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Journal

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PROMOTING ASTRONOMY IN CANADA

October/octobre 2019
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Inside this issue:

Scorpius's stinging tail

The Best of Monochrome.

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

Michael Boschat photographed the Moon using an ETX90 + Canon XSI at prime focus. The image was taken at 1/25 of a second, at 400 ISO. Finally, two images were stacked in Registax.

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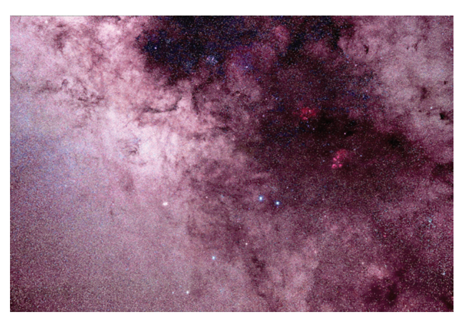

Klaus Brasch imaged the centre of Scorpius's tail from Wupatki National Park. This was the first test of his new 135 mm lens, made by Zhong Yi Optics. Klaus says, "This is a stack of 2 x 1-minute exposures at f/4 and ISO 6400 with a modified Canon 6D. The Crab and Cat's Paw nebulae are visible along with a lot of dust, dark nebulae, and a mind-boggling number of stars."

Journal

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

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President's Corner

by Chris Gainor, Ph.D., Victoria Centre (cgainor@shaw.ca)

There were two exciting announcements at our 2019 General Assembly in Toronto in June that show how fundraising is paying off in the form of new services for our members and for everyone in Canada who is interested in astronomy.

First, we heard from Dr. Allan Carswell, a renowned physicist who developed LiDAR systems and applications for airborne surveying, 3-D imaging, atmospheric measurements, and space systems. As president of the Carswell Family Foundation, Dr. Carswell announced that the foundation will provide funding of $100,000 a year for three years to the RASC for astronomy education and outreach.

This grant allows the RASC to engage a marketing and communications coordinator to provide vital support for Centre and national astronomy initiatives. The funding is matched, meaning RASC must raise an additional $100,000, which will have the effect of doubling the value of this generous gift.

The following day, RASC Kitchener-Waterloo member Rudolph Dorner pledged a $1.5 million bequest to establish the Dorner Telescope Museum. The museum's mission will be to showcase the remarkable and largely unknown story of astronomical optics in Canada by forming an institution to "tell the story" of the instruments, their makers, and their users.

Mr. Dorner envisions an artefact-rich museum that will offer a robust interactive aspect to visitors. Randall Rosenfeld has been named Director, and he will use bridging funding being provided by Mr. Dorner to set up the museum.

We have also been raising funds from many members to support our Robotic Telescope Project. We are looking forward to getting that telescope fully on-line soon.

The best news is that there are more donations coming in, and I look forward to more news about new initiatives in astronomy supported by donations.

We on the Board of the RASC want to establish our Society as the go-to place for astronomy in Canada. Many of our members are prepared to give financial support to programs that boost astronomy, and our challenge in the RASC is to reinvigorate our current services and create new ones that will appeal to Canadians of all ages and backgrounds.

None of these plans are possible without a solid grounding of sustainability. And that's where fundraising comes in.

I would like to thank our excellent fundraiser, Lisa Di Veto, who has been working with us for the past two years to turn our hopes for fundraising into reality. Above all, I also thank those members who are stepping forward and making donations large and small to help the RASC in its work of promoting astronomy to all. ✶

News Notes / En manchette

Compiled by Jay Anderson

Rings of Uranus glow at microwave and infrared wavelengths

The rings of Uranus are invisible to all but the largest telescopes—they weren't even discovered until 1977—but they stand out as surprisingly bright in new images of the planet taken by the Atacama Large Millimetre/submillimetre Array (ALMA) and the four-telescope Very Large Telescope (VLT) in Chile. ALMA observed the ring system at 3.1-, 2.1-, and 1.3-mm wavelengths, while the VLT conducted measurements in the mid-infrared (18.7-mm) band. All of these wavelengths detected radiation emitted by the rings in contrast to observations at shorter (visible) frequencies that show only reflected sunlight.

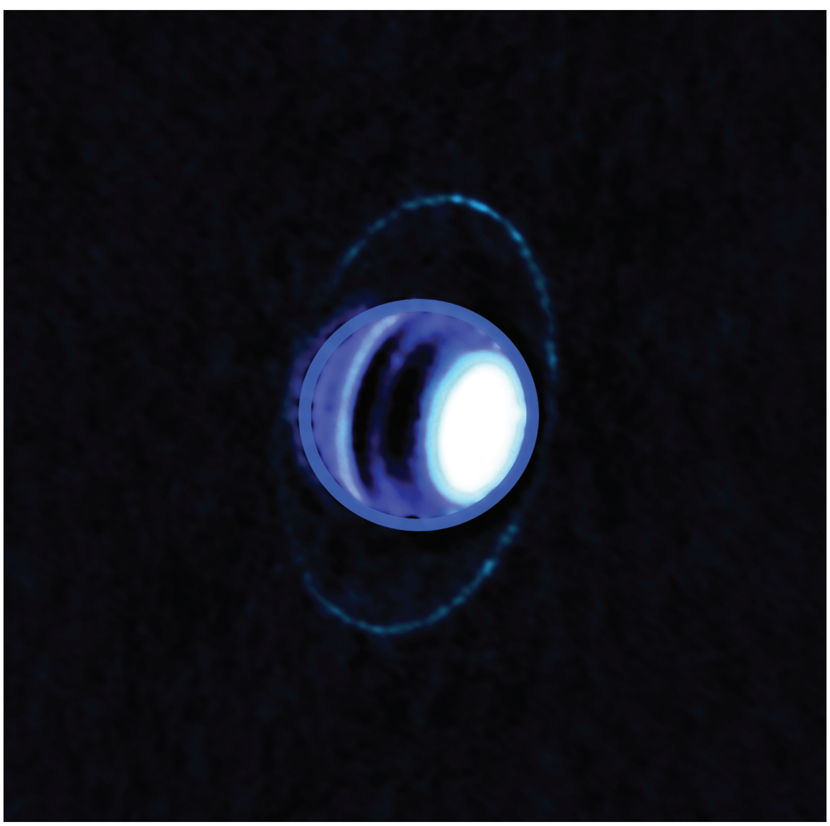
The new images taken by ALMA and the Very Large Telescope (VLT) allowed the team to measure the temperature of the rings: a cool 77.3 ±1.8 K (kelvin), or 77 degrees above absolute zero—the boiling temperature of liquid nitrogen and equivalent to 195 degrees below zero Celsius.

The observations also confirm that Uranus's brightest and densest ring, called the epsilon ring, differs from the other known ring systems within the Solar System, in particular the spectacularly beautiful rings of Saturn.

"Saturn's mainly icy rings are broad, bright, and have a range of particle sizes, from micron-sized dust in the innermost D ring, to tens of metres in size in the main rings," said Imke de Pater, a UC Berkeley professor of astronomy. The new observations show that the main rings of Uranus are composed of centimetre- to metre-sized particles, with a very small or nonexistent dust component.

By comparison, Jupiter's rings contain mostly small, micron-sized particles. Neptune's rings are also mostly dust, and even Uranus has broad sheets of dust between its narrow main rings.

"We already know that the epsilon ring is a bit weird, because we don't see the smaller stuff," said graduate student Edward Molter. "Something has been sweeping the smaller stuff out, or it's all glomming together. We just don't know. This is a step toward understanding their composition and whether all of the rings came from the same source material, or are different for each ring."



De Pater and Molter led the ALMA observations, while Michael Roman and Leigh Fletcher from the University of Leicester in the United Kingdom led the VLT observations.

"The rings of Uranus are compositionally different from Saturn's main ring, in the sense that in optical and infrared, the albedo is much lower: they are really dark, like charcoal," Molter said. "They are also extremely narrow compared to the rings of Saturn. The widest, the epsilon ring, varies from 20 to 100 kilometres wide, whereas Saturn's are hundreds or tens of thousands of kilometres

Figure 1 — Composite image of Uranus's atmosphere and rings at radio wavelengths, taken with the ALMA array in December 2017. The image shows thermal emission, or heat, from the rings of Uranus. Dark bands in Uranus's atmosphere at these wavelengths show the presence of molecules that absorb radio waves, in particular hydrogen sulfide gas. Bright regions like the north polar spot (yellow spot at right, because Uranus is tipped on its side) contain very few of these molecules. Credit: Edward Molter and Imke de Pater/ UC Berkeley.

wide." The new work also confirmed that the epsilon ring is two to three times brighter at apoapsis than at periapsis (farthest and closest points to the planet).

The lack of dust-sized particles in Uranus's main rings was first noted when *Voyager 2* flew by the planet in 1986 and photographed them. The spacecraft was unable to measure the temperature of the rings, however. To date, astronomers have counted a total of 13 rings around the planet, with some bands of dust between the rings. The rings differ in other ways from those of Saturn.

"It's cool that we can even do this with the instruments we have," Molter said. "I was just trying to image the planet as best I could and I saw the rings. It was amazing."

Both the VLT and ALMA observations were designed to explore the temperature structure of Uranus's atmosphere, with VLT probing shorter wavelengths than ALMA.

"We were astonished to see the rings jump out clearly when we reduced the data for the first time," Fletcher said.

This presents an exciting opportunity for the upcoming *James Webb Space Telescope*, which will be able provide vastly improved spectroscopic constraints on the Uranian rings in the coming decade.

Composed in part with content provided by ALMA.

Early Universe revealed in ancient star

Ultra-metal-poor stars are believed to be offspring of the first generation of stars formed after the Big Bang. They are rare objects, typically containing iron abundances in which the [Fe/H] ratio (iron to hydrogen) is lower than -5 (that is, 10^{-5} of the Sun's ratio), and are hypothesized to have formed from the debris ejected in supernovae by the very first stars (Population III). These original stars, now long since disappeared, were composed only of hydrogen, helium, and a small amount of lithium, the first elements in the young Universe. During their lifetime, Population III stars manufactured heavier elements in the fusion reactions in their cores and in the heat and pressure of a supernova eruption. These primeval fusion products enriched the stellar environment and were then incorporated into the next generation of stars.

Because Population III stars are no longer with us, traces of their existence can only be found in the next generation of stars, which will be characterized by low iron abundances, the last of the elements formed by fusion processes before a star becomes a supernova. Low-iron-abundance stars are sought-after targets for their ability to reveal the personality of their Population III progenitors.

