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Sound Basis for Teaching: Learning the Hertzsprung-Russell Diagram

Astronomy from Coast to Coast to Coast

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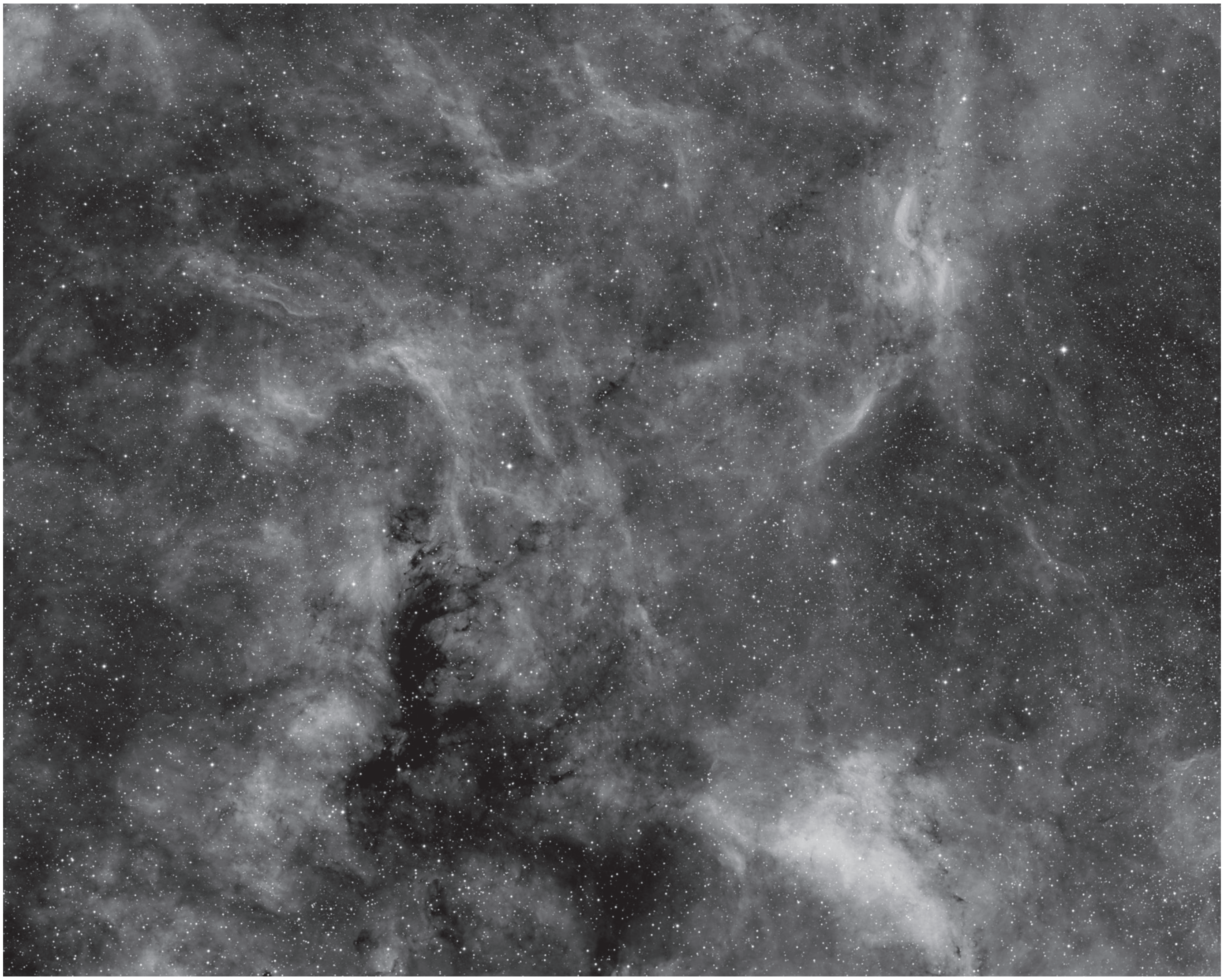
The Brilliant Veil Nebula

The Best of Monochrome.

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



There is so much going on in this image it is hard to know where to start. The image is dominated by a hydrogen-rich emission nebula lying just west of the line connecting Deneb and gamma Cygni (γ Cyg). The Propeller Nebula (DWB 111) is at upper right. The pretty blue patches are reflection nebula; from top to bottom they are NGC 6914, vdB 132, and vdB 131; dark nebula Barnard 346 is near top left, and open cluster Cr 421 is just left of centre at bottom.

All of these objects lie around 6000 light-years away, considerably farther than the 1600 light-years distance to the nearby (in the sky) North America Nebula near Deneb, and IC 1318, which surrounds γ-Cyg.

Details: Moravian G3-16200 EC camera (on loan from O'Telescope), Optolong Hα, R, G, and B filters, Takahashi FSQ-106 ED IV at f/3.6, Paramount MX, unguided. Acquisition with the SkyX, focused with FocusMax, scripted with CCD Commander. All pre-processing and processing in PixInsight. Acquired from my SkyShed in Guelph. Moderate moonlight for Hα, no moonlight for RGB, average transparency and seeing. 18x5 m in R, G, and B and 48x10 m in Hα unbinned frames (total=12 hr 30 m).

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Société Royale d'Astronomie du Canada

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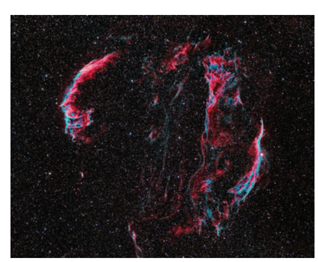

The Veil Nebula is seen here in its entirety. The image was captured by Ron Brecher using a Moravian G3-16200 EC camera and Optolong Hα, OIII, R, G, and B filters on a Takahashi FSQ-106 ED IV at ƒ/3.6, Paramount MX, unguided. The images were acquired from Guelph, Ontario, from June 8 to July 19, with processing done in PixInsight.

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President's Corner

Colin A. Haig, M.Sc.
(astronome@outlook.com)

Why did you join the Royal Astronomical Society of Canada?

For the adventure, the promise of wonderful memories, the new experiences, the friendships, the knowledge, the expertise, the sense of community. Perhaps you see it as a chance to learn, a chance to lead; a chance to inspire the next generation of stargazing enthusiasts and astronomers.

As your new President, I hope to draw on those wonderful experiences that were the reasons I became and stayed a member. In 2017–2018, we'll celebrate the joys of the past 150 years and ensure we are on the right path for the next 150. It's a great honour to serve you, and it is daunting as well. Finances are tight but healthy, membership has topped 5100 people, and things are looking up. Yet there are urgent matters to attend to, and the stars do not wait for us.

We urgently need to put our energy into four key areas: **Diversity**, **People**, **Sustainability**, and **Science**. Canada's 2016 census data is now available, and the RASC membership is not representative of the general population. This is a lost opportunity, that we must address quickly. Women represent 16% of our membership, 26% of the professional astronomy community, and 51% of our population. Children 10 to 14 years old are 5% of the population and 15 to 19 are 6%, and we have a handful of youth members. To improve our diversity, we must change our culture to be open and welcoming to more people, regardless of their background, beliefs, gender, sexuality, or age. Are you comfortable making people welcome at your Centre? Are you aware of our Anti-Harassment Policy? Do you realize that your behaviour in person or on social media creates the culture for our guests and new members? Let's create a culture that is open, welcoming, safe, and fun.

If we have the right culture, and are retaining members, this will help with sustainability. As stewards, you and I need to ensure the RASC will be around 150 years from now. This means we need to take care of our people—the volunteers and staff who make everything happen. We need to build the skills through coaching and mentorship to aid more people with presenting, running a Centre, leading a stargazing party, and cultivating the next generation of leaders. Financial sustain-ability is critical. At present, your membership fees bring you a lot of benefit, but there is nothing left over to pay for the fight against light pollution, to build better programs, to create new resources, or tackle the other important things that we aspire to do.

Past President Craig Levine shared some elements of our Strategic Plan with you. We'll be rolling that out immediately, by sharing it directly with you and at Centre meetings. One of our first results is we now have a Fundraising Committee and are looking to hire a fundraiser, to help us do more outreach and tackle the big, inspiring "moonshot" projects that will catapult the RASC into the next 150 years.

You and I need to ensure the funding is in place to create opportunities for Canadians to do real science and to inspire the next generation of young scientists. We can't do this if the piggy bank is empty. We'll be asking for your help with this in the coming months—not necessarily your money, but your enthusiasm, energy, and ideas. Can I also ask you to start tracking your volunteer hours? I'd love to see us report on how much time people generously give each year. We hope to formalize this reporting with an easy-to-use tool that builds on the past efforts by Ron McNaughton, our IT team, and others.

Thank you to the amazing and enthusiastic crew in Ottawa and the volunteers and staff in our organization that made the 2017 General Assembly a great success. I was personally touched by the opportunity to co-present many awards with Past President Craig Levine. Science writer Ivan Semeniuk brought a tear to my eyes with a small speech. Our members honoured him with the Simon Newcomb Award, and so for the first time in his career, he was recognized for science writing in astronomy. Clearly, this is long-overdue recognition. I was also touched by many Service Award winners, who felt in some way they were not deserving, yet had contributed their amazing talent for over a decade. Join me in Calgary at the next General Assembly!

Our first National Star Party was a success, and the 150th Anniversary team promises we will have a humdinger of an event in 2018. As we celebrate our sesquicentennial, our volunteers have promised a lot of fun and even quirky activities, ranging from new publications to podcasts on the weird and wonderful history of our Society. I am looking forward to seeing what you all come up with!

Whether its star parties, or eclipse chasing, members like you will be sharing their recent adventures to the USA and across Canada. We're sure to hear of new discoveries, see amazing images, and hear tall tales. This "Great American Eclipse of 2017" compelled me to look back to Manitoba's 1979 February 26 event and to discover some others. A total solar eclipse on 1959 October 2 over Massachusetts may have inspired American poet Delmore Schwartz' Summer Knowledge: New and Select Poems. Let me leave you with his words:

> Each minute bursts in the burning room,
> The great globe reels in the solar fire,
> Spinning the trivial and unique away.
> (How all things flash! How all things flare!)
> What am I now that I was then?
> May memory restore again and again
> The smallest color of the smallest day:
> Time is the school in which we learn,
> Time is the fire in which we burn.

His words should inspire a sense of urgency to do all the memorable things, so we can joyfully say to all who ask: "*At the RASC, our business is looking up!*" ✶

News Notes / En Manchette

Compiled by Jay Anderson FRASC

New high-resolution capability for the ESO

The European Southern Observatory's pride and joy is the four-unit Very Large Telescope (VLT), a part of the Paranal Observatory complex in northern Chile. In its VLT configuration, four 8.2-metre telescopes combine their signals to operate as one telescope with very high angular resolution, though they are most often used as stand-alone instruments. The four individual telescopes are named for astronomical objects in the Mapuche language: *Antu*, *Kueyen*, *Melipal,* and *Yepun*.

Yepun (a name that probably stands for Venus) has now been transformed into a fully adaptive telescope. After more than a decade of planning, construction, and testing, a new Adaptive Optics Facility (AOF) has seen first light with the Multi-Unit Spectroscopic Explorer (MUSE), capturing amazingly sharp views of planetary nebulae and galaxies. The coupling of the AOF and MUSE forms one of the most advanced and powerful technological systems ever built for ground-based astronomy.

Adaptive optics works to compensate for the blurring effect of the Earth's atmosphere, enabling MUSE to obtain much sharper images and resulting in twice the contrast previously achievable. The AOF includes a Four Laser Guide Star Facility (4LGSF) and a very thin, deformable secondary mirror. The 4LGSF shines four 22-watt laser beams into the sky to make sodium atoms glow at an altitude of 80–100 km, producing spots of light on the sky that mimic stars. Sensors in an adaptive-optics module examine the wave-front errors generated by the Earth's atmosphere to determine the correction that must be applied by the secondary mirror to smooth out the atmospheric distortions.

Corrections to the wave front are applied 1000 times per second. In particular, software corrects for the turbulence in the layer of atmosphere up to one kilometre above the telescope. Depending on the conditions, atmospheric turbulence can vary with altitude, but studies have shown that most of atmospheric disturbance occurs in this "ground layer" of the atmosphere.

"*Now, even when the weather conditions are not perfect, astronomers can still get superb image quality thanks to the AOF,*" explains Harald Kuntschner, AOF Project Scientist at ESO.

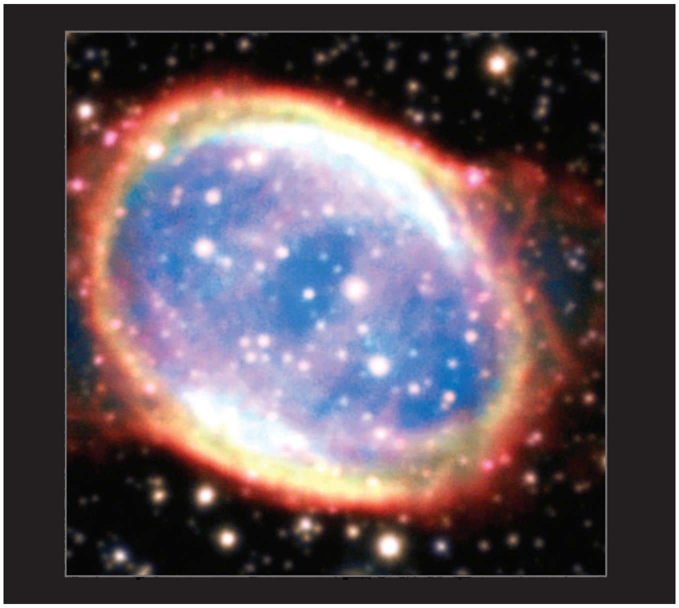 

Figure 1 — NGC 6563 is a planetary nebula located in the constellation Sagittarius. This stunning image, obtained with the powerful symbiosis between the AOF and MUSE reveals the faint nebula structures as never seen before. The image on the left is without adaptive optics and the one on the right is with the AOF. Image: ESO/P. Weilbacher (AIP)

Following a battery of tests on the new system, the team of astronomers and engineers were rewarded with a series of spectacular images. Astronomers were able to observe the planetary nebulae IC 4406, located in the constellation Lupus, and NGC 6563, located in the constellation Sagittarius. The MUSE observations using the AOF showed dramatic improvements in the sharpness of the images (Figure 1).

"*The AOF system is essentially equivalent to raising the VLT about 900 metres higher in the air, above the most turbulent layer of atmosphere*," explains Robin Arsenault, AOF Project Manager. "*In the past, if we wanted sharper images, we would have had to find a better site or use a space telescope—but now with the AOF, we can create much better conditions right where we are, for a fraction of the cost!*"

The corrections applied by the AOF improve the image quality by concentrating the light to form sharper images, allowing MUSE to resolve finer details and detect fainter stars than previously possible. The AOF currently provides a correction over a wide field of view (about 1 arcminute), but this is only the first step in bringing adaptive optics to MUSE. A second narrow-field mode of the AOF is in preparation and is expected to see first light early 2018. This new mode will correct for turbulence at any altitude, allowing observations of smaller fields of view to be made with even higher resolution.

"*Sixteen years ago, when we proposed building the revolutionary MUSE instrument, our vision was to couple it with another very advanced system, the AOF*," says Roland Bacon, project lead for MUSE. "*The discovery potential of MUSE, already large, is now enhanced still further. Our dream is becoming true*."

One of the main science goals of the system is to observe faint objects in the distant Universe with the best possible image quality, which will require exposures of many hours. Joël Vernet, ESO Project Scientist, comments: "In particular, we are interested in observing the smallest, faintest galaxies at the largest distances. These are galaxies in the making—still in their infancy—and are key to understanding how galaxies form."

"ESO is driving the development of these adaptive optics systems, and the AOF is also a pathfinder for ESO's Extremely Large Telescope," adds Arsenault. "Working on the AOF has equipped us—scientists, engineers and industry alike—with invaluable experience and expertise that we will now use to overcome the challenges of building the ELT."

Compiled in part with information provided by the ESO

Voyager moves into middle age

Humanity's farthest and longest-lived spacecraft, *Voyager 1* and *2*, achieve 40 years of operation and exploration this August and September. Despite their vast distance, they continue to communicate with NASA daily, still probing the final frontier. In about 296,000 years, *Voyager 2* will pass 4.3 light-years from Sirius, destined—perhaps eternally—to wander the Milky Way."

Their story has not only impacted generations of current and future scientists and engineers but also Earth's culture, including film, art, and music. Each spacecraft carries a Golden Record of Earth sounds, pictures, and messages. Since the spacecraft could last billions of years, these circular time capsules could one day be the only traces of human civilization.

"*I believe that few missions can ever match the achievements of the* Voyager *spacecraft during their four decades of exploration*," said Thomas Zurbuchen, associate administrator for NASA's Science Mission Directorate (SMD) at NASA Headquarters. "*They have educated us to the unknown wonders of the Universe and truly inspired humanity to continue to explore our Solar System and beyond.*"

The *Voyagers* have set numerous records in their unparallelled journeys. In 2012, *Voyager 1*, launched on 1977 September 5, became the only spacecraft to have entered interstellar space. *Voyager 2*, launched on 1977 August 20, is the only spacecraft to have flown by all four outer planets. Their numerous planetary encounters include discovering the first active volcanoes beyond Earth, on Jupiter's moon Io; hints of a subsurface ocean on Jupiter's moon Europa; the most Earth-like atmosphere in the Solar System, on Saturn's moon Titan; the jumbled-up, icy moon Miranda at Uranus; and icy-cold geysers on Neptune's moon Triton.

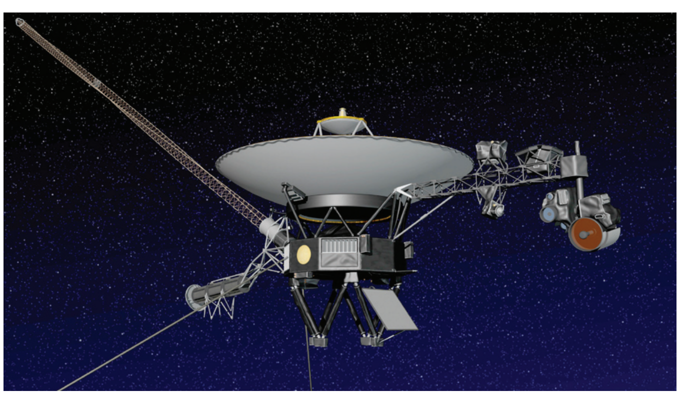

Figure 2 — Artist's concept of NASA's Voyager *spacecraft. Image: NASA/JPL-Caltech*

Though the spacecraft have left the planets far behind—and neither will come remotely close to another star for 40,000 years—the two probes still send back observations about conditions where our Sun's influence diminishes and interstellar space begins.

Voyager 1, now almost 13 billion miles from Earth, travels through interstellar space northward out of the plane of the planets. The probe has informed researchers that cosmic rays, atomic nuclei accelerated to nearly the speed of light, are as much as four times more abundant in interstellar space than in the vicinity of Earth. This means the heliosphere, the bubble-like volume containing our Solar System's planets and solar wind, effectively acts as a radiation shield for the planets. *Voyager 1* also hinted that the magnetic field of the local interstellar medium is wrapped around the heliosphere.

Voyager 2, now almost 11 billion miles from Earth, travels south and is expected to enter interstellar space in the next few years. The different locations of the two *Voyagers* allow scientists to compare two regions of space where the heliosphere interacts with the surrounding interstellar medium using instruments that measure charged particles, magnetic fields, low-frequency radio waves and solar wind plasma. Once *Voyager 2* crosses into the interstellar medium, they will also be able to sample the medium from two different locations simultaneously.

"*None of us knew, when we launched 40 years ago, that anything would still be working, and continuing on this pioneering journey*," said Ed Stone, *Voyager* project scientist based at Caltech in Pasadena, California. "*The most exciting thing they find in the next five years is likely to be something that we didn't know was out there to be discovered*."

The twin *Voyagers* have been cosmic overachievers, thanks to the foresight of mission designers. By preparing for the radiation environment at Jupiter, the harshest of all planets in our Solar System, the spacecraft were well equipped for their subsequent journeys. Both *Voyagers* carry redundant systems that allow the spacecraft to switch to backup systems autonomously when necessary, as well as long-lasting power supplies. Each *Voyager* has three radioisotope thermoelectric generators, devices that use the heat energy generated from the decay of plutonium-238—only half of it will be gone after 88 years.

Space is almost empty, so the *Voyagers* are not at a significant level of risk of bombardment by large objects. However, *Voyager 1*'s interstellar space environment is not a complete void. It's filled with clouds of dilute material remaining from stars that exploded as supernovae millions of years ago. This material doesn't pose a danger to the spacecraft, but is a key part of the environment that the *Voyager* mission is helping scientists study and characterize.

Because the *Voyagers*' power decreases by four watts per year, engineers are learning how to operate the spacecraft under ever-tighter power constraints. And to maximize the *Voyagers*' lifespans, they also have to consult documents written decade's earlier describing commands and software, in addition to the expertise of former *Voyager* engineers.

"*The technology is many generations old, and it takes someone with 1970's design experience to understand how the spacecraft operate and what updates can be made to permit them to continue operating today and into the future*," said Suzanne Dodd, *Voyager* project manager based at NASA's Jet Propulsion Laboratory in Pasadena.

Team members estimate they will have to turn off the last science instrument by 2030. However, even after the spacecraft go silent, they'll continue on their trajectories at their present speed of more than 48,000 kilometres per hour, completing an orbit within the Milky Way every 225 million years.

The *Voyager* spacecraft were built by JPL, which continues to operate both. The *Voyager* missions are part of the NASA Heliophysics System Observatory, sponsored by the Heliophysics Division of the Science Mission Directorate.

Spinning at the core

Scientists have long thought gravity waves, or g-waves, hold the key to studying the rotation of the Sun's core. Gravity waves are fluid waves where buoyancy acts as the restoring force. They are common in fluids (liquid and gas) in which density decreases with height.

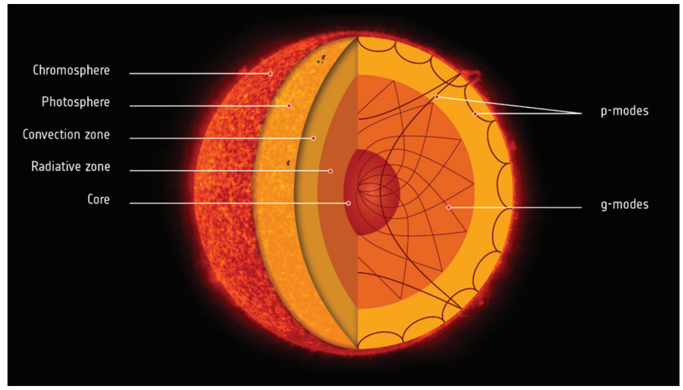

Figure 3 — Scientists have used data from ESA and NASA's Solar and Heliospheric Observatory *to detect a type of wave called g-modes on the Sun. These g-modes reveal that the solar core is rotating about four times faster than the surface. Credits: ESA.*

Typically, a lower, more-dense part of the fluid is displaced upward by some force so that it is out of equilibrium with its surroundings and no longer buoyant; gravity then causes the high-density region to sink downward. Often the sinking parcel will overshoot the balance point and it will then become buoyant within its lower surroundings, rising upward again to keep the wave moving.

Gravity waves are hard to find in the Sun, because they have no clear signatures on the solar surface. Sound waves, also called pressure waves, or p-waves, on the other hand, are easy to detect on the solar surface, but they don't give us any information about how the Sun's core rotates. These waves are generated by ongoing convection beneath the solar surface.

"*The solar oscillations studied so far are all sound waves, but there should also be gravity waves in the Sun, with up-and-down, as well as horizontal motions, like waves in the sea*," said Eric Fossat, an astronomer at the Côte d'Azur Observatory and lead author of the paper describing the result. "*We've been searching for these elusive g-waves in our Sun for over 40 years, and although earlier attempts have hinted at detections, none were definitive. Finally, we have discovered how to unambiguously extract their signature*."

Eric and his colleagues used 16.5 years of data collected by SOHO's Global Oscillations at Low Frequencies, or GOLF, instrument. By applying various analytical and statistical techniques, they were able to pick out a regular imprint of the g-modes on the more easily detected p-modes.

In particular, they looked at a p-mode parameter that measures how long it takes for an acoustic wave to travel through the Sun and back to the surface again—a journey known to take four hours and seven minutes. They detected a series of modulations in this p-mode parameter: the signature of g-waves shaking the structure of the Sun's core.

The imprint of these g-waves suggests that the solar core is rotating once every week, nearly four times faster than the Sun's surface and intermediate layers, which have rotation periods anywhere from 25 days at the equator to 35 days at the poles. Detecting the signature of the solar core's rotation opens up a new set of questions for solar physicists—such as how differently rotating layers of the Sun interact, and what we can learn about the composition of the core based on its rotation.

"G-modes have been detected in other stars, and now thanks to SOHO, we have finally found convincing proof of them in our own star," Fossat said. "It is really special to see into the core of our own Sun to get a first indirect measurement of its rotation speed. But, even though this decades-long search is over, a new window of solar physics now begins."

"The most likely explanation is that this core rotation is left over from the period when the Sun formed, some 4.6 billion years ago," said Roger Ulrich, a UCLA professor emeritus of astronomy, who has studied the Sun's interior for more than 40 years and is co-author of the study. "It's a surprise, and exciting to think we might have uncovered a relic of what the Sun was like when it first formed." After the Sun formed, the solar wind likely slowed the rotation of the outer part of the Sun, he said. The rotation might also impact sunspots, which also rotate, Ulrich said.

The idea that the solar core could be rotating more rapidly than the surface has been considered for more than 20 years, but has never before been measured.

Compiled in part with material provided by UCLA and NASA

Brown dwarfs and stars: setting the limit

Stars form when a primordial cloud of dust and gas is compressed by shock waves and gravity and cooled by infrared radiation. The contracting bundle of mostly hydrogen and helium ignites and becomes a star when the density and temperature at its core become high enough to initiate and sustain a fusion reaction.

