylan, who led previous work on the planet using NASA's MIT-led mission, TESS.

The astronomers have reserved time on the *James Webb Space Telescope* to observe WASP-121b later this year, and hope to map changes in not just water vapour but also carbon monoxide, which scientists suspect should reside in the atmosphere.

"That would be the first time we could measure a carbon-bearing molecule in this planet's atmosphere," Mikal-Evans says. "The amount of carbon and oxygen in the atmosphere provides clues on where these kinds of planet form." ✶

Figure 4 — An artist's impression of WASP-121 b. Credit: Engine House VFX via Massachusetts Institute of Technology.

Featured Articles / Articles de fond

De-rotating and De-trailing Tripod Shots

by Alister Ling (Edmonton Centre)
(dawnskygaze@gmail.com)

Would you like to recover from a past mistake of short, trailed stars? Do you wonder what those three hours of exposures during the Geminids might have looked like if only you had a tracker? Maybe four years ago, you were new to astronomy and didn't have one. Perhaps you now have skills, but it will be really tough to get back to that special place. Or your tracker is busy with a telephoto shot and you have a second camera sitting on a tripod waiting for aurora. Here's how driveless tracker-processing can give them new life.

Cautionary note: Separately tracking and stacking the sky then blending it with a stacked foreground will remain the best method for some time. Five 2-minute guided exposures at an optimal ISO have less noise and greater dynamic range than 30 20-second shots at a higher ISO. If you're a newcomer or only putting your images online or screen at low-res, you'll prefer the easy, no-fuss done-in-a-couple-of-minutes land/skyscape stackers. As you gain experience and your threshold for acceptable quality rises, you may notice the limitations more, opting for a tracker and the mere five minutes it takes to polar align. Every year, the advancing tech and sensors will make the difference less obvious.

The following apps certainly make it easy (drag, drop, and click), so I recommend that you give these a try first.

Windows: Sequator (https://sites.google.com/site/sequator-global/) A "get-started" short tutorial is here https://sites.google.com/site/alistargazing/articles/driveless-tracking-with-sequator

Mac: Starry Landscape Stacker (https://sites.google.com/site/starrylandscapestacker/home)

Trailing and De-trailing

Trails appear when the exposure is long enough to reveal the sky's rotation for a particular camera-lens configuration. Imagers quickly become familiar with the "500 rule," where the exposure multiplied by focal length must be less than 500 for a full frame to have minimal trailing. Figure 2 is a result of late-night careless math "If 10 sec × 50 mm is ok, so must be 13 sec × 40 mm." For cropped sensors, you need to abide by the "300 rule."

No one will see the trails if the image is for a webpage or post, but on an 20 × 30-cm enlargement print, these defects will typically garner disappointment and a sneer.

After successfully overlaying two images taken five minutes apart during my de-rotation experiment, I immediately realized I could hide these trails by de-rotating a few seconds "ahead" and "behind" and compositing them with "darken."

In densely packed zones and with close double stars, it is not possible to "retrieve data from under the trail" as revealed in (3c), but the cosmetic repair is much more appealing to the eye. Where you simply cannot retake the shot with better technique, de-trailing lets you recover from an "only if…" situation.

De-rotating the Sky

Opportunity meets preparedness: My Star Adventurer tracker was out for repair, but I was hoping to get it back in time for the Orionids. While I was discussing potential plans with my frequent meteor observing companion Bruce McCurdy, he recounted for me his bittersweet memories of the 2018 Orionids, on the shore of Lake Annette, near Jasper. It was only a couple of hours from the shower maximum, absolutely

Figure 1 — Left: a single noisy 13-second exposure. Right: Sequator stacked the following 10 images in the time lapse, both land and sky, and merged them in under five minutes. Unless noted, all images by the author.

Figure 2 — Zoomed-in section showing trails (top), and a single frame after de-trailing (bottom).

clear, and he had his camera capturing a time-lapse of this gorgeous view of Orion perched above a mountain chain, reflected in a mirror-lake. But alas, not a single meteor! With an older camera at ISO 1000 and the individual pictures being JPGs, an enlargement seemed out of the question because it would reveal limitations.

A year ago, I had learned how to use the panorama-generating software *Hugin* to take images from an equatorially mounted dual fisheye (360) camera tracking the Sun and reproject them into a topocentric, zenith-up view suitable for displaying on a planetarium dome. It occurred to me that I could invert the reprojection sequence to track the sky and therefore stack the noisy JPGs into a smoother, higher-contrast final image. I had hoped to find an existing application, but my internet search terms did not match the "right" tags, so I saw nothing of interest. Unaware of the apps noted above, I adapted my pre-existing script to tackle this problem.

Figure 3 — Schematically trailed stars (a), copied to de-rotated positions ahead and behind, here vertically displaced to reveal the offsets (b), then compositing them with darken (c). The "true" field (d) is not completely recovered.

What an amateur astronomer does: places the camera onto an equatorial mount, angles the polar axis up by the amount of their latitude, turns it horizontally to point north, tilts the camera to make the horizon flat to an edge, and lets the mount rotate. Conceptually, I follow this same sequence, but after the rotation I reverse the tilting-rotation sequence to bring the view back to Earth. The challenge was how to actually do this using software. I was inspired by the diagram in Figure 4 from Guy Ottewell. I regularly refer to his excellent *The Astronomical Companion* large-format book during my monthly Zoom "Introduction to Stargazing" sessions.

There it is! Tilt the image so north is to the top, lean it back by the latitude to put the pole at the centre, de-rotate by the angle the Earth has turned since the first exposure, drop it back down, and finally perform a de-tilt. The panorama software *Hugin* (http://hugin.sourceforge.net/), easily imports an image, automatically decoding the EXIF data to extract the lens focal length, its type, field of view, and the camera sensor particulars for scale. Provide *Hugin* with the five-axis roll commands, carefully choosing which of yaw, pitch, or roll movements is used at each step in the particular order, get the signs right, and it outputs the final view in a minute or two per image.

Counter Points

In one sentence, the opposing philosophy is utterly sensible: "just do it right in the first place." That shot of the winter sky from the Geminids? One can do much, much better by getting a tracker, stopping the lens down a notch, and heading out next December. It's possible to argue that it might be cloudy the next four years, but that's a pretty thin premise. A $400 tracker is too much? Given that it will last for more than 10 years, the prorated annual cost is less than that of the gas to drive to a star party. A simple tripod is less fuss than pointing an equatorial at Polaris—so is not tuning a guitar before you play; those two actions take almost the same amount of time, and you'll be more pleased with the result. If you're never going to make enlargements, being happy with posting reduced images online, well, ok. If it's unlikely you will get a second chance to reshoot the stars above Uluru, then definitely de-trail and stack them for a great personal keepsake.

Conclusion

So yes, a beginner with little equipment can get away with using only a tripod and can quickly create surprisingly nice images for webpages. It is possible to repair trailed images, and for those cases when your tracker is being used for another target, driveless stacking works reasonably well. But please don't try to convince yourself that deliberately limiting your image quality is your final goal.

Reference

Guy Ottewell, The Astronomical Companion ISBN 978-0-934546-60-7. [www.universalworkshop.com/]

Appendix – Details

Dozens or even hundreds of images can be reprojected in batch mode. In this case, it was executed on a Windows platform running ActiveState Perl, using CPAN astronomical coordinates and time modules. Thank you to Thomas Modes for providing me with the *Hugin* panotools command-line methodology. The config file for panotools that contains the projection and transformations is a ".pto." Contact the author of this article for a copy of the full code. Human-readable process:

1. Tilt the view to put the north celestial pole "up," usually beyond the top of the page. The formula for this parallactic angle is given in celestial navigation references and luckily is a standard output from astronomical software libraries, requiring inputs for the latitude, longitude, elevation, and time. A field de-rotator on a large Alt-Az mount uses the parallactic angle to turn the camera body by the appropriate amount and direction. For *Hugin*, this is a roll.

2. Pitch the view so that the north celestial pole is at the zenith, by 90-latitude.

3. De-rotate (*Hugin* roll) by the angular equivalent of the time difference between the current and original image. Given that one sidereal day is 23 h 56 min = 360 degrees, then 60 seconds = 0.2507 deg. If we're facing north, then we de-rotate clockwise instead.

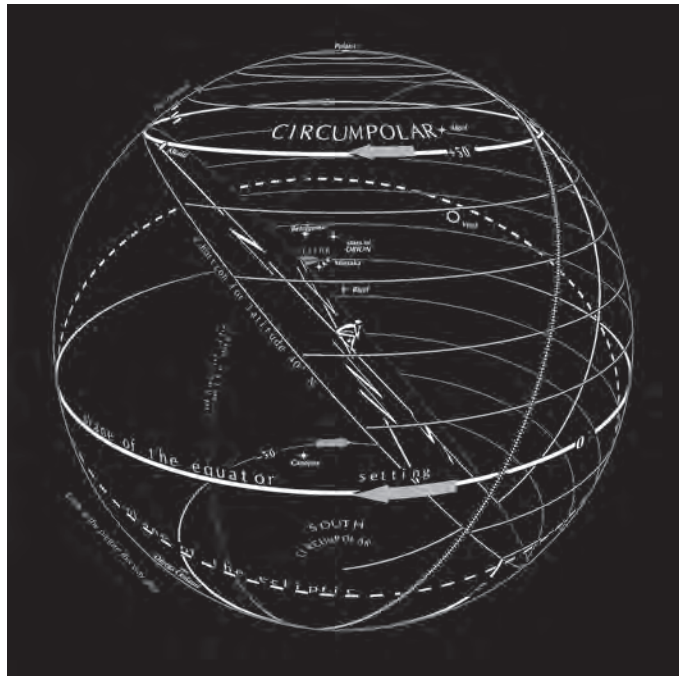

Figure 4 — Reproduced from The Astronomical Companion by Guy Ottewell, (used with permission). reference 1.

4. De-pitch to return the north celestial pole to its original place.

5. Finally, de-roll by the original parallactic angle to return the foreground to nearly horizontal. At first I thought, I had to keep changing the parallactic angle as time progressed, but because everything is rolled/pitched relative to the first image, I use that initial value.

In Perl pseudo-code:

```
foreach time do {

$roll1 =initial parallactic angle

$pitch1 = -1.0 * (90 - $Declination)

`\\bin\\pano_modify.exe --output=inirollpitch.pto --rotate=0,$pitch1,$roll1 $tripod_pto`

$roll2 = $HAfirst - $HAnow; # hourangle difference = de-rotate angle (negative generally)
```

Figure 5 — Thirty-eight 25-second images at ISO 6400 composited using "lighten." Because the pole is not at the centre of the fisheye lens (on the cropped Canon 60Da sensor) the star trails are not circular, a trade-off between sharpness, distortion, and cost, inherent in any lens design.

Figure 6 — The same 38 images processed in Sequator. It did a very respectable job handling the distortion, the light pollution reduction, and the merging of the stationary ground and stacked sky. Since "remove dynamic noises" was checked, the departing car lights (and meteors!) were removed.

```
`\\bin\\pano_modify.exe --output=roll2.pto
--rotate=0,0,$roll2 inirollpitch.pto`

$depitch = -1.0 * $pitch1
`\\bin\\pano_modify.exe --output=depitch.pto
--rotate=0,$depitch,0 roll2.pto`

$deroll = -1.0 * $roll1
`\\bin\\pano_modify.exe --output=total_reproject.pto
--rotate=0,0,$deroll depitch.pto`

# re-project via the command line:

`\\bin\\nona.exe -m TIFF_m -o $imgfin total_reproject.pto
$imgini`

} # end loop
```

Before running this script, I generated the pto for my desired output projection and canvas size, giving enough room for the gradually angled de-rotated images. ✶

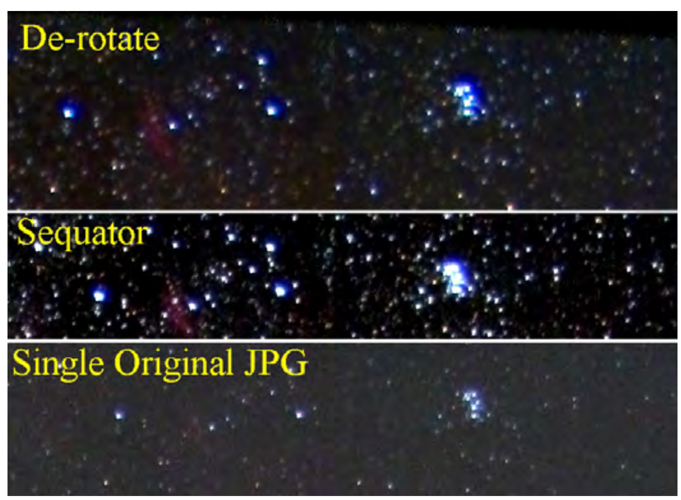

Figure 7 — A comparison of star shapes at the very top-right edge of the frame. The single image shows lens aberrations at the most open f/3.5 of this relatively inexpensive Opteka 6-mm fisheye. The de-rotated approach is nearly perfect, while Sequator's handling is only slightly inferior (I did not spend time trying to make the backgrounds identical, since their stacking and curve processing are different). As long as the Sequator image is viewed on-screen or not overly enlarged, the result is quite pleasing. The comet at right is 46P Wirtanen.

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Visual Observation of a Curious Structure on the Near Side of the Moon

by Hossein Alizadeh Gharib, Ludlow, Shropshire

I wish to report my observation of a curious feature on the near side of the Moon. In April 2019, I was comparing the image quality of three telescopes: a Sky-Watcher SkyTravel 80 refractor, the Celestron C90, and a Meade ETX90.

One night before the full Moon, I noticed a bright patch on the eastern limb of the crater Byrgius. I could not resolve it in the Sky-Watcher 80-mm refractor, but it was clearly visible as a bright ray crater in the Meade and Celestron Maksutovs. I also noticed several dark patches to the south of Byrgius. In my Meade ETX125, they looked like small versions of lunar maria, with dark and smooth floors. However, they were not circular.

Referring to the lunar maps in Antonin Rükl's *Moon, Mars and Venus*, I noticed that they are mapped but not named. Several other sources—which since then I have consulted—have not recorded them as named lunar features. This was strange, because I thought we had already conducted thorough surveys of the Moon by generations of telescopic observers. I was asking myself how these can be unnamed when the International Astronomical Union (IAU) was assigning names to the surface features of faraway objects like the dwarf planet Pluto. The lunar dark albedo features were among the first observed and named structures on the Moon when the age of telescopic observations started in the 17th century.

Even the smallest telescopes reveal that some of the maria are darker than others. Examples of these are Mare Serenitatis, Grimaldi, Mare Tranquillitatis, Mare Vaporum, and, curiously enough, three arcuate parallel patches to the southwest and southern parts of the Mare Humorum (Figure 1). They are recorded on some of the earliest lunar maps.

When I started to look at the lunar atlases and software in 2019, it gradually emerged that these parallel features appeared to be somehow related to the unnamed mare-like depressions I observed south of Byrgius crater. They were roughly making concentric half circles. The giant leap in this story came when I purchased a second-hand Bresser 110-mm Astro Spotting Scope that had a binoviewer and was equipped with two 21-mm ED eyepieces. Being able to observe with both eyes was such a comfortable and relaxing experience that I started to actually look at the Moon like a field geologist when using their stereoscopes on aerial photographs for 3-D effect.

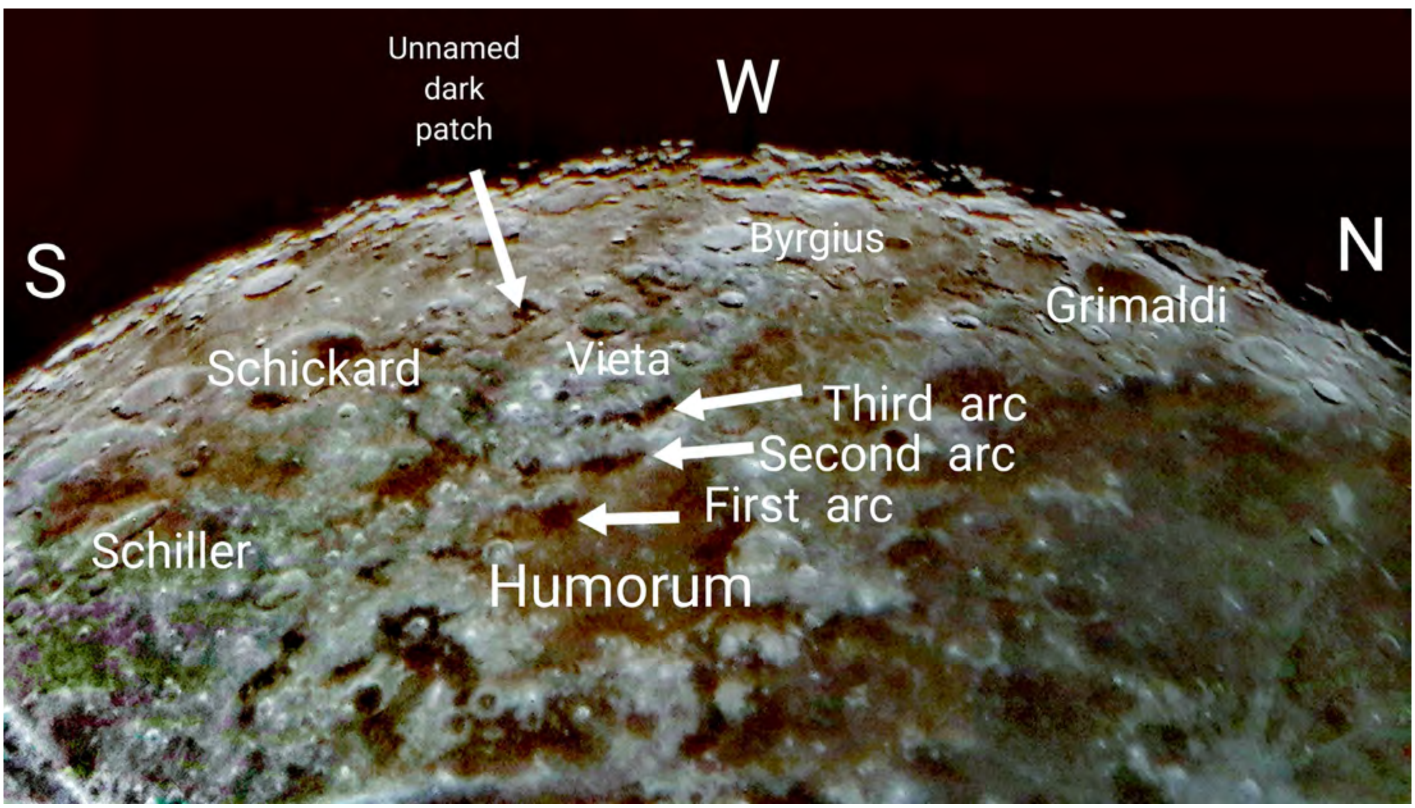


Figure 1 — View of the west side of the lunar limb area from Grimaldi to Schickard. Three parallel arc-shaped dark areas above the Mare Humorum are clearly visible. They define the eastern rim of a curious multiple-ring structure. These dark patterns might be due to effusive volcanic eruptions triggered by Humorum impact along the existing ring faults. Image was captured using a Huawei P10 Plus mobile phone camera held against an image produced by Asahi Pentax 60-mm refracting telescope and magnified by a Svbony 23-mm aspheric eyepiece used on a 0.96 to 1.25 inch eyepiece adapter.