In a paper published in the journal *Monthly Notices of the Royal Astronomical Society: Letters*, researchers led by Dr. Thomas Nordlander of the ARC Centre of Excellence for All Sky

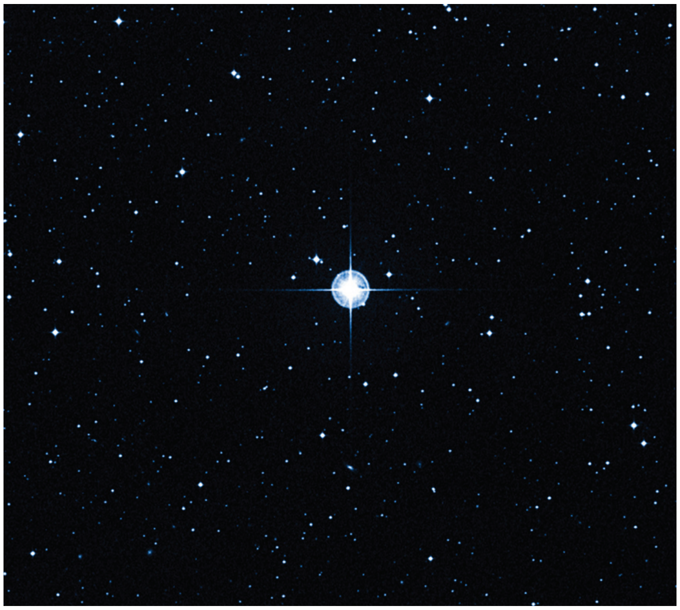


Figure 2 — Digitized Sky Survey image of the oldest star with a well-determined age in our galaxy. The aging star, catalogued as HD 140283 (informally named the Methuselah star), lies 190.1 light-years away at magnitude 7.2. HD140283 has a metal content that is a factor of 250 lower than the Sun. It is one of the closest Population II stars to Earth.The Anglo-Australian Observatory (AAO) UK Schmidt telescope photographed the star in blue light. Credit: Digitized Sky Survey (DSS), STScI/AURA, Palomar/Caltech, and UKSTU/AAO

Astrophysics in 3 Dimensions (ASTRO 3-D) reported the discovery of an ultra-metal-poor red-giant star, located in the halo of the Milky Way, on the other side of the galaxy about 35,000 light-years from Earth. The new star, SMSS 1605–1443, a red-giant-branch star with an effective temperature of about 4850 K, has a remarkably low abundance of heavier elements, including an extremely low amount of iron at an abundance level of -6.2 (that is, one part in 50 billion of the Sun's iron content). Its diminutive iron content is enough to place the star into the record books, but it is what that low level implies about its origin that has the astronomers really excited.

As none of the first stars have yet been found, their properties remain hypothetical. They were long expected to have been incredibly massive, perhaps hundreds of times more massive than the Sun, and to have exploded in incredibly energetic supernovae known as hypernovae. The confirmation of the anemic SMSS 1605–1443, although itself not one of the first stars, now modifies this view of Population III stars.

Dr. Nordlander and colleagues suggest that the star was formed after one of the first stars exploded. That exploding star is found to have been rather unimpressive, just ten times more massive than the Sun, and to have exploded only feebly (by astronomical scales) so that most of the heavy elements created in the supernova fell back onto the neutron star left behind.

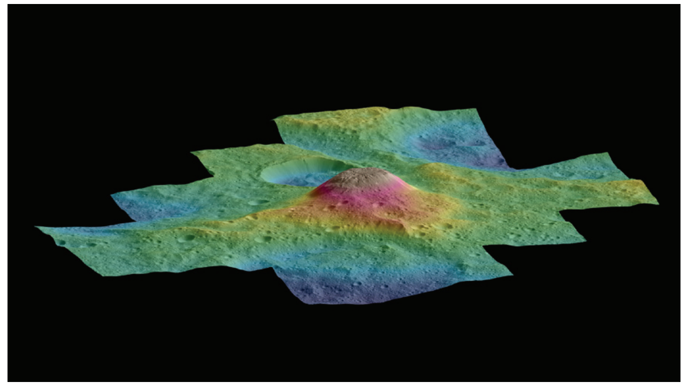


Figure 3 — Elevation map of Ahuna Mons on Ceres, with colors representing different heights above the average. Ahuna Mons is 4 km high. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

Only a small amount of newly forged iron escaped the remnant's gravitational pull and went on, in concert with far larger amounts of lighter elements, to form a new star—one of the very first second generation stars and one that has now been discovered.

These fallback supernovae, in which heavier elements are not ejected but lighter ones escape, can explain the high carbon abundance of the newly discovered star and the lack of other, heavier, elements. Models of supernova processes computed to mimic the abundances in SMSS 1605–1443 show a good fit for stars of about 10 solar masses with low explosion energy. Stars heavier than 20 solar masses are incompatible with the observed metal abundances.

"Population III stars exploding as fallback supernovae may explain both the strong carbon enhancement and the apparent lack of enhancement of odd-Z and neutron-capture element abundances," the astronomers noted.

In concluding remarks, the researchers underlined that SMSS 1605–1443 has the lowest metallicity among the stars for which iron has been detected, exhibits carbon overabundance, and that it does not show strong enhancement nor a strong abundance trend among elements heavier than carbon. Further observations of this star, studying higher-quality spectra, could deliver more detailed chemical analysis, which could provide more hints into the nature of its Population III progenitor star.

The study was conducted in collaboration with researchers from Monash University and the University of New South Wales in Australia, the Massachusetts Institute of Technology and Joint Institute for Nuclear Astrophysics, both in the U.S., the Max Planck Institute for Astronomy in Germany, Uppsala University in Sweden, and the University of Padova in Italy.

Compiled in part with material provided by the Australian National University.

Mud Volcano on Ceres

Asteroids, even large ones, were believed to be rather uninteresting, beat-up bodies in the Solar System, so it was quite a surprise when images from the *Dawn* spacecraft revealed some unique structures on the crater-strewn surface of Ceres. One of these was a cone-shaped, smooth-sided mountain sticking out of the side of the asteroid, towering 4000 metres above the surrounding surface. Now named Ahuna Mons (after the traditional post-harvest festival *Ahuna* of the Sumi Naga people of India), it was recognized from the start as a volcanic dome, formed when thick molten material squeezes upward through the crust to form a bulge on the surface of a planetary body. Ahuna Mons is one of the most unusual features in the Solar System.

The interior of Ceres is partially differentiated, which means that its internal constituents became segregated and separated when it was forming and still hot. Components with a higher proportion of heavy elements, such as magnesium and iron, sank into the centre of the body, while lighter components, like rocks with a high aluminum silicate or water content, rose. A 40-km-thick crust formed on top of a 400-km-deep mantle. Heat generated by the decay of radioactive elements may keep the mantle partially liquid. The lowest and warmest part of the mantle will gradually overturn, exchanging places with the cooler upper parts. This warm mantle material presses against the underside of the crust, occasionally escaping to the surface through cracks and weak spots.

When the *Dawn* mission arrived at Ceres, it captured views of these extraordinary, almost snow-white spots on the dwarf planet's surface. The escaping aqueous solutions had frozen in temperatures of around –100 ˚C, leaving a white, briny footprint on the ground.

But how did enough material collect to form Ahuna Mons?

A study involving scientists led by Ottaviano Ruesch (European Space Agency, European Space and Technology Centre), Antonio Genova (Massachusetts Institute of Technology and Sapienza Università di Roma), and Wladimir Neumann (German Aerospace Centre (DLR)) has now proposed a solution to this mystery. Using variations in the orbit of *Dawn*, the research team was able to map the gravitational pull of the underlying surface, finding areas of high and low gravity that gave clues to the underlying structure. Computer modelling revealed a 30-km-deep plume composed of a mixture of saltwater, mud, and rock beneath Ahuna Mons, pushing the ice-rich crust upward. At a structural weak point, the muddy substance of salts and hydrogenated silicates flowed onto the surface and solidified in the cold of space, piling up to form a mountain. In effect, Ahuna Mons is an enormous mud volcano. With a base area of 20 km in diameter and heights of 4000 to 5000 metres above the surrounding area, Ahuna Mons has similar dimensions to Mont Blanc, the highest peak in the Alps.

"In this region, the interior of Ceres is not solid and rigid, but moving and at least partially fluid," explains Neumann. "This 'bubble' that formed in the mantle of Ceres beneath Ahuna Mons is a mixture of saline water and rock components." The scientists are working on the assumption that up to a quarter of the mass of Ceres is ice or water—an even higher proportion than Earth's reserves of freshwater and ice.

"In order to explain the origin of Ahuna Mons, we had to use a new geophysical model that was specially tailored to Ceres, and thus get at the 'hidden' information behind the data from the space probe," explains Antonio Genova. Ottaviano Ruesch, the lead author of the study, adds, "We were thrilled to be able to find out which process occurring in Ceres' mantle, just beneath Ahuna Mons, was responsible for bringing material to the surface."

Cryovolcanic activity is widespread in the outer Solar System. Traces of similar volcanic activity have been discovered on moons of Jupiter and Saturn, while some structures on Pluto also appear to have been formed in this way. Ceres is the first body in the asteroid belt where this type of extrusion has been observed. Unlike Jupiter's moons Europa and Ganymede, or Saturn's moon Enceladus, where water is compressed on the surface, the "magma" in the rising bubble on Ceres is composed of a mixture of saline water and mud or rock particles. The result of the study shows that large asteroids or dwarf planets that are made of siliceous rock and ice can form bubbles of saline water and rock constituents within their interior, which can rise to the surface and escape there. Scientists assume that this process may take place in these bodies over long periods of time, possibly billions of years, creating cryovolcanoes on the surface.

Composed in part from material provided by the German Aerospace Centre and by ESA.

Unique infrared light signature on Neptune's moon Triton

Triton orbits Neptune, the eighth planet from the Sun, some 4.3 billion kilometres from Earth, at the cold fringe of the Solar System's major planets. Surface temperatures hover near absolute zero, so low that common compounds we know as

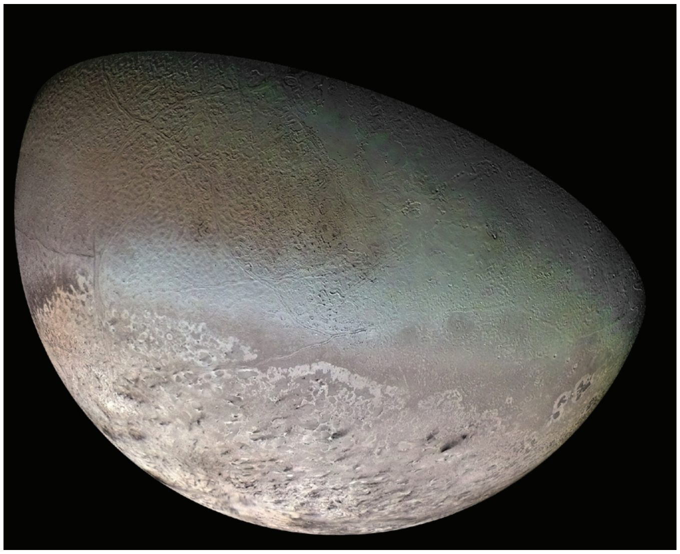


Figure 4 — Global colour mosaic of Triton, taken in 1989 by Voyager 2 *during its flyby of the Neptune system. Triton is one of only three objects in the Solar System known to have a nitrogen-dominated atmosphere (the others are Earth and Saturn's giant moon, Titan). Triton has the coldest surface known anywhere in the Solar System; most of Triton's nitrogen is condensed as frost. The pinkish deposits constitute a vast south polar cap believed to contain methane ice, which would have reacted under sunlight to form pink or red compounds. The dark streaks overlying these pink ices are believed to be an icy and perhaps carbonaceous dust deposited from huge geyser-like plumes, some of which were found to be active during the* ***Voyager 2*** *flyby. The bluish-green band visible in this image extends all the way around Triton near the equator; it may consist of relatively fresh nitrogen frost deposits. The greenish areas include what is called the cantaloupe terrain, whose origin is unknown, and a set of "cryovolcanic" landscapes apparently produced by icy-cold liquids (now frozen) erupted from Triton's interior. Image: NASA.*

gases on Earth freeze into ices. Triton's atmosphere, which is 70,000 times less dense than Earth's, is composed of nitrogen, methane, and carbon monoxide.