But not all collapsing gas clouds are created equal. In many cases, the collapsing cloud makes a ball that isn't dense enough to ignite fusion. These "failed stars" are known as brown dwarfs. Because of their dim infrared radiation, brown dwarfs are notoriously difficult to find, but the numbers detected in the immediate solar neighbourhood suggest that they may be as numerous as all the other stars together. These tiny objects

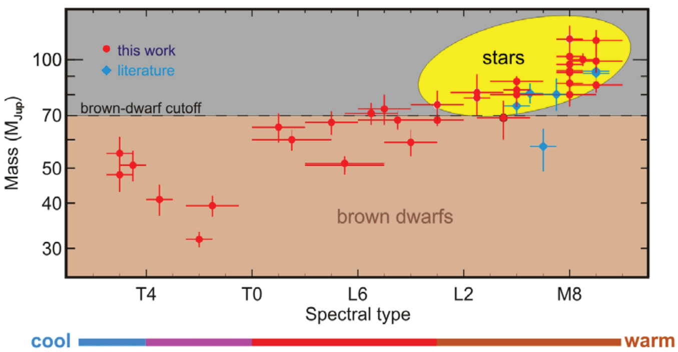

Figure 4 — Plot of mass versus surface temperature (represented as spectral type) for the selection of brown dwarfs and cool stars. Objects above a certain mass are always on the warm side of this plot. There is a critical mass below which objects of the same mass have very different surface temperatures, and this is at roughly 70 Jupiter masses. After Trent & DuPuy, AAS meeting, Austin, Texas.

occupy the mass range between the heaviest gas giant planets and the lightest stars, but just what is the maximum mass limit for a brown dwarf is relatively uncertain—or at least it was, until now.

Theoreticians had narrowed the maximum mass for a brown dwarf to between 75 and 80 Jupiter masses, but new observational results, led by astronomers Trent Dupuy of the University of Texas at Austin and Michael Liu of the University of Hawaii, have placed the dividing line more precisely, and it turns out to be a bit of a surprise. The new observational value is equal to 70 Jupiters or 6.7 percent of the mass of the Sun.

"When we look up and see the stars shining at night, we are seeing only part of the story," said Dupuy, a graduate of the Institute for Astronomy at the University of Hawaii at Manoa. "Not everything that could be a star 'makes it,' and figuring out why this process sometimes fails is just as important as understanding when it succeeds."

How did they reach that conclusion? For a decade, the two studied 31 faint brown-dwarf binaries using two powerful telescopes in Hawaii—the W. M. Keck Observatory and Canada-France-Hawaii telescopes—along with data from the *Hubble Space Telescope*. To define the mass limit, they needed to accurately measure both the temperature and mass of a selection of very cool stars and similar brown dwarfs.

Their goal was to measure the masses of the objects in these binaries, since mass defines the boundary between stars and brown dwarfs. To determine the masses of a binary, one measures the size and speed of the stars' orbits around an invisible point between them where the pull of gravity is equal (known as the "centre of mass"). However, binary brown dwarfs orbit much more slowly than binary stars, due to their lower masses. And because brown dwarfs are dimmer than stars, they can only be well studied with the world's most powerful telescopes.

To measure masses, Dupuy and Liu collected images of the brown-dwarf binaries over several years, tracking their orbital motions using high-precision observations. They used the 10-metre Keck Observatory telescope, along with its laser guide-star adaptive optics system, and the *Hubble Space Telescope*, to obtain the extremely sharp images needed to distinguish the light from each object in the pair.

However, the price of such zoomed-in, high-resolution images is that there is no reference frame to identify the centre of mass. Wide-field images from the Canada-France-Hawaii Telescope containing hundreds of stars provided the reference grid needed to measure the centre of mass for every binary. The precise positions needed to make these measurements are one of the specialties of WIRCam, the Wide-Field InfraRed camera at CFHT. "Working with Trent Dupuy and Mike Liu over the last decade has not only benefited their work but our understanding of what is possible with WIRCam as well," says Daniel Devost, director of science operations at CFHT. "This is one of the first programs I worked on when I started at CFHT so this makes this discovery even more exciting."

The result of the decade-long observing program is the first large sample of brown-dwarf masses. When the masses and surface temperatures were plotted on a graph, the sample of true stars formed a straight-line segment (because mass and luminosity are tightly related for stars), while the brown-dwarf candidates were scattered across the mass range. The limiting mass was determined as the point where the random distribution became linear. The information they have assembled has allowed them to draw a number of conclusions about what distinguishes stars from brown dwarfs.

Objects heavier than 70 Jupiter masses are not cold enough to be brown dwarfs, implying that they are all stars powered by nuclear fusion. Therefore 70 Jupiters is the critical mass below which objects are fated to be brown dwarfs. This minimum mass is somewhat lower than theories had predicted but still consistent with the latest models of brown-dwarf evolution.

In addition to the mass cutoff, they discovered a surface-temperature cutoff. Any object cooler than 1,600 K is not a star, but a brown dwarf.

This new work will help astronomers understand the conditions under which stars form and evolve—or sometimes fail. In turn, the success or failure of star formation has an impact on how, where, and why planetary systems form.

"As they say, good things come to those who wait. While we've had many interesting brown dwarf results over the past 10 years, this large sample of masses is the big payoff. These measurements will be fundamental to understanding both brown dwarfs and stars for a very long time," concludes Liu. ✶

Sound Basis for Teaching: Learning the Hertzsprung-Russell Diagram

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Abstract

This is a case study of academic research into astronomy education from two perspectives—making astronomy education more approachable and interpreting astronomy content with sound—revealing interesting twists for each along the way. On the one hand, a course professor opens an aspect of university instruction as a case study for sharing best-practice findings from unconventional assignment development. In the process, the professor discovers that undergraduates can surprise you if such opportunities are well facilitated. On the other hand, a case example of unconventional work by a non-science major taking that introduction to astronomy class creates music that may become a tool for others to use in exploring and learning about astronomy. Again a surprise in the process of undertaking work, the student discovers a familial relationship with a historical person of astronomical science along with an equally interesting question about that well-known figure.

Question, reaching all astronomy learners

In developing an entry-level undergraduate science course about astronomy, the professor questioned if a student-centred assignment could deepen engagement of science concepts, especially for the non-science major. The rationale is echoed back to educator Jean Piaget, that education's principal goal is the development of learner creativity, invention, and desire for discovery (Ginsberg and Opper, 1969). And yet "discipline-based education research" to improve undergraduate university teaching and learning, especially in astronomy and for the non-science major, is a relatively new pursuit (Bailey and Lombardi, 2015).

Canadian astronomical education evolves. A mainly upper-level mathematical course at its start, with little to no practical work, astronomy education now includes both observation and research considered essential to the learning experience, and more recently accommodates the non-science student through introductory coursework (Percy, 2015). Further, skills education within astronomy courses is desired, but few examples appear in the research literature, perhaps because this objective is left for resolution through external professional development courses.

Why skills education? "University professors receive years of training in research, but little or no training in teaching, supervision, or mentorship," which studies confirm as leaving students feeling poorly trained for "oral and written communication, teaching, project management, and especially in working in an interdisciplinary environment" (Percy, 2015). Not everyone becomes a professor, nevertheless more than content should be taught at university. For many of the non-science majors, this introduction course is also their terminal astronomy course, thereby placing greater importance on learning skills of scientific processes, for enjoyment of science, and in instruction that models effective teaching especially to undergraduates selecting a major of preservice education (Prather et al., 2004).

Astronomy education research has become more important since the recent cessation of the Astronomy Education Review publication (Bailey and Lombardi, 2015), and greater value is placed on examples, in particular those conducted in the manner of this case study by the professor of the course, because it aligns more with the interests of colleagues. Therefore, a case study is presented below, starting with the course professor's perspective and then examining a case example from the student perspective.

Answer, unconventional pedagogy

Unconventional pedagogy used in this astronomy course is open-ended authentic inquiry in context. Learners are given some control over the application of learning (open-ended), and new concepts build on practical aspects of their major of study (authentic learning, be that a science discipline or otherwise). Undergraduate assignments with an open-ended component assist students in learning invaluable skills, including project management, problem-solving, and how science and research can apply to everyday life (Allen et al., 2013). After all, if the assignment is of interest and relevant (even enjoyable), it may be completed well.

Limiting criteria provides students with boundaries in undertaking the term assignment. Participants are limited to choosing an objective with close ties to course goals (the key requirement), creating something (a product) that will not cause harm, a product that helps educate others about astronomy, and work that does not invoke ethics committee approval (reducing paperwork and time). The open-ended component is just that, students make major decisions from inquiry methodology to product medium, but with guidance to keep the frustration level low and the product achievable. A sample product created by the professor, and demonstrated for the class, provided a model of the process and result. Students choose their topic and medium, seeking approval and then support from the professor on an ongoing basis.

Active student engagement in the learning process is supported in the research literature as greatly improving achievement of "Earth and space science" course goals (Prather et al., 2004; Tasch and Tasch, 2016). One account describes a student-friendly open-ended approach to learning geomorphic content by permitting students to choose their medium to demonstrate connections and comprehension of course objectives (Allen et al., 2013). The learners were responsible for method and product form, with guidance on scope by the professor, ultimately gaining "clearer understanding of what a scientific research project can entail."

The assignment of this case study is a term project expecting creativity, possibly incorporating another discipline area, and developing a product that is informative if not educative for others. Ideally, products are a science inquiry, or at least consider science philosophy, content, and process taught throughout the course, including analysis and scrutiny of science claims and results—science content knowledge that is otherwise highly managed in traditionally framed assignments (McFarlane, 2013). Products, then, could become another solution to the barrier of accessing learning if put back into service (with permission) within the same course.

Method of inquiry into astronomy education

There is quite a bit of methodological support for qualitative research that is grounded systematically (Glaser and Strauss, 1967). Case analysis of the experimental assignment is conducted clinically by the course professor, leading to refinements for later trials and study. A similar strategy called action research is conducted in the field of education. Grounding of claims is made based on personal, practical, "knowledge-on-action," through piloting a teaching-learning experience that may lead toward the development of an exemplar (Schön, 1983; 1987; 1991). The work of novice science students could then inform professor reflection on the program component and improve instructional practice in science education.

Several hundred students completed Introduction to Astronomy, and therefore this assignment, providing a rich diversity of feedback and validation. To put a face on the outcome of this inquiry, an example is used to back analysis and ground exploration of open-ended projects and related practice. Following the course, both professor and student recounted events by collecting notes, emails, and the anecdotal comments of others for analysis along with "reflection-on-action" of the learning experience (Schön, 1983). This case example within the study demonstrates achievement of course goals and an intention to advance communication of science along with encountering some science fun.

The December *Journal* deadline for submissions is 2017 October 1. See the published schedule at

www.rasc.ca/sites/default/files/jrascschedule2017.pdf

Discovering a familial relationship

The case example is of a music and composition major who utilized those same discipline areas as the intended unconventional route to learning, by describing a scientific concept of astronomy through reinterpreting it as sound.

A process unfolds with learning which begins with uncertainty, leads to research and experiment, and is followed by realisation and accomplishment. Learning for this student is no different, initial thoughts uncertain about what to compose are recalled—first thinking perhaps of setting some content of the course to music. In researching what to do for the assignment, which for this student was an enthusiastic scan of the textbook for possible themes, a familiar name was uncovered. Here history emerges. Hertzsprung, a renowned Danish astronomer, is coincidentally a maternal family name that, on further investigation, proves to be a distant relation to the student.

Ejnar Hertzsprung's greatest contribution to astronomy is his method of combining the spectral classes of stars with their energy output and size onto a single diagram. Having independently conceived this diagram at approximately the same time as American astronomer Henry Norris Russell, the naming of the diagram is divided between the two, the Hertzsprung-Russell (H-R) Diagram. The astronomy student in this case also discovered family reports (a recollected letter from Hertzsprung, as yet to be found) of a conflict between the two scientists, suggesting Hertzsprung was the major developer and none too pleased with the lack of effort by his colleague. (More about this claim we hope to uncover for the next *Journal* paper.)

A "sound" case example

Compared to most graphs, the H-R Diagram presents a barrier to learning astronomical science for many undergraduates. It is viewed as complex and difficult to unpack. Divergent scales explain properties of a star including luminosity (L) which compares with absolute visual magnitude (M_V), temperature (T), radius (R), mass (M), and age (y) with our star (the Sun, symbolized ⊙) as the benchmark (Figure 1). A question emerged for the student, therefore: could the H-R Diagram be converted to music by use of contemporary composing techniques? That question, and the approach, was approved.

Produced is a score of music interpreting the H-R Diagram (Figure 2). An audio clip of the score is available for downloading www.rasc.ca/sites/default/files/Hertzsprung-Russell-Diagram.mp3).

Represented in the score are main-sequence, dwarf, and giant stars in that order of appearance. Dwarf stars are placed in the score simultaneous with relatively high-mass B spectral-class stars because of similar spectral colour; similarly, giant stars appear along with G-class stars. This composition does not include super-giant stars, but those stars are being considered for the next refinement of the score. The pitch of a note is linked to star luminosity, e.g. high-note pitch is a bright star, while the volume of a note conveys star colour/temperature, e.g. forte (loud) note volume is a blue/hot star. Stars are "played" reading from left to right on the standard H-R Diagram (i.e. Figure 1). Corresponding notes assigned in a logical order across each scale produce a solo piece for piano—a music score. Middle-C is the note corresponding to the Sun. The Sun as middle-C is coincidental, a discovery made after the student ascribed notes to star spectral classes on the completed score. The humour in this finding was not lost on us, an uncalculated "music of the spheres" discussed next.

Music, sound, and science

Appreciation for astronomy-related music themes traces back to historical flute pieces from ancient Rome, some likely heard by Galileo,[1] and interest in astronomers producing music includes the compositions of William Herschel, a musician himself, along with his sister Caroline, a soprano soloist (Chung, 2013; Gaherty, 2013). Astronomy enthusiasts restore and play early tunes (Gaherty, 2013) along with preserving early concepts, for example the now-incorrect assumption of ancient Greeks and historical figures such as Pythagoras and Kepler seeking quantification of sound as a mathematical means of describing the Universe as perfect—a *music of the spheres* that defines the ratio or resonant harmony of planet orbits about the Sun (Chung, 2013; Gingras, 2003; Percy, 2016).

Think about more contemporary music in relation to astronomy and be reminded of Gustav Holst's *The Planets* (1914–1916), which is astrological in origin, not astronomical. Claude Debussy's *Clair de Lune* has an affective quality, stirring feelings, so too in the first movement of Beethoven's *Moonlight Sonata*. John Phillip Sousa's *The Transit of Venus* is a commemorative piece, and recent space-themed classical and popular music is inspired by astronomy as well (Fraknoi, 2012; Percy, 2016), but as with those before, these listening pleasures are uncommunicative about the subject matter of astronomy. Some research is published about discipline content in song lyrics (Allen, et al., 2013), but songs too are rarely composed for astronomy and unlikely accurate over time.[2] No wonder, then, that music is not associated with practical or research astronomy (Chung, 2013).

Obviously, sound itself matters to astronomy. In a field so closely tied to "light as the great informant,"a wealth of sound

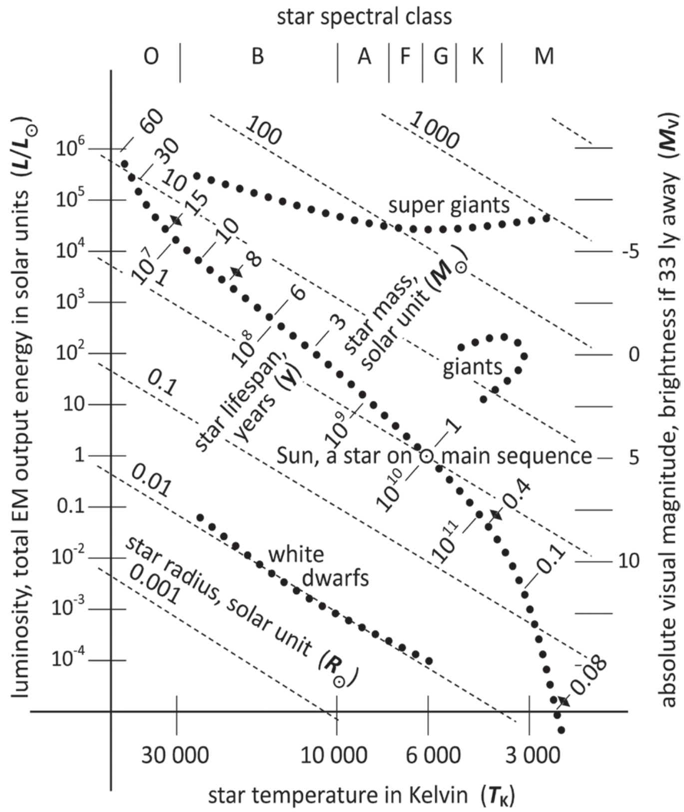

Figure 1 — Idealized H-R Diagram for comparing stars. Only one star is named, the Sun (⊙), the benchmark, situated along the main sequence (a band of stars meandering from top left to bottom right within the figure). Graphic by Stephen Jeans, Ph.D., course professor.

examples can be found. Sound capturing technologies include geophones listening to internal sound waves (both natural and manufactured) from our moon and Doppler shift measurements in spectra capturing "sunquakes'" on the surface of our star (Global Oscillation Network Group). Radio telescopes capture EM emission data, which astronomers convert directly into audible sound of clicks and hums now associated with pulsars and fast radio bursts (likely active galactic nuclei). These waves are not naturally audible sound. For example, the resonant frequency of the Earth is E flat at about 23 octaves below middle C. To be audible means having to decrease or increase frequencies up to 10,000 times (comet 67P/Churyumov-Gerasimenko by NASA's Rosetta mission) to a billion times (central black hole from a galaxy in the Perseus Cluster by NASA's *Chandra X-ray Observatory*).

Attaching sound to the numerical values of scientific data and expecting music is disappointing. One such attempt in Earth science is the work of a geologist in conjunction with an artist to make "geophonic" soundscapes from the addition of a sound (e.g. ocean waves and seagulls) to property changes of core-sample data (Rossetti and Montanari, 2004). "Music" from the raw data lacked something, so the artist re-organized and/or transposed data portions. The result is novel compositions, but strictly an artistic interpretation of the concept of

Figure 2 — "Hertzsprung-Russell Diagram" aleatoric music composition interpreting the H-R Diagram. Composition by Richard Charter, course student.

deep time because data is altered and/or edited by the artist to please traditional western musical sensitivities.

Gleaning meaning from sound requires serious attention to the data set and interpretation. The intent behind the student product in this case study is to honestly represent the data. Through a strict adherence to data-note matching, the resultant music is raw and entirely unpleasing to the ear. This method is much more akin to the work of astrophysicist Wanda Diaz Merced, whose mid-career loss of sight prompted her to translate light emitted by gamma-ray bursts into sound that she could better study.[3] Begged still is the question, is it music?

Aleatoric music product analysis

The H-R Diagram composition is unique in seeking fidelity to data that is used to compare stars, a method to produce sound not objectively "beautiful," but spacey and within an astronomical aesthetic. This is a form of "aleatoric" or "chance" music in keeping with certain contemporary works (Burkholder, Grout, and Palisca, 2011). Composing in this manner requires an extensive knowledge of contemporary idiom traced largely to the contributions of John Cage (1912–1992) the famed composer and music theorist (Burkholder et al., 2011). To write an aleatoric piece of music based on external motivation, the original data is first converted into musical analogies. In works of this nature, the composer perhaps interprets a table of numbers and assigns a note to each number. Furthermore, one could use a visual aid, such as texture and shape of an object to determine musical variables such as tone and timbre, or in this case example the luminosity and temperature as pitch and volume.

H-R Diagram interpretation criteria were decided upon when the student and professor met to refine the product in process. Limitations had to be set for the product based on the instrument and time available for the assigned task.

Musical variables including tone and timbre were set aside because they could possibly complicate the process. Timbral range of the piano is quite narrow, for example, which could fail to adequately represent features of the H-R Diagram. In future exploration, however, an orchestral arrangement (multiple instruments) offers more variety of musical variables. Dividing orchestra sections according to star spectral class may produce a chamber work including strings for the main sequence, brass for supergiant stars, woodwinds for white-dwarf stars, etc. Or, in the truest John Cage fashion, a "prepared" piano may also be implemented, where certain strings are given additional pieces of material, thus prepared in such a way that striking these strings produces different timbres and pitches.

The budding composer, the music and composition undergraduate, sought an earnest attempt to compose a work of science and a thoroughly avant-garde piece of music as the assignment product. Representative stars listed on a published H-R Diagram taken from *Scientific American* (Croswell, 2011) became the test in a composition called "Nocturne for Eijnar Hertzsprung" explained to, and played for, peers in the introduction to astronomy class. Silence fell over the audience of peers, and on completion of the piece applause and meaningful questions. Perhaps the class reaction was largely due to the shock of hearing a seemingly arbitrary array of notes played in a manner akin to an infant hammering at a keyboard. But there was something more in the content of questions, a comprehension of the concept—complex as it

is—seen in a new way, its purpose unleashed within a new medium.

Surprisingly good science

Unfortunately for some, star data is rarely represented as audible sound which would be another way to encounter an otherwise visual medium. Novel additions of sound to celestial phenomena is a growing area to watch and new examples are being attempted, including tactile representations for the blind.[4]

The product of this case example delivered sound, creative music, communicated the concept, and was deemed successful in the view of the class and the student who composed this product. Far from explained, tested, calibrated, or refined, there is much work to do, but certainly there is potential for development and research in this area. By following the processes of science in further refining this example there is a hope that the product can be among the contributions valued from amateur astronomers (Chung, 2013).

Most significant to this case example is the creative attempt to develop a practical tool. To our knowledge, this is the first instance of the H-R Diagram being interpreted as music. Validating this product as a tool for further study and possible contribution to the field requires a number of tests and refinements that are currently under development. Next steps arose out of the class performance, later discussion, thought, and a desire to revisit the product by both authors. The following ideas are just the start, including: applying the current model to simple star clusters that have been charted to the H-R Diagram, converting the model to a digital platform for star interpretation, and/or refining the model to include stars at all stages (and therefore size/mass).

Expanding the model and testing it on star clusters may reveal particular cluster signatures (or songs), no different than recording multiple spectra to identify star-cluster composition. Through experimentation, these elements could provide an auditory analogy understood according to our western musical temperament as well, an added bonus in promoting astronomy. Additionally, observation of the heavens based on light is so vital to astronomy that there is an unintended tendency to exclude those who experience the world through non-visual means. Now however, we could augment comprehension of data through hearing stars as a complement to seeing them.

Open-ended instruction opens doors for many learners of science. Presenting this student-created model in the future, along with the original professor-created model, could demonstrate to the next class how learner creativity, invention, and discovery are valued and achievable goals of their introductory Earth- and space-science course. What about the pedagogical outcome from the perspective of the future development of the course and for the course professor?

Unconventional assignment analysis

Educational outcomes of this unconventional assignment are no less than those for conventional assignment counterparts. Issues raised thus far are similar in scope to any other assignment type and with a similar frequency. More specific discussion points are grouped below into four areas: the student, course objective, skills education, and remarks of the assignment developer.

First, for our student in this case, authenticity fostered personal connection and incentive to explore science. Having a composition and music disciplinary background made tackling the assignment easier than for a non-music major. Likewise, the non-science major had much to learn to analyze and interpret the H-R Diagram. Certainly the assignment goal was met (considering philosophy, content, and processes of science), perhaps even becoming a science inquiry—if proposing another interpretation for differentiation among stars and putting it to the scrutiny of peers qualifies.

Second, the course objective, a looking at the assignment's value to learning, reveals successful adherence. The majority of students gave high ratings and positive comments about the course assignment in the term-end survey of student satisfaction. During class, students engaged in conversations parallel to the course agenda (e.g. "fun fact": Hertzsprung may have completed some of his work in the Netherlands, as the course textbook states, but his place of origin was Denmark, raising the question of what counts as historically more significant to science). Therefore a student-centred assignment demonstrated engagement of the concept of stellar differences, which for the whole class may have improved comprehension of the H-R Diagram. More research into the level of student comprehension is suggested as a later case study.

Third, academia may have benefited from a blending of traditional delivery with skills enhancement. Written communication continues as foundational to academic learning, because each student completed a paper that accompanied the assignment product. Oral communication and teaching others begins to enter the undergraduate experience, even if brief, which for many is a task not easily stomached (butterflies are common, but the enjoyment in sharing a deeper understanding of a science concept with peers could be visibly seen on a student's face). Interdisciplinary work and managing a project were new experiences that taxed a few undergraduates. Without limitations and ongoing feedback, some projects tended to become larger than could be completed in a term. So, care is taken to provide direction and focused questions that permit the student room for developing the skill of problem solving. Therefore, open-ended assignments such as this require clinical direction from the course professor, as opposed to assuming the student is a completely independent researcher and writer.

Finally, the course professor, choosing to change the assignment, changed the role. Not every student understood how to integrate subject areas, some lacking the experience to find a connection and/or uncomfortable in engaging in academic creativity. The course professor, therefore, discusses with students their post-secondary pursuits, capabilities, and interests to help reveal a product direction. As class meetings progress, listening to the feedback of participants and gauging the direction of their assignment in-progress, revealed that reframing the assignment was required to maximize time-on-task. Still, some students stray off topic, which occurs in traditional instruction also. Increases in office hours and email correspondence were noted, and valuable class time was reorganized to accommodate product presentations. This leads to a future research question of what upper limit on class size is reasonable for such an assignment (thus far working with 76 participants in a term). Regarding assessment of assignment products, colleagues are curious about how to mark those with an interdisciplinary companion content area or approach outside the experience of the course professor (e.g. marking an interpretive dance). This is addressed through an assessment rubric and assistance from colleagues of the other discipline.

Overall, the educational value of developing the assignment outweighed the additional effort, making this assignment an activity worth refining and repeating. Opening instructional practice to study benefited the developer as well, and may offer examples for the continuing evolution of undergraduate pedagogy. Perhaps, then, discipline-based education research in astronomy should be furthered and shared—academic instruction but also informal outreach—through the ongoing support of journals such as this and with encouragement from the whole astronomy community.

Two perspectives, shared conclusion

This case study highlights the value of a different approach to learning: open-ended instruction with authentic interaction. Unconventional instruction of this type is effective teaching when the process is modelled for students and their progress supported. The case example, converting a data set into a composition through application of musical analogies, demonstrates understanding of concepts embedded within the H-R Diagram. In undertaking an unconventional task, a learner comes to better recognize processes of science, enjoyment of science, and about self. Surprisingly, the product of this academic risk-taking has the potential to be a learning aid for future classes and in possibly leading to an auditory tool for the study of stars.