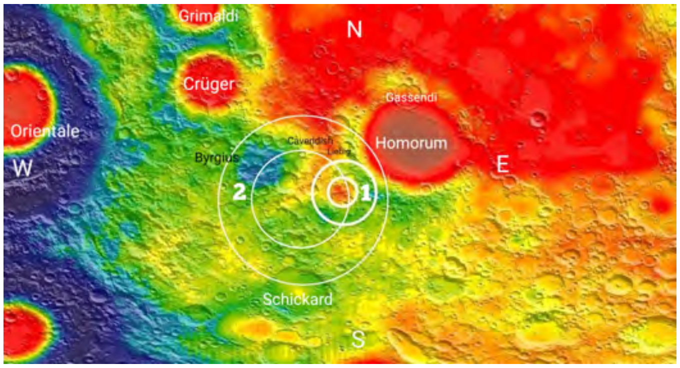


Figure 2 — Bouguer gravity map and shaded relief of lunar surface features for two structures mentioned in this work. It shows the presence of a dense, near-surface gravitationally anomalous candidate peak-ring basin (1) underneath the four craters of Fourier A, Fourier D, Palmieri A, and Palmieri H. The second structure (2) does not display a clear gravitational signature of impact origin. Source: GRAIL primary mission gravity maps (AGU 2012) in https://svs.gsfc.nasa.gov/4014 accessed in 2020.

On the Moon, I was looking for structures, boundaries, and contacts between different lithologies, and ignored, at least for a while, the countless craters that crowded the lunar landscape and looked like superficial shallow features compared to the wealth of tectonics visible to a trained eye. I could see evidence everywhere for fault lines, thrusts, and even detachment of huge lithospheric blocks that could fit together like the pieces of a giant jigsaw puzzle. The ability to use both eyes was the best thing I have experienced in visual astronomy.

During the phases before and after the full Moon, it can be seen that the aforementioned parallel arcs inside the western and southern margins of Mare Humorum are darker than the rest of the basin (Figure 1). There are also dark smooth mare-like patches that cut across and extend beyond the Humorum ring. They can be traced as far as the vicinity of craters Schickard, Lacroix and Piazzi about 500 km to the south and west and, with less distinction, as far north as the bright-rayed crater Byrgius A.

These patches are lowlands that are bordered by circular high platform massifs. Tracing these alternating low, smooth patches and the corresponding high, rough platform massifs define the outline of a ringed structure partially buried, shattered, and superimposed. The outline of the structure roughly measures about 600 km. The west and northwest portion of this structure appears to be covered with a topographically high blanket of material, which probably is the ejecta blanket from the Orientale impact structure. A similar, but less conspicuous ejecta blanket from Humorum basin covers the east and southeast of the structure. As far as I know, this structure has not been detected or mentioned before in scientific literature.

Having said that, I understand that visual perception of circular outlines and linear features potentially can be due to a known psychological phenomenon called *gestalt*. This is due to the tendency in human psychic to complete broken lines and curves and perceive a complete circle by filling the visual gaps. The resulting visual perception potentially can be an illusion. Geological mapping in principle is partly based on *gestalt*. We make geological maps and infer cross sections by filling up the visual gaps that are not visible or accessible to us. One way around this problem of *gestalt* is to complement the mapping surveys with other data that can infer the deeper structures within a planetary body. Here I present a few geophysical evidences that can strengthen the case for the physical existence of this curious lunar feature. However, I invite further evaluation of the evidence by others.

The data from the GRAIL mission indicate a complex pattern over the proposed structure. The most striking is an anomaly

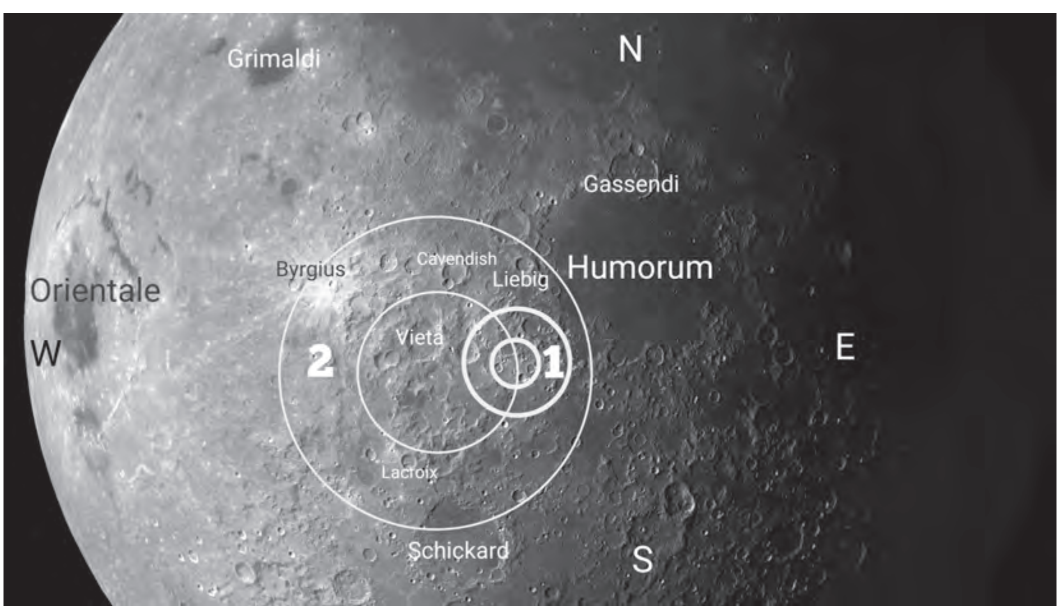
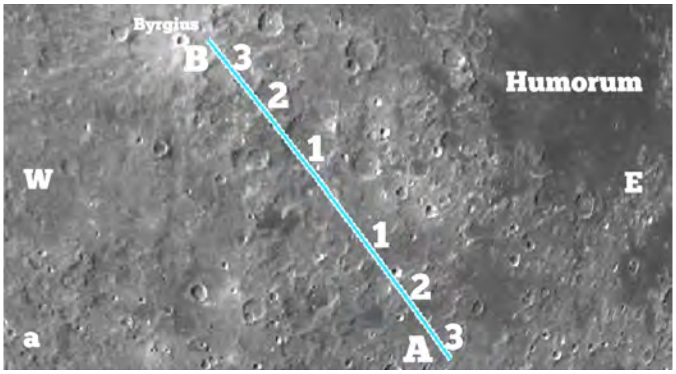
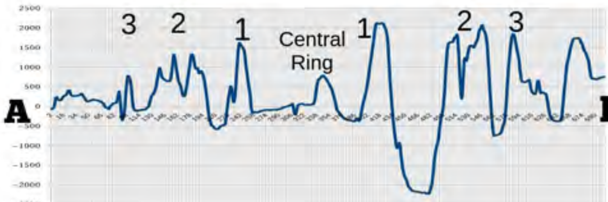


Figure 3 — Chaotic terrain west of Mare Humorum may hide two interesting lunar structures. Number 1 is a hidden pattern of thinner crust and Bouguer anomaly signature of a candidate peak-ring basin that is only visible in GRAIL geophysical data. Here the inner 90-km and the outer 200-km rings are marked. Number 2 is a visible topographic feature reminiscent of a transitional degraded peak-ring to multi-ring basin. Screenshot from MoonGlobe HD app, above globe viewpoint, north on top.



4a



4b

Figures 4a and 4b — Off-centre elevation profile through the structure 2. Horizontal axis is in kilometres and covers 640 km from A to B. Vertical axis is in metres. First and second rings in (a) are better defined than the third ring, which is deeply excavated by later cratering and covered by Orientale ejecta blanket. Profile (b) is made using the quickmap.lroc.asu.edu website.

mapped as a circular pattern of thinner crust over the four craters of Fourier A, Fourier D, Palmieri A, and Palmieri H. However, it is possible to trace the Bouguer anomaly signature reminiscent of a highly modified peak-ring structure here, too. This is done by removing the gravity effect due to topography that reveals the underneath structure. By doing this, a round, central, high-peak anomaly appears, which on the surface roughly corresponds to the four craters of Fourier A, D and Palmieri H, A (Figure 2).

This central high-peak anomaly is offset by about 90 km from the surface topographic centre of the structure at Fourier crater. Such an offset is odd and may indicate that here we are dealing not with one, but two distinct lunar structures (Figure 3). The first one is a candidate peak-ring structure, visible in GRAIL data but absent in visible topography, that has a diameter of 200 km. The second structure is a resurfaced, partially buried transitional degraded peak-ring to multi-ring basin, about 600 km in diameter, without a pronounced gravity signature, but visible at the surface in the form of a series of mare patches and highland arcs that I observed visually.

In the first structure (the 200-km candidate peak-ring structure designated as number 1), the central positive anomaly is immediately followed by a ring of anomalous low gravity that starts from the mare patch to the east of de Gasparis crater (east of the Rima de Gasparis graben), continues clockwise to Palmieri crater with its Rimae Palmieri grabens, then turns south toward the crater Palmieri G and continues in a northwesterly direction until south of the main crater Fourier itself. From there toward the northwest, there is a high Bouguer anomaly that may correspond to a spur of Procellarum KREEP Terrain feeder dykes on the near side of the Moon.

On the surface, there are further arc-shaped hills bounded by three mare patches, one unnamed, located south of Vieta, and two named as Lehman E and Drebbel E. This arc is mirrored to the north by similar arcuate high hills and mare patches that extend from west of crater Liebig and disappear into the Rimae de Gasparis graben to the north. These are related to the 600-km transitional degraded peak-ring to multi-ring basin that I have called number 2. An elevation profile is provided in Figure 4.

Existence of KREEP Terrain feeder dykes near and under the structure may mean that the visible dark patch features can be explained by fissure eruptions from KREEP Terrain feeder dykes in a pre-existing concentric ringed structure that may have been reactivated following the Humorum impact.

The mare patches that originally led me to the position of the proposed structure number 2 are darker than their adjacent lava fields in the Mare Humorum. An age estimate of 3.94 Gy to 3.62 Gy are proposed for them (Hiesinger et al. 2011), which partly overlap but generally is older than the age estimate of 3.75 Gy–3.10 Gy for the rest of Humorum basin. There are two dark patches in the south and north floor of Schickard that follow a similar arc and are of the age of 3.72 Gy–3.62/3.75 Gy. If these age estimates are correct, the lava from the fissure eruptions that created the lava patches of proposed number 2 structure may not be the result of the Humorum impact, because Humorum ejecta partially cover this structure.

In conclusion, I wish to reiterate that there is evidence that surface albedo and topography define the outline of a transitional degraded peak-ring to multi-ring basin (number 2) to the southwest of Humorum basin. This structure is on top of a gravity anomaly but offset by 90 km, where lunar lithosphere appears thinner and I propose it as a separate candidate peak-ring basin (number 1). Formation of these two structures may predate that of the Humorum basin. As there are no previous designated names for these structures, I wish to propose later two names, rather than numbers, in reference to these two structures from among the Iranian rocket pioneers and geologists. This is in line with the modern trend in IAU to diversify lunar nomenclature from its current Eurocentric tradition. ✶

Reference

Hiesinger, H. *et al.* (2011), "Ages and stratigraphy of lunar mare basalts: A synthesis", in Ambrose, W.A., and Williams, D.A., eds., *Recent Advances and Current Research Issues in Lunar Stratigraphy: Geological Society of America Special Paper 477*, 1–51.

Canadian Visits of Early Spacefarers

by Christopher Gainor, Victoria Centre

The first persons to fly into space came from the United States and the Union of Soviet Socialist Republics, but no Canadian flew into space until 1984. However, Canada hosted early astronauts and the first cosmonaut shortly after his flight in 1961. This article tells the stories of Canadian visits by Yuri Gagarin in 1961, U.S. astronaut Virgil Grissom in 1966, and the more recent visit of the first Chinese spacefarer, Yang Liwei, in 2004.

Yuri Gagarin—First in Space and First in Canada

The first human to fly in space was Yuri Gagarin, the Soviet Air Force Major who made a single orbit of the Earth on 1961 April 12, on board the Vostok 1 spacecraft. Less than four months later, he became the first space traveller to visit Canada.

In August 1961, Gagarin visited Pugwash, a village in Cumberland County, Nova Scotia, with a population of about 800 people. Located on Northumberland Strait opposite Prince Edward Island and not too far from the New Brunswick border, its main industries are lobster fishing and salt mining.

Gagarin's visit to this usually quiet village came about because of Pugwash's political claim to fame from the depths of the Cold War between the United States and the Soviet Union in the decades following World War II. Cyrus Eaton (1883–1979), a millionaire investment banker who was born in Pugwash but resided in the United States where he made his fortune, set up the first of a series of conferences of intellectuals and scientists in Pugwash in 1957 to discuss issues arising out of the existence of nuclear weapons.

The Pugwash conferences were more warmly embraced by the leadership of the Soviet Union than the United States, and so not long after Gagarin made his historic space flight, Soviet Premier Nikita Khrushchev decided to dispatch Gagarin to Pugwash.

Immediately after his historic space flight, Gagarin had been feted in Red Square in Moscow and in other capitals of Soviet-aligned countries in Eastern Europe. In July, Gagarin visited Great Britain and met Queen Elizabeth II. Later that month he headed for Cuba and Brazil.

On Saturday, 1961 August 5, Gagarin arrived from Brazil at Halifax International Airport, where he was greeted by a crowd of more than 300 people. In those days, passengers walked onto the tarmac to board and exit aircraft, and airport visitors had access to an open observation deck overlooking the tarmac and to a grassy area alongside the gates to the aircraft, and both these areas were filled with spectators for Gagarin's arrival.[1]

Among the spectators was a girl not yet eight years old who stood with her parents on the grass next to the small fence that lined the aircraft gate. Later in life, Mary Lou Whitehorne would go on to a career as an astronomy educator and service as National President of The Royal Astronomical Society of Canada.

After the aircraft landed and its passengers disembarked and walked to the terminal in front of a cheering crowd, Whitehorne's location in front of the other spectators gave her a good view of Gagarin. "I remember exclaiming, 'But he's so SMALL!'" she recalled. "Gagarin's compact stature was an advantage in his successful selection as the first man in space. But he was a hero, and I believed all heroes were large and imposing people.

Figure 1 — Major Yuri Gagarin and Cyrus Eaton arriving in Pugwash, Nova Scotia, 1961 August 5. (Thinker's Lodge, Pugwash, Nova Scotia)

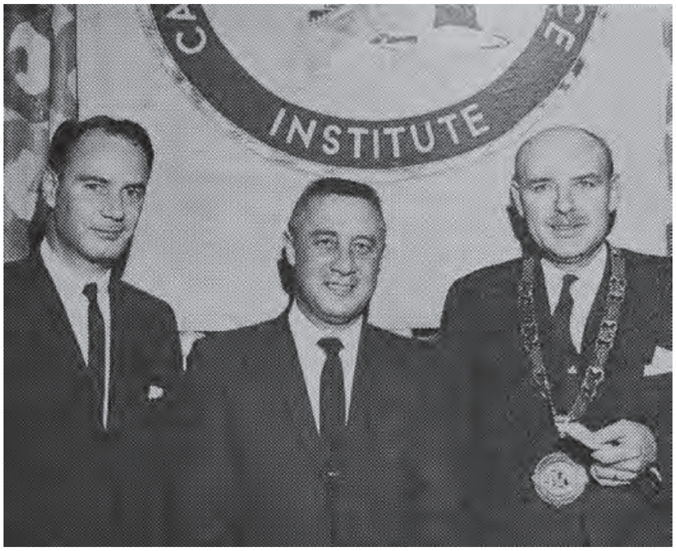


Figure 2 — USAF Colonel Virgil I. Grissom (centre) with CASI Toronto Branch President Dr. Phil Lapp (l) and CASI President J.L. Orr, 1966 March 10. (Canadian Aeronautics and Space Institute)

"Certainly, he was very smart-looking in his uniform, pleasant of face, and he appeared energetic and happy to be in Halifax. It was exciting to see him, but I was disappointed that he wasn't the big, imposing man I had imagined," Whitehorne said.[2]

Gagarin and his party were immediately driven the 100 miles to Pugwash, passing through villages where curious locals, many of them children, lined the roads.

There was no conference going on at the time in Pugwash, so a program for Gagarin was improvised. He was paraded through the village to a local bandstand where he was entertained by the Amherst Legion Brass Band and the Dunvegan Girls Pipe Band and Dancers, and took in presentations from the Little League, local 4-H clubs and a Red Cross swimming class.

Eaton spoke to a crowd estimated at 2,500 people, along with Soviet Ambassador to Canada, A.A. Aroutunian, and local dignitaries. A newspaper account called the event "an abbreviated version of the Gathering of the Clans." Gagarin spoke highly of Eaton's political work and of his own devotion to the cause of peace. He also read a letter from Premier Khrushchev. [4]

Gagarin also visited Thinkers Lodge, the rambling white clapboard house on one of the most spectacular spots in Pugwash that Eaton had donated for the Pugwash conferences, and promised reporters that there would be exciting new Soviet space achievements "very soon."