A situation in which photons of appropriate energy excite molecules and atoms is commonly seen in the laboratory or in astronomical spectra; occasionally a single photon may excite two or more vibrational modes (for example, a bend and a stretch) in a molecule. Less common is when a single photon excites two adjacent molecules in ice, a process that has now been identified on Neptune's largest moon, Triton. The relevant wavelength of the photon involved in the multiple $CO\text{-}N_2$ excitation was identified in the laboratory at 2.238 mm in the infrared.

The research team then used the 8-metre Gemini South Telescope in Chile to search for that infrared wavelength on Triton. The discovery, recently published in the *Astronomical Journal*, offers insights into how this volatile mixture can transport material across the moon's surface via geysers, trigger seasonal atmospheric changes, and provide a context for conditions on other distant, icy worlds.

"While the icy spectral fingerprint we uncovered was entirely reasonable, especially as this combination of ices can be created in the lab, pinpointing this specific wavelength of infrared light on another world is unprecedented," said NAU professor Stephen Tegler, who led the study, collaborating with Will Grundy and Jennifer Hanley of Lowell Observatory.

In the Earth's atmosphere, carbon monoxide and nitrogen molecules exist as gases, not ices. On distant Triton, however, carbon monoxide and nitrogen freeze solid as ices. They can form their own independent ices or can condense together in the icy mix detected in the Gemini data. This icy mix could be involved in Triton's iconic geysers first seen in *Voyager 2* spacecraft images as dark, windblown streaks on the surface of the distant, icy moon.

Looking ahead, the researchers expect these findings will shed light on the composition of ices on other distant worlds beyond Neptune. Astronomers have suspected that the mixing of carbon monoxide and nitrogen ice exists not only on Triton, but also on Pluto, where the *New Horizons* spacecraft found the two ices coexisting. This Gemini finding is the first direct spectroscopic evidence of these ices mixing and absorbing this type of light on either world.

The *Voyager 2* spacecraft first captured Triton's geysers in action in the moon's south polar region back in 1989. Since then, theories have focused on an internal ocean as one possible source of erupted material. Or, the geysers may erupt when the summertime Sun heats this thin layer of volatile ice on Triton's surface, potentially involving the mixed carbon monoxide and nitrogen ice revealed by the Gemini observation. That ice mixture could also migrate around the surface of Triton in response to seasonally varying patterns of sunlight.

"Despite Triton's distance from the Sun and the cold temperatures, the weak sunlight is enough to drive strong seasonal changes on Triton's surface and atmosphere," adds Henry Roe, Deputy Director of Gemini and a member of the research team. "This work demonstrates the power of combining laboratory studies with telescope observations to understand complex planetary processes in alien environments so different from what we encounter every day here on Earth."

Seasons progress slowly on Triton, as Neptune takes 165 Earth years to orbit the Sun. A season on Triton lasts a little over 40 years; Triton passed its southern summer solstice mark in 2000, leaving about 20 more years to conduct further research before its autumn begins. ✶

Compiled from material provided by Northern Arizona University.

Combining Two Hobbies

by James Edgar, Regina Centre
(james@jamesedgar.ca)

Figure 2 — Saturn, in all its glory, carved in African rosewood (bubinga)

Figure 3 — M51, carved in oak

In 2017, I was emailed by Jennifer West, formerly of the Winnipeg Centre and now at the Dunlap Institute of the University of Toronto. She was inquiring to see if I could supply a wood carving of Saturn's rings for a demonstration to take place on 2017 September 15, the day the *Cassini* spacecraft was to dive into Saturn's cloud tops. Cassini was at the end of its mission, so it was a momentous day. Jennifer West's co-investigator, Matt Russo, had designed the proposed carving with the rings' prominent features marked in Braille, so that visually impaired people could get a feel for the rings, their density, the gaps, and he even provided sounds of the spacecraft passing through the rings to complement the tactile sensation.

So, I got busy with my CNC carver, creating a piece that ended up at 32 inches long, by 7 inches high. My carver could only handle 16 inches at a time, so I made the carving in two pieces to join them later.

This is what it looks like as a finished piece (Figure 1).

I understand the event was a great success. A while afterward, I was again approached by email, this time by a Christine Malec of Toronto. She and her husband, Jason Fayre, were both at the Dunlap Institute event on that eventful September 15 and she wanted to know if I could make some carvings for them—something they could have in their home, so they could feel the entire rings of Saturn, for example, or perhaps a spiral galaxy. I had just the thing they were seeking, a carving of Saturn from a 2016 *Cassini* image (Figure 2) and one of M51, the Whirlpool Galaxy (Figure 3). This was a commercial order—they weren't looking for a gift, and I was happy to oblige, quickly shipping them the finished products.

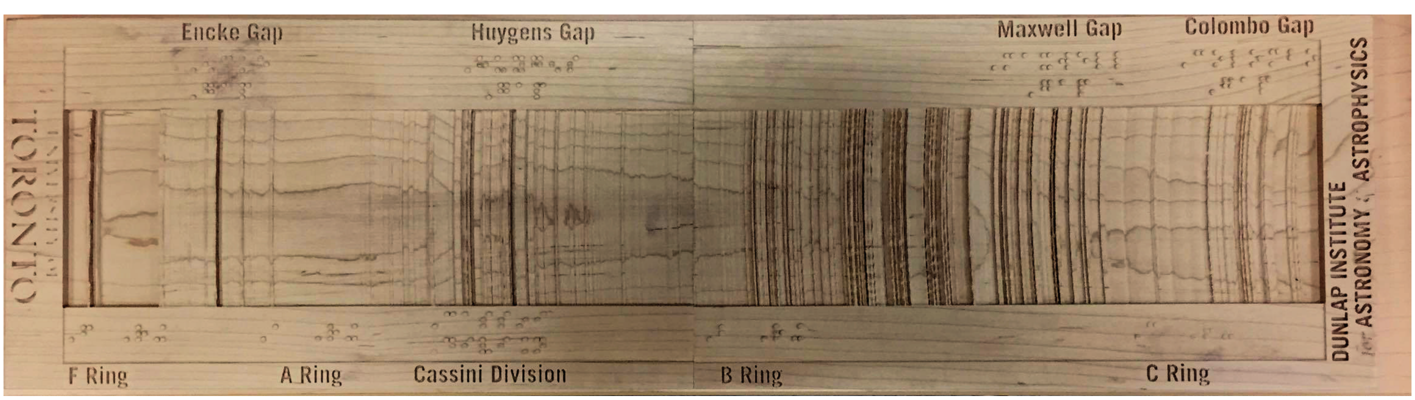


Figure 1 — A slice of Saturn's rings, with Braille markings for the prominent features

Figure 4 — Jupiter's "Dolphin"

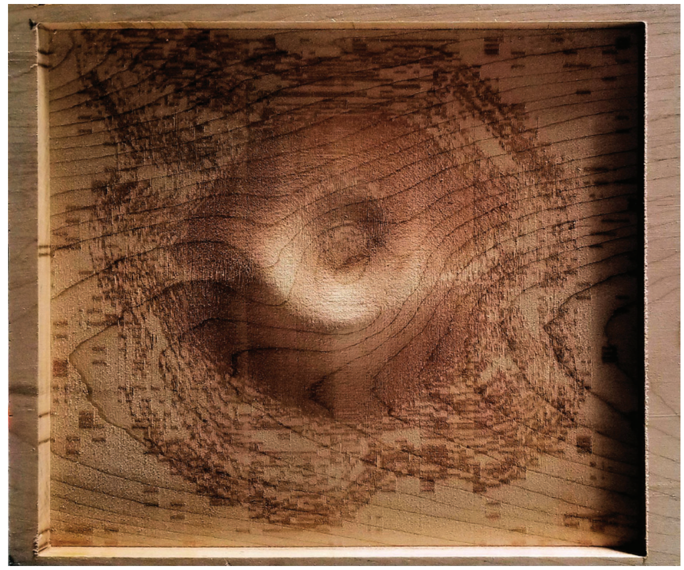


Figure 5 — M87's black hole

A couple of months later, I sent the couple a gift of Jupiter's clouds carved in walnut, one that showed "The Dolphin," a feature of the clouds that closely resembles a leaping dolphin. (Fran Bagenal, who addressed the Regina and Saskatoon Centres last year, had sent me the Jupiter image, captured by the *Juno* spacecraft during Perijove 16.)

When the now-iconic image of M87's black hole was released to the public, I carved it in maple (Figure 5). My carving bit, solid carbide with a titanium oxide coating, doesn't usually burn the wood, but it had previously been carving a high-resin object that left some "junk" on the bit. It burned the maple just enough to darken the wood slightly, adding to the black hole's visual appeal. I thought Chris and Jason would enjoy adding the carving to their growing collection, so I sent it to them. They insisted on paying for it!

In late May, Chris, who works at the Canadian National Institute for the Blind (CNIB), emailed to say that she had been given a budget to buy some of my carvings for the Toronto office, and could I give her an idea of the cost and what carvings might be suitable—she thought she could get four, based on my prices and the shipping cost. I jumped at the idea, writing back that I was going to be in Toronto in June for the RASC General Assembly, and I could bring them with me to avoid the shipping expense. That way, she could possibly buy more than the proposed four carvings. I got busy making some new carvings to add to some I already had on hand. The ones I

Figure 6 — Jupiter's cloud tops

Figure 7 — Jupiter's moon, Io, with an erupting volcano

Figure 8 — NGC 253, the Sculptor Galaxy

Figure 9 — The total solar eclipse of 2017 August 21, as compiled by Miloslav Druckmüller

Figure 10 — Mimas, the "Death Star" moon of Saturn

selected are: Jupiter's clouds from a Juno image during Perijove 9 (Figure 6); Io, showing an erupting sulphur volcano erupting above the surface (Figure 7); NGC 253, the Sculptor Galaxy (Figure 8); a total solar eclipse image created by Miloslav Druckmüller of the Czech Republic (with his permission, of course) (Figure 9); and Mimas, showing the prominent impact crater, resembling the Star Wars "Death Star" (Figure 10).

There was enough money in the budget to get two more, so I suggested the first two I had sent the couple, Saturn and M51, and those, too, will grace the CNIB office in Toronto, as well as Chris and Jason's home. The whole idea, of course, is to have the wooden carvings on display so that the seeing impaired can touch them and "get a feel" for the very different parts of our vast Universe.

To get a perspective from a blind person, here is a quote from Christine:

For the non-astronomer, astronomy is a very visual thing. My partner and I are both totally blind, and share a long-standing interest in space science. We're avid readers of popular science, and science fiction, so the first time we got our hands on the carvings, it took concepts that had been only ideas and words and gave them form. To me, they're like tiny windows into the universe. Carvings of galaxy clusters really convey the way bright stars stand out against the background glow. The carving of Saturn with its rings made the concept 3-dimensional for me in a way it hadn't been before. The carving of the total solar eclipse helped me to really understand that an eclipse allows us to see things we couldn't normally see. It's possible to do some of this with 3-D printing, but these carvings take something educational and informative, and turn it into something that's beautiful as well.