Above all, experimental unconventional pedagogy at university, especially in the astronomy discipline, in an introductory course and for the non-science major, is leading to undergraduate research. This helps fulfill the mission of academia, promoting the growth of astronomy in Canadian universities and academic research into astronomy education. This case study, therefore, is a practical example of an instructional methodology with potential to enhance the learning of science. Introductory astronomy courses can provide a place to celebrate the joy of discovery, avenues for the contribution of amateur astronomers, and the power of undergraduate research helping to inform practice in teaching about the science of space. ✶

Introduction to Astronomy is among new Earth and space science courses developed and taught by Stephen Jeans, Ph.D., at Ambrose University in Calgary, Alberta. Interest in astronomy began for Dr. Jeans as a youth in Halifax, Nova Scotia, supported by borrowed equipment and involvement in a light-pollution study with the RASC. Today's Calgary Centre is an active part of yearly joint star parties with Ambrose University and in telescope loans, thereby showing a new generation (Richard Charter included) the wonders of the night sky—so appreciation is sent out to members, specially those dedicated to outreach including Larry McNish, Don Hladiuk, Robyn Foret, Logan Kameda, Susan Yeo, Roger Nelson, Alan Dyer, David Brown, Greg King, Ken From, Justin Simms, and Scott Oliver.

Endnotes

1 Personal communication by email and transcription from *Music of the spheres: Astronomers as musicians, & musicians as astronomers* the Annual Peter Sim Lecture given in Calgary on 2016 March 17, by Randall A. Rosenfeld, RASC Archivist [Ed: and contributor to this *Journal*.].

2 Interview comment by Eric Idle in a television look-back on *Monty Python* when he described his composition, *The Galaxy Song*, as difficult to continually update because astronomers keep "changing the numbers."

3 TEDTalk published 2016 July 13, *How a blind astronomer found a way to hear the stars—Wanda Diaz Merced* (accessed online at www.youtube.com/watch?v=-hY9QSdaReY).

4 Sound aiding research includes: a technique to measure star size by converting starlight flicker from *Kepler Telescope* data to an audible hiss, Vanderbilt Research News 2013 (https://news.vanderbilt.edu/2013/08/21/surface-gravity-of-stars), and numerical simulation software to play a piano note each time an exoplanet transits its star, along with drum beat for each planetary conjunction, using star system TRAPPIST-1 as the test created by Matt Russo, Dan Tamayo, and Andrew Santaguida, 2017 (system-sounds.com), and Saturn's rings represented in wood (carved by James Edgar, Production Manager, RASC *Journal*) and represented in sound with patterns of waves increased by 27 octaves to audible sound by astrophysicists at the University of Toronto (www.thestar.com/news/gta/2017/08/31/astrophysicists-make-music-out-of-the-death-of-a-spacecraft.html).

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Astronomy from Coast to Coast to Coast

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This article is based on the Ruth Northcott Memorial Public Lecture given 2017 July 1, on the occasion of Canada Day 150 during the RASC GA in Ottawa.

Canada is a triangle-shaped country, roughly speaking. We all know that the Atlantic Ocean is at its eastern corner in the Maritimes, and off the west coast of British Columbia is the Pacific Ocean. The Arctic Ocean, however, makes up the bulk of Canada's coastline, along its pointy "top." That peaks closest to the North Pole in Nunavut, on the shores of Ellesmere Island. Running down this island, as on our western flank in the Rockies, is a range of permanently snowcapped mountains, with one topping 2600 m. It is a propitious geography, which along with that of northern Greenland, provides plenty of ice-locked, and windward, elevated coastal terrain, potentially perfect for astronomy. Actually, these mountains are about the same distance from either Halifax or Victoria (or Halifax to Victoria) as Victoria is from the amazing 4200-m summit of Maunakea, on the Big Island of Hawaii – although they are not as easily reached.

Looking for the best location can make even the most arduous travels worthwhile though. Over the last decade, site testing beyond 80° north latitude on Ellesmere Island (near a place appropriately named "Eureka") has shown that Arctic coastal mountain sites can provide excellent astronomical sky conditions.[1] It had already been well established over several decades that Antarctica provided great locations for astronomy, at latitudes similarly close to the South Pole, atop its roughly 3000-m high interior ice plateau. A challenge for both places has been to overcome the difficulties of access. In the middle of the icecap of central Antarctica, such as Dome C at 75° south latitude, scientists and engineers visit an incredibly harsh, effectively sterile place for a few months at a time, surrounded on all sides by hundreds of kilometres of glacier.

Canada's High Arctic is not easy to cross either, but it is alive. There are flowers and birds, muskox and wolves, fish and seals. And, of course, there are polar bears. Although "arctic" may come from the Greek word arktos for bear, as in the celestial Ursa Major and Ursa Minor, it is the Inuit who have made this land home for many centuries, navigated with a separate tradition of watching and understanding the polar sky. Nunavut today has hamlets this far north, communities with families, not just research stations. Succeeding in the Far North still depends on finding your way, learning what tools have worked before, and adapting. This is true for precision astronomical instruments too, and I will present some examples that are illustrative.

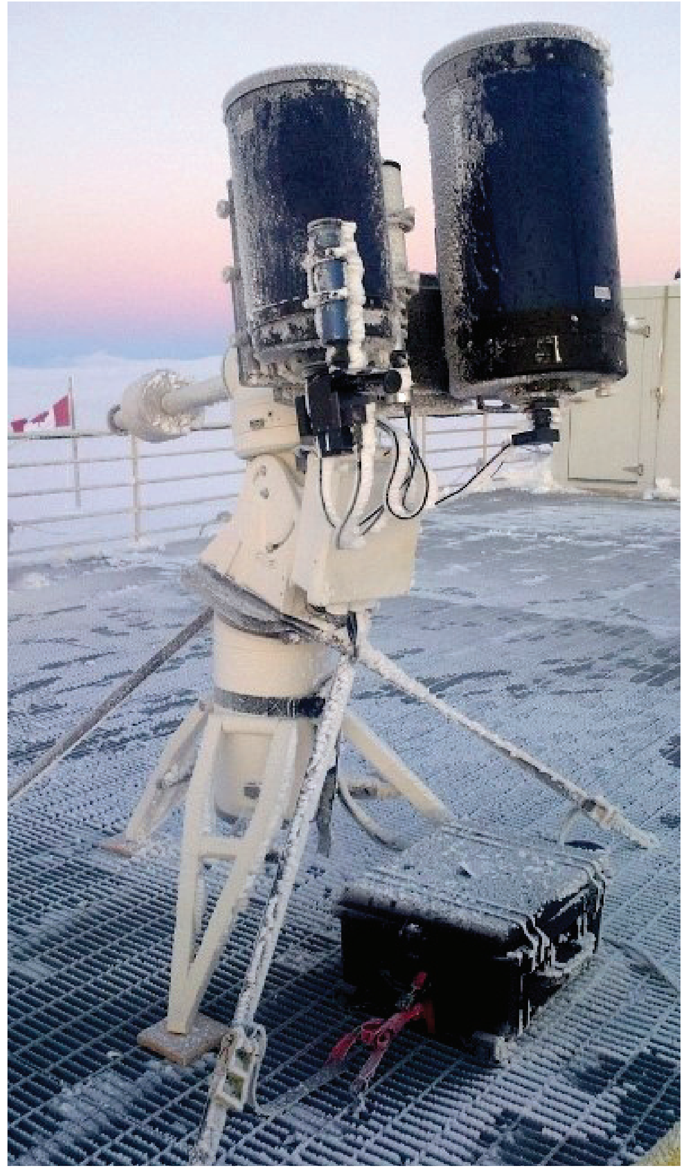
Going to Extremes

Despite being the most hostile place to live, space is ostensibly the ideal environment for astronomy. It is very cold, there is no atmosphere to obscure the view and the seeing is always perfect. There are some major caveats to that, of course. Beyond the cost to develop and launch a satellite, once deployed, it is still potentially subject to a night/day or target-field duty cycle depending on orbit and spacecraft orientation, and it will have an inherently restricted operational lifetime. Balloon-borne missions might take advantage of the space-like conditions afforded by the stratosphere, but these too will have samples limited to something between a few hours up to weeks while that fragile balloon is aloft, and depending on both flight hardware and the vagaries of upper-atmospheric winds. From the ground, an alternative could be a large network of mid-latitude sites, although those will have another disadvantage: requiring their data to be laboriously stitched together under varying sky conditions and from different telescopes and instruments. For polar sites, extreme latitude instead ensures months-long windows of darkness, and combined with sufficient, altitude this can offer a stable platform above much of the atmospheric water vapour, turbulence, and cloud. A single location can give the same view, almost uninterrupted, for months. From the poles, targets have uniform airmass, each simply circling overhead and maintaining elevation.

An observer must get up fairly high to get above all the cloud though. In winter the High Arctic is usually blanketed in a strong atmospheric thermal inversion. Weirdly, it can be much colder at the surface than higher up. It might be -40 °C at sea level, but "only" -25 °C at 1000 metres above. But that helpfully keeps the clouds—mostly suspended ice crystals—below. Overhead is an isolated mass of cold air. Mountains on Ellesmere reach into this pristine region, but can be accessed by helicopter only in summer. Sadly, a helicopter cannot fly there in darkness. No matter how beautiful the view will be once the Sun goes down, a person cannot safely remain. The trick is to install a robot that can.

Learning from the Experts

There is plenty of existing know-how to make this work. Military infrastructure for Alert, the northernmost outpost on Ellesmere Island, is part of that legacy. A series of microwave-repeater stations stretches down to Eureka, which is the furthest north from which one can still see a geosynchronous communications satellite. This is the wireless "backbone" of Ellesmere Island, and it is powered by batteries and serviced



The Ukaliq autonomous site-testing telescope setup on the PEARL rooftop seen dusted with frost, just at sunrise after one long "night" of observing Polaris.

by helicopter. Many other similar, but smaller, examples are a host of autonomous weather stations at various locations in the Arctic, and elsewhere. These too are visited, typically, just once a year to replenish batteries, download data, and fix broken parts. Many of these geophysical stations are operated by government and university-led groups, and their fieldwork is supported—complete with helicopters, bushplanes, tents and cookstoves—by the Polar Continental Shelf Program facility from Resolute Bay, at 75° N.

That model was followed for the deployment of three stations on the northernmost isolated Ellesmere Island mountains, between 1100 m and 1900 m elevation, closest to the coast, and that were not in the restricted region of Quittinirpaaq National Park. These were nicknamed "Inuksuit" like the stone waymarkers of the north.[2] Unlike the iconic inuksuk, however, each was equipped with an autonomous weather station, a camera, a satellite antenna and a wind turbine. A later addition was "Ukpik," which in addition to a fuel cell for generating electricity, had a 3-cm aperture telescope for continuously monitoring Polaris.[3] An all-sky-viewing camera made the analogy to its Inuktitut namesake of "snowy owl" even closer, as its smooth, white cowling looked a lot like one hunkered down in the snow. And better yet, when confronted with strong winds and blowing snow—or daylight—a protective cover would slide over both of those. Ukpik was asleep. These systems completed their work after 5 years, and were removed. Weather and sky clarity measurements nicely matched predictions, with some evidence that seeing is good. The necessary logistics were demonstrated. But the complexity of those logistics is not trivial, nor is the cost.

Otherwise, a compromise is closer to Eureka, a facility called the Polar Environment Atmospheric Research Laboratory (PEARL). Again, that is an apt name, as this unique shiny "pearl" is rather precious, sitting all by itself on a 600-m-high ridge. It can be accessed by large 4-by-4 diesel pickups along a winding 15 km-long gravel road from the sea-level base at Eureka. That is operated by the federal weather service of Environment and Climate Change Canada, with a year-round rotating crew of eight. Eureka is a homey research station with real beds, proper meals, a jet-capable airstrip, and a yearly resupply ship. PEARL is a practical observatory, designed for continuous atmospheric studies with optical instruments, with a large flat observing platform on its roof. This has supported various astronomical observations, with many thanks to a university-led consortium known as the Canadian Network for Detection of Atmospheric Change, which maintains many other instruments there, and has lots of experience doing so.

From those atmospheric-science instruments we know some of the good basic qualities of PEARL. All-sky-monitoring camera images taken over many winters showed half were obtained under perfectly photometric conditions (no cloud at all), about two-thirds were clear (no clouds visible to the unaided eye) for periods of up to 100 hours at a time, with just over 15% "unusable," so more than 2 mag. of extinction in V band.[4] That is about the same as Maunakea, among the best optical/infrared observatory sites. And the sky is similarly dark in the visible: down below 20 mag. per square-arcsec. But here is where the -30 °C and colder conditions really start to show their advantage, which can be teased out from years of archival spectrometer data. In the thermal infrared, past 2.4 micron wavelength, the sky emits something like only 18 mag per square-arcsec, similar to South Pole. But this is 10 to 20 times darker than what is typical for Maunakea, which usually dips just below freezing at night, and will be even warmer during the day.[5]

The PEARL facility has much easier access than the high Ellesmere Island mountains. You can arrive in Eureka via a large aircraft chartered from Yellowknife, in the Northwest Territories, during dead of winter. Best of all, observations can be in campaign mode, meaning that a person will be on site to operate the instrument. When something breaks, or some snow accumulates on a lens, he or she can go and fix the problem. Maybe that just means going out on the roof with a broom. But the value of that should not be underestimated. Although there is not much precipitation here year-round, and precious little snow in winter, winds can make troublesome snowdrifts. This becomes particularly evident in the humbling situation when the observer gets the big 4-by-4 truck stuck in a mere two-foot-high snowdrift on the way down from the summit. Snowpack here is bone dry and very hard. It is much more styrofoam-like than the fluffy snowball-making snow we southern Canadians are more familiar with. I was assured that even the most seasoned drivers get stuck once in a while, but still embarrassed the one time a heavy-equipment operator had to come up with a front-end loader to help me.

Seeing a Way Forward

An important advantage of PEARL is that standard site-testing instruments employed elsewhere in the world, often using commercial Cassegrain telescopes of about 30-cm aperture, can be used. Granted, these are not quite off-the-shelf solutions. Mounts and electronics must be modified to operate under stricter conditions. Also, the usual method of continuously heating a Schmidt plate to keep it clear of dew or frost is best not done if you want to look at Polaris to measure seeing. To do, so you always point straight overhead, essentially. That was the job of "Ukaliq", as in the arctic hare.[6] Just like the well-adapted hare, which sometimes gets up on its hind legs to get a better view, Ukaliq tips up only when observing. Of course, under calm observing conditions, ice crystals precipitate nearly straight down and stick to the telescope corrector plate. Worse, accumulated melted crystals will pool. It can be better to turn the telescope down-facing at intervals and gently blow on it with a fan to sublimate frost, which is also easily automated. Or simply wipe it off with some alcohol. The glass is a lot easier to reach this way than when it is well above head height and pointed straight up.

Deployment of this and other instruments has shown how astronomy from Canada's northern tip can fit into the worldwide picture. We know the seeing at PEARL is very good, in part due to a clever device called the Arctic Turbulence Profiler (ATP), a lunar scintillometer.[7] The full Moon will be up in winter, and then conveniently stay at the same low elevation the whole time, which is perfect if you want to watch it to monitor scintillation. Data from the ATP, and from measurements of binary stars with another specialized instrument called a Slope Detection and Ranging (SloDAR) device have confirmed that most deterioration takes place close to the ground.[8] The part of seeing associated with just the upper atmosphere is typically 0.23 arcsec full-width at half-maximum. Half the time, total seeing measured from 8-m elevation is 0.76 arcseconds or better.[9] Again, these numbers are comparable to the best mid-latitude sites. Autonomous cameras have also shown that high-precision, millimag-level photometric accuracy is possible from PEARL, just as has been done already from Dome A (80° south latitude) by the Chinese Small Telescope ARray (CSTAR), for example. Like those, the Arctic Wide-field Cameras (AWCams) were meant for variable-star and exoplanet transit detections with small, roughly 10-cm apertures.[10] That is limited primarily by scintillation, and takes particular advantage of wide, uninterrupted clear swaths of sky. Cold-hardening larger, pointable telescopes is a bigger challenge that can be overcome, and justified by strong scientific cases that require the special conditions only the Poles provide.[11] The history here has been one of choosing the right path and tools by sharing knowledge, learning from experience, and adjusting course when needed. ✶

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Astronomy, the RASC, and Me

by Ken Hewitt-White

The following is based on excerpts from the keynote opening address delivered to the 2017 RASC General Assembly in Ottawa on 2017 June 30.

Introduction

As many of you know, I hail from Ottawa. But long ago I heard a voice say: Go west, young man! (The voice may have belonged to my father.)

Heading west triggered a wide-ranging career I never could have anticipated. Looking back on a half-century of communicating astronomy, two things come to mind. The first is: 50 years; Gee, where did the time go? Second, I'm not sure my career would've worked out nearly so well without my initial grounding in the RASC.

To find out what I mean, we must go back…

Early Days

I was a teenager when I joined the Ottawa Centre of the *Royal* Astronomical Society of Canada. Oh, how that *Royal* rolls off the tongue. Truthfully, though, it was a little intimidating to that Ottawa lad of 16.

I learned about the RASC from a friend in high school. We were in grade 10 and we had identical telescopes—a 4.5″ Tasco reflector (and we'd both started out with Tasco 60-mm refractors, too). My friend's first name was Mark. All these years later, I can't remember his last name, but I recall that Mark was the son of a diplomat. We met in science class. We got talking, astronomy was mentioned, and there was instant friendship.

Mark asked if I'd heard about the *Royal* Astronomical Society of Canada. I said no. Mark encouraged me to attend one of their meetings. Ooh, scary stuff. Would I have to get dressed up, bring a notepad and look studious? Well, there was no need for that. But somewhat nervously, I joined the Ottawa Centre—and, oddly enough, never saw Mark again. His dad got posted to Washington, and that was the last I saw of my astro-buddy. Little did I know that I'd soon have lots of new friends in the RASC.

So, when was that? Well, it was the year of Expo; the year Canada turned 100; the year Ottawa hosted the Grey Cup Game for the first time; and the year the Maple Leafs last won the Stanley Cup. In other words, it was 1967.

During the late '60s, the Ottawa RASC Observers Group—a very active subset of the main Centre—maintained a rural observing site an hour's drive west of town. Some folks here will remember it as the partly decommissioned radio observatory called the Quiet Site. Thanks to some carefully nurtured contacts between our club and their researchers, we obtained permission—literally, the keys—to that perfect, private Quiet Site. We were so fortunate to have access to such an out-of-the-way spot. Back in the 1960s, not many RASC Centres had a secure, dark, observing place all to themselves. We did.

It was at the Quiet Site that I learned the ropes of serious nightwatching. Throughout the late '60s and early '70s, I was there a lot, meteor observing with a group or deep-sky observing alone with my pier-mounted, 8″ reflector. My dedication often meant a long hitchhike or leaning on buddies for a ride, because they had cars and I didn't. Either way, "being there" was worth the trouble.

One friend bought a cargo van and camperized it. In the spring of 1972, he got the bright idea that four of us should climb into the Star Truk—we actually called it that—and drive all the way to Vancouver for the 1972 General Assembly on the Victoria Day weekend. And if that wasn't enough, we'd head south to California to visit some of the big American observatories. So, off we went.

As I say, there were four of us, and all four are in this room today. In addition to myself, there was Jon Buchanan, Robert Dick, and the captain of the Star Truk, Allen Miller. Forget my west coast jetlag this morning, Allen has just flown in from England!

Westward Ho

Back to 1972: After our university exams (each of us were enrolled in different programs at Carleton University), we drove nonstop to Rocky Mountain House, in Alberta. There we picked up Ottawa member Peter McKinnon, who had just started a summer job with Parks Canada. We needed Peter to help with the driving!

With Peter at the wheel, we blasted through the Fraser Canyon, then on to Vancouver and the University of British Columbia, where the conference was being held. At UBC, we stayed at a new high-rise student residence. The view outside my tenth-floor, north-facing window entranced me: the glittering waters of English Bay…long, sandy beaches…downtown skyscrapers…all of it backed by a panorama of snow-capped mountains. In a heartbeat, I fell for "the city by the sea."

The conference was a blur. I remember a side-trip to Vancouver Island, where the Victoria Centre was sponsoring a day of sightseeing that included a visit to the venerable Dominion Astrophysical Observatory on picturesque Observatory Hill in Saanich, just north of Victoria. There, we viewed the 72″ reflector that briefly in 1918 had been the largest telescope in the world. Even more than the historic scope, the breathtaking views of the surrounding landscape and distant Gulf Islands made a huge impression on me.

And, so did the people I met at the conference. Interestingly, there was strong representation by members of both the local RASC and the staff of Vancouver's new H.R. MacMillan Planetarium, which at that time had been open for less than four years. I'd heard good things about the modern, innovative "HRMP" from friends who'd seen shows there. Sadly, though, none of us at the 1972 GA were able to visit the MacMillan star theatre, as there was a civic strike at the time—and the HRMP was a civic institution. Even so, it took only a few conversations with those fine folks (not to mention the incredible views of the city) to realize that I wanted to live and work in Vancouver.

A Door Opens

After our long trip—to Vancouver, Victoria, California, and Arizona—we returned to Ottawa and (for me) a final year of university. Midway through the spring term, I wrote to the planetarium asking about employment opportunities. And, thanks in part to the RASC, I got a positive answer. The planetarium director, David Rodger, had recently been President of the Vancouver Centre and knew about me through various RASC contacts—in particular, those I'd just met in Vancouver. In a return letter, David offered to train me on the planetarium equipment should I decide to relocate in Vancouver. Well, I was never going to get a better invitation, so, after my final exams, I was off to a new life in Vancouver.

I started out at MacMillan in the summer of '73 as a show presenter, but over a period of years worked my way up…and down…and up again, both as a freelance contractor and on staff. Eventually, from 1988 to 1991, I found myself running the place from the office that David Rodger had occupied way back in the summer of '73. It was a heady time—all of it.

But honestly: had it not been for the RASC, I might not have embarked on that planetarium career. I'd taken a few university courses in astronomy, but I hadn't majored in the subject. Many of the skills needed for planetarium work I learned mostly within the creative environment of the RASC; in particular, the Ottawa Centre Observer's Group.

Mindful of my background as an aspiring amateur astronomer, I was determined to keep active in both the Vancouver planetarium and the Vancouver RASC. Throughout the 1970s and 1980s, I was on the Vancouver Centre Council, became editor of NOVA (the Centre newsletter), and was president for a few years. But it wasn't just me. During that roughly 20-year span, at least half a dozen planetarium staff members volunteered for positions on Vancouver Council. Most of us took turns as president at one time or another.

And the reverse was true: RASC volunteers assisted the planetarium, especially on public star nights. It was a mutually beneficial relationship. I realize that similar relationships existed (and still do) with other Centres and planetaria to varying degrees. But, in Vancouver—in my day at least—it was a grand alliance.

A few months ago, David Rodger (now retired) delivered a speech to the Vancouver Centre in which he spoke about the early years of the MacMillan Planetarium. Reviewing the factors that contributed to the planetarium's world-class reputation in the 1970s, David included the RASC. "We invited the Vancouver Centre to make its home with us," David said. "They left UBC, where they'd met for many years, and henceforth held their meetings in our main auditorium. Instantly, this gave us a hundred well-informed ambassadors for the new planetarium."

I must say the relationship became very close. Indeed, at times the Vancouver Centre seemed like a planetarium "farm team." Nearly half of our production and presentation staff were members of the RASC. Our staff featured a wide variety of skills, but it was our faithful RASC recruits who were most into the night sky. For many years, the success of the HRMP was due in no small measure to that portion of its enthusiastic crew whose interest in astronomy had been nourished by the RASC. Had there been no Vancouver Centre, our planetarium would have been the lesser for it. I was proud to be a member of both.

It's All About The People

I want to go back to the beginning—50 years ago—when I joined the RASC and came in contact with so many wonderful people who affected my outlook on life. I'm sure many of you here today can recall your own first years in the Society—remembering those who mentored you…guided you…inspired you. In my case, here in Ottawa, I was schooled in stargazing by newfound friends who were a bit older, and a lot smarter.

Les MacDonald founded our Quiet Site meteor observing team and actually got observing results, summaries of which were reported in the RASC *Journal*. **Pete McKinnon** liked to oversee big projects—and did, with the construction of our eight-person meteor observation deck. **Rick Lavery**, a natural leader, took junior members (me!) under his wing. **Doug O'Brien** and **Rick Salmon** were inspirational in the way they kept winning prizes at science fairs. Rick's aptitude for instrumentation resulted in a career at the CFHT on Mauna Kea.

At our monthly Observers Group meetings, I came to appreciate the older folks—literally, the adults in the room. They realized our biggest dream: North Mountain Observatory, located well south of Ottawa. (The NMO eventually moved to a site west of the city.) Completed in 1971, NMO featured a 16″ Newtonian, a fairly big telescope for its day. It was Rick Lavery who pushed the idea, and sparked a fundraising drive that brought in money from all over, including the RASC National Council. A few senior Ottawa Centre members then became observatory trustees, whose annual fees ensured the project's long-term survival.

One of those trustees, **Dr. Fred Lossing**, was a mentor to many of us. That man was wise beyond words, and an ace telescope maker—the first Canadian, I think, to win a prize at Stellafane. Fred was literally "instrumental" in bringing the 16″ telescope to life and was so involved in the development of the observatory that, after his passing in 1998, it was renamed the Fred P. Lossing Observatory. Another observatory trustee, **Tom Tothill**, was editor of *Astronotes* during my most active years in Ottawa. Tom patiently indulged my growing interest in writing about the night sky. Unwittingly, he was preparing me for a career in that very subject.

The obsession to write culminated in a "book" I concocted with Allen Miller—a 162-page, manually-typed opus on summer deep-sky objects, featuring awkwardly written descriptions (mine) and some very fine eyepiece sketches (Allen's), made with our home made scopes at the Quiet Site. It was **Barry Matthews**, another fellow who truly believed in club spirit, who volunteered to photocopy, at work (after hours!), 50 copies of the thing, which we then assembled into hardcover books, and peddled to unsuspecting members at $5 apiece.

Barry, Tom, Fred, and our tireless librarian, **Stan Mott**, who was always on hand with the latest astronomy publications—these friendly adults and others too many to name—displayed endless know-how, a willingness to share, and genuine friendship. I shall never forget them.