The world's first spaceman was as good as his word. That evening he went to Eaton's farm in Deep Cove on Nova Scotia's South Shore, where he looked forward to a day off from his official duties. But Gagarin was roused early the next morning with news that his backup and friend, Gherman Titov, had been launched into orbit on a 17-orbit, 25-hour flight. Gagarin was granted his wish to quickly return to the Soviet Union, and a few hours later, he was back at Halifax airport, this time with a crowd of nearly 1,000 people to see him off.

Mechanical problems delayed the Illyushin-18 airliner's takeoff for two hours, and Gagarin was cheered by the crowd whenever he appeared during the wait. But in the middle of the afternoon, barely 30 hours after he arrived, he was on his way to Moscow for the celebrations of Titov's flight.[5]

Although Gagarin would travel widely in the years ahead, he only returned once to North America for a 1963 visit to the United Nations in New York. He died in the crash of his jet aircraft in 1968, and entered the pantheon of Soviet heroes, and his popularity outlived the Soviet Union. Starting in the 1970s, other Soviet and Russian cosmonauts have visited Canada for special events.

The Pugwash Conferences on Science and World Affairs have also outlasted the Cold War. Pugwash's continuing work to eradicate the threat from nuclear weapons was recognized in 1995 with the Nobel Peace Prize, which was on view in the Thinkers Lodge in Pugwash along with photos of Gagarin's visit when the author came to visit in 2015.

Virgil I. "Gus" Grissom Visits Toronto

Canada's location next to the United States made it easy for Canadians to follow the exploits of the early U.S. astronauts on the Mercury, Gemini, and Apollo flights on television and other media. Some Canadians journeyed to Cape Canaveral in Florida to see the launches for themselves.

The first visit of a flown U.S. astronaut to Canada known to the author was a low-key visit of a few hours to the Toronto International Airport area in 1966 made by Virgil I. "Gus" Grissom, the second American to fly in space and the commander of the first crewed Gemini mission.

Grissom was an Air Force test pilot before he became one of America's original seven Mercury astronauts. He nearly lost his life on 1961 July 21, when his *Liberty Bell 7* capsule filled with water and sank in the Atlantic Ocean at the conclusion of the suborbital Mercury-Redstone 4 flight. Along with John Young, Grissom flew on the Gemini 3 flight on 1965 March 23.

By the time Grissom flew his T-38 jet from a meeting in Las Vegas into Toronto International Airport on 1966 March 10, he was already training for upcoming flights on the Apollo spacecraft that would carry astronauts to the Moon. At that time, Gemini had carried five crews of astronauts into space in 1965, and the sixth Gemini crew was preparing for an ambitious flight a few days after Grissom's Toronto visit. On February 26, the first Saturn IB rocket had carried the first production Apollo Command and Service Module into space.

Figure 3 — Yang Liwei (right) with Chinese officials at the Vancouver Convention Centre, 55th International Astronautical Congress (Chris Gainor)

Shortly after he arrived in Toronto, Grissom held a short press conference and spoke about computer predictions that it might take three attempts before Apollo astronauts would successfully land on the Moon. "When we were beginning the Mercury series, computers predicted we would lose two out of seven astronauts," he said. "They were wrong then and I think they'll be wrong again. I don't think we'll lose any Apollo astronauts."

Grissom said he hoped to be the first human on the Moon, and a newspaper account of the event quoted unnamed NASA officials as saying he was the "best bet" to get his wish.[6]

The astronaut was the main dinner speaker that evening at the first Avionics Symposium held by the Canadian Aeronautics and Space Institute, which took place at the Constellation Hotel, located near the airport at Dixon Road and Carlingview Drive, which then was located in Etobicoke but now is part of Toronto.[7]

The need to accommodate the crowd of 350 people had caused the dinner to be shifted to a larger room than planned, and when Grissom was introduced, "the whole room rose to its feet in prolonged applause." His talk began with an acknowledgement of the work Canadian aeronautical engineer James A. Chamberlin and others who went to NASA from Avro Canada in 1959 after the Canadian government cancelled the CF-105 Avro Arrow jet interceptor program. Chamberlin and his colleagues helped make the U.S. space program look Canadian, Grissom said.

Much of the talk was given over to technical explanations of the Gemini and Apollo programs, and included a 20-minute film of highlights from the 1965 Gemini flights. Grissom concluded with a discussion of some of the effects of weightlessness, including the need for sleeping astronauts to place their arms in restraints. "As he finished, the room again rose to its feet with enthusiastic applause. The Institute has seen nothing like it before," an account of his talk related.

Institute President J.L. Orr presented Grissom with a letter opener, and Toronto Mayor Philip G. Givens gave the astronaut a set of gold cufflinks accompanied by a "sparkling tribute." The audience was told that during the day, the hotel's menu had included a "Grissom pie."[8]

Eleven days after Grissom's appearance in Toronto, he was named as commander of the first crewed Apollo flight, which became known as Apollo 1. Before they could fly into space, Grissom and his crewmates Edward H. White II and Roger B. Chaffee died on 1967 January 27, when a fire burned through the spacecraft during a ground test.

No Apollo astronauts were killed in flight, and the first attempt to land astronauts on the Moon succeeded in 1969. Five of the six landing attempts that followed also succeeded. Much of Apollo's success has been credited to the changes that were made to the spacecraft as a result of the loss of Grissom, White, and Chaffee.

The author is unaware of other visits to Canada by other members of America's original seven astronauts, although doubtless some visited for vacations or other private purposes. John Glenn, who was the first American to orbit the Earth on his Mercury-Atlas 6 flight on 1962 February 20, is reported to have visited a car dealer in Vancouver, B.C., before his flight, where he is said to have purchased a car rarely seen in North America, a German-made NSU Prinz, which was known for its fuel economy.[9]

China's First Spacefarer in Vancouver

The crew of the first Apollo lunar landing flight—Neil Armstrong, Buzz Aldrin, and Michael Collins—was received for an official visit to Ottawa and Montreal in December 1969[10]. In the 1970s and afterward, visits by astronauts and cosmonauts to Canada became more frequent. In 1970, a group of U.S. astronauts visited a Canadian Forces testing ground in Alberta as part of their geological training for Apollo's final lunar flights, and in 1971 and 1972, astronauts that flew on the last two Apollo lunar expeditions trained for their lunar traverses near Sudbury, Ontario.[11]

NASA's *Space Shuttle* program began in 1972, and soon Canada joined the program when it agreed to supply the *Space Shuttle* Remote Manipulator System, better known in Canada as the Canadarm. Well before the Canadarm flew for the first time on the second shuttle mission in 1981, astronauts began coming to Canada to train on simulators of the Canadarm, which they continue to do to the present day for the Canadarm that is installed on the International Space Station. The first shuttle astronauts to use the Canadarm, Joe Engle and Richard Truly, toured Canada early in 1982 and gave presentations on the Canadarm.

Because of Canada's contributions to the shuttle program, NASA invited the government of Canada to fly astronauts on board the shuttle. Canada selected its first six astronauts in 1983, and in October 1984, Marc Garneau became the first Canadian to fly in space. The Canadian astronaut program has continued since that time.

Astronauts who had flown in Apollo and even a few cosmonauts began to visit Canada in the 1970s for a variety of reasons, including book promotions, academic meetings, and as attractions at trade shows, engineering meetings, among other things. Both the Russian and American space programs have flown people from other countries into orbit. Spacefarers have formed their own organization, the Association of Space Explorers, and its 1996 Congress took place in Montreal.

Since 1950, an International Astronautical Congress has been held annually, and since human space programs began, these meetings have drawn many astronauts and cosmonauts, some of whom have gone on to management positions in their space programs. Canada first hosted a congress in 1991 at Montréal, and congresses have also taken place in Vancouver in 2004 and Toronto in 2014.

A notable visitor to the 55th International Astronautical Congress in Vancouver was the first spacefarer from China, Yang Liwei, a Colonel in the People's Liberation Army Air Force, who flew into space aboard *Shenzhou 5* on 2003 October 15. The flight lasted 14 orbits over 21 hours.[12]

On the first day of the congress in Vancouver a little less than a year later, the Chinese government announced that Yang would appear at the congress the next morning, his first appearance outside of China or Hong Kong. Despite the short notice, spectators filled one of the larger meeting rooms at the Vancouver Convention Centre on 2004 October 5, to see Yang. When he appeared, Yang received a standing ovation, but the only speaking at that event was done by a Chinese government official.

The author was supposed to give a presentation at the same time as Yang, but he and other participants in the author's session chose to join the crowds at Yang's appearance. That session resumed after Yang's appearance. ✶

Endnotes

1 "Gagarin Cuts Short Visit to N.S.," The Gazette, Montreal, 1961 August 7 , p. 2. The present Halifax airport opened in 1960 and has been rebuilt since Gagarin's visit. In 2005 the airport was named after former Nova Scotia premier and federal Opposition Leader Robert Stanfield.

2 Mary Lou Whitehorne, "Yuri Gagarin in Halifax," recollection shared with author, 2022 January 29.

3 "Gagarin Cuts Short Visit." Details of the Gagarin's visit to Pugwash are also available in Marcus Gleisser, The World of Cyrus Eaton (New York: A.S. Barnes & Co., 1965) pp. 226–227; a pamphlet for the event available at Thinkers Lodge, Pugwash, N.S.; and Cathy Eaton, Thinkers Lodge: Its History and Legacy (Creative Authors Press, 2018) pp. 70–72. See also www.thinkerslodgehistories.com

4 Eaton, Thinkers Lodge.

5 "Gagarin Cuts Short Visit."

6 "Grissom debunks 'brain,'" Toronto Telegram, 1966 March 11. The Toronto International Airport was named in 1984 after Lester B. Pearson, who was Prime Minister of Canada from 1963 to 1968.

7 The Constellation Hotel was built in 1960 and demolished in 2012. In later years it was known as the Regal Constellation Hotel.

8 An account of the dinner is included in the May 1966 issue of the Canadian Aeronautics and Space Journal's article on the Avionics Symposium, pp. 204–206.

9 Randy Raine-Reusch, "Extraordinary People, John Glenn – Astronaut," Within the Wind, 2014 September 14. https://withinthewind.wordpress.com/2014/09/14/john-glenn-astronaut/ ; "John Glenn Had The Coolest Car Of Any Astronaut," Jalopnik, 2016 December 9. https://jalopnik.com/john-glenn-had-the-coolest-car-of-any-astronaut-1789933831 Both pages accessed 2022 March 14.

10 Christopher Gainor, "The Apollo 11 Astronauts Visit Canada," JRASC, April 2022, 43–47.

11 Christopher Gainor, "Apollo Geological Training in Canada, 1970–1972," JRASC, February 2022, 9–15.

12 Although Yang Liwei was the first Chinese Citizen to fly in space, Shanghai-born Taylor Wang flew on board the shuttle in 1985, but he was a U.S. citizen by that time. U.S. Apollo astronaut William Anders was born in Hong Kong of American parents. Spacefarers from China are often called Taikonauts by western media.

Figure 1 – Bruce Murray (Hamilton Centre) took this stunning image of the Triangulum Galaxy (Messier 33) in November 2021 from his cottage at Desert Lake in South Frontenac, Ontario. He used an Explore Scientific FCD100 127-mm CF on an iOptron CEM70 mount with a ZWO ASI2600MC Pro camera cooled to –10 °C. Guiding was done with a StarField 50-mm Guide Scope with a ZWO ASI290MM Mini Guide Camera. 32 × 300 secs QUAD Band-Pass (Hα, Hβ, S, OIII) 39 × 300 secs IDAS-P2. Processing was done in PixInsight.

Figure 2 – This great capture of the zodiacal light is from Andrea Girones. Andrea says, "I waited for astronomical twilight to descend and, while I was setting up my star-tracker for a shot of Orion, I imagined I saw a bright glow to the west. Although it was visible [to the] naked eye, it became very apparent in the photo. I never thought I would be able to see the phenomenon and was very pleased to capture on camera." She shot the image on the night of the new Moon, 2022 April 1, looking west into Lake Huron in Port Albert, Ontario. She used a Nikon D750, with a Rokinon 14-mm 2.8 lens at ƒ/3.5. 25 seconds at ISO 6400. 2 × 1 panorama.

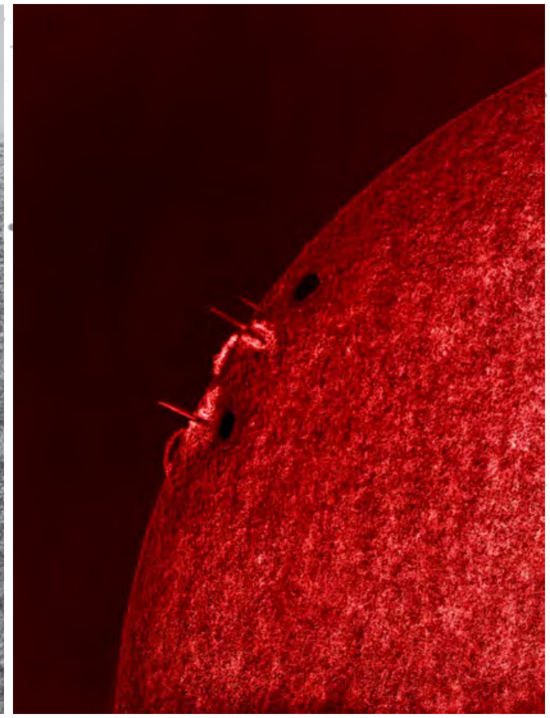


Figure 3a/b – This incredibly detailed sketch was done by Gerry Smerchanski from his home in Teulon, Manitoba. He used graphite and charcoal pencils on white paper with White Out for the sunspots. It was made as a "negative" image (3a) to be inverted using MS Paint, re-oriented and coloured with an ancient version of iPhoto, to give the sketch a look similar to the hydrogen-alpha visual experience. Observed with a Lunt 50-mm pressure-tuned Hα solar telescope at 50×. North is up and east to the left in the coloured sketch (3b).

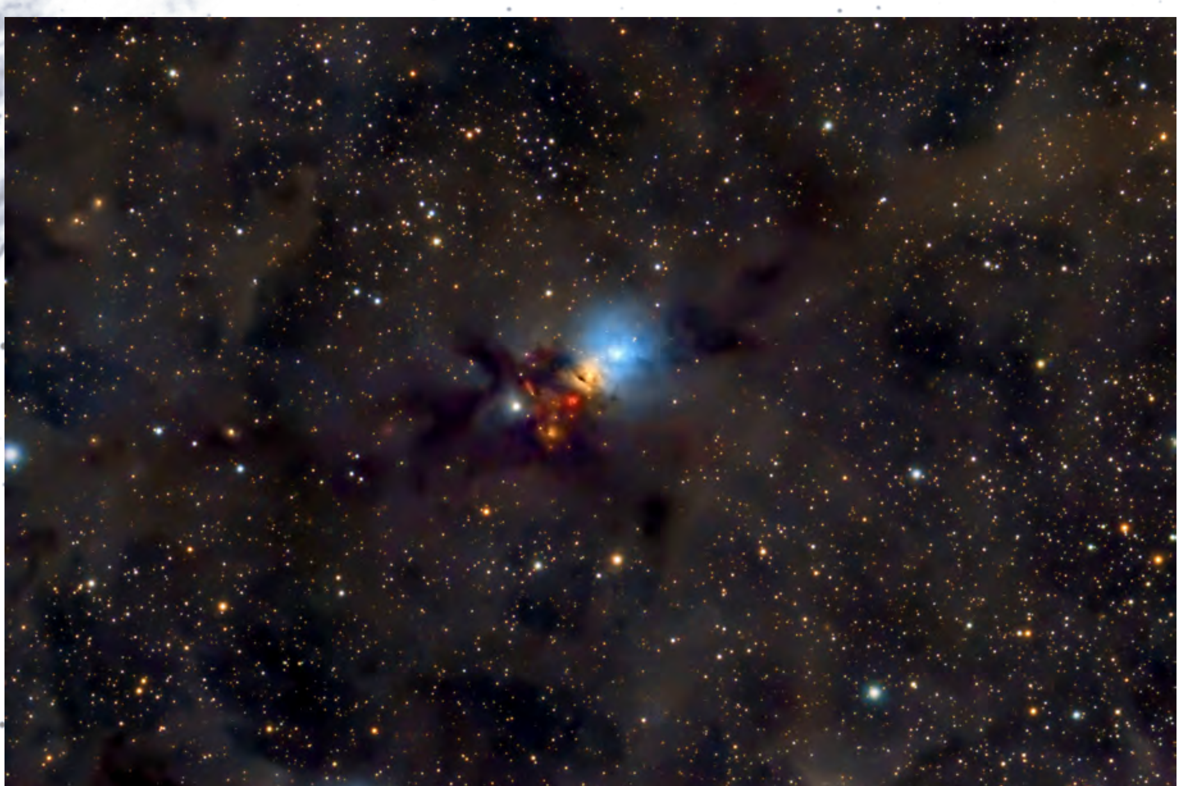


Figure 4 – Shawn Nielson took this amazing image of NGC 1333—a reflection nebula located in the northern constellation Perseus, along with its dusty surroundings—between January and March 2022 from his backyard in Kitchener, Ontario. He used an Explore Scientific 127CF triplet, QHY268M and Optolong filters (LRGB). Total integration was 13 hours. Processed in PixInsight.

AAVSO

Your Monthly Guide to Variable Stars – Series Two

by Jim Fox, AAVSO

W Virginis (W Vir) (May)

In 1866, W Virginis was discovered to be a variable star by German astronomer Eduard Shonfeld while he was working as an assistant to Frederick Argelander who is often considered the father of variable star astronomy. As a yellow giant, pulsating star, W Vir was classified as a Cepheid-type variable. However, it was not until 1950 when Walter Baade developed the concept of Population I and Population II stars that W Vir was reclassified and became the prototype of the Population II Cepheid.

Also called Type I and Type II Cepheids, stars of the two populations have different period-luminosity relationships. A Type I Cepheid averages about 1.5 magnitudes brighter than its Type II counterpart having the same period. Since Population II stars date from the origin of the Milky Way Galaxy, they are made almost entirely of hydrogen and helium, having much less metal content than younger, Population I stars. As a Type II Cepheid, W Vir is one of the oldest stars in the galaxy and may provide clues to stellar and galactic evolution!