I'm really excited about sharing them with other blind people. I work at the CNIB Foundation Hub in Toronto, and the clients who had access to these carvings are as enthusiastic about them as I am. They take something very abstract and bring it under your hands, turn it into something graspable. ✶

James Edgar, Journal *Production Manager,* Observer's Handbook *Editor, and Society Past President, enjoys combining his two hobbies of astronomy and woodworking. They give him much satisfaction, creating astronomical objects for others to enjoy.*

[Note: This article first appeared in the Regina Centre's July/August 2019 newsletter, *Stargazer.*]

Figure 11 — A photo taken by a helpful stranger while we three met in Toronto at York University Student Centre; Jason, James, and Christine

Andrew McKellar and the Temperature of Space

by Donald C. Morton
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Abstract

During 25 years at the Dominion Astrophysical Observatory (DAO) from 1935 to 1960, Andrew McKellar became an international authority on molecular astrophysics through his investigations of comets, cool stars, and the interstellar gas. In 1940, he identified the molecules CH and CN between the stars from some weak absorption lines superposed on stellar spectra and a year later deduced a background temperature of 2.3° kelvin from two ultraviolet transitions of CN. The full significance of his result became clear only in 1965 when Arno Penzias and Robert Wilson obtained a similar temperature at 7 cm with a radio telescope.

Early Years

As recorded by Carl Beals (1960) in this *Journal*, as well as Gerhard Herzberg (1960) and William Petrie (1961), Andrew McKellar (Figure 1) was born in Vancouver, B.C. in 1910 and graduated from the University of British Columbia in 1930 with first-class honours in physics and mathematics. Then he began three years of graduate study at the University of California in Berkeley with the eminent spectroscopist, Francis A. Jenkins. McKellar analyzed molecular spectra to determine mass ratios in isotopes resulting in a joint paper on boron (Jenkins and McKellar 1932), a Ph.D. thesis on lithium (McKellar 1933), and later another paper on lithium

Figure 1 — Andrew McKellar 1910–1960. (DAO/NRC photo)

(McKellar and Jenkins 1939). With a fellowship from the United States National Research Council, McKellar continued his spectroscopic research at the Massachusetts Institute of Technology writing two papers on deutero-acetylene in collaboration with another NRC Fellow, Charles Bradley (McKellar and Bradley 1934, Bradley and McKellar 1936).

Figure 2 — The staff of the Dominion Astrophysical Observatory in around 1945 or 1946. Left to right around the table are the instrument maker Sidney S. Girling, the astronomers Robert M. Petrie, Joseph A. Pearce, Carlyle S. Beals, Andrew McKellar, Kenneth O. Wright, Jean K. McDonald, and the administrative assistant, Joan Cooke. Mini biographies of Beals and McDonald by Morton (2018a, b) are available from this Journal. *(DAO photo), but now with the correct first name of Joan Cooke.*

Dominion Astrophysical Observatory

During the summer of 1930, before going to Berkeley, as well as the summers of 1931 and 1932, McKellar worked as an assistant at the Dominion Astrophysical Observatory (DAO) near Victoria, B.C. Consequently, it is not surprising that he joined the scientific staff of the DAO in 1935. There he quickly took advantage of the spectroscopic capabilities of the 72-inch telescope, then the world's second largest, to obtain spectra of the binary Boss 4217 and derive the orbital parameters. These he published in a paper presented at the December 1935 meeting of the American Astronomical Society in Princeton, New Jersey (McKellar 1935, 1936). Whether he made the trans-continental trip is uncertain because the DAO had the economical practice for distant conferences of sending only one person who would present papers for all the staff.

His analysis of spectroscopic binaries continued throughout his career, often with seasonal assistants (McKellar and Reeves 1953) or colleagues (McKellar and Richardson 1955). He also joined in the continuing DAO observations of Zeta Aurigae and the similar binaries 31 Cygni and VV Cephei in which a red supergiant eclipses a hotter dwarf star. The analysis of spectra of the hot star shining through the outer layers of the supergiant atmosphere during ingress and egress provided information about the chromosphere of the cool star. (McKellar and Petrie 1952, 1957; Wright and McKellar 1956).

McKellar had a continuing interest in astronomical instrumentation. His first contribution related to calibrating photographic plates for the intensity of the incident light (Petrie and McKellar 1937). Other papers followed, including the design of a new optics for the prism spectrograph on the 73-inch telescope (Beals, Petrie, and McKellar 1946) and procuring a second telescope, the 48-inch reflector with a coudé (elbowed) spectrograph at the *f*/30 focus (McKellar 1958). Directing the star light off the moving telescope in an elbow-like path to a large fixed spectrograph would permit recording spectra with much better wavelength resolution.

I had the opportunity to meet Andrew McKellar during his 1952–1953 appointment as a Visiting Professor at the University of Toronto. During the summer of 1952 I had had an enjoyable and stimulating time as a student assistant at the David Dunlap Observatory observing with the 74-inch telescope and measuring spectrographic plates, so I inquired about a similar opportunity in Victoria. He was most encouraging, but I decided to stay at home in Toronto and avoid the complications of finding accommodation for three months and getting to and from the observatory without an automobile. Now, after having the DAO as part of my responsibilities from 1986 to 2000 and occupying an office there after 1994, I much regret not making this early acquaintance with the DAO. From McKellar's sabbatical at the University of Toronto, I much remember a colloquium he gave on the completion of the new grating spectrograph for the 74-inch telescope and his particular praise for the observatory machinist, Sidney Girling, who appears in the staff photograph in Figure 2.

Molecules

However, it was the extension of his Ph.D. and post-doctoral investigations of molecular spectra to astrophysical sources

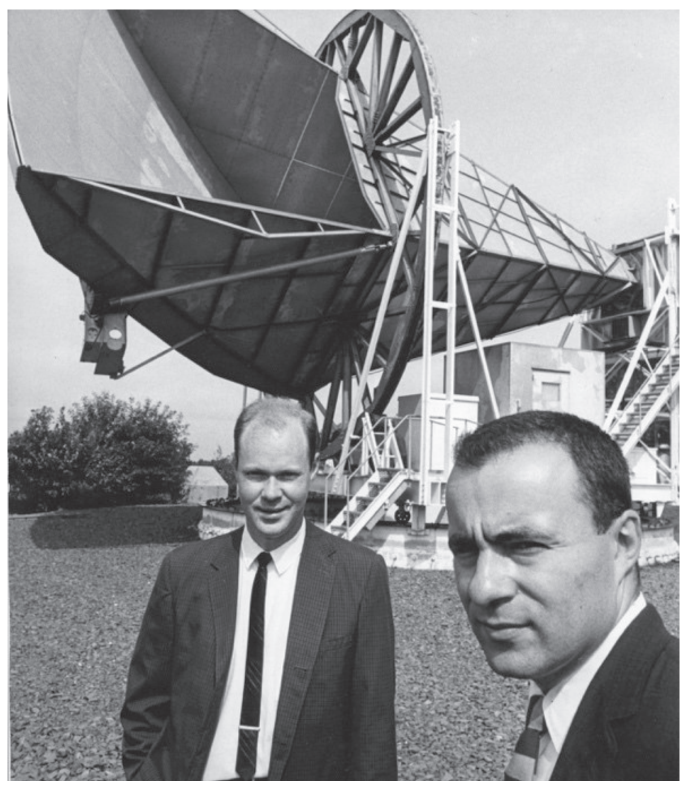

Figure 3 — The horn antenna at Crawford Hill with which Robert Wilson Penzias (left) and Arno Penzias (right) accidently discovered the cosmic background radiation. (AIP Emilio Segrè Visual Archives, Physics Today Collection)

that dominated his DAO research and made him a recognized international authority. By observing the dependence of cyanogen (CN) bands on the heliocentric distances of two comets, McKellar (1944) established the importance of the absorption and re-emission (fluorescence) of solar radiation. He also wrote informative articles on comets for the *Reviews of Modern Physics* and the *Encyclopaedia Britannica* (McKellar 1942, 1947a). Through the analysis of $C^{12}C^{12}$ and $C^{12}C^{13}$ bands in R stars, McKellar (1947b) distinguished two types, those with $C^{12}/C^{13} \geq 50$, consistent with the terrestrial ratio of ~90, and others with a ratio of ~3.4, indicating different nuclear processes. In another paper, McKellar (1948) identified bands of CH_2 in cool N stars, the first detection of a triatomic molecule in an astronomical object.

Molecules also are also found in the gas between the stars, where, like the atoms of sodium and the ions of calcium, they appear as sharp absorption lines superposed on stellar spectra because there is minimal broadening in the cool interstellar gas. Often these features were referred to as *stationary lines* because their wavelengths remained fixed in spectra of binary stars while the Doppler effect displaced the stellar lines in photographs taken at different times. At the DAO, the strong atomic absorptions were easily seen, but the weak narrow lines attributed to molecules were at the limit of detection in a few bright stars, so McKellar depended on results from the 100-inch telescope on Mt. Wilson and its high-resolution coudé spectrograph.

CH, CN, and Black-Body Radiation

In his most cited publication, McKellar (1940) identified one interstellar line found by the Mt. Wilson astronomers as CH at 4300.31 Å and a second as cyanogen CN R(0) at 3874.61 Å, both as absorptions from the ground states of these molecules. (A third identification with NaH at 3934.29 Å was not confirmed by later investigations.) These were the first evidence of molecules between the stars and established the presence of the elements hydrogen, carbon, and nitrogen and that they could form organic molecules.

McKellar also noted that evidence of the presence or absence of CN R(1) absorption at 3874.00 Å or P(1) at 3875.77 Å from an excited rotation level only 3.39 cm^{-1} above the ground state would provide useful information about the temperature of the surrounding gas, stating "...if R(1) is not more than one-third, one fifth, or one twentieth as intense as R(0), the maximum 'effective' temperature of interstellar space would be 2.7° K, 2.1° K, and 0.8° K respectively."

The following year, also in the *Publications of the Dominion Astrophysical Observatory*[1] McKellar (1941a) presented his second-most-cited paper. He listed 29 diatomic molecules with transitions between 3062.5 and 9041.59 Å that possibly could be observed as narrow interstellar absorption lines in stellar spectra obtained with ground-based telescopes. Our atmosphere prevents observations shortward of about 3000 Å while photography was ineffective longward of about 10 000 Å. These were transitions from the lowest molecular levels that might be populated in the cold interstellar space. When McKellar completed his paper in early 1941, there were three unidentified narrow lines at 3745.33, 3957.74, and 4232.58 Å, which he deduced must be due to a diatomic hydride and he reported his prediction in a paper at a meeting of the Astronomical Society of the Pacific (McKellar 1941b). While the 1941a paper was in press, Douglas and Herzberg (1941) at the University of Saskatchewan in Saskatoon published their measurement of the laboratory spectrum of the molecular ion CH^+ and confirmed it as the source of these three absorption lines superposed on stellar spectra. Feldman (1999) has added further details about the astrophysical contributions of Douglas and Herzberg.