At the main Centre meetings, I was exposed to real, live professional astronomers, who either worked at the Dominion Observatory or were visiting researchers. **Halliday**, **Locke**, **Millman**, **Gaizauskas**, **Fernie**, **Beals**, **Thompson**, and **Covington**, were some of the big names who presented engaging talks to the Centre. As an academically challenged teenager, I didn't realize what a privilege it was to be exposed to that much brain power. But a lot of that knowledge slowly sunk in.

I remember a gentleman named **Earl Dudgeon**. In 1967, when I joined up, he was the Ottawa Centre President and, coincidentally, my former Sunday School teacher! When we first recognized each other at a meeting, he came up to me and said, "Oh my, how you've grown!"

And I can't forget **Mary Grey**, a pillar of the Ottawa Centre, who got me a summer job at the Dominion Observatory, assisting her on public star nights. Without realizing it, Mrs. Grey was nudging me toward a career in astronomy outreach.

The RASC: Canada-Wide

People in other RASC Centres had an impact, too. I think first of the Vancouver Centre because it was at their GA in 1972 that I encountered a great bunch of people, including a deluge of Daves—**Dave Rodger**, **Dave Hurd**, **Dave Dodge**—who became my fellow workers for 20 years at the MacMillan Planetarium.

I had close family relatives in Edmonton, so there were trips there, and visits to the Edmonton Centre where I met **Alan Dyer** and **Paul Deans**. Between them, Alan and Paul have been on the staff of numerous astronomical magazines, science centres, and planetaria (in the late 1980s, Paul was my second-in-command at the HRMP). Today, both are among my colleagues at *SkyNews*.

During my Ottawa years, we'd visit our observing counterparts in Montreal—it was only a couple of hours on the bus. One weekend in, I think, the fall 1968, a few of us attended a meeting of the Montréal Centre inside their observatory on the McGill University campus. It was a lovely building—a dome with a large refractor inside, plus a kind of clubhouse below. As I recall, it was a long, narrow room in which they'd set up chairs for the monthly gatherings.

So, picture this: before the meeting, a couple of lanky teenagers, both really interested in comets, were yacking away at the back of the room. One of them was me; the other was some guy named **David Levy**. Apparently, I'd observed one or two more comets than David had (this was before he began discovering them). I made the mistake of challenging David H. Levy to see which one of us could bag the most comets. Well, we all know how that turned out!

I didn't visit the Toronto Centre very often—it was a much longer bus ride—and yet the person who's been the greatest inspiration, and has had the strongest effect on my career, began his RASC life-membership as a Toronto member. Allow me to reflect again for a moment . . .

Two of our members, first Tom Tothill, then Rick Lavery, became a driving force behind the idea of a *National Newsletter* to go with the *Journal*. Rick wanted to consult the Toronto member for advice. Later, at one of our monthly meetings, Rick took me aside and whispered into my ear: "I asked Terry about the newsletter idea and he likes it." Even then, **Terence Dickinson** was a guiding light.

It was Terry who inspired me to pursue planetarium work. Remember that road trip out west to the Vancouver GA and the big observatories down south? Our last stop, before crossing the border back into Ontario, was at the Strasenburgh Planetarium in Rochester, New York, where Terry was a producer at the time.

Terry gave us a private tour, ending up at what he knew I'd enjoy the most: the control console. After minimal instruction, he stood to one side in the dark theatre, me at the controls of the Zeiss star projector, and said: "Have fun, but don't break anything." Well, I turned on a thousand stars, and made the heavens move all by myself. I was hooked—a planetarium career it would be.

Years later, Dickinson taught me how to navigate the rocky road of freelancing. I followed his work closely, kept in touch, and invited him to Vancouver several times to give well-attended RASC talks and public presentations. In August 1991, I was delighted to have him address the hardy souls at our annual Mt. Kobau Star Party, near Osoyoos. I always enjoyed his company, either under the stars or just talking about them.

In the fall of 1991, my wife and I moved to an acreage in the Okanagan Valley, near Penticton. Soon, with the aid of some accommodating individuals at the nearby Dominion Radio Astrophysical Observatory, I helped organize a little astronomy group that met monthly at the DRAO. From Penticton, interest spread up the valley to form allied clubs in Kelowna and Vernon. I put out a newsletter called *OK Skies* that went out to all three sectors. Those informal clubs were the earliest "seeds" that would eventually grow into the Okanagan Centre, of which I'm now a proud member.

It was amid all this enthusiastic amateur activity, that another career "door" opened for me. The pivotal moment came in early 1995 when Terry phoned to say that Mary Grey, who was editor of the quarterly bulletin called *SkyNews*, was retiring. Terry would be taking over *SkyNews* and was going to turn it into a bi-monthly subscription magazine. He asked if I wanted to be a regular columnist. Needless to say, I responded in the affirmative. I've been with the magazine ever since.

The Bottom Line

I didn't mean this to be an exercise in name-dropping. My point is that all these people—and many of you here this morning can make a similar list—*all* these people, I met through the RASC.

Would I have met, befriended, and worked with those individuals had they not been under the nation-wide umbrella of the Astronomical Society? Maybe. I don't think so. A great deal of what unfolded in my career was due to the welcoming embrace, and the incredible human resources, of the RASC.

And so, this is my chance to issue a heartfelt thank you to the Royal Astronomical Society of Canada for launching a career…for unlocking those doors of opportunity so long ago…for swinging them open just wide enough to allow an eager young man to push through.

Fifty years—it's been a blast! ✶

Ken Hewitt-White, an RASC member first with Ottawa, then Vancouver, and now the Okanagan Centre, is a well-known astronomy writer and communicator. His career at the MacMillan Planetarium in Vancouver spanned 20 years. Later, he co-wrote and co-hosted the Discovery Channel Canada series Cosmic Highway. *A long-time contributor to* Sky & Telescope, *Ken is currently Associate Editor of* SkyNews.

Observing Tips

Setting Up a Sky-Watcher SynScan Dobsonian Telescope

by Dave Chapman, Chair, RASC Observing Committee
(observing@rasc.ca)

(As of July 2017, I am Chair of the RASC Observing Committee [thanks to Alan Whitman, previous Chair, for his years of service]. I would like to inaugurate this new column, Observing Tips, by writing the first article; however, it is not my intention to write ALL the articles, only to solicit them from active observers and to offer editorial help. Please send your ideas to me at the email above.)

The main telescope at the RASC Halifax Centre's Saint Croix Observatory is a 400-mm (16″) Sky-Watcher SynScan alt-azimuth collapsible Dobsonian. I have its 300-mm baby brother and Keji Dark Sky Preserve has the 250-mm version. I have become familiar with the operation of these telescopes, so I am writing down some tips for setting up beyond what the basic manual provides. I have spoken to a few members and others who have experienced problems, and usually the fix is something quite elementary. This may be for you! However, I am assuming that the reader is already familiar with the basic telescope operation procedure through training and/or reading the manual. I'm not trying to rewrite the manual here! The manual for these telescopes can be downloaded from the Service & Support menu at ca.skywatcher.com, but be aware that manufacturers often make small changes to things. Even if you do not operate this telescope brand, some of the following tips may still be helpful.

I have no experience with the Sky-Watcher EQ (equatorial) versions and I do not recommend EQ mounts for beginners—an alt-azimuth mount is much more intuitive and the SynScan technology that drives these models is perfectly adequate for visual observing. I also prefer the Dobsonian design because optically it is a classic Newtonian with an inverted image, which is the same as a 180° rotation. This means the observer can use standard star charts and lunar maps with a minimum of confusion. Most refractors and many other telescope designs employ star diagonals for ease of observing, but this introduces another reflection that results in a left-right mirror-reversed image, which can confuse the beginner.

Preparing to Observe

Before initializing the telescope and beginning to observe, there are several things you should take care of, perhaps in daytime: make sure your battery is charged (if rechargeable) or sufficiently fresh (if not). Have backup power handy. Make an observing plan (even in your head) and go through the checklist of all the things you need to take to the observing site. Review the initialization and alignment procedures and pick out some bright alignment stars appropriate to the season.

Figure 1 — The author with the 400-mm Sky-Watcher SynScan Dobsonian at Saint Croix Observatory, Nova Scotia.

Figure 2 — The larger Sky-Watcher dobs have adjustable bearings on both axes.

At the observing site, place the telescope base on a level spot, with an eye out for trees or buildings that might interfere with your plans. Level the mount as best you can—things just work out better, believe me! I bought a bubble level for my telescope and glued it to the base, or you can use a smart phone app. (It's a pity the manufacturer did not provide a built-in level and a means of levelling the base.) Place the telescope on the base (if it's not already there), install and firmly tighten the locking screw, then check the level again.

This is a good time to check optical collimation, particularly if the telescope has been moved (if collimation is important to you and if you know how to adjust it). Typically, the secondary mirror holds its alignment, but the primary mirror might have shifted, particularly if you have taken the telescope for a ride down a bumpy road. In daytime or twilight, a quick peek down the focusing tube will identify any obvious problems. You should see a series of concentric circular reflections of the various components of the optical train, including a centre

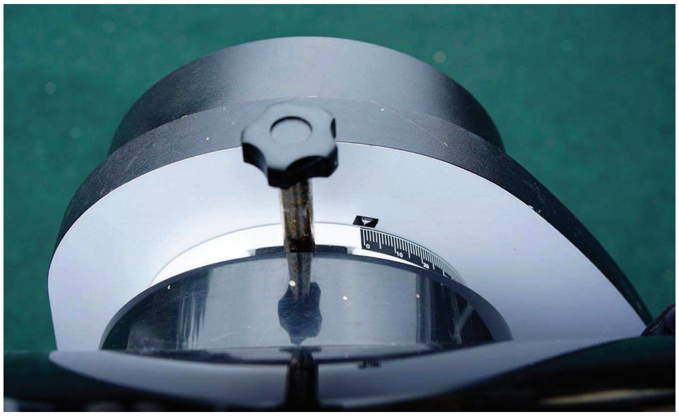

Figure 3 — The altitude axis has a scale for leveling the tube before initialization.

Figure 4 — Consider replacing the secondary mirror adjustment hex-screws with knobs to eliminate the need for a tool.

bullseye on the primary mirror. If things look off-kilter, take action or seek help. Better now than later in the session! If you are new to the concept of collimation, start with garyseronik.com/a-beginners-guide-to-collimation.

Now align the finder telescope to the main telescope, using a distant terrestrial target or bright star. Again, better now than later (you can always tweak it later). If you are not using the GPS dongle, have ready your observing longitude and latitude in degrees/minutes/seconds (not decimal degrees), the date, and the accurate local time. For simple Auto-Tracking mode (what I call No-Star Alignment), you also need to know the direction of True North. Use a magnetic compass, correcting for the magnetic declination of your location (roughly 17° W in Nova Scotia), or a smart phone app.

I need to say a few words about data entry: be mindful of the US mm/dd/yyyy date format; enter your STANDARD time zone (Daylight Saving Time is handled independently); use NEGATIVE hours for time zones west of Greenwich.

By using the optional GPS dongle, you can skip a lot of manual entry below, thereby avoiding manual entry errors. The GPS needs to be plugged in to the hand control before powering up. When you do power up and initialize, don't be fooled by the message "GPS FOUND!" You must proceed and enter the time zone and DST info, then wait for "GPS FIXED". Sometimes the GPS takes a while, but not too long if the telescope hasn't been relocated. After GPS fix is achieved, you can unplug the dongle.

Are you ready?

Aligning the Telescope

There are three basic approaches to alignment (which I think should really be called sky orientation), with variations:

1. Manual or Push-To Operation. Without electricity, you can manually push the telescope to point in any direction, using the finder to place a target in the telescope's low-power field of view. The larger Sky-Watcher telescopes have hand-adjustable clutches on both axes for adjusting the bearing friction to your liking. With electrical power, you could use the hand control to move the telescope at a variety of speeds to follow a target or to slew to a new target; however, you should turn OFF tracking in the Setup menu, because the telescope will have a mind of its own if you don't orient it to the sky. Honestly, if you are going to use the electronics, consider...

2. No-Star Alignment or Auto-Tracking. This is an under-appreciated mode of operation that does not use stars to orient the telescope to the sky, but provides sufficient orientation to track celestial objects once found. With care, this method can situate a bright planet within the finder's field of view in twilight (possibly daylight). Accordingly, it is especially suited for solar observation, and lunar or planetary observing in twilight, but obviously works just as well at night. The trick is to place the telescope in HOME position before turning on the power—to do this, manually level the telescope tube using the scale on the altitude axis (assuming the base itself is level) and manually rotate the telescope to point True North. After you turn on the electronics, follow the Initialization procedure on the hand control—this includes entering Longitude and Latitude (in that order), Date, Standard Time Zone, Local

Figure 5 — Take the time to align the finder with the telescope before initializing the electronics.

Time, and Daylight Saving Time: Yes/No. The hand control will ask Begin Alignment? which you decline and bypass. The telescope will now track a target pretty well, once you find and centre it in the eyepiece. The Go-To function will actually work in a crude way, but you will normally need to use the finder and hand control to centre the target. The tracking will be decent, but you will need to correct it from time to time. It is worth pointing out that, with the SynScan telescopes, at any time you can push the telescope to point where you want without interfering with its automatic positioning. Also, at any time, without shutting down, you can opt to perform a Star Alignment. I successfully used the Auto-Tracking mode to setup my telescope in daylight to observe the Transit of Mercury in May 2016—the telescope tracked the Sun almost perfectly all day.

3. Star Alignment or Go-To Mode. This is the typical mode of operation of these telescopes, which assumes the observer has some familiarity with the bright stars in the sky. You can start up with the telescope pointing in any direction; however, there still is a case to be made for levelling the telescope and pointing roughly north—then the telescope will track while you centre the alignment stars. Either way, first Initialize the telescope as described in section 2. At this stage, the telescope knows where it is and what date and time it is, but may not know where it's pointing. This time, when the telescope offers asks Begin Alignment? you accept. There are two flavours: classic Two-Star Alignment and an assisted version called Brightest Star. In both cases, the first star orients the telescope to the sky with the assumption that the base is perfectly level; the second star corrects for any small deviation from levelness. All true in principle; however, I have found that the more care taken to level the base at the very start, the better everything turns out after that. The telescope's tracking performance and especially Go-To performance will just be better.

Let's begin with Two-Star Alignment. As far as choosing stars goes, the telescope makes fairly smart suggestions, but is unaware of any obstructions to viewing the sky (in my yard, there are plenty!). You can choose alternate stars, but be sure you know where they are and that you can see them! Use the hand control and finder to place the first star in the telescope field (it's important to centre the star in the telescope, not the finder—if you discover the finder "off," then readjust it). To make centring easier, start with a low-power eyepiece, but switch to a higher power and re-centre for the most accurate alignment. Some observers like to use an eyepiece with crosshairs for centring. Also, you might want to centre in the (aligned) finder first, using a moderate slew rate (5–6) and then switch to the eyepiece and centre with a slower slew rate (3-4). For precise positioning, the last motions should be UP and RIGHT on the hand control. Once the first star is centred and accepted, the telescope will suggest a second star. If it is not obstructed, choose it, otherwise choose another with the hand controller. It is good practice to choose a second star that is roughly 90° different in azimuth from the first star. Once the second star is centred and accepted, you are good to go! Happy Observing!

Brightest Star Alignment is similar to the Two-Star Alignment, but you don't have to know the names of the stars. You DO need to know your cardinal directions NEWS, and their in-between directions. Look up in the sky, find a bright star, face it, and figure out in which of the eight sectors it lies: north, northeast, east, etc. Also confirm that it is the brightest star in that direction. Then scroll through the hand control menu until the appropriate sector is displayed, and enter it. The hand control will (with luck) identify the star. There may be a list of star candidates, which you can often discriminate by their altitude above the horizon. If you are happy with the star, accept the choice. After that, the alignment proceeds as with Two-Star.

Here's the best-kept secret about the Brightest Star option: it recognizes bright planets as "brightest stars"; however, when you centre and accept the planet, the telescope proceeds to find two actual stars to complete the alignment. In this way, when it's dark enough to pick out planets with the unaided eye, but too bright to pick out stars with the unaided eye, you can still proceed with star alignment because the stars might be visible in the finder and telescope, owing to their greater aperture. Cool, eh?

Parking. If you would like to shut down your telescope briefly and restart later without having to go through the entire initialization procedure, there is a hand-control menu item for that, including options for the park direction of the telescope. For example, you might want to replace a weak battery (note that there is a hand control-menu item for monitoring the battery voltage). When restarting, you only have to enter the date (if changed) and time. For best positional accuracy, use as accurate a time as possible: every minute out is equivalent to a minute of image drift in the eyepiece. Actually, it's best to use the same time source as before, for consistency. On one occasion, I aligned my telescope for night-time observing at the observatory, parked it for the night, and returned in daytime to start from park and find Venus in the daytime sky. That was fun!

I hope this first article has been useful to the reader. I'd love to hear your thoughts, and ideas for future articles. ✶

Dave Chapman is a Life member of the RASC and Emeritus Editor of the RASC Observer's Handbook *(2012–2016 editions). He has been observing with telescopes for over half a century. He received the Simon Newcomb Award for astronomical writing in 1986 and a Service Award in 2015. Currently, he is Chair of the RASC Observing Committee.*

CFHT Chronicles

Just like New

by Mary Beth Laychak, Outreach Program Manager, Canada-France-Hawaii Telescope.

A telescope mirror is exposed to the elements almost every night, year round. The winds on the summit of Maunakea blow small pieces of dust and debris into the dome. And, while the mirror is covered during daytime hours, it is impossible to protect the mirror at night. As a result of this subtle wear and tear, CFHT's mirror loses some of its reflectivity over time. The blue band (u band for those familiar with our filters) sees the greatest impact. The only fix for the loss is to recoat the mirror.

A mirror recoating or realuminizing is a multiday process. Along with coating the mirror, a shutdown provides CFHT with the opportunity to conduct more in-depth maintenance on the telescope and facility. The first step begins weeks, if not months before the shutdown begins. We can realuminize in house, which means we have a recoating chamber on the ground floor of the observatory. The recoating room and vacuum chamber inside must be spotless. The room is only used every 2-3 years, so it naturally becomes a bit of a storage area in the interim. Everything not essential for the mirror coating must be removed and the room must be cleaned. Generally, the room receives several good scrubbings, with the final cleaning coming the week before shutdown. Once the final cleaning occurs, no one can access the room until the big day.

At the same time, the prime-focus cage is prepared. In CFHT's early days, astronomers used to ride in the prime-focus cage with their photographic plates to conduct their observations. When we switched from photographic plates to digital detectors, the prime-focus cage was recycled. It now houses Wircam. Once the mirror aluminizing is complete, the primary mirror must be realigned to ensure it sits exactly where we need in the optical path. To realign the mirror, an engineer must take a crane to the top of the telescope, then transfer into the prime-focus cage on the upper end. There is not enough room for an engineer and Wircam, so Wircam must be removed and safely locked away a few days before.

We observe the night before the telescope shutdown begins, so the shutdown team removes all the instruments from the telescope as soon as they arrive at the telescope. CFHT staff switches instruments roughly twice a month and they have the process refined to an art. This year, Megacam was on the telescope for the nights leading up to the shutdown, so the team took several hours in the morning to remove it from the upper end.

The next step is removing the primary mirror, a process that again takes several hours. The 14-ton mirror is held into place by very large bolts. Looking at the first picture, you may notice two parallel red lines running along the floor below the telescope. These red lines are actually covers for the mirror cell cart track. The covers are removed and the mirror cell cart is slowly moved into place below the mirror. This is an "all hands on deck" moment as our priceless mirror is gently lowered onto the cart. The edges of the mirror are covered and a cover is lowered down onto the mirror to protect it for the upcoming journey. And with that, day one is complete.

Figure 1 — CFHT staff begins the process of removing the primary mirror. The parallel red tracks are where the mirror cart slides under the primary.

Day two begins with the lowering of the mirror to the ground-floor aluminizing chamber. The mirror is lowered five floors via crane, then moved into the coating room. The coating team begins to wash the mirror and removes the old coating.

In the meantime, work begins on other projects around the observatory for the next two days. This year, our operations group worked on rebuilding the telescope cosine regulators, upgrades to the electrical system including monitoring and regulating power, and maintenance on the building chiller and telescope hydraulics. Several rooms in the building also got a fresh coat of paint, the first since the 1980s.

CFHT's instrumentation group worked on inspecting and conducting maintenance on systems generally covered by the primary mirror like the Cassegrain environment. They also worked on the solar sail. The solar sail was installed in 1991 to aid observations of the total eclipse. Instead of removing the solar sail post-eclipse, it is now deployed to cover the primary mirror anytime overhead work occurs. Even though the mirror has covers, the solar sail protects against small tools or screws falling onto the mirror covers and causing issues.

CFHT's software group also had a large task list that primarily involved cleaning up wiring and Ethernet cables in the

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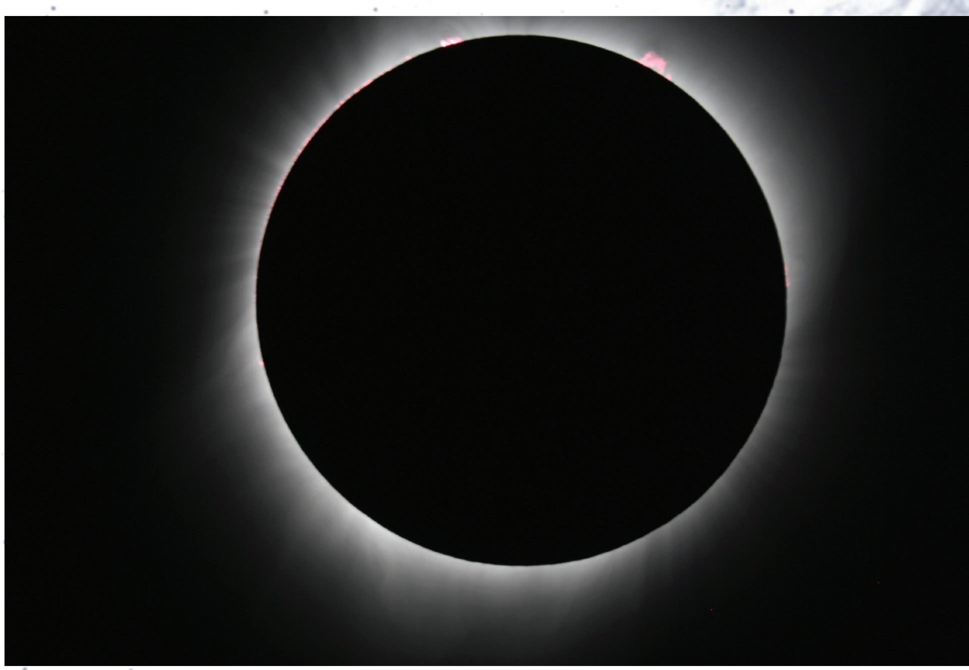
Pen & Pixel

Doug Jiang photographed the Iris Nebula (NGC 7023) from Toronto Centre's Carr Astronomical Observatory in Thornbury, Ontario, on the weekend of 27 August 27. He used an Officina Stellare RH-200 MKII on a Takahashi EM-200 2Z and a QHYCCD QHY814A camera for a total of 13.6 hours.



Garry Stone took this image of the August 21 total solar eclipse approximately 10 kilometres north of Lost Cabin, Wyoming. He used his Celestron C8 with a 6.3 focal reducer and a Canon XS camera, shooting at ISO 100 and 1/160 seconds.

Pen & Pixel

The image of NGC 7380 is a 6 ½ hour narrowband taken with a Tele Vue NP127is telescope and a QSI583wsg camera.

Dan Meek took the image over a few nights in July from Calgary.

Michael Bradley, imaged Messier 101 with a Megrez 120mm ƒ/7.5 refractor and Canon 60Da DSLR. The mount was a pier-mounted HEQ5 guided by PHD. Exposures ranged from 60-600 seconds for a total of almost 3 hours controlled by Backyard EOS and stacked with Deep Sky Stacker. The image was taken from my SunMoonStars observatory in Roberts Creek on the Sunshine Coast of British Columbia on 2017 June 22.

Pen & Pixel

Blair MacDonald captured the Sadr region of Cygnus from his observatory in St. Croix, Nova Scotia, as well as Marion Bridge, Nova Scotia. MacDonald used a Canon 60Da at ISO 1600 on a 120-mm SkyWatcher ƒ/7 and an Esprit120 refractor for a total of 142 minutes.

This image of the Rho Ophiuchi region was acquired by Sailendra Nemana at the Carr Astronomical Observatory on 2016 July 2 using a full-spectrum Canon T3i (modded by Renaud Venne Landry) on an unguided Star Adventurer mount, IDAS LPS-D1-EOS clip-in filter, Canon 50-mm ƒ1.4 lens at ƒ3.5, 20 light frames at 210 seconds each at ISO 800, 10 dark frames, 25 flat frames.

Lights, darks, flats, and bias frames processed and stacked using Deep Sky Stacker. Final cropped image processed in GIMP 2.9.5 (with 16-bit image support) and Raw Therapee.

General Assembly 2017 Ottawa

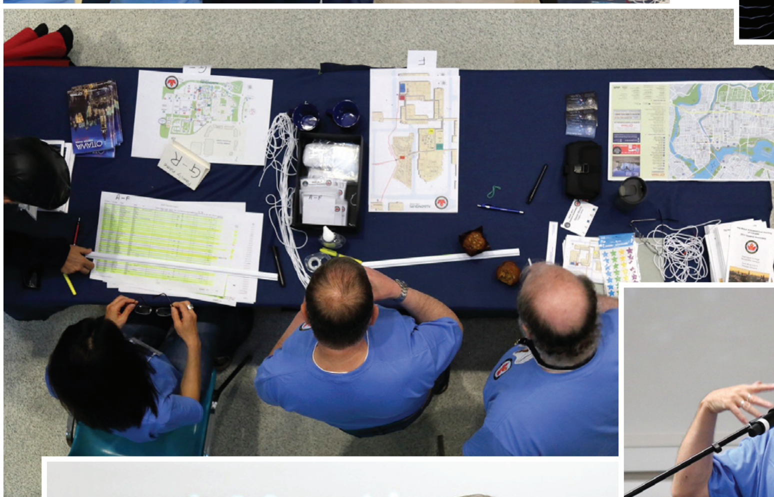


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Figure 2 — A close-up of the mirror cart tracks.