Light curves of W Vir variables often show a hump or plateau in the descending portion of their light curves, a characteristic not seen in the light curve of Type I Cepheids. As Type II Cepheids continue to evolve, they are expected to evolve in their place on the Hertzsprung-Russell diagram and their periods are expected to change as well. However, additional observations are needed over several decades to prove if this theory is correct. That is where your observations can help.

W Vir varies between visual magnitudes 9.46 – 10.75 with a period of just over 17 days. It can be found at 13h 26m 02s, –03°22′43″, about 1° NNE of 6.8 magnitude SAO 139322 labelled 68 on this chart. Figure 1 is not inverted with north up and east left. W Vir is the highlighted open circle. Chart courtesy AAVSO. Southern observers can follow Kappa Pavonis, the brightest of the W Vir stars, at 18h 56m 57s, –67°14′01″ and varying between magnitudes 3.9 – 4.8 over a period of 9 days.

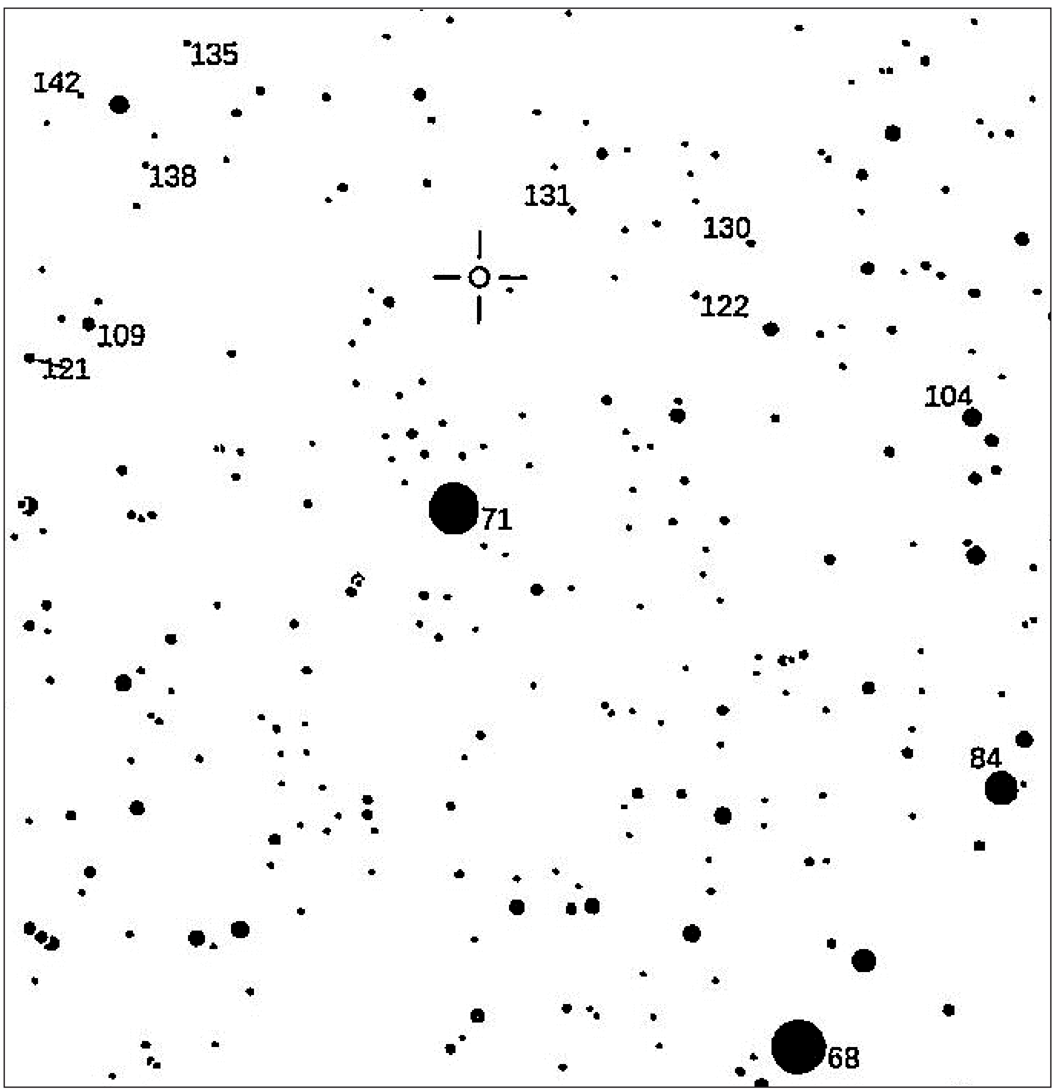


Figure 1 — W Virginis (W Vir)

RS Canum Venaticorum (RS CVn) (June)

Variability of RS Canum Venaticorum was discovered in 1914 by Russian astronomer Lidiya Tseraskaya, the wife of the director of the Moscow Observatory, as she studied photographic plates taken by her husband. It is an eclipsing binary system varying between visual magnitude 7.9 and 9.1 with a period of 4.8 days. That sounds simple enough but wait! There's more!

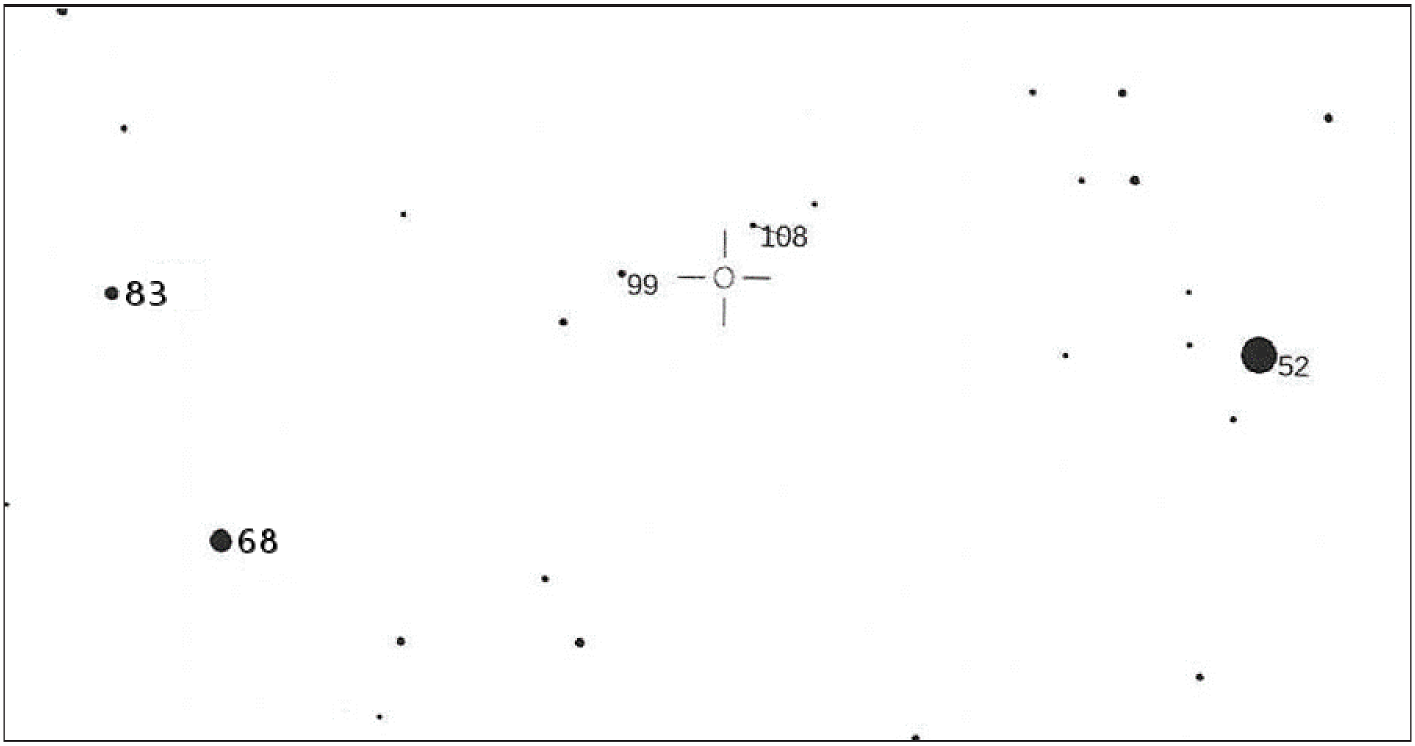


Figure 2 — RS Canum Venaticorum (RS CVn)

Everyone is familiar with the concept of sunspots on our Sun. Is it reasonable to expect "starspots" on other stars? The answer is a resounding YES! In the case of RS CVn, and others of its class, the spots can cover as much as 37% of the chromosphere's surface. This leads to a whole class of rotating variable stars as these spots move across the surface as seen from Earth. In extreme cases, they can add 0.4 magnitude to the drop in light. In the case of RS CVn, the spots cause a distortion in the otherwise sudden drop of an eclipse. During the secondary, minor, eclipse, a spot may reduce the amount of light blocked, making a shallower eclipse. In theory, spots could also cause a displacement of the time of eclipse, but such an effect is probably smaller than the "noise" of observational errors. The total spot coverage on RS CVn varies with a cycle of about 19 years compared to the Sun's 11-year sunspot cycle.

RS CVn can be found at 13h10m37s, +35°56′06″, some 3.75° southeast of Alpha Canum Venaticorum (SAO 63257). It is also 1° east of 14 Canum Venaticorum (SAO 63348) the star marked as 52 on the chart. Stars labelled 68 and 83 are not "official" comparison stars for RS CVn, but they can help you follow its brightness changes as they occur. Figure 2 is not inverted with north up and east left. RS CVn is the highlighted open circle. Chart courtesy AAVSO. ✶

Jim Fox has owned many telescopes in his astronomical journey—he's even ground a few mirrors for his own. Jim has been a long-standing Astronomical League member and served as President from 1990–1994, as well as serving on the Board of the Astronomical Society of the Pacific. He was awarded the Leslie C. Peltier Award by the Astronomical League in 2014 and he has served several years as the AAVSO Photoelectric Photometry Coordinator. The IAU named asteroid 2000 EN138 "(50717) Jimfox" to honour his many achievements.

Omicron! (But not the one you're thinking about)

by David Levy, Kingston
& Montréal Centres

Over the last few months, you must have read dozens of articles, online or in print, about the Omicron variant of COVID-19. Fortunately, this is not one of them. This article is about Omicron² Eridani. It is a faint star in the constellation of Eridanus, the River.

Actually, there are two Omicron stars in that constellation. The first is brighter and is a variable star. The second one is one of the closest stars to the Sun. Omicron², also known as 40 Eridani, happens to be not a disease but one of the most interesting star systems in the entire sky.

Omicron² is a triple-star system that is only about 16 light-years away. Its brightest component is a Sun-like star faintly visible to the unaided eye on a good night. It lies in northern Eridanus, the River, just a few degrees west of Rigel at the foot of Orion. The secondary is a white-dwarf star. Unlike the companion of Sirius, this star is 9th magnitude and not near the brighter star, so it is easy to see in a small telescope. The third star is not far from the secondary, but at 11th magnitude it is also not difficult to spot. This third star is a red dwarf.

Although red-dwarf stars are the most plentiful by far in our region of the Milky Way, they are almost impossible to see because they are so small. The closest one to us is Proxima Centauri, or Alpha Centauri C, which at 4.24 light-years is the closest star to the Sun. Also, because they are so small and intrinsically faint, only a few of them are easy to find; 40 Eridani C is one of the easiest.

This interesting star has something else going for it: In 2018, astronomers discovered a planet orbiting the primary star. With a rapid orbit around Omicron², such a planet would receive much more radiation from the primary star than Earth gets from the Sun. But in 2021, new observations cast doubt on whether this planet exists at all.

Whether Omicron² Eridani really hosts a planet is subject to debate. But in the Universe of *Star Trek*, it surely does. It is the home of Vulcan, Mr. Spock's home world. In the episode "Operation Annihilate," which appears near the end of the first season, Spock is blinded by the intense light used to immobilize the invading parasites on the planet Deneva. However, his blindness is temporary because of the existence of an inner eyelid.

Figure 1 — Tim Hunter took this beautifully focused picture showing Omicron² Eridani. The primary star, named Keid, is the bright one; just to the left is the secondary, a white dwarf; the tertiary, a red dwarf, is fainter still. Used with permission and thanks.

Vulcan is said to orbit Omicron² Eridani's primary star, and since it is so much brighter than our Sun, even though Vulcan is at the same distance that Earth is from our Sun, they need the inner eyelid to protect their eyes.

I rather enjoy the idea that the fictitious Vulcan happens to orbit one of my favourite real stars. And unlike the Omicron variant, which one hopes will be eradicated soon, we admire Omicron² Eridani, the real star, and wish it to "live long and prosper." ✶

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.*

Binary Universe

FITS Liberator 4

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

Discovering FITS Liberator

I became aware of FITS Liberator about 10 years ago. My first encounter with the image pre-processor was when I started measuring double stars and wondered how to convert images to FITS format, one of the acceptable file types for the REDUC analysis software.

FITS stands for Flexible Image Transport System, and it is not your typical image file format like JPEG, PNG, or GIF. It supports digital content but can hold data in multi-dimensional arrays and use non-linear coordinate systems. In addition, files may contain photometric and calibration information along with metadata recording the images' origin and the optical train details. It was created for astronomical purposes, but it is used in other fields, including medicine. It is an open standard.

I had to reacquaint myself with FITS Liberator (FL) in a serious way when I was approved to use the Burke-Gaffney Observatory (BGO) in Halifax on Sunday 2016 February 28.

Inspired by RASC member Katrina Ince-Lum, I decided in those grey months that using the BGO would be a fun and easy (and free) way to capture images of deep-sky objects while learning how to manipulate filtered images from a monochrome sensor. I had no experience with LRGB or hydrogen-alpha processing at the time, but I was keen to learn. Because the BGO robot outputs the "raw" images in FITS format, I had to convert the files to something my final image processing software (GIMP or Photoshop) could use.

By Sunday 2016 March 13, I had FL 3.0 installed on a few of my computers. At the time, I located it on the Space Telescope website managed by the ESA, ESO, and NASA. I expected the tool would work well for pre-processing and would let me convert to TIFF (Tag Image File Format) for other apps. It is exciting knowing this same software is used in processing images from space telescopes!

I have since used FL to adjust and convert images for the 110 Finest NGC Objects list, large object mosaics, a couple hundred double stars, a few Messier Catalogue objects, supernovae, stars with high proper motion, and other miscellaneous deep-sky objects. Quick math on the back of the envelope suggests I have fired up FL some 2,000 to 2,500 times for the luminance, red, green, blue, Hα, and ionized oxygen (O-III) channels.

And I had every intention of writing about this useful tool but somehow never got around to it! Why now?

In February 2022, quite by accident, I learned of a new version of FL. In fact, FL version 4.0 was announced in the summer of 2021, but I didn't get the memo! Immediately, I hopped into the website of the U.S. National Science Foundation's NOIRLab.

When I read the "new features" list, I got pretty excited. In short order, I had the latest version downloaded and installed onto a loaner Windows 10 64-bit machine. This time I felt compelled to tell you about FITS Liberator.

A Typical Session

Perhaps if I briefly explain my workflow, it will shed light on what FITS Liberator can do and highlight some of its key features.

Of course, the first step is to open an image. In FL4, this can be done in many ways. The image, loaded into the Image Processing tab, will be sized initially to fit in the workspace (see Figure 1).

The vertical toolbar on the left offers zooming and screen controls along with a quick "fit to window." The black and white eyedroppers are for picking shadow and light pixels.

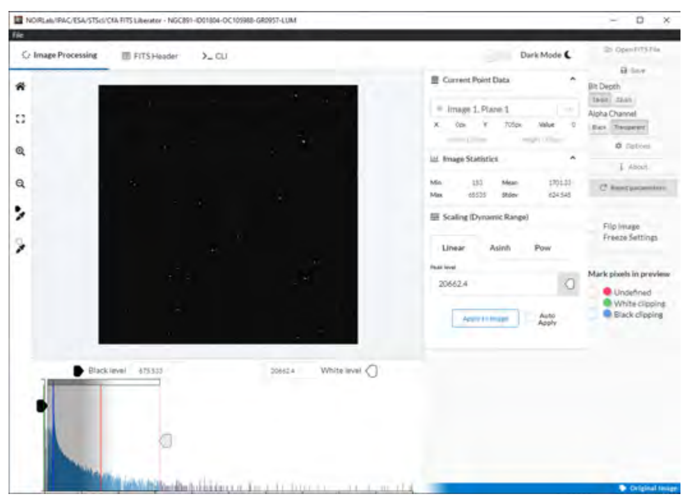


Figure 1 — The main screen of FITS Liberator with an unmodified image loaded, ready for processing.

Often, nothing appears to be in the image, but it is shown without any stretching applied to the histogram. The current image scaling shows as Linear.

If inclined, one can examine the metadata payload in the image file (Figure 2).

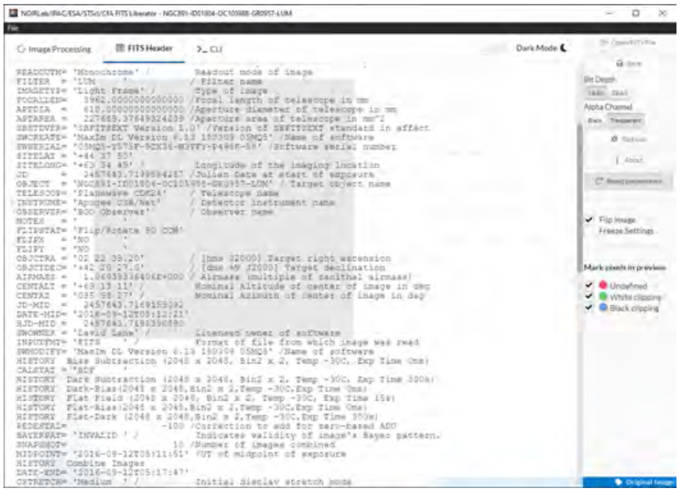


Figure 2 — Viewing the FITS header and metadata for the loaded image file.