Before McKellar returned the galley proof of his 1941a paper, Walter Adams of the Mt. Wilson Observatory had found both the R(1) and P(1) absorptions from the excited level of CN in the spectrum of the O9 star Zeta Ophiuchi and had communicated that the R(1) line at 3874.00 Å had one-fifth the strength of the R(0) line at 3874.61 Å. With a better determination of 3.78 cm^{-1} = 0.00047 eV for the excited level and the assumption of thermal equilibrium, McKellar calculated an absolute temperature of

$$T = 2.3\ ^{\circ}\text{kelvin}$$

in the interstellar gas where the lines are formed. He added that even an unlikely factor two either way in the intensity

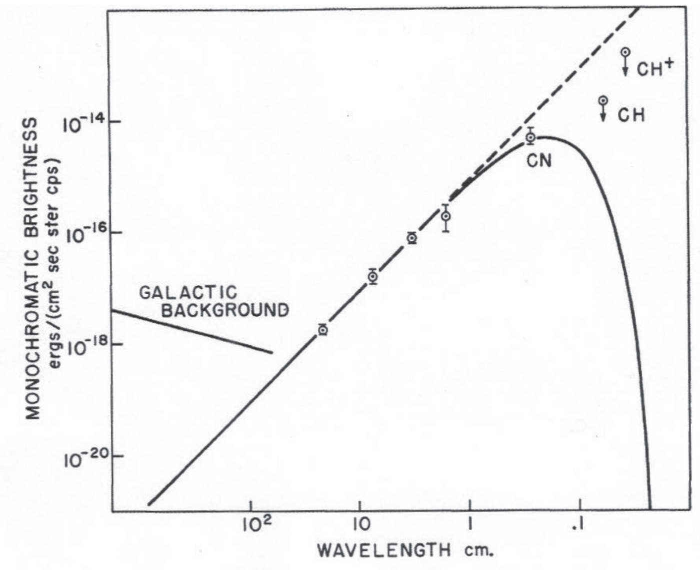

Figure 4 — The black-body spectrum of the cosmic microwave background radiation by Peebles (1969) in this Journal *showing the original Bell Labs radio measurement at 7.35 cm, Roll and Wilkinson (1966) at 3.2 cm and later radio and optical data listed by Welch et al. (1967), all consistent with McKellar's cyanogen measurement at 0.26 cm, the separation of the two CN levels observed near 3874 Å.*

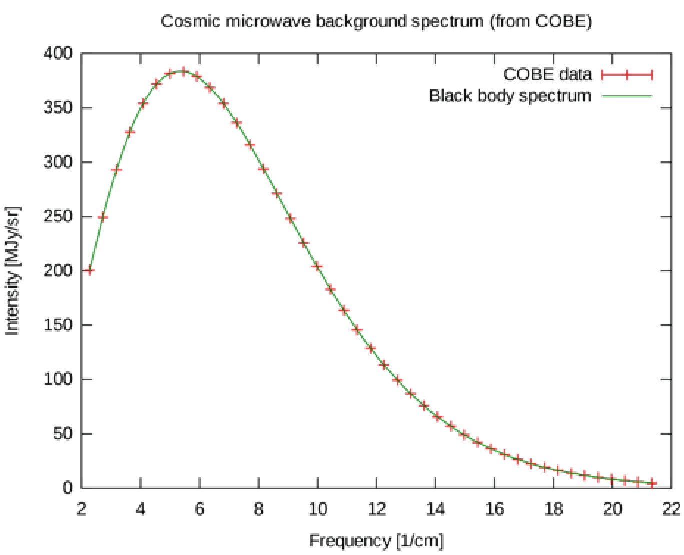

Figure 5 — The cosmic black-body spectrum measured by the Far-InfraRed Absolute Spectrometer on the Cosmic Background Explorer *(COBE) satellite. The error bars and differences from the theoretical black-body curve are too small to be seen on this plot. (NASA Graph).*

ratio still would leave the deduced temperature in the range of 1.8 °K to 3.4 °K. At such temperatures, the population of the lowest excited level of CH at 18 cm^{-1} would be insignificant, consistent with the absence of any lines from that level. Many years later, observations of Zeta Ophiuchi by Bortolot, Clauser and Thaddeus (1969) found equivalent widths of 8.40 Å for 3874.61, 2.74 Å for 3874.00 and 1.49 Å for 3875.77 corresponding to a temperature of 2.83 °±0.15 °K.

It is clear that the observatory staff understood that their colleague had found something important about interstellar space. When McKellar returned from two years service in operational research for the Royal Canadian Navy, for which he received the Order of the British Empire, the Director of the DAO, Dr. J.A. Pearce stated in an article in the Victoria Daily Times of 1945 September 18, "He also showed the presence of diatomic molecules in space and measured the temperature of space to be two degrees absolute."

Cosmic Background Radiation

Neither McKellar nor anyone else realized the full significance of his result until Penzias and Wilson (1965) published their radio observations of a residual antenna temperature of 3.5 °±1 °K at 4080 MHz = 7.35 cm and Dicke, Peebles, Roll, and Wilkinson (1965) in a companion letter attributed it to a relic of the primeval fireball or Big Bang formation of the Universe. Arno Penzias and Robert Wilson, observing with the 6-m horn reflector (Figure 3) of the Bell Telephone Crawford Hill Laboratory near Holmdel, New Jersey, were unaware that 40 km away at Princeton University, Robert Dicke and colleagues were developing instrumentation to search for the radio signal from the black-body radiation from the initial Big Bang of the Universe.

According to Robert Wilson (2019), it was Kenneth Turner, previously a Dicke student, who heard a lecture at Johns Hopkins University by Jim Peebles about the Princeton efforts and mentioned it to his friend Bernard Burke at the Massachusetts Institute of Technology. Burke knew about the Bell Labs project so advised Penzias to contact Dicke, resulting in the publication of the consecutive papers in 1965. Roll and Wilkinson (1966) completed their planned measurements later that year finding T = 3.0 °± 0.5 °K at 93.2 cm. Later measurements have confirmed the predicted black-body spectral distribution (Figures 4 and 5), determined a temperature of 2.7255 °K, found a dipole anisotropy due to the motion of our Sun and our galaxy toward $\alpha = 10.8^h$, $\delta = 5°$ relative to the background, and small-scale angular fluctuations of a part in 10^5.

Both Wilson (1979) and Trimble (2006) have described earlier radio observations that had come close to finding the background signal, including Dicke *et al*. (1946), who quoted an upper limit of 20 °K at wavelengths of 1.00, 1.25, and 1.50 cm for "cosmic noise," but gave no indication what might cause such noise. On the theoretical side, Penzias (1979) has reviewed how problems about the formation of the elements led Gamow (1946, 1948) and colleagues (Alpher, Bethe, and Gamow 1948, the αβγ paper) to investigate a Universe starting with a Big Bang. Alpher and Herman (1948, 1949) developed these concepts further and estimated the present temperature to be 5 °K.

Paul Feldman (2010) learned that George Gamow had visited the DAO in the summer of 1951 and Gamow gave a seminar on "The Origin of the Atoms." According to an interview with Graham Odgers, who was on the DAO staff and present during the 1951 visit, McKellar spent part of the day showing Gamow and accompanying colleagues the observatory facilities and some time alone with him. Somehow neither of them made the connection between the CN observation and the cooling of an expanding Universe.

At that time, there was a serious problem with the concept of an explosive creation as explained, for example, in an article in this *Journal* by Grayson-Smith (1951). The age of the Universe estimated from the distances and velocities of the receding galaxies was about half that of the Earth derived from radioactive decays. Consequently, the alternative proposed by Bondi and Gold (1948) and Hoyle (1948) of a steady-state Universe with continuous creation of atoms between the galaxies as they separated was a serious competitor. The Big Bang became much more plausible after 1952 when Baade (1954, 1956) announced his discovery of two classes of Cepheid variable stars that increased the extragalactic distance scale by a factor of two, thus increasing the age of the Universe by the same factor and making the Big Bang theory acceptable again. The eventual detection of the background radiation became strong evidence against continuous creation.

Heritage

On 1960 April 8, Andrew McKellar (1960) delivered an informative review of molecular astrophysics in his Presidential Address at the General Assembly of the Royal Astronomical Society of Canada in Montréal. Just 28 days later, following his return to Victoria, he passed away on May 6 after a heroic struggle with an incurable disease, leaving his wife Mary and two children Robert and Barbara. In recognition of Andrew's contributions to the design and construction of the 48-inch telescope, particularly its *f*/30 coudé spectrograph, the observatory named the spectrograph after McKellar as shown in Figure5.

Later his daughter married, so now is Barbara Bulman-Fleming. She earned her Ph.D. in 1988 and ultimately became a Professor of Psychology at the University of Waterloo. Robert followed his father into molecular spectroscopy obtaining a Ph.D. in 1970 from the University of Toronto and joined Gerhard Herzberg's research team at the National Research Council from 1971 to 2007, and where he continues as an emeritus researcher. For 19 years of that time, he was part of NRC's Herzberg Institute of Astrophysics, which included the Dominion Astrophysical Observatory where his father had spent 25 years. Robert's research covered a broad range of molecular physics, including several papers interpreting astronomical observations.

Andrew McKellar did not live to see the cosmic interpretation of his estimated temperature, but Robert Wilson (1979) in his Nobel Prize address credited McKellar's 1941 paper as the first confirmation that the Bell Labs microwave measurement represented the black-body remnant of the Big Bang. ✶

Figure 6 — The naming of the McKellar Spectrograph in 1962 with Mary McKellar, Director Robert Petrie, Barbara McKellar and William E. van Steenburgh, Deputy Minister of Mines and and Technical Surveys. The bronze plaque states, "This spectrograph is named for Andrew McKellar 1910–1960 investigator of the molecules of earth and stars–interpreter of stellar and planetary atmospheres–designer of equipment for astrophysical research." (DAO photo by S.H. Draper)

Postscript

In 1966, while I was working at Princeton University and flying small spectrographs in rockets to observe the ultraviolet spectra of stars from above our atmosphere, Lyman Spitzer and I enhanced the program by hiring Edward Jenkins, who had just completed a Ph.D. in cosmic-ray physics at Cornell University. Sometime later, after I learned that he was a son of Francis Jenkins, the Berkeley physics professor, Ed told me that his father had encouraged him to consider careers other than physics and said that if he did choose physics, to avoid spectroscopy because it is a dying field. However, both Edward, with a productive career in astronomical ultraviolet spectroscopy, and Andrew's son Robert in molecular spectroscopy, have demonstrated the continuing importance of that branch of physics. See for example Jenkins (1978) and McKellar (1988).

I wish to thank Dr. Dennis Crabtree of the Dominion Astrophysical Observatory for his assistance in locating archival records.

Endnotes

1 Nowadays one might wonder why astronomers limited the distribution of their research this way, but up to the 1960s, this was a common practice. Instead of paying page charges to journals, observatories printed their own publications and mailed them free to all the world's observatories so other astronomers could be informed even if their institutions could not afford to purchase the journals. Thus, many of Helen Sawyer Hogg's observations of variable stars in globular clusters appeared as Publications of the Dominion Astrophysical and David Dunlap Observatories.

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Editorial

by Michael Attas (attasm1@mymts.net)

Gosh, who doesn't love telescopes? They are such cool instruments, the big ones getting bigger and bigger, seeing farther and farther, and generating fabulous photos of the universe. Plus, astronomers make discovery after discovery with them, astounding us with exploding stars, sparkling galaxies, and mysterious black holes. Until recently, I'd considered them the most benign technology imaginable.