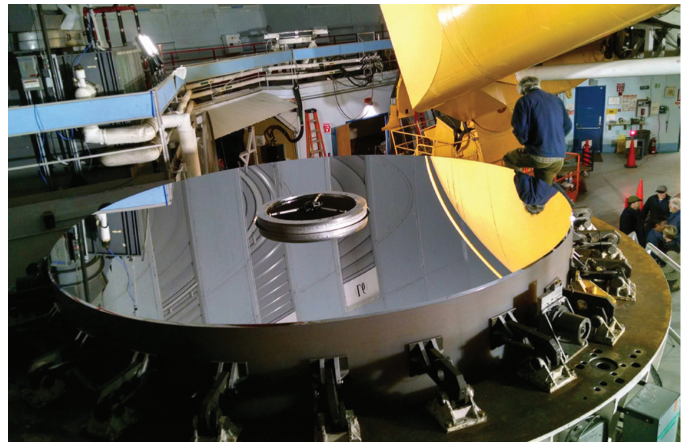

Figure 3 — The mirror upon its return to the dome floor. The new coating will last another two to three years.

computer room. That is a task that can be risky to do while we are observing. The removal of a wrong Ethernet cable can cause problems that are frustrating to locate.

The mirror-coating team is almost sequestered in the coating room during these two days. They clean the mirror repeatedly and prep it for the realuminization process. On the third day, they load the mirror into the chamber to recoat. The recoating takes place in a vacuum chamber. Above the mirror are small aluminum filaments. After the air is removed from the chamber, electricity is run through the filaments, vapourizing the aluminum. As the aluminum condenses, it settles on the mirror, creating a thin, reflective coating.

Once the mirror is coated, it is removed from the chamber and tested. The mirror cleaning and recoating process takes three days, but the shutdown is scheduled for ten days. The extra days are padding in case the coating is insufficient the first time around. It is better to get back on the sky early than late. The testing process includes putting a piece of packaging tape on the mirror and gently pulling it off. If the coating does not come off on the tape, then the coating is good. The team did four successful tape tests. Fun fact, both the tape and aluminum foil are almost clean-room "certified clean" right off the roll. Our engineer staff preform more in-depth testing by measuring the reflectivity, the thickness of the coating, and shining a bright flashlight under the mirror.

Once the engineering staff approves the coating, the mirror gets its protective lid and travels back upstairs to the dome floor. The mirror returns to its housing at the bottom of the telescope. The mirror will sit overnight, and on the next day, staff will return to test the mirror alignment. Once that checks out, we are back on the sky for science.

This shutdown ran from August 1 through 5, five days fewer than scheduled. The image quality after the shutdown is often poor because the recoating process increases the temperature of the mirror. A warmer mirror meeting the cool Maunakea summit air results in a turbulence layer directly above the mirror. As the mirror comes down to its normal temperatures, the seeing improves. To mitigate the poor seeing, Espadons is the ideal instrument to install immediately post-shutdown. Espadons tolerates poor seeing better than our imagers.

Figure 4 — Part of the team that worked on the shutdown. This was the group that worked to get the mirror back it its cell on August 4. In the front row, blue jacket and khaki pants, is CFHT's retiring director of engineering, Derrick Salmon. The Friday of shutdown was his last day at CFHT and this picture was taken in his last hour.

Figure 5 — Nikki's new camera mount

Installing Espadons also gives the SPIRou team the opportunity to test the instrument's guider.

Normally, CFHT has one realuminizing every three years. This year, we are working with two other observatories to recoat their mirrors. The core aluminization team—comprised of our engineers Greg Barrick, Tom Benedict, and Marc Baril—will repeat the process in the fall. They will clean the chamber again and prep for that coating the week after our coating is completed.

Summer intern:

Every summer, CFHT participates in the Akamai internship. The Akamai program is open to any college student who attended either high school or college in Hawaii and is majoring in a STEM field. The internship provides the students with the opportunity to intern in a high technology field and gain valuable skills for their future employment. This year, over 100 students applied for the program, with 29 receiving positions.

At CFHT, our staff keeps a list of projects that are not mission critical, but would be nice to complete if they have time. Preparations and preparing for SPIRou takes up a considerable amount of time, so these wish-list items often fall to the bottom of the projects list. Occasionally, these projects end up in the hands of our Akamai interns. This year, our intern Nikki Imanaka, ended up with one of these projects—a redesign of our Cassegrain guide-camera mount to accommodate a new guide camera. The Cass guide camera sits at the bottom of the telescope and is used for Espadons and SITELLE guiding. Espadons has its own guide camera, but the Cass guider is used for especially faint objects. SITELLE, on the other hand, relies solely on the Cass guider, so the SITELLE team welcomes the upgraded camera.

The old guider uses a TV camera and is obsolete. If it were to break, finding replacement parts would be challenging at best, impossible at worst. CFHT purchased a new guide camera, but the new camera requires a new mount. The ability to easily swap between the two camera mounts was a key requirement for Nikki's design.

Nikki started by creating a Solidworks model of the old camera and verifying the actual mount measurements with the model she generated. She then designed four mounts for analysis. For her design review, she presented the top-two designs. As with any design review, a few new issues cropped up, including the position of the camera's cabling. The cabling proved to be the deciding factor and she was left with a single design to fabricate.

Nikki worked with our machinist Greg Green to fabricate the part, then she and her mentor, Windell Jones, installed the camera on the telescope. The initial fit test was successful. The shutdown prevented Nikki from fully testing the camera and mount, but she hopes to complete the testing before she heads back to school. If not, Windell will complete the testing in her place.

Well done Nikki!

RASC meeting:

Our very own Nadine Manset was the banquet speaker at the 2017 General Assembly in Ottawa, where she talked about her explorations and adventures at the Observatoire du Mont-Mégantic and the Canada-France-Hawaii Telescope. Nadine reported that she received a very warm welcome from the organizers, and was greatly impressed by the dedication and talent of the RASC members. With a little bit if history here, tons of variable-stars data there, insights into solar eclipses, and art in the mix of fascinating presentations, her weekend was very enjoyable. She appreciated the invitation and the opportunity to speak with everyone in attendance. ✶

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

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Second Light

Imaging the Surface of a Star

by Leslie J. Sage
(l.sage@us.nature.com)

Anyone who has seen images of the Sun knows that the "surface" is constantly in motion, roiled by the energy coming up from below. Now imagine what it would take to see the motions of the gas on another star that appears only as a single point of light in your telescope. Keiichi Ohnaka of the Catholic University of the North in Chile, together with two colleagues from the Max Planck Institute for Radio Astronomy (where I was from 1989–1992) have done just that (see the August 17 issue of *Nature*). They observed the star Antares with the Very Large Telescope Interferometer on Cerro Paranal in Chile to measure the velocities of the bubbles of gas in its atmosphere, and the velocities of the gas that sink back below to maintain a surface equilibrium. The velocities are high, from –20 to +20 kilometres per second, and surprisingly the bubbles extend out to 1.7 times the star's radius, in an extended atmosphere.

Antares is a relatively nearby red supergiant star at a distance of 170 pc, and the brightest star in the constellation of Scorpius. It is a slow variable, with visual magnitude varying between 0.6 and 1.6. It is in a late stage of evolution, and expected to be a supernova within the next few hundred thousand years. When that happens, the supernova will be as bright as the full Moon and visible during the day. At the present time, it is ejecting gas through a vigorous wind, and some of that material has ended up in the atmosphere of its companion star, which is about 530 au away. The companion is a main-sequence B2.5 star. Antares started its life with a mass of about 18 solar masses. The evolutionary tracks now have it at a mass of 15–17 solar masses. It is the most massive remaining star in the nearest OB association—the Scorpius-Centaurus association. The mean age of the stars in the Sco-Cen association is about 11 million years. The nearest supernovae to Earth in the past few million years happened in this association. I wrote about those last year (2016 *JRASC 110*, 129).

Antares itself has a radius of almost 700 solar radii, with an extended atmosphere going out to about double that. The extended atmosphere is cool enough to contain molecules, in particular carbon monoxide (CO), which is what Ohnaka and colleagues used to measure the velocity of the gas. The instrument has a resolution of 5 milli-arcsecond in the near infrared, while Antares' angular diameter at those wavelengths is about 38 milli-arcsec. The extended atmosphere has a diameter of about 60 milli-arcsec, so it is well resolved.

The observations generated what astronomers call a "data cube." The x and y axes correspond to the spatial dimensions, while the third dimension is the wavelength of the CO lines. They were able to measure the redshift (sinking) and blueshift (rising) of the infrared CO lines across the surface of the star and in the extended atmosphere. (This is quite a technical achievement on its own!) Across the disk of the star the velocities ranged from –20 km per second (rising) to 10 km per second (sinking) and in the atmosphere from –10 km per second to 20 km per second. The velocities on the stellar disk are unambiguously associated with rising and sinking gas, but in the atmosphere—where the gas is not opaque, and the distribution is not spherical—they could be seeing near-side rising or far-side falling and the velocity would be the same. But such vigorous movement in the atmosphere was not theoretically expected, and cannot be explained by convection. There is some unknown mechanism that is causing the extended atmosphere and the turbulent motions of the gas within it.

This often happens in astronomy when technology allows us to study something in a new way. We find it difficult to understand what has been revealed. Unfortunately, by the time you read this, Antares will no long be visible—Scorpius is a spring–summer constellation. But keep it in mind for next May, when Antares will again be visible from southern Canada. ✶

Leslie J. Sage is Senior Editor, Physical Sciences, for Nature Magazine and a Research Associate in the Astronomy Department at the University of Maryland. He grew up in Burlington, Ontario, where even the bright lights of Toronto did not dim his enthusiasm for astronomy. Currently he studies molecular gas and star formation in galaxies, particularly interacting ones, but is not above looking at a humble planetary object.

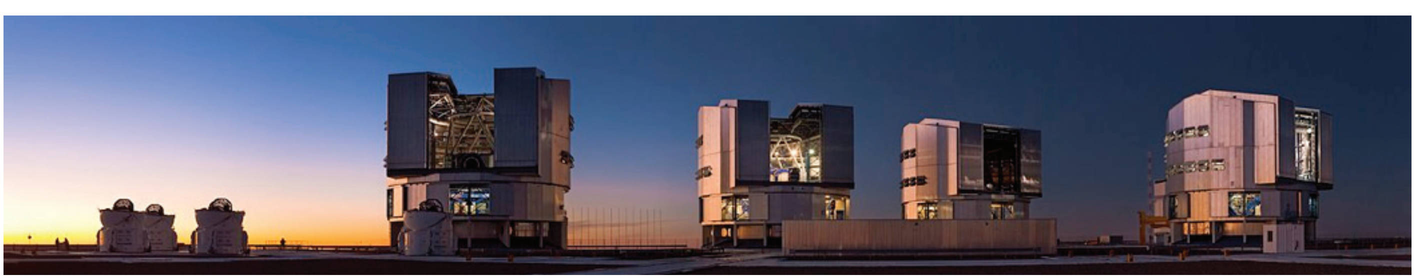

Figure — A picture of the VLTI on Paranal in Chile. Courtesy ESO.

Dish on the Cosmos

Heavy Elements from Fusion

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

In my December 2016 column, I explored Carl Sagan's statement 'we are star stuff,' explaining how the heavy elements that are essential to our chemistry were literally built in previous generations of stars. While my previous article presented this cosmic enrichment by stars from a holistic perspective, we also have the rare opportunity to see enrichment play out from individual stars.

One possible mode for enrichment is core-collapse supernova explosions. This type of supernovae mark the end of life for the most massive stars. Supernova explosions occur primarily as a consequence of the nuclear physics of stars. Stars produce energy though nuclear fusion, which is the process of combining light atomic nuclei (such as hydrogen) into heavier nuclei (such as helium). This stands in contrast with the nuclear fission that humans have harnessed, where very heavy nuclei (uranium) are split into lighter elements releasing energy.

With such high mass, the strong gravitational attraction of the material requires extremely high temperatures to support the interior of the star. With such high temperatures, the nuclear fusion that produces stellar energy can consume both the light elements, such as hydrogen and helium, and heavier elements like carbon, oxygen, and silicon. A low-mass star like our Sun only has sufficient gravitational pull to fuse hydrogen and helium. A high-mass star can fuse everything up to iron on the periodic table of elements. The reason that iron represents a major barrier is that elements heavier than iron do not release energy through fusion. Instead these elements release energy from fission, splitting into lighter elements. Iron represents the cross-over point between these two ways of making nuclear energy.

Since high-mass stars cannot fuse iron, they cannot produce enough energy to keep themselves hot, and thus cannot support their own gravity. The core of the star rapidly collapses, forming a neutron star—an ultra-dense core. This core is supported by "degeneracy pressure," which is a consequence of quantum mechanics applied to high-density materials. The formation of a neutron star yields a rigid surface for the collapsing outer layers to bounce off of, and a wave of high-speed particles produced by neutron-star formation pushes the bouncing outer layers of the star off in an explosion. The extremely hot expanding material forms an ideal location for assembling loose protons and neutrons into atomic nuclei, leading to an enrichment in heavy elements, not just in light

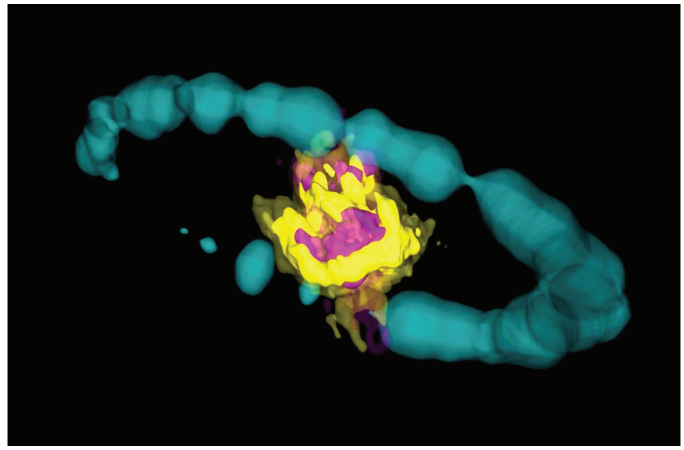

Figure 1 — A three-dimensional view of a supernova explosion. The yellow surfaces show light from CO molecules, and the purple surfaces show light from SiO molecules. The blue ring around the explosion shows a model of hydrogen emission that is brightened by the fast shock wave hitting surrounding gas. Credit: ALMA (ESO/NAOJ/NRAO); R. Indebetouw; NASA/ESA Hubble

atoms like carbon, but also heavier elements like gold and lead. This hot gas quickly cools down, setting the chemical composition of the gas.

In our galaxy, supernova explosions happen about 1–2 times per century, so it is rare for us to have a chance to see one. The best studied supernova in modern astronomy occurred in a neighbouring galaxy called the Large Magellanic Cloud back in 1987, and it is thus called Supernova (SN) 1987A. Being in another galaxy is a benefit; our view of this rare event is unblocked by other material in the Milky Way. While we have learned a great deal from the explosion itself, we have also been watching the evolution of the remnant for the past 30 years.

One such set of observations has just been made by the Atacama Large Millimetre/Submillimetre Array (ALMA), revealing the three-dimensional structure of the newly enriched exploding material. It is particularly rare that we can understand the three-dimensional structure of objects in space. The difficulty in measuring distances to different objects of the sky has been a challenge to astronomy since humans first looked up. With every improvement in our measurements of distance comes a corresponding improvement in our understanding of the cosmos. In the case of a supernova explosion, the physics of the explosion allows us to unravel the 3-D structure. This novel mapping is possible because of the combination of ALMA's excellent angular and frequency resolution. The good angular resolution allows astronomers to map the detailed structure on the sky. If we know the distance to the explosion with good precision, we can use trigonometry to translate these angular scales into distance scales in the "plane of the sky."

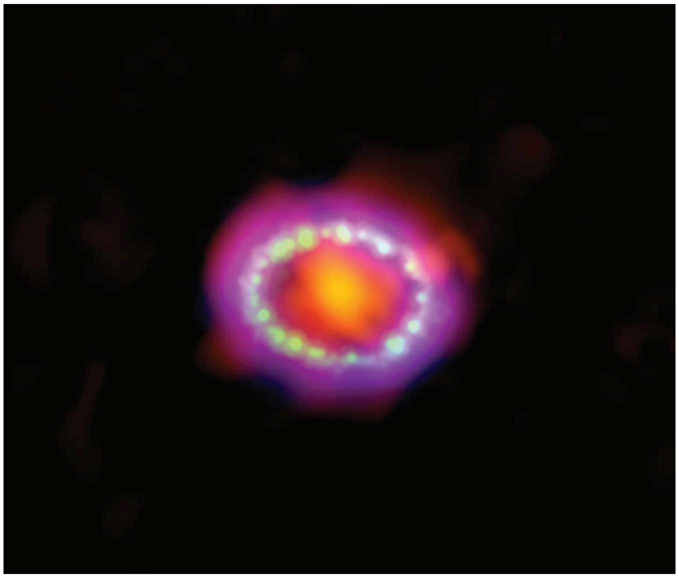

Figure 2 — Map of light from the SN1987A explosion from several different telescopes. The red light shows emission detected by ALMA from dust particles in the explosion. The brightness of this light shows that a large amount of dust has been produced in the explosion. The green light shows the hydrogen emission that is brightened by the first shockwave from the supernova explosion hitting it (see also Figure 1). Finally, the blue light shows million-degree gas that is giving off X-ray emission. Credit: NASA/ESA, ALMA (ESO/NAOJ/NRAO).

Read more about it: https://arxiv.org/abs/1706.04675

The structure along the line of sight is deduced by using the resolved velocity structure of the gas. This velocity is deduced from the Doppler effect: if material is moving toward us, the frequency of the emission appears higher than it would if it were at rest, and vice versa. ALMA has excellent frequency resolution, which essentially means that ALMA has an excellent discrimination between colours of light, although that "light" is radio waves. Since the quantum mechanics of atoms and molecules means that they emit at known, specific frequencies, we can look at the observed frequencies of different emission lines and deduce how fast that material is moving toward and away from us. If we look in one direction, some of the emission may be arising from material coming toward us and some away from us. The overall emission will then have some light at higher than the expected frequency and some will be lower. By assuming the material is exploding outward from the centre of the explosion, we can then deduce its three-dimensional structure by knowing its velocity along the line of sight and how far it appears from the centre of the explosion in the "plane of the sky." At the explosion speeds of 2000 km/s, even the vast distances of interstellar space can be crossed in a timescale seen by humans.

The authors of this recent study have made these observations of the SN1987A using ALMA. Their deduced model of the three-dimensional structure appears in Figure 1. The yellow surface represents carbon monoxide (CO) emission and the purple shows silicon monoxide (SiO). Most of the atoms that make up these molecules are from the enriched supernova explosion, showing enrichment at work. Many more of the newly formed atoms are already locked up into even larger particles collectively referred to as "dust" (shown as the red colour in Figure 2).

The first obvious result from this visualization is that the CO and the SiO are in different places. The explosion drove these molecules in different directions, implying that their origins, deep within the star, were not spherical. This picture is consistent with the idea that when a massive star explodes, huge instabilities in the explosion lead to mixing of the ultra-hot material. Prior to the explosion, the original high-mass star had the heavier elements like silicon concentrated in the hottest region near the centre. Lighter elements are found in shells around the fusing core. When fluid mixing occurs during the explosion, the silicon could be mixed with oxygen zones on their way out from the centre of the star, leading to an excess of SiO in specific directions. Similarly, the CO could be enhanced by carbon-rich zones being stirred with oxygen-rich material. All these studies point to the hearts of supernova explosions as messy places where the particulars of turbulence drive the future chemistry of the explosion. These results are being compared to supercomputer simulations of the physics in the milliseconds after the explosion to see if our models of those early times can actually produce the chemistry seen now, 30 years later.

The initial comparison suggests more work needs to be done. The amounts of dust and these molecules are significantly higher than expected from initial modelling. Even more-clever approaches can offer deeper insights. The conditions in those first few milliseconds after the explosion also leave traces in the isotopes of the different elements. For example, the standard silicon atom only has 14 neutrons in its nucleus. However, we can use the spectral radiation to measure the emission from silicon with 15 or 16 neutrons. The ALMA data point to a relatively low fraction of these heavy silicon atoms, which suggests that the supernova explosion likely had fewer free neutrons than standard models.

All this sleuthing comes from being able to measure the light from the supernova explosion with extremely high resolution, both in angle and in the frequency of the light. We will also get to observe how this emission changes over the next 10 years as the rich cargo of new elements spreads out into cosmos. ✶

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.

Binary Universe

Hacking your Canon P&S

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

If you know me, you know I like hacking. If you don't know me, you might think I'm trying to break into sensitive computer databases or secure networks and I use a cryptic handle on Wikileaks. I use the term in the broad sense. I hack my car, my music players, cameras, electronic projects, camping gear, and astronomy stuff. I like improving and enhancing things or extending them. Often when I'm fixing items, I see opportunities for improvement. Wikipedia describes hackers as "a subculture of individuals who enjoy the intellectual challenge of creatively overcoming limitations...to achieve novel and clever outcomes." I see the resurgence of the do-it-yourself (DIY) culture and "maker" groups embracing this philosophy.

For electronic devices where you don't like the built-in behaviour, you may be interested to know that in some cases you can change things up.

Many years ago, I hacked my 4th-generation iPod with Rockbox, a firmware replacement for the iPod operating system, so to support the superior Ogg format and extend its capabilities. After I started using a digital single-lens reflex camera, I began to have similar feelings. As much as I enjoy using the Canon 40D, I find it limited. I was interested in extending the DSLR's general capabilities, and in particular wanted better handling for multiple exposures, ideally without purchasing an external intervalometer. Internet searches exposed an article at http://lifehacker.com entitled "Turn Your Point-and-Shoot into a Super-Camera." Here I learned about CHDK (Canon Hack Development Kit), a firmware enhancement for a wide array of cameras (http://chdk.wikia.com/wiki/CHDK). And then finally I landed at the Magic Lantern website (http://magiclantern.fm). Sadly, there were no software enhancements available specifically for the 40D (and older cameras) but with interest I noted many of the current and new DSLRs (e.g. 6D and 7D) were supported.

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In this article, I will only concentrate on one particular application but the overarching principles and techniques should be similar for any compatible point-and-shoot (P&S) or reflex camera. In fact, I chose to emphasize the P&S option as many amateur astronomers just starting into the hobby may only have this type of camera. I used a Canon PowerShot sx100 IS with the CHDK version 1.00C. The total feature set of CHDK is rather vast and I cannot cover it in depth; instead, I will focus on capabilities helpful for astronomy, like image format control, exposure settings, live histogram, and scripting (for multiple exposures without an intervalometer). I chose the bootable method as it seemed easier to use.

I took advantage of the Simple Tool for Installing CHDK (STICK) for Windows to rapidly prepare a new SD memory card with the appropriate firmware. At the end of the process I had an SD card that, when used in the camera, automatically loaded the CHDK environment. The CHDK splash screen briefly appeared when I started the camera, verifying all was well. On the sx100, I pressed the PRINT button briefly and this displayed the CHDK screen for accessing the special tools (Figure 1). I was now operating the camera in an alternate way or ALT mode. In particular, the MENU button now showed the rich CHDK options (Figure 2) as opposed to the built-in camera menu choices.

Given the sx100 is an old camera, the SD card turned out to be formatted in a complex way with two partitions (not unlike a dual-boot computer). The first segment is referred to as the boot partition, with the alternate camera software installed such that it will automatically load. This partition is initially active and easily viewed. The second region is reserved for data and this is where you'll find your JPEG files and any RAW (unprocessed) files. Attempts to access this data partition on your computer is awkward at first, and since Windows itself cannot access the second partition, you need another app. The STICK software author makes the needed tool. Once WASP is installed (Windows App to Switch Partitions), you can flip as needed.

You have to keep your wits about you. Keep track of all your SD cards. Lock them, label them, and work slowly and carefully. When you want to start the camera with CHDK, you need the boot partition active and the SD memory card in the locked or write-protected state (yes, you read that right). But when you want to read the captured images from the SD card, you need to unlock the card and then make the data partition active. WASP is pretty easy to use. You just follow the prompts and note the reminders. Still, I found this all bewildering.

With a properly prepared memory card, I was able to commandeer the Canon.

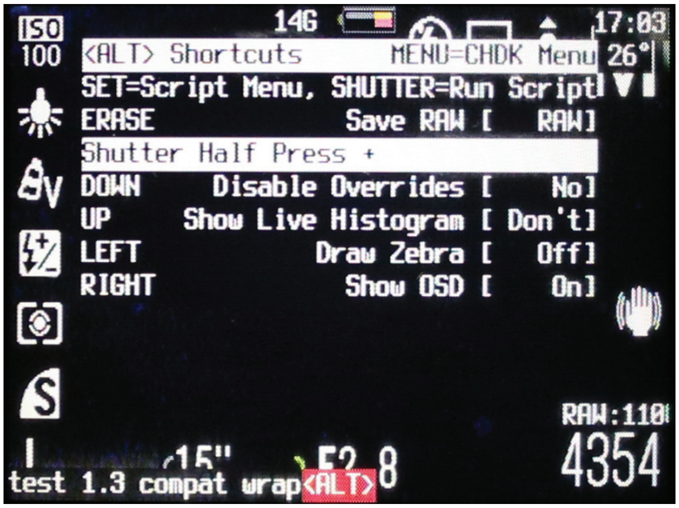

Figure 1 — The CHDK alternate mode menu overlaid on the Canon PowerShotscreen.

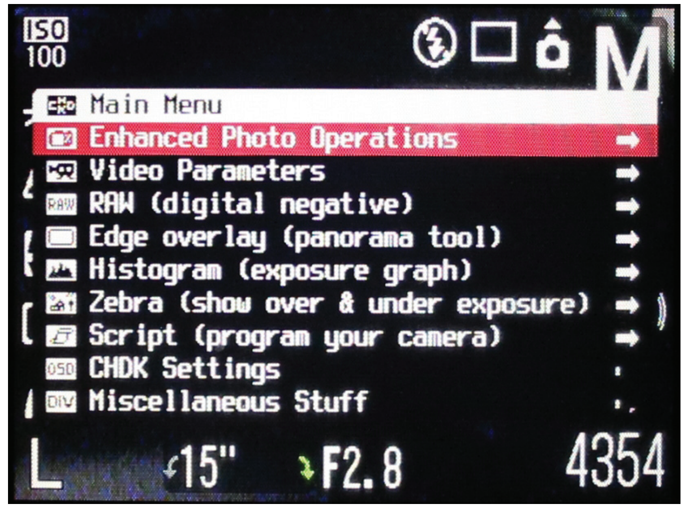

Figure 2 — The full CHDK menu showing image, file format, histogram, and script control.