Useful facts are noted such as the azimuth, altitude, airmass, Julian Date, and filter used. Now, let's get to work!

Clicking the Asinh tab applies an inverse hyperbolic sine stretch to the image histogram (Figure 3). The entire histogram is enhanced with a steep and immediate boost in the blacks or faintest parts of the image and a fairly substantial push of whites, which might cause oversaturating the bright parts.

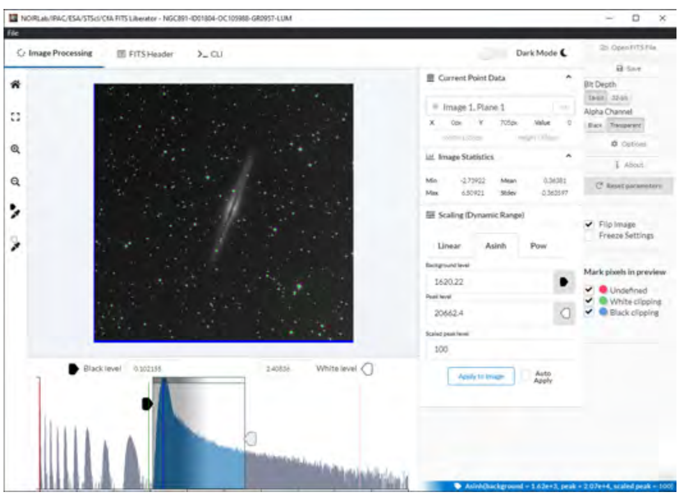


Figure 3 — Same image as before but stretched now, with background level and scaled peak adjusted.

In the histogram, the black marker is moved from the left, past the spurious data, to the beginning of the main image data. The Insert Black Level button is used to set the Background level for the image going forward. Changes can be manually or automatically applied.

In the histogram, the white marker was moved from the far right inward, brightening all the elements in the image. And suddenly the galaxy pops! Unfortunately, the stars are bloated, but we can shrink them in post-processing.

Finally, the Scaled peak level is bumped from 10 to 100 to further enhance and reveal faint parts of the edge-on galaxy. A slight gradient has emerged, but we can deal with that later.

The White clipping and Black clipping options are available to help an editor gauge if they have gone too far in their adjustments, blowing out bright elements, or leaving valuable data on the cutting-room floor. In the galaxy image, there is no black clipping or undefined regions. The Flip image checkbox toggles vertical flipping.

By improving the dynamic range in this luminance frame of NGC 891, we have a good working dataset for subsequent processing in post. A fine-looking galaxy.

The last step, of course, is to click the Save button to convert the data to TIFF.

What's Wonderful?

FL 3.0, as good as it was, was maddening in many ways. There are a number of fantastic improvements in FITS Liberator 4.

At long last, FL4 offers Dark Mode (Figure 4)! Thank the Universe. This turns the white interface panels in the program to a dark grey and the image workspace to a medium grey. This allows an editor to get a much better sense of the image brightness. And it's good for night owls, too.

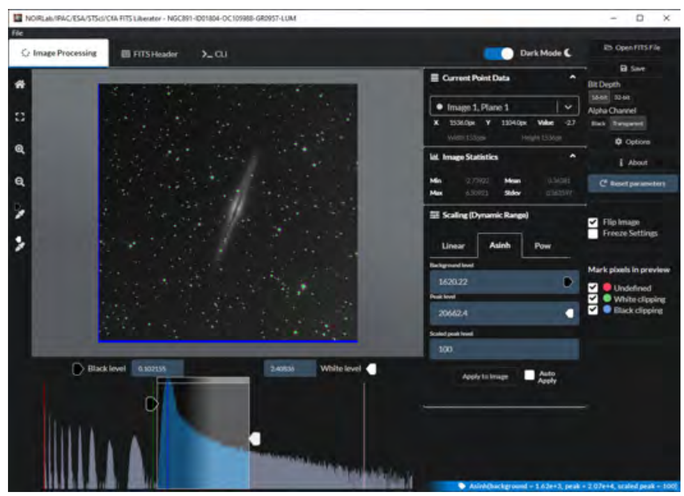


Figure 4 — FITS Liberator 4 now allows operation in dark mode like many modern image editors.

The third edition ran in a small window, a mere 919 pixels by 653 pixels total, and it could not be resized. This meant that the image canvas size was a tiny 468 x 364 pixels! While you could zoom the image, it was a very cramped workspace. The fourth generation of FL permits the user to size the application window as they see fit (no pun intended). Go big or go home! Maximized on a medium-sized laptop screen, this immediately gives you four-times the area for an image. On a big external monitor, it's pure joy.

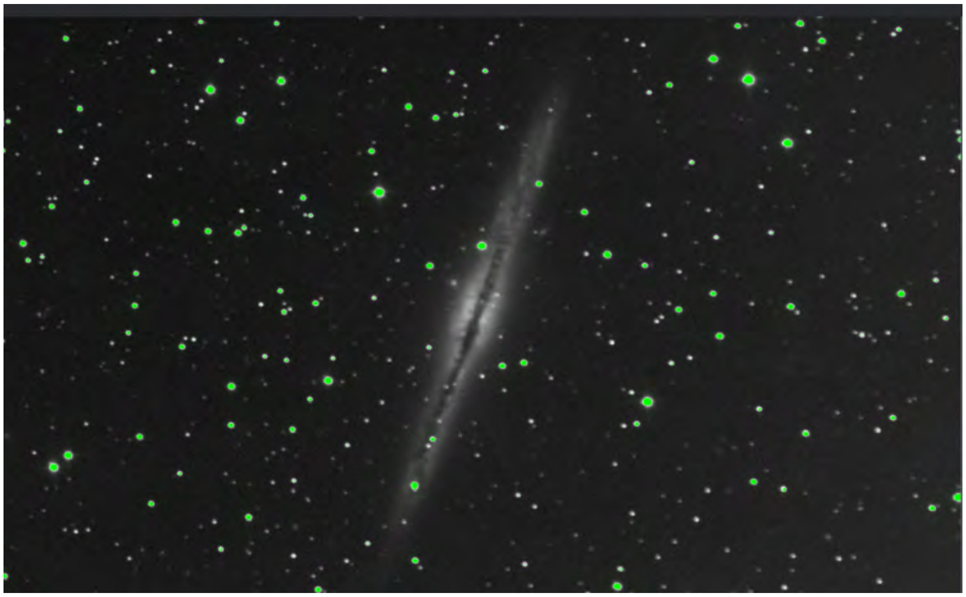


Figure 5 — Full screen mode, filling the entire computer display, is excellent for previewing. The stars are green as we've clipped the whites.

It also makes for a cleaner interface with everything feeling less crowded.

And then—are you sitting down?—the app can be run in Full Page mode! When activated, all the chrome and controls disappear, and you are previewing the image using the full height and width of your monitor (Figure 5).

Drag-and-drop into the image workspace is supported. This makes for a much faster and more fluid routine when processing many images.

The Power stretch tab supports a factor so you can achieve any direct or fractional root power required.

The app can be now used at the command-line level for batch processing.

The fourth iteration now supports much larger data files, should the need arise. You can configure a "scratch" disk to load images larger than the memory in your system.

FITS Liberator 4 remains a stand-alone application; in its early history, FL was a plug-in for Photoshop. As a stand-alone tool, it can be used with your favourite image processing software, be it GIMP, PixInsight, SiriL, Lightroom, etc.

What's Awkward?

Still no Ctrl-z keyboard shortcut or Undo command. Many a time I have made a mistake and wanted to quickly revert. Without the common rapid recovery option, I have often abandoned a run and started over.

They took away the zooming of the histogram. I don't understand that at all. It makes it very challenging to precisely set the Background level.

Another peculiar feature removal is zooming with the mouse on the image. FL3 offered controls like Photoshop: click the Zoom tool then, with the mouse pointer as a magnifier, click in the image to zoom in tighter. Or hold the Alt key to zoom out. That's all gone. Zooming in FL4 can only be done using the appropriate button in the toolbar.

A large spinning "in work" indicator atop the image workspace is extremely distracting. It is actually counter-productive for making tweaks or minor changes. It is almost impossible to assess the before and after effect.

The app still lacks vertical *and horizontal* flipping controls.

FL4 now requires a 64-bit operating system. Previously I used FL3 on 32-bit OS computers.

Getting Support

At the time of writing, I could not find a decent user guide. The Quick Start guide is lightweight. For FL3 there was a good document from ESA explaining how to use the application. Sadly, the many videos available on YouTube by amateur astronomers were lacking, confusing, or inconsistent.

The great news regarding FITS Liberator version 4 is that there are two videos available by Robert Hurt, one of the project originators, to help one get up to speed. They are quite good and I learned a lot despite all my past experience.

I expect that, over time, more materials and videos will pop up for those wanting still-more support and information on this useful and powerful tool for pre-processing FITS and converting to TIFF. If you're still using FL3, I would encourage you to upgrade.

FITS Liberator 4 is free and available for Windows, Mac OS, and Linux.

Bits and Bytes

Stellarium 0.22.0 is out! They fixed the bug we found during an RASC Stellarium Training Series course while trying to use the Online Search tool to add a comet! I reported the problem to GitHub and the programmers got it working again.

I also heard from Jean Vallières, author of COELIX. He shared that some users have difficulty printing the almanacs and sky maps in PDF format, so he added a webpage to his site describing how to obtain high-quality results. ✶

https://www.ngc7000.com/en/coelix/printPDF.htm

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.

Diving into a Magnetic Polaris

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

We are taking a deep dive into a recent discovery by James Barron, a Ph.D. candidate at Queen's University in Kingston, Ontario. James kindly sat down (via Zoom of course) for a discussion with me about his recent paper.

Before we dive into James's paper, let's look at the news release put together by James, his advisor Greg Wade, and the Queen's media team.

(Author's note: I did not write the release but have permission from James to reprint it here as context to my discussion with him.)

The Answer is in the Stars: Researchers Discover the North Star "Polaris" is Host to a Magnetic Field

Astronomers at Queen's University in Kingston have discovered for the first time that Polaris— more commonly known as the North Star—is host to a remarkable magnetic field. Stellar magnetic fields exert forces on charged particles in their atmospheres, impacting how the star evolves and changes over time. Magnetic fields can alter the winds of stars, their internal structure, and their rotation speed. Polaris is a member of a foundational class of pulsating stars called the classical Cepheids, which allow astronomers to measure extragalactic distances and study the expansion of our Universe. Little is known about the influence of magnetic fields on Cepheid behaviour and evolution, as their magnetic fields are very difficult to detect.

Figure 1 — Star map showing the position of Polaris (the North Star), which is located almost directly above the Earth's polar axis. Polaris is visible to the naked eye.

Understanding the magnetic field of Polaris will help researchers understand the mysteries of the Universe.

Polaris, the brightest star in the constellation Ursa Minor, is the closest star to the north celestial pole, lying almost directly above Earth's rotational axis. Historically, Polaris has been essential to astronomical navigation and, due to its immobility in the sky, it became a symbol of steadfastness and reliability in many cultures. Polaris pulsates with a four-day period, during which its diameter, temperature, and brightness change. As the nearest and brightest Cepheid, Polaris should be a reliable cornerstone in setting the extragalactic distance scale. However, over decades Polaris has shown puzzling changes in its pulsation that astronomers have been unable to satisfactorily explain and that may be related to its magnetic properties.

Queen's Ph.D. candidate James Barron (Physics, Engineering Physics and Astronomy) is leading a team of Canadian and international astronomers in exploring the magnetism of the classical or Type I Cepheids. It was during an observing run at the Canada-France-Hawaii Telescope (CFHT) on Maunakea, Hawaii, that Barron's team discovered a singular magnetic field of Polaris. Their discovery was recently published in the journal *Monthly Notices of the Royal Astronomical Society*.

"I was analyzing the data that had been obtained the night before, and I was excited to see that Polaris's magnetic field had been observed. When I saw the results, I couldn't believe my eyes! I actually checked with my thesis advisor that the results were real," said Barron.

Similar to how the Earth has a magnetic field that can be detected with a compass, many stars are also hosts to magnetic fields. Stellar magnetic fields are generated by the motion of charged particles inside the star's interior in what is known as a convective dynamo. We see the powerful effects of magnetic fields in the Sun through observable phenomena like sunspots and solar flares.

"This is the first magnetic field detection of Polaris and the signal is detected very clearly," says Barron. "It is also a very different magnetic signature than we see in the other Cepheids and this may be due to its low amplitude pulsation, or differences in its evolution. It is also unclear whether its magnetic properties are related to its strange variability. These are all questions we want to explore."

Barron and his team have started to monitor Polaris by obtaining more observations at CFHT. This will allow them to look for variations in the magnetic field over long periods of time. Ultimately, the aim is to combine the observations to develop a "map" of its magnetic field by taking many observations as it rotates across our field of view.

"Mapping Polaris's magnetic field will provide the first view of the global magnetic structure of any Cepheid and will serve as the basis for a deeper theoretical understanding of the role of magnetic fields in Cepheid evolution and behaviour," says Gregg Wade, Professor, Astronomy, Astrophysics and Relativity, Physics, Engineering, Physics and Astronomy at Queen's University.

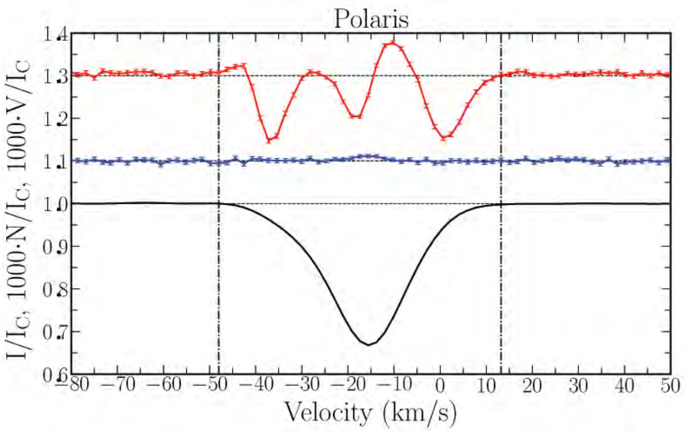


Figure 2 — The magnetic signature of Polaris detected at high signal-to-noise. The mean Stokes V circular polarization profile is shown in red and indicates the presence of a complex magnetic field. Observations were obtained using ESPaDOnS at the Canada-France-Hawaii Telescope.

Discussion with James

After the release came out, James and I set up a time to talk about his project and where it might lead. James is a third-year graduate student researching the magnetic fields of massive stars, focusing specifically on O stars and cepheids.

First up, James's work with O stars, the topic of his Master's thesis. O stars are the rock stars of stellar classification—burning brightly, hot, blue-white stars with surface temperatures ranging from 30,000 to 52,000 K. The coolest O stars have masses around 16 M_{sun}. The upper mass limit is unclear. Theoretically, the mass limit on a star with a solar-type metallicity is 120–150 M_{sun}. However, if a star's metallicity is lower than the Sun's, a larger mass is possible. None of these potential low-metallicity giant O stars have been discovered yet, most observed O stars fall into the lower end of the mass range. Very little is known about the magnetic fields of O stars. That is where James, his advisor Dr. Gregg Wade, and a larger collaboration come into play.

James is a MOBSTER, or more precisely, a member of the MOBSTER (Magnetic OB[A] Stars with TESS: probing their Evolutionary and Rotational properties) team. From their website, MOBSTER "is an international collaboration aiming to leverage photometric data from the Transiting Exoplanet Survey Satellite (TESS) to better characterise and understand magnetic stars in the upper H-R diagram. It also aims to identify new magnetic candidate stars for which spectropolarimetric follow-up observations can be obtained." James and Dr. Wade are members of the OB stars working group.

MOBSTER builds upon previous observations, including ones taken at CFHT as part of the Magnetism in Massive Stars (MiMeS) large program. The science goal of MiMeS was to use ESPaDOnS to fill in the gaps in astronomers' knowledge of the magnetic properties of massive stars. The program, led by Dr. Wade, ran for 640 hours over 9 semesters from 2008–2012.

Even with projects like MiMeS, astronomers know of only 11 O type stars with magnetic fields. Why so few? The magnetic fields of O stars tend to be faint despite the stars' brightness, requiring the need for hours of integration time per star. Two, only a handful of instruments in the world can observe the magnetic fields of stars; ESPaDOnS at CFHT, NARVAL at Télescope Bernard Lyot at Pic due Midi in France, and ESO's HARPSpol in La Silla, Chile. Finally, trying to identify magnetic O stars requires observing one star at a time—a slow process.

James's Master's thesis aims to tackle the final issue. He is investigating if the photometry of an O type star gives clues to the presence of a magnetic field. He looks for commonalities in the photometry of the known magnetic O stars to determine if astronomers can find candidate magnetic O stars for spectroscopic follow-up based on either changes in a star's photometry or common photometric shared by magnetic B stars. James's thesis work is ongoing, and we hope to see results soon.

Tangentially to his study of magnetic O star photometry, James began a survey of classical Cepheids in an attempt to add to the number of known magnetic classical Cepheids, i.e. one.

As outlined in the news release, classical Cepheids are stars which vary in brightness, diameter, and temperature over a

The Royal Astronomical Society of Canada is dedicated to the advancement of astronomy and its related sciences; the Journal espouses the scientific method, and supports dissemination of information, discoveries, and theories based on that well-tested method.