But it turns out that telescopes aren't totally benign. Some people object to the construction of telescopes, not so much for what they are, but for where they're built: on tops of mountains. Mountaintops are special places for us all. They are destinations for skiers and climbers. They provide great views. They are holy places too, for many cultures. Machu Picchu is a famous Incan sanctuary high in the Andes. In Greece, churches to the Prophet Elijah were often built on mountaintops, sometimes right on the foundations of ancient temples. In modern times, mountaintops are also prime locations for radar stations, cell towers, wind-powered generators, and telescopes. Visibility, weather, and isolation are key factors for those devices to work well. Their presence on peaks can be seen as a sign of progress, or high technology (pun intended), but also as a sign of the encroachment of civilization on nature.

What happens when a mountaintop is desired by several groups for different purposes? Who does the mountain top "belong to?" Is it possible to share the space, or are the purposes incompatible? Are there enough mountaintops to go around, to allow all needs to be met? Perhaps, but some of these tops are special. Some are very special, for multiple reasons. Maunakea in Hawaii is one of those very special mountains, and problems with space on its top have recently made the news.

Mauna Kea is an extinct volcano, in fact the tallest mountain on Earth when measured from its submerged base. The air on top is thin, dry, and rarely turbulent. It is an ideal location for observing the heavens, and over a dozen large telescopes have been built there. The infrastructure to operate the telescopes is well developed, and astronomers on the Big Island of Hawaii support the local economy by their presence. Design of an even bigger instrument, the Thirty Meter Telescope, has been in progress for at least a decade. But the start of construction this past July has triggered blockades, demonstrations, and arrests. Clearly there is opposition.

The opposition comes primarily from Indigenous Hawaiians, and their supporters. To them, Maunakea is sacred, a place of worship, a holy site. I use these words sacred, worship, holy, since they are the best English words I can find to help me understand the role of the mountain in the Indigenous Hawaiian culture. Although the opposition only now has become an international media story, it has been longstanding. Proponents of the telescope have detailed on the website maunakeaandtmt.org the planners' accommodations in response to the objections. There is also a description of the process followed to gain approval from the relevant authorities to begin construction. That process, long and convoluted as it was, is actually the crux of the issue. Indigenous Hawaiians dispute the validity of the process as well as the authority of those granting the construction permit. Native Hawaiian scientist Rosie Alegado explained the issue in a column in *Nature* (www.nature.com/articles/d41586-019-02304-1). In short, not only must the project gain approval, but the process itself must be deemed valid by all engaged parties. Is this even possible?

There have been many voices speaking this past summer, with a variety of viewpoints and stakes in the issue. How can one hope to engage them all, satisfy them all, and find an outcome for which the emergence of "winners" does not result in "losers"? It will take discussion, negotiation, and compromise. Above all, it will require trust and a conviction that an acceptable solution exists. Call me an optimist, but I'm sure that the parties can aim for this goal, and can reach it. Let us support them in their efforts. ✶

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Bert Petrie, Ken Wright, and the Dominion Astrophysical Observatory

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Abstract

Following post-graduate study at the University of Michigan, Robert Petrie in 1935 and Kenneth Wright in 1936 returned to their home province to take positions at the Dominion Astrophysical Observatory (DAO) in Victoria, British Columbia. Both had productive research careers there and each eventually became the Director of the Observatory.

Figure 1 — Robert Methven Petrie (1906–1966) (DAO/NRC photo)

Introduction: Dominion Astrophysical Observatory

In recognition of the 2018 centenary of the DAO, this article is a continuation of mini-biographies of the early staff. Here, I am adding two directors who I had known personally, Bert Petrie and Ken Wright. The references for the previous accounts are Morton (2018a, b, 2019) respectively for Carl Beals, Jean McDonald and Anne Underhill, together and Andrew McKellar. Both Petrie and Wright appear in the staff photograph from about 1945 or 1946 reproduced in the second and third references above. The biography by Broughton (2018) thoroughly covers the first Director, John Stanley Plaskett.

Robert Methven Petrie (1906–1966)

The life of Bert Petrie (Figure 1) is well described in the obituaries by his colleagues Carl Beals (1966) and Alan Batten (1966). At age 5, Bert moved with his family from St. Andrews, Scotland, to Victoria, B.C., where his father worked as a master printer. Following basic schooling in Victoria, Bert studied mathematics and physics, initially at the local Victoria College branch of the University of British Columbia (UBC) and then at the Vancouver campus, graduating with honours in 1928. He had joined The Royal Astronomical Society of Canada at age 18 (Broughton, 1994) and during his second year at Victoria College wrote his first contribution for the *Journal* (Petrie, 1926a), in which he discussed amateur observing of variable stars and encouraged membership in the American Association of Variable Star Observers.

While still at high school, Bert had been a volunteer assistant at the DAO (Wright, 1968) and had formal appointments as a summer assistant during 1926, 1927, and 1928, photographing stellar spectra with the 72-inch telescope and measuring the plates for radial velocities. He completed his first research paper in September 1926 (Petrie, 1926b) giving the orbital solutions for two spectroscopic binaries, one of which revealed the lines of both components thus permitting the direct determination of the mass ratio. By the end of the 1927 summer, he had finished a second paper, which reported his radial-velocity measurements of 59 stars and 2 more binaries (Petrie, 1928). Canadian astronomer Peter Millman was also a student at the DAO during the summer of 1928.

To further his astronomy education, Petrie enrolled at the University of Michigan in Ann Arbor in the fall of 1928, receiving his Master's degree in 1929 and his Ph.D in 1932, with a thesis on the Cepheid variable star RT Aurigae (Petrie, 1932, 1934a) supervised by Heber. D. Curtis (Tenn, 2016). Petrie remained in the Michigan Department of Astronomy as a lecturer for three years, publishing papers on motion pictures of solar phenomena (McMath and Petrie, 1934), masses and luminosities of binary stars (Petrie, 1934b), the solar chromosphere (Petrie, 1934c) and Nova Herculis (Petrie, 1935).

Following the retirement of Plaskett and the departure of Frank Hogg to Toronto, Petrie, along with Andrew McKellar, joined the staff of the Dominion Astrophysical Observatory in 1935 with William Harper as director and Joseph Pearce and Carl Beals as senior colleagues. There, Petrie further developed his interest in spectroscopic binary stars publishing orbital elements for at least 28 different systems during his career. In the binaries AR Cass and HR8800, measurements over several decades permitted the determination of the apsidal motion, the rotation of the semimajor axis due to the gravitational distortion of one star on the other (Petrie, 1944, 1960, Petrie and Petrie, 1967b).

With so much effort in measuring spectra for radial velocities, Petrie recognized the importance of selecting reliable absorption lines and adopting standard wavelengths for those to be measured. Depending on the resolution of the spectrograph, some lines can be blends with weak contributions from transitions in other elements that shift the mean wavelength. Thus Petrie's (1953) list of constant-velocity B stars and the wavelengths to use with dependable spectral lines became one of his most-cited papers. All observations for radial velocities should include checks with a few standard stars of similar spectral type.

Another major research project for Petrie was to develop a quantitative method for determining the absolute visual magnitudes M_V of the B-type stars using the strength of the Hγ absorption line of hydrogen. Luminous stars with expanded envelopes have lower-density envelopes with less broadening of the hydrogen lines by the Stark effect than main-sequence stars. The final version by Petrie (1964a, 1966) used cluster sequences fitted together with the accurate three-colour UBV photometry of Johnson (1957), all placed on an absolute scale using accurately known A-star parallaxes, visual binaries with solar type companions, and eclipsing binaries with well-determined radii and temperatures from which the luminosity was calculated. On average, Petrie's system was only 0.1 mag. fainter than Blaauw's (1963) luminosities for the Morgan–Keenan spectral classes. Petrie and Lee (1965) used this alternative to the subjective examination of each spectrum to obtain M_V for 571 field stars. With these data and the radial velocities published by Petrie and Pearce (1962), he determined the parameters of galactic rotation for O8 to B5 stars. (Petrie, 1964b, Petrie and Petrie, 1968).

With the retirement of Pearce in 1951, Petrie became the director of the DAO and Dominion Astrophysicist in Victoria under Beals as Dominion Astronomer at the Dominion Observatory in Ottawa. In 1964, when it came time for Beals to retire, he encouraged Petrie to move east to manage geophysics as well as the observatories, but Petrie preferred to remain in Victoria (Batten, 2019), so he became Dominion Astronomer as the senior astronomer in Canada. In Ottawa, geophysicist John Hodgson then had overall responsibility as Director Observatories Branch, Department of Energy, Mines, and Resources. In 1961, the Royal Society of Canada recognized Petrie's prominence as a Canadian scientist with the award of the Henry Marshall Tory Medal.

Throughout his life, Petrie had been active with the RASC in Victoria and contributor to the *Journal*, with three papers while he was a student in British Columbia, two while he was in Michigan, and 40 more, including seven with colleagues, after returning to Victoria. He also served as RASC National President in 1955 and 1956. His last article for the *JRASC*, (Petrie, 1964c), displayed a photograph of Queen Elizabeth, Prince Phillip, and Prime Minister Lester Pearson viewing a model of the 150-inch QEII telescope to be built on Mt. Kobau, south of Penticton in British Columbia. Petrie had taken a leading role encouraging government and community support for the project, as in Petrie (1963) where he discussed the importance of a large optical telescope for the future development of Canadian astronomy. Although the government eventually cancelled the Mt. Kobau project, as described below, our successful participation in the Canada-France-Hawaii Telescope and the twin Gemini Telescopes have fully confirmed Petrie's view of the importance of large optical telescopes for Canadian research.

In 1960, following the passing of his first wife, Petrie married Jean McDonald, a colleague at the DAO since 1943. Jean then left the DAO and began teaching astronomy at Victoria College and was involved in its evolution in 1963 into the independent University of Victoria. For the practical part of her course, Jean often would have the Director of the DAO as her lab assistant. After Bert died suddenly in 1966, Jean completed three of his unfinished research projects (Petrie and Petrie, 1967a, 1967b, 1968). She also gave an invited paper summarizing his research (Petrie, 1970) at a symposium in connection with the November 1969 opening of the R.M. Petrie Science Building at York University in Toronto shown in Figure 2. Ralph Nicholls, the Chairman of the York Department of Physics, had proposed naming the building after Petrie (Batten 2019).

Figure 2 — R.M. Petrie Science and Engineering Building, York University, Toronto (Photo by DCM)

Figure 3 — The summit of 2900-m Mt. Petrie in British Columbia. Left to right are George Wallerstein, University of Washington, his wife Marsha, Lyman Spitzer, Director of the Princeton University Observatory, Bob O'Dell, Director of the Yerkes Observatory, University of Chicago, and Tom Grenfell, a Yerkes graduate student. (Photo by DCM)

Further recognition of Bert Petrie resulted from a 1967 mountaineering expedition to what is now Kakwa Provincial Park in the Rocky Mountains of British Columbia east of Prince George. Without fully revealing the challenges of this area, George Wallerstein with his wife Marsha organized a party of astronomer colleagues to explore the area and ascend some of the unclimbed, unnamed peaks (Morton 1968). On July 24, a float plane from Prince George landed us on Dimsdale Lake, which drains into Jarvis Creek. The next day we climbed above the lake to the summit of an attractive snow-topped peak that we decided to name after the eminent B.C. astronomer and observatory director, Robert Petrie. Figure 3 shows the team on the summit of Mt. Petrie, while Figure 4 in Morton (2018b) shows the peak above the lake and Figure 3 of Morton (2011) reproduces the official topographic map with the name Mt. Petrie as well as Mt. Plaskett resulting from my proposal to the Board of Geographic Names.