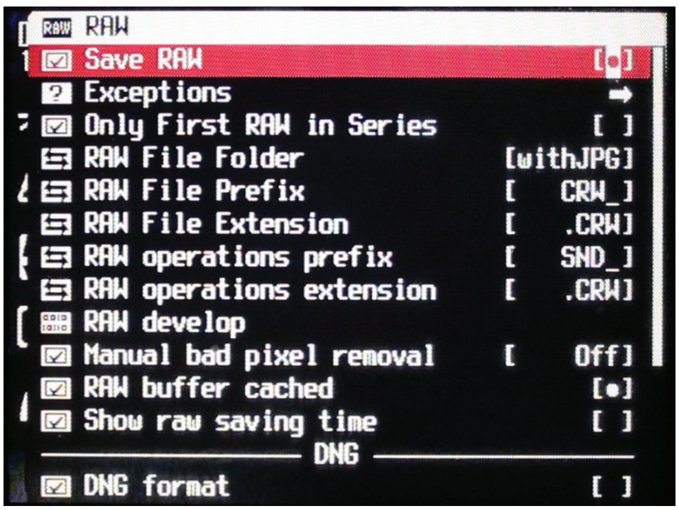

Figure 3 — The RAW imaging submenu with RAW, DNG, and naming control.

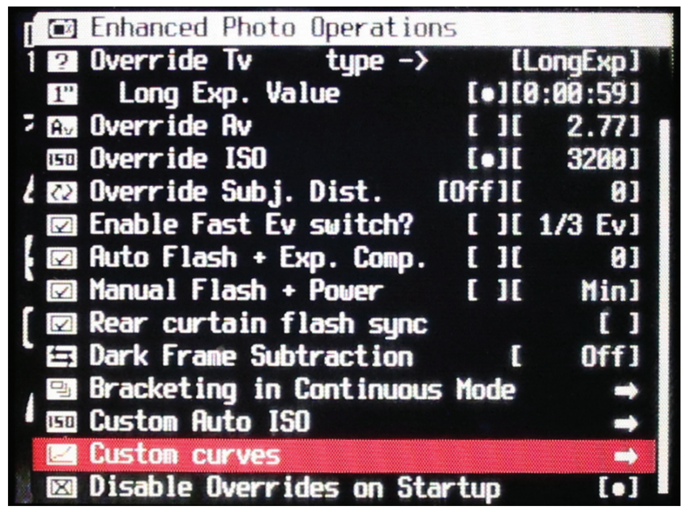

Figure 4 — The Enhanced Photo Operations submenu with overrides and dark-frame control.

Additional image format control

P&S cameras normally shoot in JPEG format. More correctly, the data collected from the sensor is in a native, raw format but inside the camera the image is processed and cropped and saved in the highly compressed, "lossy" format made popular by the Joint Photographic Experts Group. The image data in the raw format inside P&S cameras is normally not accessible, but CHDK allows this.

To enable the capture of RAW data, I did the following:

1. activated the ALT mode
2. accessed the MENU (the CHDK menu now)
3. accessed the RAW (digital negative) option
4. enabled the Save RAW option
5. enabled the DNG format option

There are many other settings you might adjust like where the RAW files are stored and how they are named (Figure 3).

The selected format shows at the bottom-right of the camera display while shooting.

When you compare the file sizes, it is obvious you have more data to work with. Typical .jpg files were 2700 to 3500 kilobytes, whereas the DNG files were over 10,000. Yeah, uncompressed data!

I was able to read in the DNG files with Adobe Bridge and edit the images with Adobe Camera Raw, which, of course, offers some corrections from shooting errors and much more creative control.

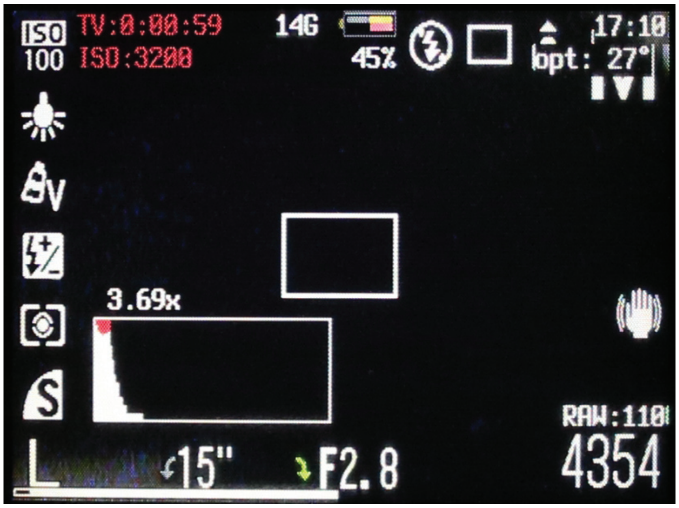

Figure 5 — Shooting screen with live histogram. Note red text for exposure and ISO overrides.

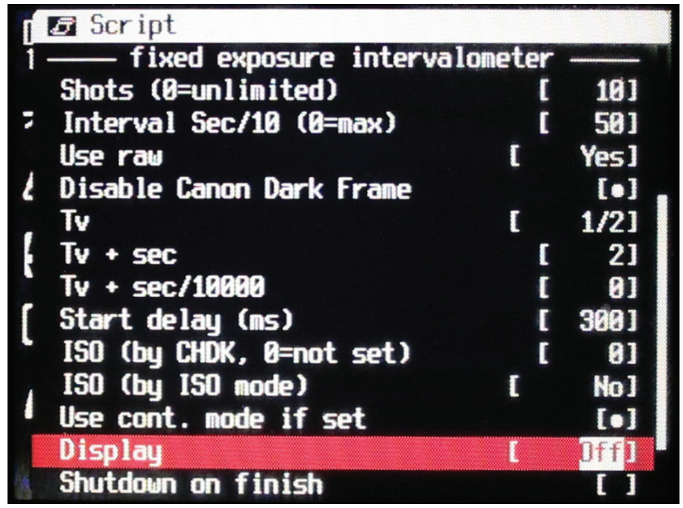

Figure 6 — CHDK Script submenu with specific user parameters available.

Extended exposure settings

The sx100 normally allows shutter speeds from 1/2500 sec to 15 sec. My 40D, like many DSLRs, has a 30-sec limit. Many budding Canon astrophotographers procure an intervalometer for this reason alone, to get past the maximum exposure time. CHDK allowed me to get well past the 15-sec boundary without an accessory or use of a computer as a remote control (Figure 4).

Similarly, CHDK allowed me to extend the aperture range. Raising the upper limit is probably only useful for terrestrial photography.

Lastly, CHDK allowed me to enter any ISO value from zero through 10,000. However, the camera constraints will still generally limit what can be done. I tried ISO 3200.

CHDK can record bad pixel information and the camera can perform on-the-fly dark-frame subtraction. For those who prefer to shoot darks at the end of their session, CHDK allows you to override the subtraction process.

For extended exposure settings, I did the following:

1. activated the ALT mode
2. accessed the MENU
3. accessed the Enhanced Photo Operations submenu
4. accessed the preferred Override option
   a. for exposure control
      i. set Override Tv type to LongExp
      ii. set the Long Exp. Value to 00:00:59
   b. for ISO control
      i. set Override ISO to 3200
5. set Dark Frame Subtraction to Off

The selected override options show in red text on the display.

Live histogram viewing

A very useful feature on my DSLR is the live or dynamic histogram. I try to remember to use it when shooting night-sky subjects to ensure I'm not terribly underexposed with the histogram all squashed up against the left or shadows edge.

The Canon sx100 has a histogram feature in the default configuration, but it is after the fact. That is, a bar graph can be shown for shot images when reviewing them. While still useful, it might mean you end up shooting a dozen throw-away images before you settle on a preferred exposure. CHDK lets you show a small frequency-distribution chart on the live-view screen (Figure 5). As you adjust settings, you can gauge the exposure, and in particular avoid underexposing your astroimage.

To show the live histogram, I did the following:

1. activated the ALT mode
2. accessed the MENU
3. accessed the Histogram (exposure graph) submenu
4. set Show Live Histogram to Always

Again, there are many other settings you might change to suit your preference. For example, you can show the graph in a monochromatic or blended RGB colour mode. By default, over- and under-exposure markers are shown.

In shooting mode, I needed to toggle the graph on. This required holding in the shutter button at the half-press position while pressing the up button on the dial—a little tricky if moving about.

Multiple exposure control

When attempting deep-sky astrophotography of faint fuzzies employing the common practice of image stacking, invariably we want to shoot a dozen or so light (normal) frames along with a dozen or so dark (capped or black hat) frames. If we want to shoot star trails, we might need a couple hundred lights. If we want to make a decent time-lapse movie of the Earth slowly spinning under the Milky Way, we might need hundreds or a couple thousand pictures.

Without an automated remote shutter or intervalometer control, these types of projects are impractical. With a Canon DSLR, you can tether a computer and use EOS Utility. Many Canon and Nikon owners prefer to use the Backyard software (see my review in the October 2015 issue). Canon DSLRs do not have onboard intervalometer controls, whereas Nikons do. CHDK adds this capability to P&S cameras so an external accessory or tethered computer or tablet is not required. CHDK refers to this feature as scripting.

Scripting is not for the faint of heart. There are two script languages and the more-modern one, Lua, is strongly suggested. It took me a couple of hours to figure out how to download and install the correct tool kit. And while I found a number of interesting pre-written scripts, the one I chose was poorly documented, surprise, surprise. My first experience in 1978 with computers was coding. I've learned many computer languages since. I continue to write programs, albeit small ones in Visual Basic for Applications. I learned the importance of internal and external documentation. And still I found this path mind-numbingly confusing. It's a shame really and may discourage some users.

In the end, it was partly for naught. After three attempts and learning the Lua Nested Comments syntax and the Shorthand Parameter syntax all inside the Script Header from the abysmally slow wikia.com server, I came to finally understand that the script would in fact prompt me for the necessary values, meaning, happily, I didn't need to dive into the code.

I downloaded and tried the Fixed Exposure Intervalometer version 1.2 by "reyalp" as it seemed well suited for astronomical use (see the author's page http://chdk.wikia.com/wiki/Lua/Scripts:_Fixed_Exposure_Intervalometer for example photos). It offered control over the number of shots, interval times, exposure time, and start delay. It had some clever features like Make Dark Frames and Shutdown On Finish and the ability to keep the display off (Figure 6). I briefly tried the script after setting some parameters and it performed OK overall; it did not work perfectly but that is probably due to programming issues or camera limitations. Seems like I'd have to do some hacking after all... Regardless, scripting promises tremendous control for those inclined to learn CHDK scripting.

To use the Fixed Exposure Intervalometer script, I did the following:

1. downloaded the FIXEDINT.LUA file from the author's website
2. after unlocking the SD card and switching partitions, I copied the file to the CHDK/SCRIPTS directory
3. after switching SD card partitions and locking it, I inserted the prepared memory card into the camera

To access the script, I did the following:

1. activated the ALT mode
2. accessed the Script Menu
3. accessed the Load Script From File… command
4. selected the FIXEDINT.LUA file

The script's user-adjustable parameters displayed on the lower part of the screen, whereupon I began to customize the intervalometer settings.

After returning to the main ALT display, I noted the active script name at the bottom-left corner of the screen. I pressed the Shutter button to run the script.

In summary, if you have a point-and-shoot Canon camera and you want to use it for astronomy without tethering, you can start using the free, rich, and powerful CHDK software instead of your camera's built-in firmware. You should be computer savvy and prepared to jump through some hoops to obtain and configure the necessary software tools. You might want to buy another memory card.

For some, this may mean they can use a compact camera they thought unsuitable for astrophotography. For others, this might mean dusting off an old camera and having some fun. For me, I can tackle more than one astrophotography project in a given evening.

Update Bits

Just learned that a new version of *Stellarium* is available: 0.16.0. Some new features and updates include peculiar galaxies catalogues, the Hawaiian sky culture, non-spherical Solar System objects, and GPS location support. ✶

Blake's interest in astronomy waxed and waned for a number of years, but joining the RASC in 2007 changed all that. He volunteers in education and public outreach, supervises at the Carr Astronomical Observatory, and is a councillor for the Toronto Centre. In daylight, Blake works in the IT industry.

Earliest RASC Star Party Antecedents II

How Old is the Term?

by R.A. Rosenfeld, RASC Archivist, and Clark Muir (K-W Centre)
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Abstract

Building on the work of the second author, this paper provides citations for the astronomical use of the term "star party" in the popular press ca. 1920, which is two decades earlier than it commonly occurs in the astronomical literature, as reported by the first author in the June 2017 *Journal*. Here we present evidence that "star-gazing party" was in common use by the popular press to refer to "an occasion for astronomical observation involving more than one person" by the final decades of the 19th century.

Evidence beyond the earlier finding

The first author published data indicating that the term "star party," the meeting together of people to do observational astronomy, was an American coining, dating from 1939–1940, and localized to the mid-West of the United States (Rosenfeld 2017). This conclusion was based on mining the historical astronomical literature for occurrences of the term "star party," and analyzing the internal features of the texts. That paper also observed that observational star parties were centuries older than the introduction of the term, and discussed a simple typology of star parties. In addition, the time frame for the adoption of the practice by the Toronto Astronomical & Physical Society (the nascent RASC) was found to be 1890–1900. This was a sign that the Society was coming to see education and public outreach (EPO) as part of its mission. That change has had a profound effect on the RASC. As the Society membership has greyed, EPO has somewhat paradoxically gained a greater proportion of its energies and resources, to the point where EPO has become paramount in the organization's sense of its own mission.

After that publication appeared, the second author then discovered a definite instance of the astronomical use of "star party" from 1922, and an equivocal one from 1901, and brought them to the attention of the first author (Muir 2017a). The 1922 article reads:

> "Miss Helen Whitaker, instructor in astronomy at Washburn college, will give a "star party" tonight at Washburn Observatory. With the aid of the big telescope she will exhibit an assortment of stars to students and the public as 7:30 o'clock. The public is invited to attend. The telescope as the Washburn observatory [sic.] magnifies 750 diameters, and has been in use there since 1902" (Anonymous 1922).[1]

The 1901 example occurs in an article by an astronomically inclined Lutheran pastor, intended to excite local interest among the citizenry of the tri-cities of Geneva, Batavia, and St. Charles, Illinois, in a forthcoming lecture by Sir Robert Ball (1840–1913), the Lowndean Professor of Astronomy and Geometry at Cambridge University, and Director of the Cambridge Observatory: "Let us go out in a big "star party" and listen to Sir Robert Ball when he sails the infinite azure" (Hemborg 1901). The meaning of the term, while astronomical, does not refer to observing.

Spurred by the second author's success in locating citations of the astronomical use of "star party" in the popular press earlier than those found in the astronomical literature, the first author gratefully followed his lead. The combined result of their researches follows. The earliest astronomical use of the term "star party" we have (yet) found remains that from 1922, but there is no reason to think that this need be the earliest occurrence of the term. More significantly, we have discovered that "star party" appears to be a contraction of an earlier form, namely "star-*gazing* party" (e.g. the title of Anonymous 1902; note there was some temporal overlap in the employment of the two terms). In what period can the earliest citations of "star-gazing party"—an occasion for astronomical observation involving more than one person—be placed?

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Star-gazing party—earliest common citations?

In an appreciation of the noted American telescope maker John Clacey (1857–1931), it is recounted that:

> "At this time, in the early 80's, amateur astronomy was on a high wave of popularity. Wealthy people in the vicinity of Boston were buying small telescopes and star-gazing parties were the latest fad. Clacey made large numbers of four and five-inch lenses for these enthusiastic amateurs… He loves to tell of the "telescope parties," held on the spacious lawn of his Glendale [MD] home [ca. 1895-], for the school children of the village, and of their surprise and amazement at seeing the features of the moon, the rings of Saturn, of the components of a double star" (Anonymous 1930, 474–475).

Clacey's reminiscence of star-gazing parties being common in early 1880s New England is retrospective, and reported in print a half-century after the time in question. The earliest contemporary citation of star-gazing party used in an astronomical sense uncovered in the course of this study dates from 1887. The passage in *The Indianapolis Journal* is immediately arresting, because it appears to imply that young female astronomy students are more dedicated to observing than are their male counterparts:

> "The astronomy class of Boston University arranged for a "star gazing" party, with telescope and other accessories to take place on the Common. The night selected proved rough and threatening, but the girls were all there. Not a boy put in an appearance. The weather was too cold for them" (Anonymous 1887).

There are problems with taking this story as literal fact, however. Boston College didn't accept female students till the 1920s (nuns, as it happens; Higgins 1986, 59–61). In the 1880s, the institution functioned as a seminary. And it doesn't appear to have acquired astronomical equipment till ca. 1928 (Udías 2003, 239–240). The story may be true in its essentials, but the author has misidentified the institution, or the story may be wholly fabricated protestant polemic to cast aspersions on the "manliness" of Catholic male students, and was not intended primarily to say anything positive about the fortitude, or aptness of female students for astronomy. It does, however, count as evidence for the astronomical use of the term, whether the story is fact, or fiction.

It is important to note that there is nothing in the passage in the 1887 *Indianapolis Journal* article to hint that the author thought he or she had invented the astronomical use of the term, or that it was novel. The column in which it occurs, "Concerning Women," is generally in support of female emancipation. It is difficult to say whether the rhetorical strategy of its author would be helped or hindered by the use of a neologism, or a word of rare occurrence. If Clacey's reminiscence is reliable, then it is reasonable to expect citations from earlier in the 1880s, and before.

For a fuller view of how writers in the popular press understood "star-gazing party," the best course is to examine the context of its occurrence in the texts themselves. Doing so allows some unexpected aspects of the social practice to emerge.

Star-gazing party—contexts of use

Before turning to the astronomical citations of the term, something should be said about those that are not.

Many 19th- and early 20th-century instances of "star-gazing party" (and "star party") are non-astronomical. Numerous false positives occur when searching through large bodies of texts, either by rapid visual scanning of non-digitized printed texts, or through computer-assisted searches of digitized corpora. In the context of such work they are the equivalent of unrecorded nebulae or clusters to an 18th-century comet hunter, or plate defects posing as astronomical objects on a glass plate to an early 20th-century astronomer, or hot pixels in an digital image to a astrophotographer of the present.

Very common are references to activities of service organizations with "star" in their name, or hosting parties featuring symbolic, or decorative stars. An example of the former is the American Masonic-related Order of the Eastern Star.[2] For the latter, the following should suffice:

> "The Oriental Lodge Entertainment. Oriental Rebekah Degree Lodge, No. 90, gave a "star-gazing party" in Prospect Hall, Odd Fellows' Building, last night. The walls of the hall were decorated with stars, and stars were distributed during the grand march" (Anonymous 1891).

As disappointing as these occurrences are, they are constituents of the wider background in which "star-gazing party" might refer to astronomical activities. The non-astronomical "star-gazing parties" could always be invoked in references to the astronomical ones, or vice versa. One example is the star-gazing party as a metaphor in political commentary:

> "Idaho is politically star-gazing, its several parties—republican, democratic progressive, socialist and prohibitionist—endeavouring to read aright the signs of the times" (Anonymous 1914a; 1914b).

Another is the brand of American humour, which is taken by the courtship opportunities to subvert the astronomical business of star-gazing:

"Query. Has that star-gazing party yet decided the question, Why astronomy and courtship go together?" (Anonymous 1892),

and

"The double wedding dance of October 16 was well supplied with brides and whiskey, (not that the same party supplied both) and, in consequence some parties were star gazing" (Anonymous 1908).

Turning now from the ridiculous to the sublime, a significant aspect of the social practice of star-gazing parties is how often it attests to female participation in astronomy. Women function as formal, or informal students, and as experts.

One cultural club mixed astronomical activity with knowledge of classical music, ancient history and literature, and art criticism:

"The Eidelweiss Chautauqua Circle, of Mount Vernon met on Tuesday evening with Miss Ada Foggin, and when the roll was called each member gave the name of a celebrated composer and two or three of his principal works. After this came a map drill on Greece, conducted by Frank Hickock, and a study of the constellations for January and February by all of the members. Miss Jeanie Pearson then gave a concise but short outline of Homer's "Iliad." Each member was called upon to state which article in this month's "Chautauquan" had been most interesting to him, and why, and the exercises closed with a reading from Ruskin. After the meeting adjourned the members formed themselves into a "star-gazing" party, and proceeded to locate in the heavens a number of the constellations they had been studying. As the night was particularly bright and clear, the work proved very interesting" (Anonymous 1897a).

From this report, it appeared that the aim was to cultivate a broad, rather than a deep knowledge of the subjects. If the members were encouraged to make relevant allusions between the fields, the experience could have been quite stimulating.

Some of the star-gazing parties were covered in the society pages of newspapers, meaning that the cultivation of an interest in astronomy among the women of the upper-middle classes and above in those local areas was seen as appropriate. The venue for the following event was an academic teaching observatory, the same observatory as was noted in the citation from 1922 (see above):

"A star gazing party which spent last evening at the Washburn observatory included Miss Grace Osborne of Coffeyville, Miss Grace Mason Welch, Miss Florence Welch, Miss Ethel de Obert, Miss Pearl Burdge, Miss Agnes Burdge, Miss Ida Denis, Miss Emma Dennis, Mrs. Hiram Landrus, Mrs. Smith and Miss Miriam-Bunker" (Anonymous 1905).

Some all-female educational institutions did not discourage impromptu star-gazing parties, particularly if a major celestial event was to be experienced, like the apparition of Halley's comet:

"Star-gazing parties among the students of astronomy [at St. Mary's Academy] have been frequent throughout the year, but those of the past week were somewhat out of the ordinary, being held in the morning instead of the evening. Halley's comet was the wonder-worker that took a good number of sleepyheads out of their cosy beds an hour or two before the rising signal eager to get a view of the object they have been hearing and reading so much about all year. The comet was found by the telescope, of course. Tuesday morning, between 4:30 and 5 o'clock: and, in addition to four or five of the sisters, about a dozen girls had the satisfaction of looking at it before it faded in the light of day. Another large party was on hand at an early hour Wednesday morning, and again each one was rewarded for her zeal by a clear view of the misty little object. After the reports of its being visible to the naked eye, there was another observation party on the roof Friday morning, but scarcely any change was noted in the appearance of the comet, nor did any of these succeed in seeing it without a glass" (Anonymous 1910).

The citation above refers to voluntary and apparently course-related star-gazing parties within the context of academic courses, in an institution provided with observational instruments. Less serious, although not necessarily frivolous, is the recommendation of star-gazing parties as summer-camp activities for young women requiring relief from the tedium of professional life in the city:

"The business girl who is exhausted by hard work in a city environment that offers little relaxation can take things as easily as she likes...A marshmallow roast around the camp fire at night, a watermelon feast, or a star-gazing party are forms of recreation that even the weariest of city-dwellers will be ready for when the day is over" (Anonymous 1921).

Not only female professors and instructors of astronomy could fulfil the role of astronomical expert. Inez A. Budd (ca. 1851–1911), spouse of a former Governor of California, instituted her own "planet parties," invitation-only affairs, in her private observatory. Her astronomical erudition is particularly noted by the writer (without further research, it is difficult to judge at this remove if such praise is purely the product of social deference, or is in fact merited):[3]

"[From the] San Francisco Examiner. There is something absolutely new under the sun, or perhaps in this

> instance the old saying should be paraphrased into something absolutely new under the moon. It is the "planet" party;" and to Mrs. James H. Budd, of Stockton, wife of the ex-governor of California, belongs the honor of having originated it. ¶That statement in itself bespeaks something out of, the ordinary, for there is nothing frivolous about Mrs. Budd's "planet parties," mysteriously alluring though the title sounds. They are a new form of instruction, made doubly interesting from the delightful entertainment they afford. And what could be more romantic than a "planet party?" ¶It is intensely interesting to both young and old alike, for the "planet party" is star-gazing in the most literal sense of the term. ¶It takes the guests from the restricted limits of the parlor and the drawing-room out into the open air, across the green, grass-carpeted lawn, though the shadows of the towering trees and up the winding stairs of the observatory to revel in the glory of an autumn night under a clear, star-lit, sky. There through the big telescope the wonders of the heavens are brought down to be viewed in turn by each of those present, and following this amusement refreshments are served to please the inner man. Truly, whether it be spring, summer or autumn, the "planet party" is well calculated to turn a young man's fancy to thoughts of the most tender sentiments.
>
> Mrs. Budd's "planet parties," however, are the most sedate and exclusive little gatherings imaginable, for Mrs. Budd is very earnest in her chosen work, and brings to her entertainments a vast deal of scientific knowledge, which she imparts in a most pleasing manner. Fortunate, indeed, do those consider themselves who have had the pleasure of attending one of them. They are exclusive for two reasons. In the first place Mrs. Budd owns the only telescope in Stockton of any considerable size, and in the next place it naturally follows that the top of an observatory that is only ten or twelve feet square, will not accommodate a great many people. Through Mrs. Budd's telescope something more can be seen than the little twinkling lights in the heavens. In the object glass of her 'scope they assume distinctive form. Jupiter and his moons can be seen, together with Saturn and his rings and moons. The sight of these planets is absorbingly interesting, and Mrs. Budd's "planet parties" are considered the hit of the season" (Anonymous 1901).

Did women play a particularly large part organizing and participating in star-gazing parties during the period from the 1890s to the 1920s? Was their participation chiefly in gender-exclusive star-gazing parties? Was the nature of their participation in star-gazing parties the same regardless of gender composition, or did it vary? Was female participation in star-gazing parties important in establishing or normalizing their participation in science? More extensive work would be necessary to begin to answer any of these questions.

We earlier mentioned Halley's comet as providing opportunities for star-gazing parties, in connection with St. Mary's Academy. The Rev'd Joel Metcalf's daughter also singled out the experience of a star-gazing party for Halley's comet as memorable:

> "Once in a while, we had star-gazing parties [ca. 1910?], when parishioners and other friends would come to exclaim over the rings of Saturn and to ask if Mars were inhabited. But nothing equalled the pleasure of "demonstrating" Halley's comet to an awe inspired group of young and old" (Stoneman 1939, 25).

Spectacular meteorite showers, or rather, meteorite showers expected to be spectacular, could also provide the reason for holding star-gazing parties. These were planned for the Leonids of 1897, and 1899—as it turned out, the Leonids were underwhelming both years:

> "Several early morning star-gazing parties are being organized for the meteoric shower season" (Anonymous 1897b; 1897c).