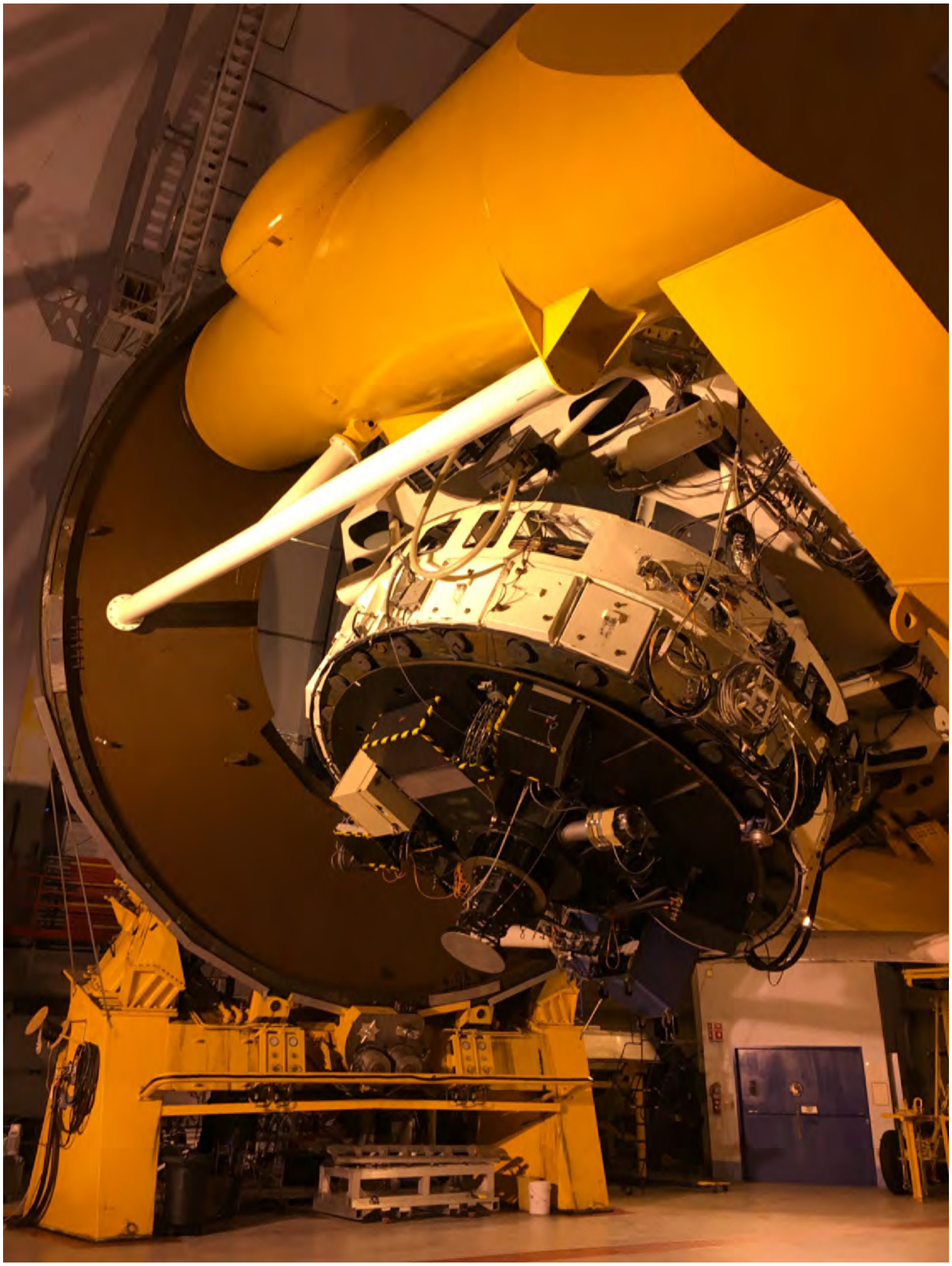


Image 3 — ESPaDOnS at CFHT.

When we talked, James emphasized how surprised he was upon seeing Polaris's magnetic field. The presence of a magnetic field may explain Polaris's changes in brightness. The team plans to take additional observations of Polaris as the star rotates to create a magnetic-field map. According to James, these observations are tricky because the rotational period of Polaris is not well known. Polaris lacks identifying characteristics, like star spots, to make the observations of the period more straightforward. He also emphasized the critical role ESPaDOnS played in these observations. It is the only spectropolarimeter that can observe Polaris with this level of precision. Stay tuned…

Polaris is not the only Cepheid James and the team are observing. They are in the midst of conducting the first systematic spectropolarimentric survey of the brightest 20 or so galactic Cepheids. The team uses the predictable nature of Cepheids to their advantage, observing them close to the maximum brightness to increase the likelihood of detection.

regular period—four days in the case of Polaris. The relationship between a Cepheid's luminosity and pulsation period are linked, which makes them ideal standard candles for measuring extragalactic distances. Polaris is an exception, so much so that James referred to it as a "very puzzling star." Since the discovery of Polaris's variability, the amplitude has changed, decreasing then increasing. The period of the variability has changed as well, slowly increasing by seconds per year.

Mahalo to James for providing more insight into his work and the broader work in trying to understand the hottest stars around—O stars. ✶

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

John Percy's Universe

Our Honorary Members

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

According to the *RASC Policy Manual*, honorary membership in the Society can be conferred "in recognition of noteworthy contributions to astronomy." We have 15 honorary members. Who are they? Buried deep in the RASC website[1] you can find a list, with short biographies. They are an impressive group—mostly professionals, but some notable amateurs as well. Their contributions to astronomy are diverse and significant.

On the website, you can also find information about past honorary members[2]—all deceased, because honorary membership is for life. They are a "who's who" of the history of astronomy since the RASC was founded. Almost all of them are professionals, but with a sprinkling of amateurs such as Frank Bateson and Sir Patrick Moore. Reading their carefully crafted bios, with references, is instructive and recommended. There are some notable omissions, such as Nobel Laureate Subrahmanyan Chandrasekhar and Carl Sagan, perhaps the best-known astronomer in his day. Maybe they were offered the honour but declined.

The manual also describes the office of Honorary President of the Society—a rather different honour. Honorary Presidents, at least recently, have been distinguished, active, long-time members of the Society who, during their four-year term, are encouraged to serve actively as advisors to the Society. Professor Doug Hube (Edmonton) is our current Honorary President.

Centres can also appoint Honorary Presidents. I was aware of this because my esteemed colleague Bob Abraham is the long-time Honorary President of the Toronto Centre. I was less aware that Honorary *Centre* membership can be bestowed by the RASC Board, on recommendation of the Centre. Centres, take note!

Who Are Our Honorary Members?

Cuban astronomer, educator, communicator, and leader Oscar Alvarez-Pomares reminds us of the remarkable achievements of astronomers in the less-affluent countries, who are often one of the few astronomers in their country—perhaps even the "lone astronomer." His achievements span research, administration, formal and informal education, and international collaboration. He became the visible face of astronomy in Cuba.

William Bottke, Southwest Research Institute, though not a household name, is a prize-winning astronomer and leader in research on the smaller objects in the Solar System—asteroids, comets, satellites, and dust. He has made special contributions to our understanding of large impacts including the one that formed the Chicxulub Crater in Mexico, and the "late heavy bombardment" stage in our Solar System's evolution.

David Crawford, a retired astronomer at the Kitt Peak National Observatory, has made important contributions to instrumentation and photometry, but is best-known as co-founder and long-time Executive Director of the International Dark-Sky Association. He has been the leading figure in the campaign against light pollution, and for energy-efficient, glare-free lighting—a cause that has been effectively taken up by the RASC. Crawford has received numerous awards, from the astronomical community, from government, and from industry.

Robert Evans, an Australian minister and one of the best-known amateur astronomers (he was featured in Bill Bryson's best-selling *A Short History of Nearly Everything*), holds the world record for visual discoveries of supernovae, which he has done with a small telescope in his backyard. Although supernova discoveries are now mostly made by automated telescopes, Evans's contributions came at a crucial time, when their importance as "standard candles" was first being realized. He has also written over a dozen books on the history of evangelism and received a dozen awards for his astronomical and theological work.

Mexican astronomer and educator Julieta Fierro, a professor at the Universidad Nacional Autonoma de Mexico, has made remarkable contributions to astronomy education, communication, and outreach through her more than 40 books, numerous lectures (including one to 100,000 schoolchildren in a stadium), radio and TV series, science centre leadership, and international networking. Her public presentations are legendary—highly kinetic and engaging—and, unlike some public figures, she radiates a warm, generous, and sincere personality. Her many and diverse honours include the UNESCO Kalinga Prize for promoting public understanding of science.

Andrew Fraknoi, long-time professor at California's Foothill College, and Director of the Astronomical Society of the Pacific, is well-known and appreciated for his college textbooks, and for the excellent educational programs and resources that he creates and/or distributes to schools and the public. These include *The Universe in the Classroom*, *Project ASTRO* (for schools), and *Family ASTRO* (for the public). He has given hundreds of deservedly popular public lectures, many of them debunking astronomical pseudoscience and misconceptions in an amusing and effective way. His dozen major awards include California Professor of the Year.

Harvard astronomer and educator Owen Gingerich made important contributions to the understanding of stellar atmospheres, and to the teaching of astronomy before turning to the history of astronomy, a field in which he is now a world leader. He has written both scholarly and popular articles and over 20 books such as *The Book Nobody Read* (about Copernicus's *De Revolutionibus*) which can be appreciated by any intelligent reader. As a person of faith, he has written articles and books effectively bridging the gap between science and religion. His many awards span these two disciplines.

Belgian meteorologist (at Brussels Airport) and amateur astronomer Jean Meeus specializes in mathematical and computational astronomy. He has written a dozen books of calculations of tables of the Sun, Moon, and planets, solar and lunar eclipses, astronomical algorithms, and three books of "mathematical astronomy morsels." In the days before personal computers, these were an essential part of the astronomy toolkit; they are still used today.

Williams College professor Jay Pasachoff is an award-winning international leader in many fields of astronomy. He is an expert on the Sun, especially the chromosphere and corona, and on solar eclipses (he has observed dozens of them), and on astronomy teaching, outreach, and communication. He is the author of widely used college astronomy textbooks, and of best-selling trade books such as the Peterson field guides to astronomy. He has also co-authored engaging and accurate science textbooks at the school level, which reach millions of users.

Canadian-born Princeton professor and astrophysicist Jim Peebles was a joint recipient of the 2019 Nobel Prize in Physics, for his work in physical cosmology, particularly the nature of the Big Bang, the nucleosynthesis and cosmic microwave background radiation that resulted from it, and the development of structure in the Universe. His books on physical cosmology—especially *Large-Scale Structure of the Universe* and *Principles of Physical Cosmology*—have had a huge impact on the field. He has received a score of honorary degrees and major awards, including Companion of the Order of Canada.

Harvard theoretical physics and cosmology professor Lisa Randall has received numerous awards and honorary degrees for her research, which examines connections between high-energy physics and cosmology, with emphasis on gravity, dark matter, the possible role of extra dimensions in our Universe, and other fundamental topics in modern physics and cosmology. She is a prolific public lecturer, the author of several books for a general audience—and the libretto for an opera—and is an effective role model for women in science.

Toronto-born Sara Seager is an MIT astrophysicist and professor, MacArthur "genius grant" recipient, and exoplanet researcher. Her other awards are numerous, diverse, and significant. Seager's research, especially the search for other "Earths," has attracted intense public and media interest. Her brilliant, highly recommended memoir *The Smallest Lights in the Universe* (Crown, 2020) details the ups and downs in her scientific and personal lives, including how she found love and happiness at an RASC General Assembly.

William Sheehan is a practising psychiatrist, amateur astronomer, historian of astronomy, and prolific and award-winning book author. His 22 books include *Planets and Perception* (1988), *Worlds in the Sky* (1992), and a highly regarded biography of E. E. Barnard. He has also written dozens of articles for both scholarly and general audiences. He is noted for his meticulous research and eloquent prose.

Toronto-born, Vancouver-raised University of Hawaii astronomer Brent Tully is an expert on galaxies. He is perhaps best-known for a paper, with colleague Richard Fisher, on *A New Method of Determining Distances to Galaxies*, in which they introduce the now-famous Tully-Fisher relation between the mass or intrinsic luminosity of a spiral galaxy, and its asymptotic rotational velocity. His observational surveys of tens of thousands of galaxies have helped to delineate the structure of the nearby Universe. His awards include the prestigious Gruber Prize in Cosmology.

Reflection

Our honorary members are all deserving of the honour, for a wide variety of reasons. They are also a diverse lot. Their interests range from the Sun (Gingerich, Pasachoff), planets (Sheehan), small objects (Bottke), exoplanets (Seager), stars (Evans), galaxies (Tully), and cosmology (Peebles and Randall). They have contributed through instrumental techniques (Crawford) and computation (Meeus). They include outstanding educators and communicators (Fierro, Fraknoi, Pasachoff), historians (Gingerich and Sheehan), and people whose achievements span many fields (Alvarez-Pomares). There are astronomers from the Hispanic world, and an increasing number of women.

Nevertheless, there are a few gaps that raise questions. There are presently no honorary members working in Canada. Canadians are eligible: Helen Sawyer Hogg and others held this honour in the past. So, Queen's University professor and Nobel Laureate Arthur McDonald is an obvious candidate, as would be Richard Bond (Toronto) or Vicki Kaspi (McGill), and others. In the past, the honorary members were more internationally distributed than today. There also seems to be some randomness or arbitrariness in choice, especially for the professional astronomers who are honoured for their research.

Honorary members are appointed for life, which makes sense. There can be only 15, and no more than two can be appointed in any year. They are usually appointed at the height of their careers—or younger—so it takes a long time to fill any gaps. New members are appointed by the Board, on the advice of the Nominating Committee, when an old member passes away. The Board and Committee, with many other things to do, may brainstorm briefly for suggestions, and choose the quickest or loudest proposal.

So, here's a modest suggestion: perhaps a committee (the Board, or the Nominating Committee, or, better still, an *ad hoc* committee—perhaps the Fellows of the RASC—should think slowly and carefully, consult widely (and confidentially, if necessary) and draw up a short list, which would then be ready to use when needed. ✶

Endnotes

1 www.rasc.ca/honorary-members

2 www.rasc.ca/past-honorary-members

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

Stars to Dust

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

In images of the night sky and the discussion of what we have learned from space, we encounter the effects of interstellar dust almost immediately. As regular readers of this column know, I like to think of interstellar dust more like soot and tiny sand grains: dusts are thought to be made of amorphous carbon or silicate grains. Interstellar dust is typically smaller than the dust we see in our house, with grain sizes that are smaller than bacteria (typically tens of nanometres up to micron sized). Dust only makes up 0.01 percent of the ordinary matter in our galaxy and others, but it plays an outsized role on the light that we see coming from other galaxies and through our own galaxy. Despite the importance, the origins of interstellar dust remain unclear, but ongoing observations are clarifying the link between dust and the last stages of a star's life.

This large impact arises because of the small sizes of the dust grains, which readily absorb and scatter light that has wavelengths comparable to or smaller than the size of the dust grains. Hence, dust determines how light flows through galaxies, and shapes the radiation that we can observe from other systems. In optical light, we cannot observe the middle of the Milky Way because of the strong absorption from dust grains. Young star systems are obscured by the dust in their natal clouds and the sky is dotted with dense, dark nebulae that are only dark because of the dust blocking the light from behind them. However, there is a trick to avoiding the effects of dust: study longer wavelength light. At wavelengths of radiation that are larger than the size of the dust grains, the light passes through the dust without being absorbed or scattered. One of the key benefits of the recently launched *James Webb Space Telescope* is its sensitivity in the infrared, which allows us to peer into dusty regions with unprecedented clarity.

Despite its transparency at long wavelengths, dust does play a role in the infrared. The light that dust grains absorb will heat them up. The warm dust then reradiates that thermal radiation in the infrared, giving off light because the grains are warm. But here "warm" only means 20 to 50 degrees above absolute zero. This radiation is one of the primary sources of light with wavelengths around 100 microns. This radiation is bright, particularly toward the galactic plane, but it is still transparent and we can see through the galaxy to see distant or enshrouded objects using infrared and short wavelength radio.

Dust grains are made of relatively rare materials in the Universe: silicates and carbon both come from the two percent of matter in the Universe that is not hydrogen or helium. Interestingly, these grains are invariably made of material with high melting points. Hydrogen and helium gases never condense in space, but these dust grains do appear to be forming out of hot gaseous material that cools and condenses. If the melting point of a material is higher, it is more commonly found in dust grains. These observations point to dust grains having a hot origin and then cooling and condensing down. The obvious source of hot gaseous material in space is stars, but ordinary stars do not shed a lot of matter, and what they do give off tends to be the lighter elements. However, these conditions are no longer true in the late stages of a star's life when it sheds large amounts of material enriched with the heavy elements that make up dust grains.

Usually, a star's light comes from the process of nuclear fusion. For most of the luminous phase of a star's life, it is producing energy by fusing hydrogen into helium in the core of the star. This fusion characterizes the Sun and all other main-sequence stars. Eventually a star runs out of fuel, contracts, heats up, and swells into a red-giant star. This process continues to heat the interior of the star enough that the core ignites another stage of nuclear fusion, fusing helium into carbon and oxygen. This fusion depletes the fuel reserves of a star quickly because it is less efficient, and eventually the star swells again into a red giant. This phase is called the Asymptotic Giant Branch (AGB) because of where these stars fall in the Hertzsprung-Russell diagram, but practically this naming just means they are quite similar to the less-evolved red-giant stars. During the AGB phase, the last stages of nuclear fusion are unstable, and the heavy elements made deep in the interior of the star begin to get mixed throughout the surface layers, enriching them with the products of nuclear fusion.

The big question really is how to get the enriched outer layers off the surface of the star. The gravity of stars is strong enough to hold them together through their lives, so the material needs to be launched with sufficient energy to exceed the escape velocity. The material then, in theory, could go on to cool off and slowly form dust grains as it blows away from the star. The heavy materials would condense out into liquids and then solid dust as the gas cools, forming the dust grains that influence radiation so dramatically.

One simple answer is when the star has a binary companion. The spinning of the two stars around each other in orbit is sufficient to throw the outer layers of the AGB star off its surface, leading to the formation of dust. Figure 1 shows this effect playing out in the star R Sculptoris, which is being spun around. The spiral pattern arises as the ejected material drifts outward while the star is being spun around. This image is from the Atacama Large Millimetre/submillimetre Array (ALMA) and it shows light emitted from the carbon monoxide molecule, a common tracer of molecules in space.