Kenneth Osbourne Wright (1911–2002)

Alan Batten and John Galt (2002) have given us a detailed obituary for their colleague Ken Wright. He was born in Fort George (now Prince George) B.C. and travelled to the University of Toronto for his initial higher studies, completing a B.A. in mathematics and physics with the astronomy specialty in 1933 and winning the Society's Gold Medal. He obtained an M.A. there in 1934 and worked as an astronomical assistant during 1934–1935. He had a similar appointment at the University of Michigan the following academic year and then returned to B.C. in 1936 to take a position at the DAO. Ken maintained his connection with Michigan and received his Ph.D. from there in 1940 from "A study of line intensities in the spectra of four solar-type stars" (Wright, 1940, 1947) based on observations of the F8 supergiant γ Cyg, the F5 giant α Per, the F5 dwarf α CMi, and the Sun, a G2 dwarf, all obtained with the 72-inch telescope in Victoria. (To study the solar spectrum with a night-time telescope, the usual procedure was to take a spectrogram of the Moon or the day-time sky.)

Continuing at the DAO, Ken frequently returned to these four stars to provide comparison standards for the intensities of spectral lines, just as Petrie had done for the wavelengths. Since the blackening of the photographic plate is non-linear for both weak and strong illumination, all plates had to be calibrated with a set of exposures of known relative intensities in order to deduce the true profile of an atomic or molecular absorption line. Then, since most lines are not resolved, the strength of an absorption line was quoted as the "equivalent width" in Angstroms of a totally saturated line with a rectangular profile that has the same area under the stellar continuum as that measured on the observed profile, since the area is independent of the spectrograph resolution. Much careful effort was needed to scan with a linear photometer both the spectrum and calibration spots on each plate, apply the calibration curve, plot the spectrum, draw the continuum between the absorption lines and measure the areas of selected ones with a planimeter. Only then could one begin to do the astrophysics of determining temperatures, densities, and element abundances in the stellar atmosphere. Consequently, there was a need for a set of reliable equivalent widths in a few standard stars so that astronomers at various observatories could compare their reduction procedures. Wright (1939) did this initially with his original four stars and later expanded to the data to 1597 lines in 12 stars with spectral types from B to G (Wright *et al.*, 1963).

Wright also became an authority on the ζ Aurigae (K4II+B8V) eclipsing binaries in which the extended atmosphere of a cool supergiant or bright giant passes in front of a compact hot star, which acts as probe of the cool atmosphere. Similar systems are 31 Cyg (K2II+B3V), 32 Cyg (K3Ib+B3V), and VV Cep (M2Iaep+O8), all studied at DAO. A third of all of Wright's publications involved one of these four stars, including his most cited paper (Wright 1970a), which was a review of the Zeta Aurigae stars. He concluded condensations must be present in the inner chromospheres to explain the observations.

Like his colleagues, Wright was active with the RASC, both in the Victoria Centre and beyond, becoming National President from 1964 to 1966, and publishing 32 contributions to the *Journal* by himself and 12 more with colleagues. His first (Wright, 1941) was a report on amateur observations of the 1940 transit of Mercury. Of particular interest are Wright's (1968) recollections at the 50th anniversary of the founding of the DAO.

With the passing of Petrie in 1966, Wright succeeded him as Director of the DAO, serving until 1976 when he reached the retirement age of 65. Ottawa did not continue the historic designations of Dominion Astrophysicist or Dominion Astronomer, our equivalent of Astronomer Royal with the addition of astrophysics, but the term *Dominion* has remained in the names of the Dominion Astrophysical Observatory in Victoria, the Dominion Radio Astrophysical Observatory (DRAO) near Penticton, B.C., and the heritage building of the Dominion Observatory (DO) in Ottawa.

The dispute about the site of the four-metre QEII Telescope on Mt. Kobau became a major issue during Ken's directorship resulting in serious tensions among the DAO staff and throughout the country, all well described by Gaizauskas (2012, 2013). The older DAO astronomers strongly supported the plan, but many others, including Don MacRae and Sidney van den Bergh at the University of Toronto, said that front-line research in optical astronomy was not possible at Mt. Kobau or any other location in Canada. We needed a large telescope on a mountain site in Hawaii or Chile, where images would be sharper and atmospheric transparency more stable. Ken, in his reports through 1967, described site testing on Mt. Kobau, progress with the design, construction of the optical shop at the DAO, and Graham Odgers succeeding Petrie as project leader. However, Odgers and Wright (1968) had to announce the government's cancellation of the project, and Wright (1970b) the formation of the WESTAR consortium of interested Canadian Universities to seek alternate funding. Consequently, the DAO continued seeing and photometric tests at Mt. Kobau.

Figure 4 — Kenneth Osbourne Wright (1911–2002) (DAO/NRC photo)

Also, while Wright was the Director of the DAO, the government acted on the astronomy part of the Royal Commission on Government Organization, (the Glassco Report of 1962–63) that recommended consolidation of government astronomical facilities in the National Research Council (NRC), which had an active group of solar and galactic radio astronomers and operated the 46-m Algonquin Radio Telescope. As related by Gaizauskas (2013), this proposal was revived as part of the 1968 report of the committee chaired by the eminent cosmic-ray researcher Donald C. Rose to deal with the Mt. Kobau controversy. Beginning on 1970 April 1, the DAO and DRAO staff, as well as the astronomers at the Dominion Observatory left the Department of Energy, Mines

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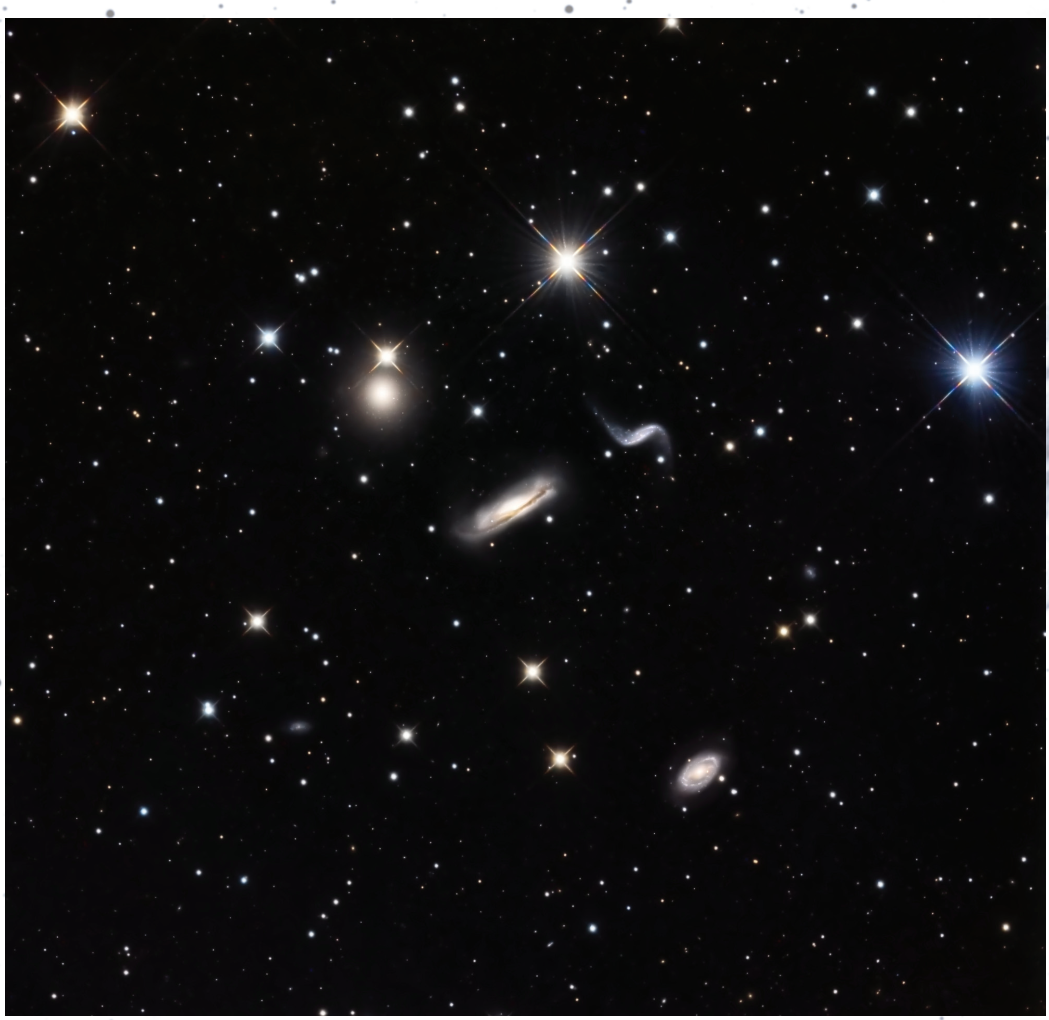
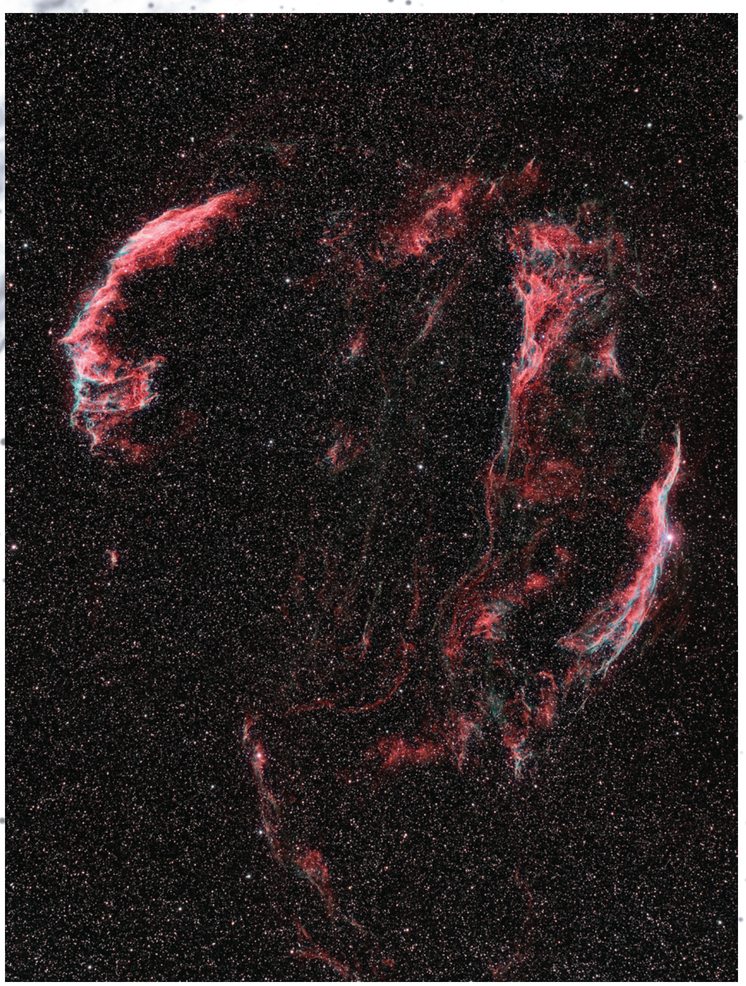
Pen & Pixel

Figure 1 — Garry Stone imaged a beautiful display of noctilucent clouds 100 km south of Saskatoon with a Canon Rebel S camera and a 50-mm lens at ƒ/1.8 and ISO 800.