> "—Many of our people are arranging "star gazing" parties for the evenings of November 13th, 14th, and 15th, as it is said the meteoric display [of the Leonids] about that time will surpass anything of the kind since 1866. Don't miss it" (1899a).

> "The shower of fiery meteors scheduled for last evening failed to appear. It has only been postponed, however, and between midnight tonight and 5 o'clock tomorrow morning the sky will rain meteors of all ages, shapes and sizes. Several star-gazing parties have been organized in Butte to stay up all night and watch the display as it only occurs once in every 33 years" (Anonymous 1899b).

> "LEONIDS NOT VISIBLE HERE. Fruitless Vigil of Many of Ottumwa's Astronomers. The shower of Leonids which has been booked for this part of the terrestrial world for the past three or four nights, and which, it is said, would surely shine forth in all its brilliancy last night failed to make its appearance as scheduled, much to the disappointment of many. In Ottumwa there were a number of "star gazing" parties, the members of which, while they were disappointed in regard to the announced purpose of the assemblies, have no special regret for having been together. The evening and a good portion of the morning were spent in social games and periodical trips to the door or window to see "if the stars were falling." Astronomers tell us that the meteoric shower may be visible tonight. Chicago, Princeton and Washington all report failures last night. Yale and Harvard saw nothing and were in despair

because an impenetrable fog hid the skies thereabouts. The University of Kansas, at Lawrance, had better luck. There more than a score of the meteors were seen, with the naked eye, between 1 and 3 o'clock. Goodsell observatory at Northfield, Minn., counted eight at about 5:30 a.m., the clouds having lifted for a few minutes on the morning breeze. Thus far Webster City and her many ton meteor, which fell yesterday, are entitled to first honors" (Anonymous 1899c).

"The meteoric display which was scheduled for this week has so far failed to appear and on that account the numerous star-gazing parties which were held have not been very successful" (1899d).

We close by remarking that it is curious that the star party, a cultural practice which is now so central to North American amateur astronomy, has attracted so little historical attention. ✶

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Endnotes

1 This "Washburn Observatory" is actually the Crane Observatory of the Washington Municipal University, Topeka, KS, and not the Washburn Observatory of the University of Wisconsin-Madison. On the Crane Observatory, see Stearns 1947, 26-27. The principal instrument was a refractor with a 29.21-cm, F/14.52 O.G. by Brashear, on a Warner & Swasey mount.

2 Snoek 2014, 413. Leslie Peltier was a member of this organization; Peltier 1967, 201. Regarding astronomical star parties, Leslie Peltier was very ambivalent about the utility of the style of observing they fostered in his day—perhaps rightly so; Peltier 1967, 40, 176.

3 The former is probably the case, given that "Mrs. Budd had devoted the last years of her life to religious and astronomical studies. She studied astronomy in connection with her biblical interpretations, having had an observatory at her home. She taught a religious sect and had her class at the house Saturday. Recently Mrs. Budd had her sect incorporated. It is designated "Christ's Doctrine Revealed and Astronomical Science Association[!];" Anonymous 1911.

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John Percy's Universe

Time Domain Astronomy: Everything Old is New Again

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

The heavens change with time. Three thousand years ago, Babylonian observers noted the motions of the Sun, Moon, and planets against the background stars, and Western astronomy (and astrology) was born. Millions of Kuiper Belt Objects, asteroids, including Near-Earth Objects, move slowly across the sky, revealing their existence and orbits, and the architecture of the Solar System. Much further away, stars exhibit slow "proper motion" due to their sideways velocity, and "parallax" as a reflection of Earth's revolution around the Sun. The European satellites *Hipparcos* and now *Gaia* have studied these motions in exquisite detail, by measuring precise positions hundreds of times over many years.

Stars also vary in *brightness*. For half a century, I have been studying variable stars—stars that vary in brightness over time due to pulsation, eruption, eclipse, or other process (Percy 2007). There's evidence that the Egyptians knew about the eclipsing variable star Algol in 1200 BCE (Jetsu, et al., 2013). Arabic astronomers may have known about it when they coined the name Algol—the demon star. The variability of Mira may have helped to usher in the Copernican revolution (Hatch, 2011). *Systematic* observations of variable stars have been made for well over a century, visually, photographically, and now electronically.

Time-domain astronomy (TDA)—the new name for the study of how astronomical objects change in position or brightness with time—is now a hot topic in astronomy, thanks to new survey telescopes in operation or on the horizon. As one indication: the prestigious international Dan David Prize for 2017 was awarded specifically for achievements in time-domain astronomy across the electromagnetic spectrum, to the late Neil Gehrels (USA), Shrinivas Kulkarni (USA), and Andrzej Udalski (Poland).

But TDA is not new. In the optical domain, it has been the basis for variable-star astronomy and asteroid hunting for centuries. Gamma-ray bursts have been known since the birth of gamma-ray astronomy in the 1960s. Radio astronomy TDA led to the discovery of pulsars in the 1960s, among many other important things.

The rebirth of TDA, at least in the visible region of the spectrum, has been driven by the gradual development of more and larger automated telescopes, and of CCDs and computers powerful enough to acquire and process their data. One example (of many) is the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS), a collaboration between several organizations, including the US Air Force. It presently consists of two 1.8-m telescopes in Hawaii. Other telescopes will be added as funding allows. The eventual goal is to survey most of the sky down to magnitude 24, every few days.

Pan-STARRS is, in many ways, a pilot project for the ultimate visible-light TDA project—the Large Synoptic Survey Telescope (LSST), an 8.4-m telescope in Chile that will image the available sky every few days for at least ten years. Although the major goals of LSST are to study dark matter and dark energy, it is also well suited for detecting and studying asteroids and Kuiper Belt Objects, and for detecting transient optical events of all kinds, and immediately alerting the astronomical community. LSST is scheduled for first science light in 2019. It was the first priority for ground-based astronomy in the most recent US Decadal Plan. According to *Wikipedia*, LSST has a 3.5-degree field of view, feeding a 3.2-gigapixel CCD camera; initial computer requirements are estimated at 100 teraflops of power, and 15 petabytes of storage. LSST will clearly require new ways of doing astronomy, and the international astronomical community has been developing these for a decade or more.

Getting Organized

The International Astronomical Union (IAU) has recently established a Working Group (WG) on TDA[1], which "promotes the study of the variability—transient, periodic, secular, or aperiodic—across all disciplines of astronomy from the Solar System to cosmological distances". Its members "represent a diversity of topics including synoptic surveys in all bandpasses, multi-messenger follow-up, stellar variability, moving objects, heritage data, instrumentation, robotic telescopes, communication, analysis, and education." The WG maintains an extensive resource list[2]. The IAU has organized a major symposium on Time-Domain Astronomy, to be held in 2017, to discuss "a broad spectrum of topics by seeking commonalities among quite different kinds of objects that display similar types of variability"—such as the topics mentioned above.

In 2014, the American Astronomical Society (AAS) established a WG on TDA[3]. Like the IAU WG, this WG's interests include surveys and their data analysis needs, need for follow-up of interesting events, data mining and management, prompt access to data, and the very important need to provide access to longer-term data, i.e. archiving the data for the future. I work extensively with American Association of Variable Star Observers (AAVSO) data, which goes back for over a century, and has fortunately been archived. There is extensive photographic data—over half a million photographic plates at the Harvard College Observatory (Sobel 2016)—being archived by the DASCH project. But for two decades

Figure 1 — CHIME: The Canadian Hydrogen Intensity Mapping Experiment is an innovative, cost-effective radio telescope, located near Penticton, BC. It has a collecting area the size of five NHL hockey rinks, but has no moving parts. The sky drifts by; powerful computers do the rest of the work. It was designed to map the neutral hydrogen in the early Universe across the northern sky, but it will also detect and study short-lived phenomena such as pulsars and fast radio bursts. Source: Dunlap Institute.

between the end of the photographic era, and the beginning of the WWW era, much astronomical data is languishing (or not) on magnetic tapes, which may soon be unreadable.

Time-Domain Astronomy in the Radio Sky

Cosmic radio sources vary on timescales of milliseconds (the Crab Pulsar, for instance) to decades or more (active galactic nuclei (AGNs) such as quasars, for instance). The timescale of variation of pulsars shows that the emitting region must be no more than a few hundred km in size. The timescale of variation of AGNs—typically 0.5 to 2 years—shows that they are typically no more than a light-year in size, and must therefore be powered by supermassive black holes.

Radio astronomy, like optical astronomy, is entering a new instrumental domain, with the advent of the Square Kilometer Array (SKA) and the Low-Frequency Array (LOFAR). Canada is a partner in SKA, but is also a leader in a modest but powerful way with the construction of the Canadian Hydrogen Intensity Mapping Experiment (CHIME)[4] near Penticton, B.C. (Figure 1). This telescope's primary goal is to survey the neutral hydrogen gas across most of the sky, and far out in space, therefore far back in time, and hence learn more about the mysterious "dark energy" that causes the expansion of the Universe to accelerate. But CHIME will also be sensitive to variable radio sources, both known and otherwise.

Indeed, there are exciting new discoveries for these instruments to work on. Fast radio bursts (FRBs) are the latest cosmic mystery: they are transient bursts of radio energy, lasting only a few milliseconds, and of unknown origin. They are most likely at cosmological distances. One has been localized in a specific galaxy, billions of light-years away. Whether they are stellar collapses, mergers of collapsed objects such as neutron stars, or flares on ultramagnetic "magnetars" is still an open question.

Implications

TDA is an example of the impact of "big data" in almost every branch of modern science—and beyond.

Artificial intelligence or machine learning will play a major role in analyzing and interpreting the data. One of the results of this is that astronomy students trained in these fields will be able to find employment, not just in astronomy but a wide range of other "big data" fields as well.

There may also be new roles for undergraduate research students, and for amateur astronomers. They could comb through the massive datasets from surveys such as LSST, looking for variable objects which are unusual in some way (as with the "Green Pea" galaxies discovered in the *Galaxy Zoo* project), or which have somehow been missed by the automated schemes for finding them (as the *Exoplanet Explorers* project does in detecting transiting exoplanets in Kepler data). Amateur astronomers were at the forefront of the personal computer revolution, and the robotic telescope revolution. There's a role for them here.

We live in the age of "information explosion" and, as with other areas of life, we will have to learn to live with it, benefit from it, and enjoy it! ✶

Notes

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2. timedomainastronomy.net/resources.html
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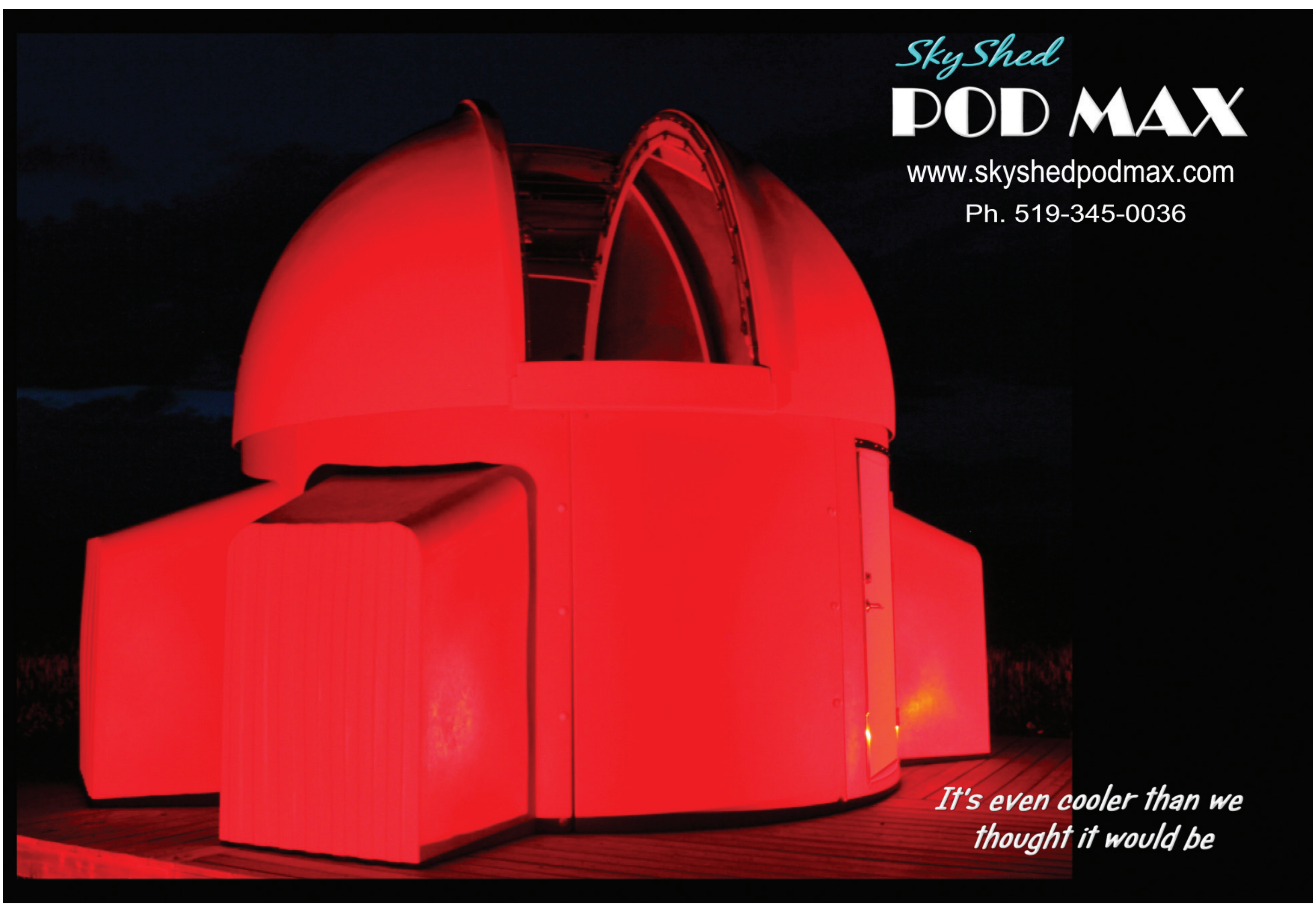


Skyward

Anger Issues and Summer Skies

by David Levy, Montreal and Kingston Centres

With cloudy night after cloudy night passing us by this summer, one wonders whether it would be appropriate to hit a baseball onto the floor or something to encourage the sky to clear, if only for an hour or so, on any one of these mild summer evenings. I used to take cloudy weather personally, and when I was much younger I had quite a temper.

In August of 1962 (I was 14 then) I carried my typewriter by bicycle to Summit Park, a beautiful wooded park atop a small hill not far from my family home. I was writing one of my first astronomy books, a little too confidently entitled *An Encyclopedia of the Universe*, and had just begun page 260 in the chapter about double stars. About halfway down the page, some minor problem befuddled my typewriter, and I had what I now call my "double star tantrum." Repeatedly striking the little typewriter against the maple tree under which I was sitting, there was nothing to do but cycle everything home.

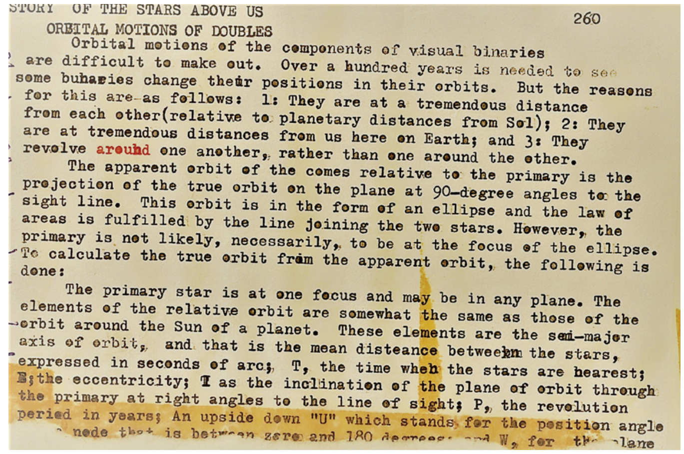
The next morning was another day, however. I asked Mother if I could borrow her typewriter, claiming that mine had been somehow damaged. I cycled back to the same tree, placed the bottom half of the torn sheet of paper into the typewriter, and calmly resumed typing.

The original typewriter was repaired while I was living in Denver at the Jewish National Home for Asthmatic Children. (Whatever did you do with your typewriter?" Dad wrote to me. "It cost me $50 to repair it!") Some ten years later, with my passion for astronomy still at a maximum, my brother Gerry gave me a poster with a quotation from Henry David Thoreau, one of my favourite writers. It is from the conclusion of his book Walden:

If a man does not keep pace with his companions, perhaps it is because he hears a different drummer. Let him step to the music which he hears, however measured or far away.

Carrying those wonderful thoughts in my mind, I returned to Summit Park and photographed the tree still healthy and pointing skyward to the stars I love so much. On these summer evenings, the tall tree points roughly toward Vega, the second-brightest star in the summer sky and a member of the Summer Triangle. Very close to Vega is a famous double star called Epsilon Lyrae. It consists of two stars close together, each of which is in turn accompanied by a faint companion.

Perhaps because of that incident from long ago, I have become a fan of double stars and am still observing them, enjoying


STORY OF THE STARS ABOVE US 260

ORBITAL MOTIONS OF DOUBLES

Orbital motions of the components of visual binaries are difficult to make out. Over a hundred years is needed to see some buharies change theìr positions in their orbits. But the reasons for this are as follows: 1: They are at a tremendous distance from each other(relative to planetary distances from Sol); 2: They are at tremendous distances from us here on Earth; and 3: They revolve arouhd one another, rather than one around the other.

The apparent orbit of the comes relative to the primary is the projection of the true orbit on the plane at 90-degree angles to the sight line. This orbit is in the form of an ellipse and the law of areas is fulfilled by the line joining the two stars. However, the primary is not likely, necessarily, to be at the focus of the ellipse. To calculate the true orbit fràm the apparent orbit, the following is done:

The primary star is at one focus and may be in any plane. The elements of the relative orbit are somewhat the same as those of the orbit around the Sun of a planet. These elements are the semi-major axis of orbit, and that is the mean disteance betweehn the stars, expressed in seconds of arc; T, the time wheh the stars are hearest; E; the eccentricity; I as the inclination of the plane of orbit through the primary at right angles to the line of sight; P, the revolution period in years; An upside down "U" which stands for the position angle ... node that is between zero and 180 degrees; and W, for the plane

Figure 1 — The original of the sheet of paper I tore out of the typewriter that afternoon.

their different colours and trying to separate them with my telescopes. I like to think that in my declining years, that my anger issues have been resolved, but what I don't forget from that day is that the afternoon ignited a strong interest in the many stars in our sky that have companions, circling each other as they parade through our galaxy.

The Summer of 2017

Summer is my favourite season, and Summer is also my favourite granddaughter. When I was growing up in Montreal, summer was the only time of year when the weather was warm enough to spend large amounts of time out of doors. With trees in full bloom, the quiet, sunny days of summer were really something to anticipate.

Summer in Arizona is different. With temperatures soaring well above 40° C each day, going outside is an adventure fraught with peril. In fact, with a predicted high of more than 45° C last Sunday, I had to cancel my weekly bicycle ride and be careful to remain indoors as much as possible

Further north, the temperatures are not quite as stifling, but on August 21, it didn't matter. On that day the shadow of the Moon worked its way across the United States, giving viewers, for the first time in 38 years, a total eclipse of the Sun. The eclipse was the obvious highlight of the summer of 2017. But as hot as the days of summer might get, the nights offer the real blessing. When the sky is clear enough, the predawn temperatures remain in the pleasant 20s. Saturn, with its exquisite rings visible even through a small telescope, shines brightly in the evening hours. The Milky Way arches overhead like a highway. And sure enough, in the constellation of Cygnus, the swan, a great dark rift resembles an exit ramp, pouring starlit traffic off that highway amongst the stars of Ophiuchus.

There were two big meteor showers this summer. Around July 21 the Delta Aquarid meteors visited, emanating as lovely,

Figure 2 — The actual tree into which I banged the typewriter.

fast-moving streaks of light coming from the constellation of Aquarius. Just two weeks later, Earth crossed the orbit of a wondrous comet. Discovered in 1862 by Louis Swift and Horace Tuttle, this comet's orbit crosses the Earth's path every 120 years, leaving a stream of dust that we encounter annually, creating meteors we call the Perseids. And this year's show was another good one.

Finally, this summer offerd something unique besides the eclipse. On July 30, Earth crossed the orbit of Comet Borisov, a large comet I observed two years ago. It was believed that when that happened there could be yet another meteor shower, visible best for observers in southern Europe and Africa. However, because the event was visible from the other side of the Earth, I do not recall anything unusual that night from here.

Wherever you were this summer, the sky offered a cornucopia of wonderful things to see, and for most of what I highlighted, you didn't even need a telescope. Summer is a time to simply enjoy the evenings and the nights, look toward the sky, and enjoy the cosmic sea of which we are a part. ✶

RASC Awards

2017 President's Award

David Garner – Kitchener-Waterloo Centre

David has made great contributions to various publications of the Society for fifteen years.

He was the Production Manager of the *Journal* from August 2002 to February 2006. He has been an Assistant Editor of the *Journal* since 2008, and he wrote a column in the *Journal* called "On another Wavelength" from February 2009 to June 2015.

David has been Editor of the monthly RASC *Bulletin* since May 2012 and is the Editor of the National *Newsletter*, which was resurrected in July 2016 and is published in the centre of Sky-News magazine.

It is critical that members receive information about the Society in a timely manner. The production of quality publications is a time consuming job. I am pleased to recognize David Garner for his contributions to Society publications.

Craig Levine
President

Service Award Nominations

Donald Town has served as the national Representative of the Belleville Centre for close to a decade. He also sits on the Society's constitution committee. But more than that, he has never let family commitments and a work schedule that regularly includes 60 hour weeks prevent him from performing those duties in a manner that can only be described as exemplary. Don has rarely failed to find the time to participate enthusiastically in matters of the society at both the Centre and national levels. I am certain that anyone who has attended, or read the minutes of national council meetings will recognize his name.

As president of the Belleville Centre, I must confess that Don's steadfast attention to society matters at the national level, in addition to allowing me to concentrate on centre activities, has served to cover up my own admitted short comings in this area. I am certain that, however unintentional, I have been the unwitting recipient of credit for Don's hard work that goes on largely unseen by most members.

In addition to his work above and beyond the call as national rep., Don is always the first with his hand in the air when the call goes out for volunteers to support Centre events, Public observing or other forms of public outreach. Each of these individual acts also tend to go largely unnoticed until one stops to consider their frequency.

I would very much like to see Don receive some much-deserved recognition in the form of the Service Award for his hard work and dedication to the achievement of the society's mission statement and the success of the Belleville Centre.

Greg Lisk, Belleville Centre President
Randy Boddam, Belleville Centre

Betty Robinson has been a RASC member for over 30 years, having joined Toronto Centre in 1981. Betty immediately used her editorial skills to manage the production of their newsletter, Scope, for four years. She ensured that the newsletter was a comprehensive report of the activities of the centre, including lists of new members, topics for upcoming meetings, upcoming public outreach events, and the requisite documents for the Annual Meeting. She wrote content, laid out the copy, and oversaw and participated in the effort to physically prepare over 1000 copies for mailing.

She also took on roles on the Toronto Centre Council, as secretary from 1984 to 1987, and National Council Representative for the 1982-83 years.

She transferred to the Mississauga Centre in 2006, and served on Council for the first year, helping to get the new Centre processes started and producing the first Mississauga Centre newsletter. Through the following years, Betty regularly attended the twice-monthly meetings, helping out as and whenever required. Betty rejoined Council in early 2016 and revived the dormant newsletter; five issues have been produced to date. Betty also assists with the selling of raffle tickets and calendars at the Centre's meetings, and is our resident cake-baker for Centre celebratory events, such as our 10th anniversary.

She also edits Centre communications sent out to our members.

On the National level, besides her stint as National Council Representative, Betty served as a copy editor for the Observer's Handbook, from 2002 to 2009 and again in 2012 and 2017. Given the size and the comprehensiveness of the Handbook, her work in the background—her attention to detail and stress on clarity of the written word—contributes significantly to the professional appearance and reputation of the Handbook.

We, the undersigned, hereby nominate Betty Robinson for the Service Award of the Royal Astronomical Society of Canada.

Leslie Strike, Past President, Mississauga Centre
Valerie Connery, Member, Mississauga Centre

Eric Briggs has been an active member of the RASC and Toronto Centre since 1997. Over the past 20 years, he has been involved in many aspects of the Toronto Centre; most notably on Council as the Recorder from 2008 – 2009, Secretary from 2009 to 2016, and Editor of SCOPE from 2009 to the present.
Eric shares his enthusiasm and knowledge of astronomy through his many presentations at the Toronto Centre Recreational Astronomy Night meetings, where his topics included astrophotography sampling, observing from Mount Wilson, tracking and observing satellites though a telescope and asteroid imaging. One of the regular features at these meetings is "The Sky this Month" which Eric has presented 32 times from 2005 to 2009.

A prolific volunteer on behalf of both the Toronto Centre and the National Society, Eric has participated at numerous events and venues such as the [Toronto] Hobby Show, the David Dunlap Observatory where he was also the co-editor of DDO Doings, Ontario Science Centre Star Parties, Science Rendezvous, and the Carr Astronomical Observatory. Over the years, Eric has video recorded the Toronto Centre's meetings to make them available for members not able to attend in person, he has digitized many historical RASC documents both for the Toronto Centre and the National Society and is a regular contributor to the various Toronto Centre Listservs, social media outlets, and the National RASCals. On behalf of the RASC National Society, Eric is the Curator of "Asteroids with a Canadian Connection," and can be counted on as a key resource for knowledge on RASC historical events and notable members.

Eric is active in astronomical pursuits outside of the RASC, as a member of the Puckett supernova search team with 10 supernova discoveries co-attributed to him, as a frequent contributing member to IOTA, the International Occultation Timing Association, and professionally with Spitz Inc. Planetariums.

Tony Horvatin, on behalf of the Toronto Centre Council

Katrina Ince-Lum joined the RASC Toronto Centre in 2000 and continues to volunteer her time in a diverse array of areas for the Society. Her passion has always been to encourage others, especially the youth, to discover and develop an interest in astronomy, whether it is with her fellow members or with the general public.