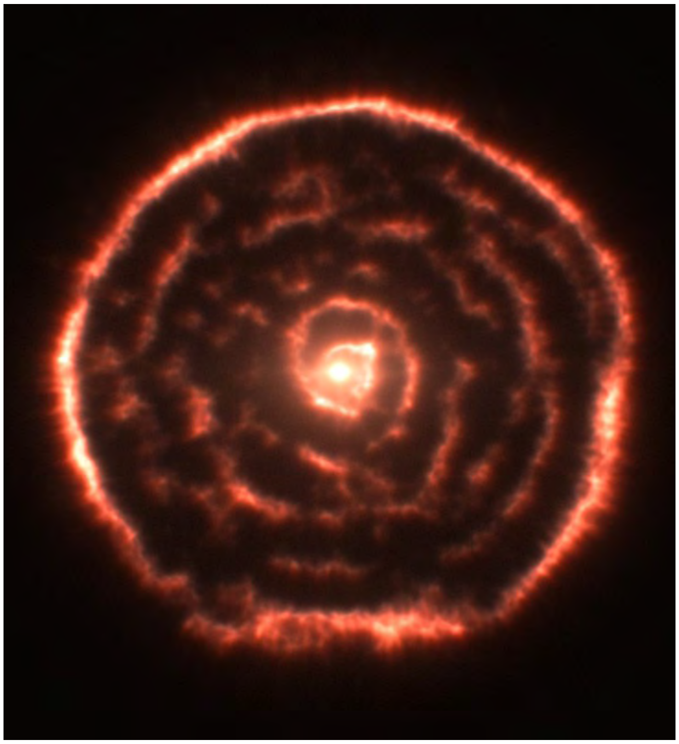


Figure 1 — ALMA image of the star R Sculptoris in CO emission. The spiral pattern arises because of a binary companion spinning the giant star around, throwing off its outer layers. Image credit: ALMA (ESO/NAOJ/NRAO)/ M. Maercker et al.

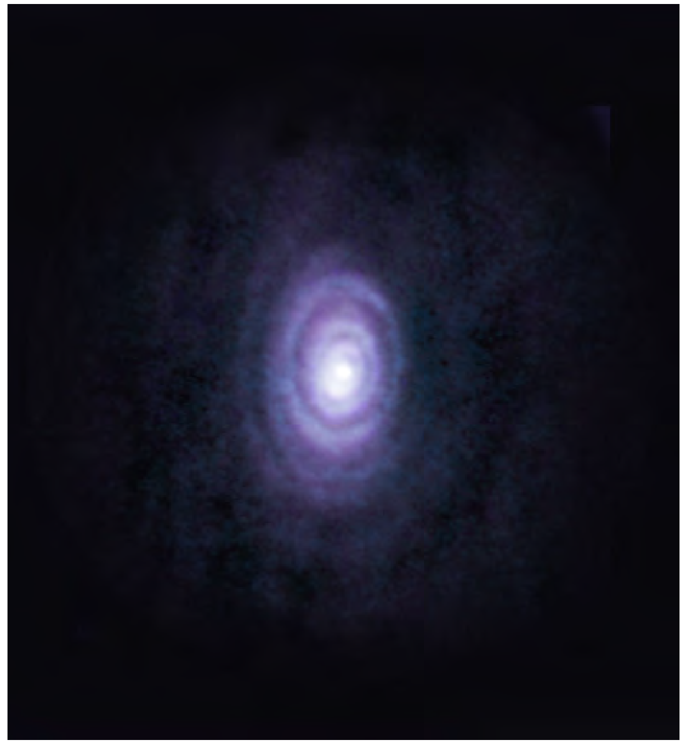


Figure 2 — ALMA image of the star V Hydrae in CO emission. In this case, the star shows several concentric shells of material being blown off the star in a different shape and structure than in Figure 1. Image credit: ALMA (ESO/NAOJ/NRAO) / S. Dagnello (NRAO/AUI/NSF)

More recently, astronomers using ALMA have chanced upon another AGB system that is shedding its outer layers into space. Recent observations of the star V Hydrae show a far more complex structure than R Sculptoris. Figure 2 shows a new images of V Hydrae, which identifying several distinct shells of material there is evidence of a bipolar jet of material blowing outward along the poles of the star. In both stellar systems the stars are losing a vast amount of material significantly faster than expected. Nearly all of their mass will be returned to space before they end of their lives as white-dwarf stars. These two systems catch the stars in the act. These new data show that the rates at which these systems lose their mass and turn those outer layers into dust are far higher than previously estimated but they happen over shorter timelines. These maps show how material is being flung off the stars but also illustrate that this phase of the star's life must be short lived, likely right at the end of the life cycle.

These observations help to close gaps in the evolution of dust. While this may not seem deeply relevant to astrophysics, it becomes important in understanding the first generation of galaxies. These systems start with no dust and quickly develop only a trace amount. Understanding what stars form dust and how quickly will be a vital aid to our observations of these early galaxies. ✶

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.

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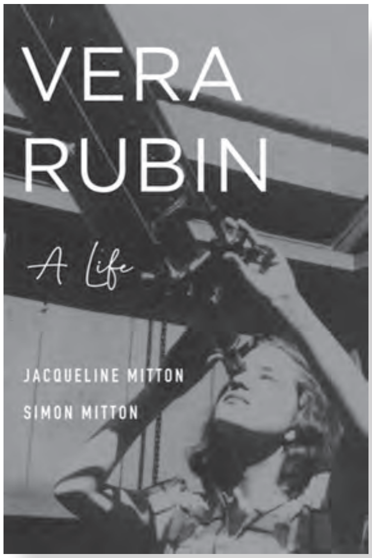
Reviews / Critiques

Vera Rubin: A Life

by Jacqueline Mitton and Simon Mitton

309 + x, 24 cm × 15 cm, Belknap Press of Harvard University Press, Cambridge, Massachusetts & London, England, 2021. Price $22, hardcover (ISBN: 978-0-6749-1-9198).

Reviewed by David G. Turner



Jacqueline and Simon Mitton have done an excellent job of transforming Vera Rubin's thorough collection of memorabilia and correspondence from her life in astronomy to produce a detailed and insightful biography of the woman who made such a momentous impact on our understanding of the Universe. Vera Rubin was born 1928 July 23, in Philadelphia, and died 2016 December 25; her life and career spanning those years when the field of astronomy was expanding rapidly and knowledge was growing by leaps and bounds. It was also an era when there were often overt or covert efforts to discourage women from seeking careers in science and engineering, so much of Vera's success can be attributed to her own continuous efforts to follow her dreams.

A Life is written in fairly standard fashion for a biographical history, beginning prior to Vera's birth and ending with a listing of all of the honours she received in her later years, summarized along with other information in an Appendix. The book begins with a brief Foreword by Jocelyn Bell Burnell, who herself experienced the same type of gender discrimination that typified Vera's life story.

Sadly, the Introduction to *A Life* refers to her discovery of evidence for the existence of dark matter. That is not what Vera Rubin discovered in her work on the orbital speeds of stars in nearby galaxies. Instead she found very solid evidence for what is called "flat rotation curves" in the outer portions of all flattened galaxies, for which a variety of explanations are possible. Vera herself never claimed to have discovered dark matter.

The biography begins with stories of Vera's parents, both of whom were Jewish immigrants with origins in regions of the pre-Great War Russian Empire where prejudice, and sometimes violence, against Jews was not uncommon. Vera's father, Pete Cooper, originally Pesach Kobchefski, emigrated from Lithuania in 1905 with his mother to join his father in Gloversville, N.Y. Her mother, Rose Applebaum, was the daughter of a woman from Bessarabia who emigrated to the U.S.A. on her own at age 16. It was in Philadelphia that Rose and Pete met, at the Bell Telephone Company offices, and they married in 1924; she met and married a man from her home country.

Pete and Rose had two children, both girls: Ruth born in 1926, and Vera born in 1928. Pete Cooper had earned a degree in electrical engineering from the University of Pennsylvania, and was employed in that profession at Bell Labs, so it seems natural that Vera should have inherited some interest in science and engineering. But she got off to a bad start in grade school as a result of poor teachers, old-fashioned schoolrooms, and an inherent left-handedness that one teacher mistakenly tried to correct. Vera's early education started in Philadelphia, and later in the northern suburbs of Washington, D.C., after Pete found employment there with the U.S. Department of Agriculture at the beginning of World War II. It was from Fuller Street in Washington that Vera had her earliest experiences with astronomical observations that tweaked a lifelong interest in the field.

With a choice of where to sleep in the north-facing bedroom shared by the two Cooper girls in their apartment on Fuller Street, Vera chose the one closest to the window so she could watch the stars on clear nights. From her vantage point Vera was able to witness the diurnal motion of the stars across the sky arising from the Earth's rotation, as well as their annual (seasonal) motion arising from Earth's orbit about the Sun. She also witnessed her first bright meteor from the room one clear December evening, and faithfully made maps of the stars she was seeing for later identification on star charts. Vera also witnessed the triple conjunction of Jupiter and Saturn in early March 1941, and, on the night of 1941 September 18–19, saw a spectacular display of the Northern Lights. The last three observations provided three of the motivating factors that led Vera to consider a career in astronomy.

Vera's preoccupation with astronomy led to a quest for additional information about the subject in the same fashion followed by many future astronomers when they first became enamoured by the subject, beginning with acquiring and reading many of the popular astronomical monographs of that era. She also attended meetings of amateur astronomers in Washington with her father, which exposed her to talks by Harlow Shapley and Donald Menzel, among others. Around age 15 she assembled her own refracting telescope, which she used in her initial efforts at astronomical photography. Her visits with family in Philadelphia allowed her to experience the Fels Planetarium first-hand. Many future astronomers can recall similar visits to either planetaria or, in my own case and that of Western's Amelia Wehlau, to nearby observatories as the event that triggered a life-long interest in astronomy.

Vera's high-school education in Washington proved to be of mixed benefit. Her fascination with astronomy found some outlets in essays prepared for English courses and for mathematics, likely because of the math puzzles introduced to her by her father when she was younger. But high-school physics and phys-ed were disasters owing to the gender bias of her instructors, who encouraged male students while ignoring others. The negative advice of one physics teacher, in particular, is recalled in detail in *A Life*.

Such negative experiences in gender bias encountered in her high-school education affected Vera's choice of higher education in pursuing a career. Only universities offering undergraduate programs in astronomy would do, which eliminated those in the Washington area. Initial possibilities of Swarthmore and the University of Pennsylvania would have allowed her to stay with Philadelphia relatives, but Vassar College in Poughkeepsie, N.Y., attracted greater interest since its astronomy program had been initiated by Maria Mitchell, a recognized woman astronomer whose career had also begun through specialization in mathematics *not* physics. Maria had also been followed at Vassar by a succession of other women astronomers.

The potential expenses of a university education were a concern, but Vera was fortunate in receiving a small scholarship to attend Vassar, so began studies there in the fall of 1945, entering an accelerated 3-year AB-degree program in which the courses of the regular 4-year program were taken over 9 university semesters as a means of reducing expenses. At that point, many good things began to happen for Vera: she was taught and worked with Maud Makemson, who provided glowing references for her graduate program applications; she met and subsequently married (in June 1948) Bob Rubin, the enlisted son of family friends who was pursuing graduate studies at Cornell University where her scientific hero Richard Feynman taught; she was the only astronomy major in her graduating year; and she made the Dean's List of 40 honours students.

With Bob in the physics graduate program at Cornell, Vera gave up plans to attend Harvard for graduate work and entered the M.A. program at Cornell with its smaller astronomy faculty and untested reputation in the field. Her thesis project arose from her reading of the current literature, possibly some cited by her supervisor, Martha Stahr, in her courses on the Milky Way Galaxy and other galaxies, addressing the question of whether it was possible to detect and measure the rotation of the local Universe. It was perhaps a bit early in Vera's career to initiate such a project, given that she was unable to access time on large telescopes to obtain radial-velocity spectra of galaxies, instead relying solely on radial velocities measured elsewhere and published or to be published in the literature. She also needed distance estimates for the same galaxies, for which she adopted a "simplistic approach" based upon brightness according to the Mittons.

The results, in conjunction with positive reviews from her examining committee, culminated in a thesis that was considered interesting enough for presentation at the American Astronomical Society meeting in Haverford (near Philadelphia) in December 1950. As it happened, Vera was expecting her first child, David, in November (born on the 28th), so her department chair, William Shaw, suggested presenting the paper in her place, in his name! That didn't suit Vera, of course, so with help from Bob, her parents, and her Philadelphia relatives, she managed to give birth to David in November, have the family driven to Philadelphia by her parents in December, and to present her thesis results in person in nearby Haverford in late December, the last to a captivated audience with many follow-up questions and requests for preprints. The abstract for her paper was soon published in the *Astronomical Journal* (Rubin, V.C., 1951, AJ, 56, 47–48) with a slightly altered title chosen by editor Dirk Brouwer, and news of the talk also spread through the *Washington Post*, which had a reporter in the audience at the time.

Vera was out of the educational system for more than a year as Bob completed his doctorate at Cornell (spring 1950) and subsequently took a position at the Applied Physics Laboratory (APL) in Silver Spring, Maryland, close to the homes of both parents in Washington. Then, thanks to her husband Bob as chauffer and her parents as babysitters, Vera was able to begin classes in the Ph.D. program at nearby Georgetown University in February 1952 with help from Father Francis Heyden, S.J. He generously allowed her to include her Cornell courses as credit for the Ph.D. program at Georgetown, as well as to be supervised by George Gamow at APL in her previous concentration on extragalactic astronomy.

It was at Georgetown that Vera began to hit her stride, for one reason because it had astronomical measuring instruments not found at Cornell. She was then able to become directly involved in observational research projects that took advantage of her energy for doing astronomy research in what little spare time she had outside of raising a family and attending classes. She defended her Ph.D. thesis in 1954 and initially took on part-time teaching in mathematics and physics at a junior college in nearby Takoma Park. The '50s decade was a busy one as she gave birth to three more children (Judy 1952, Karl 1956, and Allan 1960), gained research and teaching experience with part-time employment at Georgetown, attended part of the famous 1953 Michigan summer school as well as national and international conferences where she gained both admirers and collaborators, gained valuable observing experience at Kitt Peak and Palomar, and began publishing in regular journals. One of her first papers involved collaboration with her Georgetown students on the orbital motion of relatively nearby stars about the galactic centre, a project that evolved from her Master's thesis work. But it was her later papers from that decade in collaboration with Geoffrey and Margaret Burbidge that initiated her succeeding work on galactic rotation curves.

By 1965, Vera felt secure enough in her own abilities and growing reputation to seek employment at Carnegie Institution's Department of Terrestrial Magnetism, which had only one astronomer on staff. It was then that she struck a chord with Kent Ford, an instrument builder who had developed an image-tube system for astronomical use and was at the point of needing an observational collaborator to test his equipment. Vera's work on spectroscopy of faint galaxies was the ideal match, and from 1965 on the ADS (Astronomical Data System) database reveals a steady flow of published papers by Rubin and Ford on the rotation curves of external galaxies, nearly all of which levelled off in their outer regions in contradiction with expectations from primarily a central force acting on the stars.

The Mittons continue the story into later years, when Vera's discoveries brought the recognition she had always sought, although personally I have always believed that most scientists desire to make positive contributions to knowledge rather than to gain recognition. In a sense, growing recognition was a nuisance to Vera since it brought with it requests to serve on various committees and boards as a *de facto* women's representative, at the expense of the valuable research time she loved so much.

The Mittons have also interwoven into the story brief life summaries of the various individuals who were part of Vera's life, in some cases extending them into interesting offshoots describing specific events of the era in which she lived. One that I recalled from my own graduate student days was the supposed attempt by George Gamow and Hans Bethe to submit a research paper to the *Astrophysical Journal* (ApJ) in the '60s in collaboration with Ralph Alpher in the order Alpher, Bethe, and Gamow, humourously mimicking the initial letters of the Greek alphabet: alpha, beta, and gamma.

RASC members might be interested to know that there was a similar Canadian attempt c. 1980 by Bob McLaren, Chris McAlary, and Barry Madore to submit a paper to the ApJ on the Cepheid near-infrared distance scale authored by McLaren, McAlary, and McDore, i.e. three macs (Mcs). But by then the editorship of ApJ had passed from Subrahmanyan Chandrasekhar to Helmut Abt, both of whom would likely have frowned on such attempts at levity in the ApJ pages.

What I did find surprising was a rather irregular knowledge of astronomy in the Mittons' writing. The first instance occurs on p. 6 describing Vera's late-night view of the northern sky one winter evening from her home in northern Washington, D.C. The locations of the various constellations relative to one another are quite accurate, but the placement of the Big Dipper below the northern horizon about to rise appears to conflict with its more probable location at the time in the northeast about to set. On p. 16 the triple conjunction of Jupiter and Saturn in Aries that Vera observed from late 1940 to early 1941 is described as one of the rare events that sparked her interest in astronomy, and correctly noted as being rare, given that it was the first since 1683. But it is somewhat misleading to describe such conjunctions as occurring on average about once every 120 years when they are so irregularly spaced and the next triple conjunction was the well-separated one of 1980–81 in Virgo, only 40 years later when the two planets again passed one another in their orbits. The next one will occur 258 years later in 2238–39. I also wish that the Mittons had described Vera's M.A. thesis in greater detail. She must have had a copy in her collection of memorabilia. The AJ abstract is scanty on details of the methodology and results, and the brief description given implies only that Vera was using too small a value for the orbital speed of the Sun about the centre of the Milky Way, what would seem to be an essential first step if one is attempting to establish an unbiased "rotation" speed of the collection of nearby galaxies. Even today the true orbital speed of the Sun is much higher than typical values used in many recent studies (see Turner, 2014, CanJPhys, 92, 959–963).

What is implied to be a humorous incident on p. 47 describes Department Chair William Shaw's two brief comments on her M.A. thesis, namely that the work was "sloppy," and she incorrectly used the plural Latin noun "data" with singular verbs. Actually, I would agree with both of Shaw's comments, given the results of my own study cited above, although I would probably have used a milder adjective than "sloppy" when addressing a graduate student. Also, the misuse of singular English verbs with Latin and Greek plural nouns continues to be the bane of my existence as an editor, doubly so in the case of *A Life* since the Mittons proceed to make the SAME blunder themselves, e.g. on pp. 82 & 180. Otherwise the text is remarkably free of other types of errors, and those that remain could readily be corrected by good copyediting.