Katrina served as a member of the Toronto Centre Council from 2006 – 2008 and was the Centre's prime organizer for the monthly public solar-observing sessions held monthly at the Ontario Science Centre for many years. In 2008, when Toronto hosted the General Assembly, she was a key member of the event planning team, and was a very visible volunteer who helped ensure a successful weekend for all participants. Katrina volunteers at the Carr Astronomical Observatory both as a site Supervisor and at work parties, and has been a regular fixture during public outreach events at the David Dunlap Observatory and Ontario Science Centre. During the Transit of Mercury in 2016, Katrina broadcasted live over the Internet video of the event from the Carr Astronomical Observatory for the world to see.

Katrina is an avid contributor on social media and is one of the founding volunteers for the Toronto Centre's various Twitter and Facebook pages. She also posts regularly on her own social media accounts, directing her denizen of followers to the RASC and the Toronto Centre, and informing readers of current astronomical events. In a spectacular public relations win, Katrina convinced astronaut Chris Hadfield and the Canadian Space Agency to transport within the Space Shuttle to the International Space Station a sticker bearing the RASC Seal. Commander Hadfield posed for a picture with the Seal in the Cupola and emailed it back to Katrina.

In recognition of Katrina's continuous service to the RASC Toronto Centre, she was awarded the H.A. Winearls Award in 2008 (also called the President's award) for service to the Centre and the Ostrander-Ramsay Award in 2012 for astronomical writing. In 2016, Katrina was honoured by the Ontario government with the 10-year Ontario Volunteer Service Award, a prestigious award granted for her service to the RASC.

Further afield, Katrina enjoys astronomy-themed travel, and has brought other astronomy enthusiasts with her to the Kennedy Space Centre for Space Shuttle launches, the Sudbury Neutrino Observatory, Algonquin Radio Observatory, NEAF (the Northeast Astronomy Forum) and to Australia for OzSky Star Safari, where she has helped many "Northerners" discover the wonders of the southern sky.

Tony Horvatin, on behalf of the Toronto Centre Council
[JSE – She is also one of the three Special Projects Program Trustees.]

Randall Rosenfeld

Eight years ago, Randall Rosenfeld approached the History Committee with a proposal to use materials in the RASC Archives to prepare an exhibit for the 2008 GA of astronomical art and artifacts. Before long, Randall became a member of the History Committee and he agreed to become the Society's archivist in 2008 and chairman of the committee in 2011. His training as a mediaeval scholar gave him credibility in archival practices that no one else on the committee could claim. He produced usage policies and an archive disaster protocol in 2008 that reflected practices of various national archives. When our leadership decided that the Society would no longer maintain its library, it was Randall who managed to save it from oblivion by finding a home for it at the National Museum of Science and Technology. Without question, he is the most productive member of the History Committee and he is an inspiring leader. His ideas for projects that would relate our astronomical history and heritage have included "Canada and the Stars" for IYA2009, a cooperative program among several committees relating to the 2012 transit of Venus, cooperation with CASCA, and so on. He has revolutionized the committee's operation so that it is now a very active one with a much larger membership. With the help of Walter MacDonald, Randall has given the history of the Society, its publications, and archives, an impressive presence on the web that attracts many users. He has successfully encouraged and personally made valuable contributions to our collection; his "reports" for the National Council belie their title since they are more like beautifully composed and illustrated articles. His regular contributions to the Journal are examples of his scholarship and wit, which are widely read and enjoyed. Randall's connections to historians outside the Society have raised our profile as an organization. His ability as a writer has been recognized outside the Society through his prize-winning entries in the Boeing Griffith Observer Writing Contest.

Aside from his expertise as Archivist and chair of the History Committee, Randall has a breadth of understanding of the Society's mandate and operation. One example was very evident in his role as chair of the Membership and Promotion Committee. Whatever Randall undertakes, he carries out with thoughtfulness, thoroughness, and utmost modesty.

Society Past President James Edgar writes that he is the epitome of a member who serves the Society well. He is dedicated, engaged, creative, thorough, and clever. No part of what he does is left to chance—not only is he all of the above, his rapier wit and great humour enlighten whatever challenge he takes on.

As for his accomplishments, he is highly deserving of the Society's Service Award for his dedication to the committees he has worked on or chaired; most recently he chairs the History Committee. In addition, his work as the Society's Archivist is second to none.

Dr. Chris Gainor, Society 1st Vice-President, reports that he has known Randall for the past six years while serving on the History Committee, and enthusiastically agrees that Randall is a strong promoter of the committee and, incidentally, of all its members. He has helped all of us with our work as historians. That's on top of the more than 40 articles he has written about the history of astronomy in Canada and the history of the RASC, along with many speaking engagements.

Randall has also become a strong voice for unattached members of the RASC. While our Society has strong traditions of governance through our Centres, we also have had a durable tradition of unattached members, and Randall has become the most prominent representative of the RASC's unattached members.

As well, Randall spearheaded the RASC's early work on the issue of laser pointers, including liaison work with Transport Canada.

He has also entertained RASC members and others with his own "music of the spheres," based upon the music of William Herschel and other historical astronomers.

Randall was the recipient of the 2012 Simon Newcomb Award, and the RASC's President's Award. Asteroid 283990 was named Randallrosenfeld (2004 SG2) in his honour. He is a member of the Heritage Committee of the Canadian Astronomical Society/Société Canadienne d'Astronomie (CASCA), and is a member of several professional early music ensembles.

To summarize, Randall is a member who has gone above and beyond in his service to the Society. He has leveraged his professional skills to the benefit of the Society in a number of areas, membership and promotion, history and archives, and National Council Representative for unattached members. He is more than deserving of this award.

Dr. Randall Boddam MD, FRCPC, Director
James Edgar, Past President

The RASC Ottawa Centre will be hosting the General Assembly in Ottawa in July 2017. We would be honoured if three of our outstanding members were recognized for their outstanding contribution to the Centre by receiving a National Service Award.

Chris Teron, Ottawa Centre
Gordon Webster, Ottawa Centre President

Simon Hanmer joined the Ottawa Centre and has been a valuable member since 2000. He recently retired from a long career as a senior geologist at the Geological Survey of Canada. In 2013, he was recognized by the Geological Society of Canada for his "sustained dedicated service to the Canadian earth science community" with the prestigious J. Willis Ambrose Medal.

Simon has combined his professional career as a geologist with his interest in astronomy into a passion for the geology of the solar system bodies. Since 2001, he has been one of the Centre's most prolific and popular speakers. He has made 46 presentations to the Centre's monthly meetings on the geology of meteorites, the planets and their moons. A common theme to his talks has been to display the latest stunning images of these bodies from NASA and the ESA and explain the geology in the images in a very scientific and understandable way to the audience. He has documented many of his presentations in articles published on the Centre's web site and in its newsletter, AstroNotes.

The Ottawa Centre has given Simon awards for the Best AstroNotes Article in 2002 and 2003, the Best Presentation to a monthly meeting in 2010 and 2011, and the Ottawa Service Award in 2016.

The members and Council of the Ottawa Centre enthusiastically nominate Simon for a National Service Award.

Geological Society of Canada—J. Willis Ambrose Medal Citation

Simon Hanmer is awarded the Geological Association of Canada's J. Willis Ambrose Medal for his sustained dedicated service to the Canadian Earth Science community. As a senior scientist at the Geological Survey of Canada and GAC Councillor, Dr. Hanmer has been a tireless advocate for Canadian Earth Sciences and has been effective at both scientific and political levels in catalyzing positive change in the community on a national scale.

Simon's vision of productive working relationships among the federal, provincial and territorial geological surveys took form as the Cooperative Geological Mapping Strategies (2000-2003), at a time of decreasing funding for public geoscience at both the federal and local jurisdictional levels. CGMS received widespread support from the community and forged a path for successful national-scale collaborations, including the well-funded Targeted Geoscience Initiatives III and Geo-mapping for Energy and Minerals programs. The success of these programs is a tribute to Simon's premise that working collectively, organizations can achieve more than is possible as individual entities. Although striking in significance, mobilizing public geoscience for the benefit of Canadians is only part of Simon's legacy.

Simon played a lead role in engineering the creation of the Canadian Federation of Earth Sciences. Recognizing that the Canadian Geoscience Council was not achieving its goal of unifying and representing Canadian Earth Science organizations nationally and internationally, Simon used his influence and persuasive logic to generate new enthusiasm and a way forward that became CFES. Simon's leadership in defining and achieving collective goals has guided the community to a sustainable position of strength.

In a still higher sphere of influence, Simon served as GAC representative on the Partnership Group for Science and

Engineering, which speaks for 50,000 Canadian scientists and engineers. Recognizing Simon's leadership abilities, PAGSE appointed Simon as Chair, during which time he contributed to building stronger science-policy linkages among national science and engineering organizations, industry and government.

Most recently, Simon led the successful delivery of the 2011 Ottawa GAC-MAC annual meeting in his capacity as General Chair. The extraordinary success of this event in terms of participation, sponsorship, and media coverage was largely due to Simon's indefatigable drive and enthusiasm to inspire volunteer efforts from the entire community.

The Earth Science community is in a more robust position today as a result of Simon's dedicated efforts in both stimulating collaborative approaches, and informing decision-makers about the relevance and importance of our science. Because of all of the above, we enthusiastically submit to the GAC that Dr. Hanmer is most deserving of the J. Willis Ambrose Medal.

Michael Moghadam

Mike joined the Ottawa Centre in 2003 and immediately started to make his mark in the field of public education and outreach. While he held the formal role of Outreach Director in 2009-2011, he has been the driving force in outreach for over a decade. His work includes the public star parties every month in summer held at the Carp Public Library / Diefenbunker and routinely attended by hundreds of interested public. He has organized astronomy workshops for members and the public, the Centre's participation in Natural Resources Canada's Science FunFest, the International Year of Astronomy events in 2009. Recently, he co-organized the daytime Transit of Venus event on Parliament Hill with federal Science Minister Kirsty Duncan, Transport Minister Marc Garneau, and 2,500 other people attending.

In addition to his outreach work, Mike served as Meeting Chair in 2014-2015 and successfully brought in many external guest speakers. He was just elected as Vice President for 2017.

The Ottawa Centre would be honoured if Mike's contributions to the Centre were recognized with a National Service Award.

Charles O'Dale

Chuck likes to show his long involvement in the Ottawa Centre by showing his young face in the group photo from the 1973 General Assembly in Ottawa, and most GAs in Ottawa since.

Chuck has served the Ottawa Centre as Meeting Chair in 2005-2006, President in 2007-2008, National Council Representative in 2009-2011, SmartScope Director in 2011, and Webmaster from 2012 to now.

Notwithstanding these important roles, Ottawa members know Chuck best for a different reason. Chuck loves to combine his three hobbies of astronomy, flying and geology into one, which he titles as "Big Holes in the Ground". He has flown his small plane (C-GOZM or GO ZooM) to almost every meteorite crater in Canada from east to west to the high Arctic, as well as many in the US and as far south as Arecibo in Puerto Rico. He has documented his aerial and ground explorations, the science and the identification of these craters (and craters-not) in 43 presentations to monthly meetings in Ottawa since 2001, on the Centre's web site and in numerous articles in AstroNotes. He likes to finish his talks with a favourite quote from Isaac Asimov – "How bright and beautiful a comet is as it flies past our planet … provided it does fly PAST it."

Brian Pihak is the one who introduced me to the RASC back in 1999. His passion and enthusiasm for astronomy was captivating. I inquired about a round chunk of glass sitting on a shelf at his office and he explained all about the telescope he was going to build. The outreach began… He encouraged me to come out to a meeting that night. I've been a member ever since. Brian has been a friend since the early 80s but astronomy has made us really great friends. He is a mentor to all our members, his memory is amazing and his will to teach people of all ages never stops. In his 23 years in the RASC Brian has held most positions on our executive, serving as National Representative and on many more committees. He and Stan Sammy swapped the roles of Vice-President and President so many times in the 2000s that I lost count.

Brian and Stan have taught a great number of grade 6 astronomy lessons at schools across the region, many public star nights, and given audio/video presentations to Scouts, Girl Guides, the Niagara Parks Commission, Heartland Forest, multiple museums, and more groups and clubs. Brian's ability to create a new Powerpoint presentation with only a few hours' notice is legendary. With every slide comes facts, more facts and humour. His ability to deliver it clearly to all age groups is beautiful to watch and admire. Even our cloudy public starnights are a success because of Brian's talks. We in the Niagara Centre are lucky to have such a dedicated and devoted member like Dr. Brian Pihack.

Stan Sammy joined the Niagara Centre in 2000. Some of his co-workers were members and convinced him to join the club. Stan is a quick learner, an avid photographer and a very devoted member. He jumped in with both feet and became an executive member within a few years. His retirement hobby became a passion and he wanted to share it with others. That's where Stan began with outreach, and he organized various public events, created flyers and brochures, ran workshops, and has gone to many schools and clubs for A/V presentations.

Stan has held various roles with the Niagara Centre, including Public Events Coordinator, President and Vice President. Stan is a joy to be around and has also become a great friend.

Brian and Stan are two outstanding gentlemen, they are true ambassadors for the RASC and the Niagara Centre. Their outreach in teaching and recruitment for the club and the understanding of astronomy and science is a force to contend with. They are wonderful role models for all.

Stan Sammy and Brian Pihack deserve this recognition, not just because of how much work they do, but because they both excel at it and they love to do it. With or without an award, what they do is important to them. They have always exceeded the expectations of the board and general membership at everything they do for the club. They are knowledgeable and passionate about the hobby and are the best ambassadors that any club could ask for. Nothing is ever "half done". They have never wavered from their commitments even when dealing with issues that have happened in their lives outside of the club. It has been a complete and utter pleasure participating on the Board with them and we look forward to continuing that relationship in the years to come.

Dan Frigault and members of the Niagara Centre

Gerry Smerchanski is a bit of a legend around Southern Manitoba for his indefatigable efforts to spread a love of astronomy within the community. He does so largely unheralded: most of the presentations that he makes in the schools and to community groups are largely unknown to the Winnipeg Centre except by rumour, comment from the public, or from other members who helped him out. That those community efforts are widespread and numerous is apparent from the comments we receive and the reputation he enjoys within the community and local media.

Gerry's forte is his Binocular Sky Tour in which he leads the audience through the night's astronomical delights using an encyclopedic knowledge of star names, constellations, and stories and equipped with nothing more than a laser pointer and a small binocular. Broken cloud? Not a problem, as he dives between the gaps to point out treasures in the minutes they are visible. The beauty of his tours is not as much his knowledge, but the way that he helps everyone to understand that you do not need expensive equipment, only the binoculars you probably already own. Many new members to RASC can be directly attributed to his Bino tours while many others have an ongoing and greater appreciation of the night sky and our galaxy.

Gerry has a charming presentation manner, which combined with his 6-foot-plus stature, hippy locks, and absent-minded professor look, disarms the audience before he leads them through the skyways to a new experience in night viewing. He has an answer for every question from the audience that not only helps them to understand astronomy, but also diverts him and them down other entertaining pathways.

Gerry is a frequent contributor to Winnipeg Centre meetings with his participation in the Beginner's Sessions that start each of our monthly gatherings. He is a stalwart at public presentations at Spruce Woods Provincial Park, at Bird's Hill Park, and at the Nature Conservancy site south of Winnipeg. He has been a member of the team from the Winnipeg Centre helping Riding Mountain National Park, Spruce Woods Park, and the Nature Conservancy's Weston Family Tall Grass Prairie Interpretive Centre obtain Dark Sky status, projects that will soon be implemented. As a result of the efforts of Gerry and others from the Centre, Spruce Woods now has a telescope to use and a dedicated student astronomer to teach about astronomy during the summer season.

Gerry seldom talks about himself and his activities unless pressed and then only minimally. He is a favourite son of the Winnipeg Centre, never without a moment to help with a problem, or share an amusing anecdote, or consume a jug of beer. We are pleased to submit his name on behalf of the Winnipeg Centre.

Jay Anderson
Dennis Lyons

Simon Newcomb Award

Ivan Semeniuk

A member of the Toronto Centre since 1988, Ivan Semeniuk received his BSc in physics and astronomy from the University of Toronto. He joined the staff of the Ontario Science Centre in 1986 where he developed exhibits and programs and oversaw the centre's planetarium. When the McLaughlin Planetarium was closed in 1995, he facilitated the Toronto Centre's move to the OSC, where member meetings were held regularly for the next 20 years. He became a Life Member of the Society and served on Toronto Centre Council as 2nd Vice-President from 1996 to 1997.

Ivan earned his Master's degree in Science Journalism at Boston University in 1999 and became a producer and columnist for Discovery Channel, Canada. In 2005, he moved to the USA as US Bureau Chief for New Scientist magazine and in 2007 was named a Knight Fellow in Science Journalism at the Massachusetts Institute of Technology. He was Journalist-in-Residence at the Dunlap Institute of the University of Toronto from 2008 to 2010. After working as Chief of Correspondents at the US offices of Nature from 2010 to 2012, he moved back to Canada to become the science reporter for the Globe and Mail in 2013. He has also pursued a career as a freelance science writer, journalist and broadcaster, producing many print, radio and TV works, including the 30-episode TV series Cosmic Vistas.

He has received a Gemini nomination and two other film awards. In 2016 he was named the recipient of the prestigious Sandford Fleming Medal by the Royal Canadian Institute.

[A sampling of Ivan Semeniuk's print articles on astronomy is attached.] The Toronto Centre strongly believes that Ivan Semeniuk's accomplishments as a science journalist qualifies him as a worthy recipient of the Simon Newcomb Award.

Dr. Ralph Chou, Toronto Centre President
Tony Horvation, Toronto Centre 1st Past President

QILAK Award

Paul Heath has been a member of the Halifax Centre for 17 years. Many of those years have also included an active role on the Centre executive committee, and full engagement in all Centre activities. But his astronomy outreach has a history that goes back well before he joined the RASC. Starting in the late 1960s Paul was showing friends and family the moon through his small telescope. Then, from 1989 – 2004, came 15 years as a Scout leader, where he developed and regularly presented astronomy programs for the Boy Scout groups in his local area. He joined the RASC in 1999, became actively involved, and by 2009 he was fully involved with a dedicated focus on education and outreach.

Paul's contributions to astronomy communications and educational outreach are truly remarkable. His outreach work is characterized not only by the number of events and people that are reached, but also by the broad range of topics, venues, and audience types with which he interacts. It is both formal and informal, in classrooms, the planetarium, libraries, youth groups, star parties, parks, campgrounds, trade shows, media interviews, and other venues. As a school bus driver, he also used his school bus to engage and educate his daily riders about upcoming astronomical events, to challenge them to investigate relevant topics, and to encourage them to view special astronomical events. He works with children of all ages, as well as adults. Using everyday materials, he has developed many unique, hands-on demonstrations, and numerous engaging presentations to bring the subject alive for his audiences.

Not only does Paul do an enormous amount of outreach himself, but he also coordinates the outreach activities of the Halifax Centre. Phone, web, and email requests come in from all over Nova Scotia. Paul answers them, searches out, supports and organizes volunteers, and then picks up the slack when volunteer response is a bit thin on the ground. He is the outreach go-to guy in the Halifax Centre.

In just ten months this year (January through October, 2016), Paul has lead and/or participated in 29 outreach events attended by 526 youth and 2251 adults. Scaled up to a full year, that's about 3000 people per year, being introduced to the universe by Paul Heath. And he's been doing outreach at that scale for several years. We do not have complete numbers. Paul is too busy doing outreach to remember to record and track all the events, hours and participants. We can't keep up with him! With only incomplete numbers available, Paul has averaged 1500 people per year for six years running. We know the true numbers are higher than this. Every year the numbers keep getting larger, climbing to three thousand in 2016! Attached is a summary of Paul's outreach for 2016, with brief descriptions of each event, to illustrate the breadth and scope of his outstanding contributions.

In summary, we believe Paul Heath is highly deserving of the Qilak Award for Astronomy Education and Communication. His energy, creativity, and dedication are remarkable. The breadth and scope of his presentations, and his ability to engage people of all ages, is striking. Carried by a passion for the night sky, Paul Heath is an astronomy outreach force unto itself. Every year, thousands of people benefit from his expertise and effort. His extraordinary contributions deserve to be recognized with the 2017 Qilak Award.

Respectfully submitted,

Paul Gray, President, Halifax Centre

Judy Black, Secretary

Mary Lou Whitehorne, FRASC, Past President, RASC

Roy Bishop, FRASC, Past President, RASC

Dave Chapman, 1st Vice-President

Ian Anderson, 2nd Vice-President

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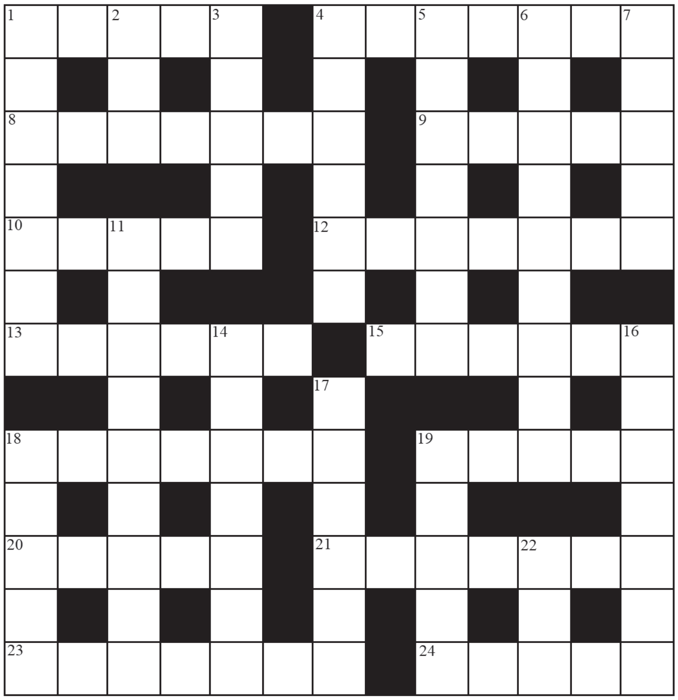
Astrocryptic

by Curt Nason



ACROSS

1. Planet discoverer involved in legal mix-up (5)
4. His nearby star is likely found in key area to the north (7)
8. Latvian capital palace transformed by a celestial mechanic (7)
9. Nodes disrupted electromagnetic waves in France (5)
10. Daily rotation of an asteroid (5)
12. Latin transposed into English for the dragon's eye (7)
13. Comet discoverer best known for his two physicians, I hear (6)
15. Do you know a cup from a hole in the ground? (6)
18. Unearthly spheroid spins port ale (7)
19. First named astronomy historian spent ages around the pole (5)
20. Pass out fuzzy sky companion (5)
21. It follows old iridium boundary sporting casual top of impact glass (7)
23. Desert area around Kitt Peak Observatory (7)
24. Mislabel his cluster of galaxies (5)

DOWN

1. Guy's date discovered Io around the French telescope maker (7)
2. Crater's top detected in mid-eclipse (3)
3. The Spanish altar seen around Jupiter (5)
4. Ring gap seen stretching from Carina to part of Eridanus (6)
5. Richard or Mary gives oversight in the examination room (7)
6. Astrophysicist misinterpreted odd tinge to Neptune (9)
7. N as in November returns another month (5)
11. John and Ian make a popular telescope (9)
14. Creator destroyed by the Sun's core, essentially (7)
16. Astronomer implicated Superman in ruse to meet Lex Luther (7)
17. New England town drunk is a force in physics (6)
18. Gently blows off gas or smokes (5)
19. New kid starter in Triple A is a star in Phoenix (5)
22. Kuiper Belt component as described in Nice model (3)

Answers to August's puzzle

ACROSS

METONIC (anag); **5** SAROS (s(ARO)s); **8** EMEND (anag, a=n); **9** RAINIER (homophone); **10** SAMPSON (s(anag)on); **11** DISCH (hom); **12** HALLEY (H(all)ey); **14** HELIUM (2 def); **17** TOTAL (t(OTA)l); **19** WILHELM (Wil(he)l+m); **22** ELLIPSE (E(anag)E); **23** GLOAR (anag, l=r); **24** THYME (anag+e); **25** ESPENAK (hom)

DOWN

1 MEEUS (re(EE)v); **2** THERMAL (anag); **3** NODES (N+anag);**4** CORONA (2 def); **5** SPINDLE (ana(dl)g); **6** RAILS (R(AI)LS); **7** SORGHUM (s(anag)m); **12** HOTTEST (hot test); **13** ECLIPSE (an(L)ag); **15** ICE MOON (anag-e); **16** TWO EYE (2 def); **18** TULLY (2 def); **20** LEG UP (Le(gu)p); **2** MERAK (M(rev)K)

It's Not All Sirius

by Ted Dunphy

"The Nebraskan Corn Moon Caper"

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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Observer's Calendar
Paul Gray, Halifax

Great Images

by James Edgar

Journal Production Manager and past RASC President James Edgar captured Venus and the Moon shining brightly below the Pleiades over the lights of Melville, Saskatchewan, on a cool March evening in 2007. He used his then-new Canon EOS 20D for 1/10 sec at ISO 800, with the 18–55-mm kit lens at ƒ/3.5.

Journal

Great Images

Perseids / Alan Dyer

A composite of the Perseid meteors over Dinosaur Provincial Park on the night of August 12/13. A faint aurora is on the northern horizon at left. The meteors are accumulated over three hours—recording 14 meteors extracted from a total of 645 images. One meteor obligingly appeared at centre that was particularly bright and left a long-lasting "smoke" train. The Double Cluster in Perseus is the diffuse spot at centre near the radiant.

This is a composite of a single image for the ground and sky taken as the start of the sequence, layered with 14 other images of meteors taken over 3 hours, masked to reveal just the meteor. The camera was on a Sky-Watcher Star Adventurer Mini tracking device to follow the sky, so the stars in each frame remained in alignment throughout the three hours of shooting. So the meteors are in their accurate places in the sky relative to the background sky, retaining the effect of the radiant point in Perseus at centre.

However, the composite is a bit of a cheat in that the waning Moon rose about 30 minutes after the sequence of 645 frames started, brightening the sky a lot. So most of the meteor images had to be colour adjusted to make them blend into the "start-of-the-night" dark sky background well. The shower was not so active that this many meteors were visible during the brief hour or so of dark sky this night before moonrise. Thus the image is not a realistic depiction of the night, but serves as an illustration of the shower radiant over a scenic landscape with the aurora a bonus.

Each image was 15 seconds at ƒ/2.2 with the Sigma 20-mm Art lens and Nikon D750 at ISO 3200.