Overall I enjoyed reading about the life of Vera Rubin, likely because many of the events overlapped with my own career in astronomy and were already familiar to me. I have also experienced some of the types of prejudice experienced by Vera in her career, except for gender discrimination, of course, so can relate to the hurdles she surmounted. I also found it extremely heartening to read of the support she received from her parents, spouse, and research colleagues. She was indeed fortunate to have lived and worked in an era when that was more commonplace. But enjoy her biography for yourself with your own copy of *A Life*. ✶

David Turner is editor of Book Reviews for JRASC, and frequently calls upon himself to review new monographs when the need arises. He himself had a varied career in astronomy, teaching at four different universities and directing the planetarium activities of one. His career in observational astronomy fostered collaborations with many other observers and resulted in publications in a variety of astronomical fields as well as numerous interviews in the news media. He may be best remembered as the astronomer who deciphered the hidden meaning behind the star pattern originally placed on the chancel ceiling of Saint John's Church in Lunenburg, Nova Scotia.

RASC Awards for 2022

RASC Awards Committee:

Chris Gainor, Chair
Randy Boddam
Nicole Mortillaro

Qilak Award

The Qilak Award recognizes individuals or groups that have made an outstanding contribution to the understanding and appreciation of astronomy in Canada.

Jenna Hinds, Society Office

Jenna Hinds began working with the RASC in 2018 as its youth coordinator. She quickly got the Astro-Bug and began to teach herself how to work with the RASC's robotic telescope, eventually becoming the Chair of the Remote Telescope Working Group. Her work with new young RASC members eventually led to the formation of the NextGen Committee. She became active with the Education and Public Outreach Committee, and in general immersed herself in everything RASC. When COVID-19 disrupted the RASC's operations, she played a key role in supporting the 2020 and 2021 Virtual General Assemblies. Ms. Hinds soon became the face of the RASC in our expanding Social Media footprint, and her efforts took her far beyond expectations, and her love of the Society and its members was evident in everything she touched.

Simon Newcomb Award

This award is given for excellence in astronomical writing by an RASC member.

Chris Vaughan, Toronto Centre

Chris Vaughn is known as the "AstroGeoGuy" since he is also an Earth Scientist. Aside from his hard work at the Toronto Centre where he is an operator and tour guide for the David Dunlap Observatory's 74″ telescope, he is also the co-creator and presenter in their Skylab planetarium. In between his public outreach appearances, he writes a weekly astronomy news bulletin called *Astronomy Skylights* that is geared towards non-astronomers. In this newsletter, he not only points out what's in the sky, but he also explains things in an easy-to-understand manner and educates his readers, who can be found in all parts of the world. As well, Mr. Vaughan has been writing for Space.com since 2016; he is also a regular contributor to *SkyNews* magazine. His content is used in the very popular app Star Walk 2 as well as the Starry Night software package. Most recently, Chris co-authored *110 Things to See with a Telescope*, together with RASC member John Read of the Halifax Centre.

Ken Chilton Prize

The Ken Chilton Prize is awarded for a specific piece of astronomical research or work carried out or published recently.

Francois Chevrefils, Michel Duval, Centre francophone de Montréal, and **Normand Amyot**

Two members of the Centre francophone de Montréal, Francois Chevrefils and Michel Duval, plus a non-RASC member, Normand Amyot, have done outstanding research and reporting on the fabled "black drop effect" observed during the transits of Venus and, more recently, the transit of Mercury. The case of Venus's transit is where the effect was first observed, whereby the planet's disk appears to stretch into an oblong when right at the Sun's cusp—the black-drop effect. Francois Chevrefils has been a longtime member of the Centre francophone de Montréal and served as president in 1998–1999. He is a keen observer, and he collaborates with Michel Duval on the *Observer's Handbook* section, Coloured Double Stars, and the accompanying Supplement. Michel Duval, also of Centre francophone de Montréal, has written three articles for the *Journal* explaining the Black Drop Effect seen during the 2004 Transit of Venus and the 2016 Transit of Mercury. In their paper that appeared in the October 2021 *Journal*, "Effect of Diffraction Halos on the Position and Size of Baily's Beads and Diamond Rings during Eclipses of the Sun," they made a solid case that the effect, the cause of which has long puzzled observers, is a result of diffraction halos distorting images, and have even shown that it applies to the solar eclipse Diamond Ring effect and Baily's Beads.

Service Award

The RASC Service Award is a major award of the Society given to a member in recognition of outstanding service to the Society and/or a Centre, rendered over an extended time of at least 10 years.

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Robert Babb, St. John's Centre

For most of his 20 years in the RASC, Robert Babb has served as an Executive Committee member of the St. John's Centre, including terms as President, Vice President, and Observing Director. Mr. Babb has been a reliable volunteer at Star Parties, Science-in-the-mall days, Observe the Moon nights, for events related to eclipses, comets, and transits, new telescope owner workshops, Astronomy Day, and other Centre public events. He has been a frequent speaker, writer, media contact, and liaison with other groups. The St. John's Centre's efforts to establish an observatory have been helped tremendously by Robert's expertise, experience, and sweat equity. He is chief liaison with Provincial Parks personnel at the site where the Centre observatory is being built, and the location of the St. John Centre's annual Star Party.

Philip Downey, Niagara Centre

Philip has held many positions in the Niagara Centre since he joined the RASC in 2001. He has served as Secretary for more than 10 years. He also served as newsletter editor, he created and updated the Centre's social media pages, kept the membership informed by sending out bulletins on all Centre events, and produced a Centre calendar. Mr. Downey also gave new members instruction on the use and operation of equipment at the Centre's observatory. He has led in outreach programs and made astronomy presentations at schools and service clubs.

Robert Lewis, Niagara Centre

Robert Lewis has held many positions in the Niagara Centre since he joined in 2004, including serving as treasurer for 10 years and as webmaster for four years. He has maintained the observatory and the grounds, and he has brought outreach programs to the general public, schools, Cubs, Boy Scouts, Brownies, Girl Guides, and service clubs. At any event, Mr. Lewis is usually one of the first there engaging with early birds on astronomy topics.

Ron Macnaughton, Toronto Centre

Ron Macnaughton is well known in the Toronto Centre and around the Society for his presentations about astronomy in person and online. He has been a contributor to the Toronto Centre's newsletter *Scope* and a frequent presenter at Recreational Astronomy Nights. In addition to presenting "The Sky This Month" occasionally, he also discusses a wide range of topics in astronomy that catch his eye. His presentations have drawn many viewers to the Toronto Centre's YouTube channel. He has been a participant in work parties at the E.C. Carr Astronomical Observatory and at our various outreach programs conducted in co-operation with the Ontario Science Centre and the University of Toronto. He received the Ontario Volunteer Service Award in 2017 in recognition of his contributions to Toronto Centre education and public outreach programs. At the national level, Ron served for several years on the Society's Education and Public Outreach Committee. He continues to encourage members across Canada to become active observers and participate in the Society's many observing programs.

Merlyn Melby, Saskatoon Centre

Merlyn Melby is a life member of the RASC who first joined the Saskatoon Centre in the 1970s. Since then, he has held various positions within the Centre, including newsletter editor, General Assembly organizer, builder, and councillor. During Mr. Melby's stint as editor, he raised the quality of the newsletter creating better content, a more professional look and higher-quality printing with the intent of putting the newsletter onto local bookstore shelves. He helped organize the 1982 Saskatoon General Assembly and participated in many public outreach events. Mr. Melby, however, is best honoured as a major builder of the facilities of the Saskatoon Centre, including its three club observatories, the first being the snow-block Igloo Observatory, the permanent Rystrom Observatory (1977–1997) and the Sleaford Observatory (1997 to present). His meticulous work created the high-quality observatories we continue to use to this day.

Tenho Tuomi, Saskatoon Centre

In his two decades in the RASC, Tenho Tuomi has rendered great service to the Saskatoon Centre and at the national level. He is the author of the Digital Astrophotography section in the *Observer's Handbook*, served as the first chair of the RASC Astroimaging Committee, and helped develop the Astroimaging Certificate. He has served as newsletter editor and on the Board of the Saskatoon Centre, and he has conducted outreach activities around the province of Saskatchewan and at events like the Saskatchewan Summer Star Party, often with the help of his wife Velma.

Barbara Wright, Saskatoon Centre

After 25 years as an active member of the RASC at the Saskatoon Centre, Barb Wright has recently retired to Victoria and has become an active member of the Victoria Centre. During Ms. Wright's time in Saskatoon, she held several positions including President, Vice-president, and Event Coordinator. Barb was also an organizer of the Saskatchewan Summer Star Party for more than 20 years and has attended the star party as Chair or a volunteer for all 24 years of the star party's existence. Barb also represented the Saskatoon Centre at more than a dozen General Assemblies and was also an organizer of and the Chair for the 2009 General Assembly at Cypress Hills/SSSP. Barb organized and participated in over 100 public outreach events in Saskatoon and area. She also organized many of the Saskatoon Centre's social events, club and guest speaker suppers, and its Christmas meeting socials.

President's Award

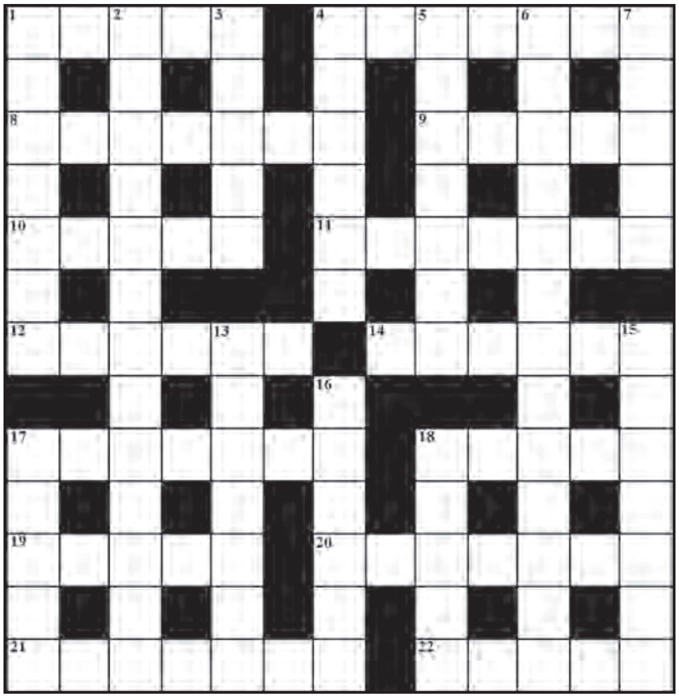
This award is given at the President's discretion, usually once a year, to a member or members who has/have made an important contribution to the Society.

Emilie Lafleche, Montréal Centre

This year's President's Award recognizes the pioneering efforts and vision of an extraordinary youth member of the Society. Emilie Lafleche agreed to chair and create a new committee within the Society to address the needs of, and attract, young Canadians with an interest in astronomy and the related sciences. Emilie and her team represent a young, vibrant, and diverse group within the RASC, which in its first year created new awards, branding and "merch," and programs. They also put together a Youth Day for GA2021 and had a big influence on the entire General Assembly. As its terms of reference states, this committee serves to represent the unique viewpoints, values, and experiences of the Society's youth members as they apply to their RASC membership, including a core dedication to upholding the ideals of respect, inclusivity, and diversity within the Society.

Astrocryptic

by Curt Nason



ACROSS

1. Author is a man of colourful changes (1,4)
4. Jupiter leads or follows them in a safe state (7)
8. Author first seen off-centre to the east (7)
9. String theory feature makes Arneb rotate (5)
10. A tree grows wildly on a ridge of the Apennines (5)
11. I see unusual alien at the base of the air pump (7)
12. Lunar astronauts go pee a long way from Earth (6)
14. Hot spots on the Sun and the Riviera (6)
17. Urania's sister inspired music of the spheres (7)
18. Number one officer of the next generation (5)
19. Radiative eruption rubs out the beginning of time (5)
20. Asteroid ones could endlessly ruin campsite (7)
21. Old time medium for astroimaging by Caelum perhaps (7)
22. Alternative modes for building observatories (5)

DOWN

1. A star spins toward each asteroid (7)
2. Key Rotarian or otherwise in the author's town (6,7)
3. Early lunar spacecraft lost its tail in the Rockies (5)
4. Abridged astronomy book is assured when in it (3,3)
5. Space mechanics in USA labor about it (7)
6. Author's website resembles Amazon sick gym (7,3.3)
7. Atmospheric phenomenon seen over most every night (5)
13. I enter the ruined crater at inconsistent times (7)
15. Lunar periods bring flowers from South America (7)
16. He added humour and time with White as guest author (6)
17. Plumber's bend for a bowel movement (5)
18. Supernova process resulted from incomplete diaper change (5)

Answers to previous puzzle

1 GALLE (hom); **4** PAVONIS (P(anag)s); **8** MATTHEW (2 def); 9 SIMON (2 def); **10** IDEAL (hid); **11** HEALERS (2 def); **12** ALFVEN (an(v)ag); **14** MEISSA (an(E)ag); **18** ASEPTIC (anag); **20** EVENT (2 def); **22** CHINA (2 def); **23** RETICLE (2 def); **24** SEGINUS (S+anag); **25** ATENS (2 def)

1 GOMEISA (anag); **2** LITRE (anag); **3** ECHELLE (e(che)lle); **4** POWEHI (an(w)ag); **5** VESTA (2 def); **6** NUMBERS (2 def); **7** SINUS (rev); **13** FLEMING (2 def); **15** ELECTRA (anag); **16** AETHERS (anag); **17** ICARUS (2 def); **18** ARCUS (hid); **19** TRAIN (2 def); **21** ENCKE (E+anag)

The Royal Astronomical Society of Canada

Vision

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

Mission

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

Values

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

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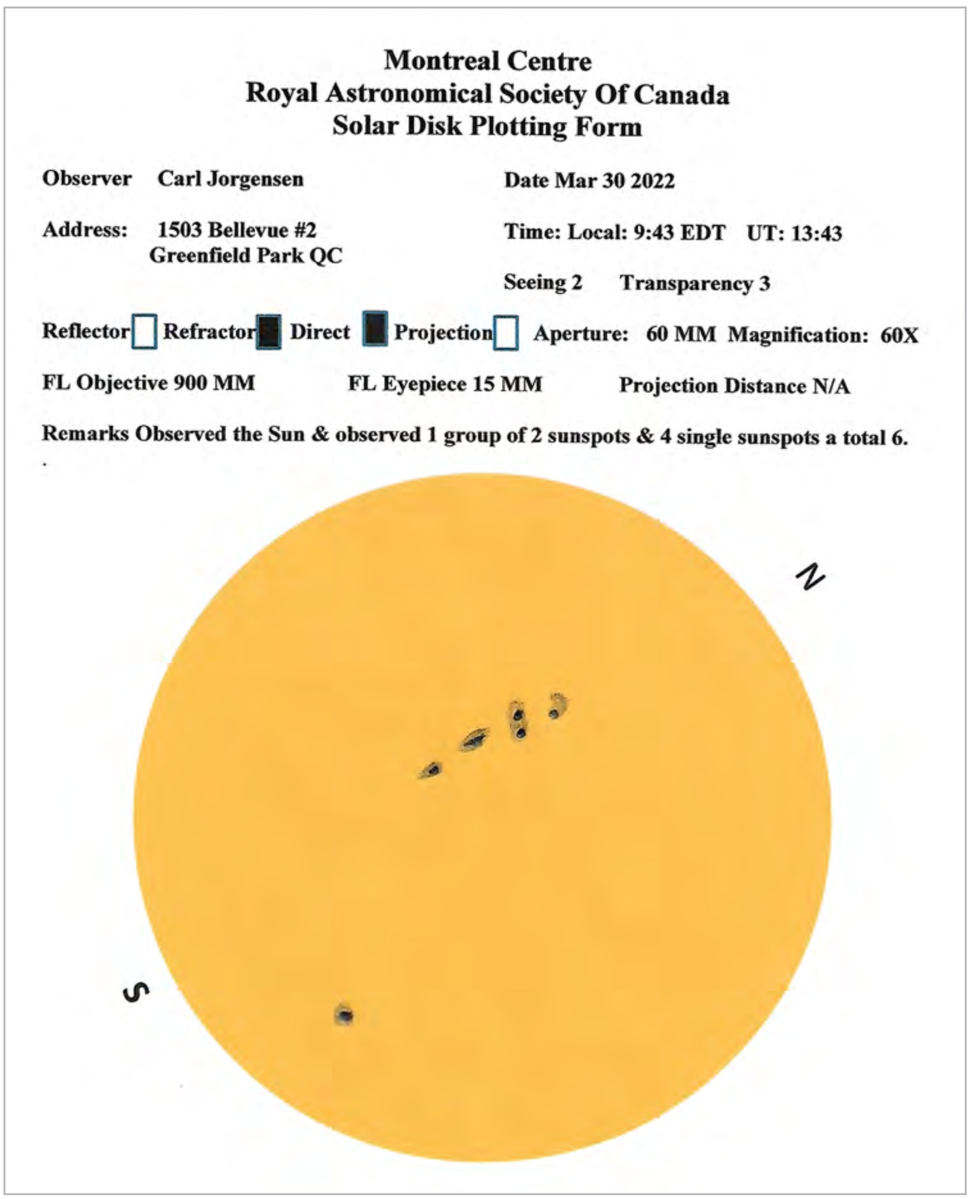
Great Images

by Carl Jorgensen



Montreal Centre
Royal Astronomical Society Of Canada
Solar Disk Plotting Form

Observer Carl Jorgensen

Date Mar 30 2022

Address: 1503 Bellevue #2
Greenfield Park QC

Time: Local: 9:43 EDT UT: 13:43

Seeing 2 Transparency 3

Reflector ☐ Refractor ■ Direct ■ Projection ☐ Aperture: 60 MM Magnification: 60X

FL Objective 900 MM FL Eyepiece 15 MM Projection Distance N/A

Remarks Observed the Sun & observed 1 group of 2 sunspots & 4 single sunspots a total 6.

The Sun has been alive with activity lately, as we seem to be in the early stages of Solar Cycle 25. Carl Jorgensen sketched out a group of sunspots on 2022 April 2. He used a 60 × 900-mm Altair refractor along with a 15-mm eyepiece and a Baader Planetarium solar filter, sketched from Greenfield Park, Québec.

Journal

The Lion Nebula (SH2-132) was taken by Dave Dev from his backyard in the Greater Toronto Area in August 2021. He used a Sharpstar 94 APO with an ASI 2600 mono camera with narrowband filters. Total integration was 12 hours.