This beautiful dance of galaxies, Hickson 44, was imaged by Dalton Wilson from Rodeo, New Mexico, using an Astro Tech 10-inch RC on a Mesu 200 mount and a QSI540wsg. The image is a total of 7 Lum x 900 sec and 5 RGB x 360, binned 2 x 2.



The Milky Way stretches across the night sky over Nancy Greene Lake, British Columbia. This single exposure was imaged by Stefanie Herron, who used a Canon 5DS with a 28-mm ƒ/1.8 lens with light-pollution filter.



The Veil Nebula is a favourite of many astrophotographers. "This is a first-light image with the QHY367C one-shot colour camera fitted with an Optolong L-eNhance narrowband filter designed for colour cameras," Ron Brecher says of the image. He also notes that the image was acquired under "intense moonlight."

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and Resources to report to the NRC (Wright 1970b) with Jack Locke as overall Director.

By the early 1970s, Canada's options for optical astronomy had broadened with invitations from the Carnegie Institution of Washington to join in duplicating the Palomar 200-inch (five-metre), the 48-inch Schmidt and the 60-inch telescopes in Chile, and from France to partner in the construction of a 3.6-m telescope at 4200 metres on Mauna Kea in Hawaii. At the same time there was strong support for a four-metre Canada-only telescope in Chile while, in the background, WESTAR was looking for alternate funds for a telescope on Mt. Kobau (Gaizauskas 2013). Following a critical meeting of the NRC Associate Committee for Astronomy chaired by Ken Wright (1972), he reported that the committee had recommended as first priority a large all-Canadian optical telescope, but if that were deferred, the NRC should accept the French proposal. According to Gordon Walker (2019), Secretary of the Associate Committee, "I was present when Ken presented the French collaboration to Schneider (the President of NRC) whose eyes lit up with enthusiasm." This was a proposal he could take to the government. The following year, the Canadian Government approved the partnership with France (Wright 1973), resulting in the wonderfully successful 3.6-m Canada-France-Hawaii Telescope. In the end, the DAO contributed the first spectrograph and used the optical shop to figure the Cer-Vit mirror blank France had purchased, while Coast Steel of Port Coquitlam, B.C., provided the dome.

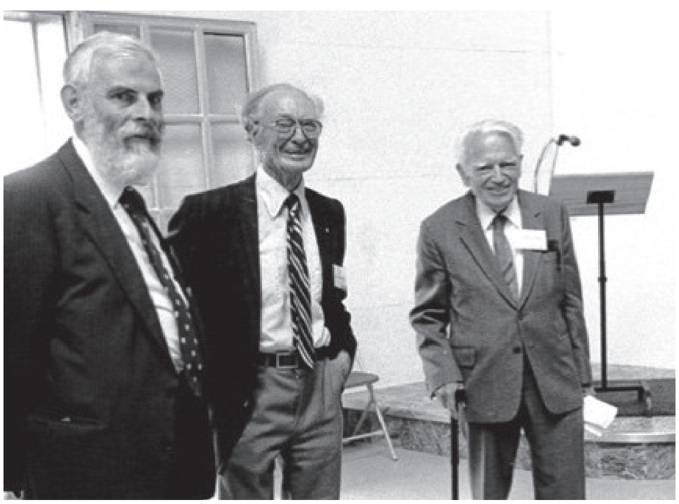

Figure 5 — Left to right: Alan Batten, Ken Wright, and Gerhard Herzberg in the dome of the 72-inch telescope celebrating 75th anniversary, 1993 June 4. (DAO/NRC photo)

Later, in September 1974, at an international spectroscopy symposium in honour of Gerhard Herzberg's 70th birthday, Schneider (1974) announced the formation of an Institute of Astrophysics stating, "In recognition of Dr. Herzberg's outstanding scientific contributions, his interest in and contributions to astrophysics, and his distinguished role as a scientist and scientific leader at the NRC, the new Institute is to be named 'The Herzberg Astrophysics Institute'" (Stoicheff, 2002). Consequently, on 1975 January 1, research in solar-terrestrial physics, cosmic rays, and molecular spectroscopy at NRC joined the astronomers under Locke in the Herzberg Institute of Astrophysics. When Ken Wright retired in late 1976 and construction of the Canada-France-Hawaii Telescope had started on Mauna Kea, the NRC appointed Sydney van den Bergh as the Director of the DAO.

In October 1976, at the time of Ken's retirement, colleagues from across Canada as well as Lawrence Aller, Charles Cowley, Jesse Greenstein, Bev Oke, and George Wallerstein from the United States, Anne Underhill from Holland, Giusa Cayrel de Strobel from France, and Yoshio Fujita from Japan honoured Wright with a symposium in Victoria (Batten, 1977). Ken's own contribution (Wright 1977) was a comprehensive analysis of 20 years of observations of the Hα line in the system VV Cephei providing evidence of gas flowing from the M star through the central Lagrangian point to the O star.

Personal Remembrances

It was during the summer of 1953 as an assistant at the David Dunlap Observatory (DDO) that I first learned about ζ Aurigae binaries and Wright's central role in their studies, when I helped Ed Weston (1953) draw some diagrams for a paper he was preparing on 32 Cygni. A summer or two later at the DDO, in connection with the double-line spectroscopic binary I was measuring, Dr. Heard suggested that I look into Petrie's (1939, 1950a, b) method of determining the magnitude difference of the components, which provided a way to obtain the slope of the mass-luminosity law. Although I did not pursue either of these interesting projects, I enjoyed meeting both Petrie and Wright in later years at astronomical conferences. Thus, in 1961, I was grateful when Bert proposed me for membership in the Royal Astronomical Society.
On another occasion in the late 1960s, after I had given a colloquium at the DAO, I remember Ken and his wife giving me a tour of the very attractive city of Victoria, not anticipating that many years later my wife and I would enjoy living there for 21 years.

Both Ken and I attended the 1974 Symposium honouring Herzberg at Mt. Tremblant, where the NRC President announced the formation of the Herzberg Institute of Astrophysics (HIA). I gave an invited paper on the far-ultraviolet spectra of stars observed with the *Copernicus* satellite, never imagining that in 12 years I would have the privilege of directing the HIA with a staff of active researchers, that included Gerhard Herzberg.

I am grateful to Alan Batten, Dennis Crabtree, Vic Gaizauskas, and Gordon Walker for helpful information. ✶

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Skyward

Untaken Roads and a Dog's Star

By David Levy, Kingston and Montréal Centres

On Friday, June 14, my latest book, my autobiography entitled *A Nightwatchman's Journey: The Road not Taken* was launched at The Royal Astronomical Society of Canada's General Assembly in Toronto. It is a book I have been working on for almost a decade, and it is the story of my life. The book begins *in medias res*, in the midst of a suicide attempt that happened shortly after I graduated from Acadia. I have suffered from depression throughout my life, but this book describes my efforts to conquer it. It tells of how I made many poor decisions in my life, but how two of them were good. The best decision was marrying Wendee, which I did in 1997, and with whom I have had 22 happy years. The other one was to begin, on 1965 December 17, a search for comets.

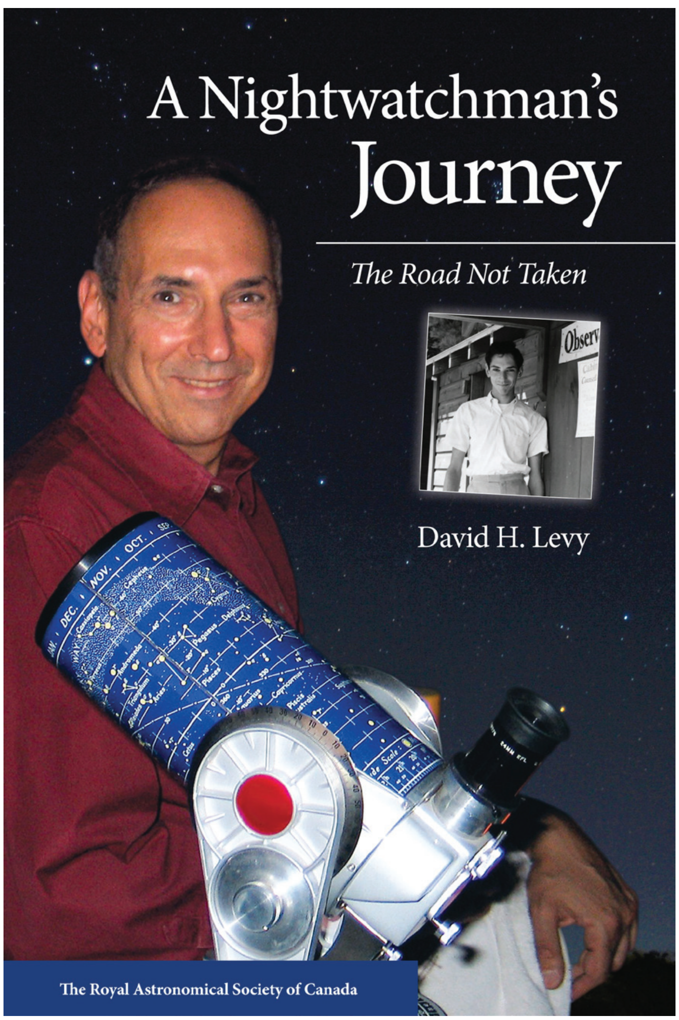


Figure 1 — The cover of A Nightwatchman's Journey: The Road not Taken.

It took me 19 years, searching with telescopes for 917 hours 28 minutes, before I finally found my first comet in 1984. Since then I have found 22 more. One was an electronic find shared with Tom Glinos in 2010. Thirteen were photographic film discoveries shared with Gene and Carolyn Shoemaker (including Shoemaker-Levy 9, which collided with Jupiter in 1994), and there were nine visual comet finds. If the first 71 years of my life had been just staring through the eyepiece of a telescope, however, there would not have been much to write about. What happened on the road less travelled, like Robert Frost, has made all the difference.

Comets, I learned, are not just for viewing. They are for reading and for studying. At first, I did some high-school reading about the discovery of Comet Ikeya-Seki, the brightest comet of the 20th century. Years later in graduate school at Canada's Queen's University, I prepared a Master's thesis based on the 19th-century English poet Gerard Manley Hopkins, who observed Comet Tempel in 1864 and subsequently wrote a beautiful poem about it. But the writer who seemed to be most into astronomy, and whose love of the sky I turned into my Ph.D., was none other than the great William Shakespeare, whose collected works contain more than 200 references to the sky, including the opening lines to *1 Henry VI*, Part I of his earliest plays:

> *Hung be the heavens with black, yield day to night!*
> *Comets, importing change of times and states,*
> *Brandish your crystal tresses in the sky.*

Even now, when I spend an evening or all night under the stars, I am amazed to be able to share my experiences with so many people, in all walks of life, who have come before me. Taking a road "that was grassy and wanted wear" might have been risky, but it did point me toward many adventures I'll never forget.

A Dog Star

There are so many good reasons for acquiring an interest in the night sky. Mine wasn't one of them. It turns out that I was extraordinarily shy as a child and had few friends. One July evening, at Twin Lake Camp in Vermont, while walking with my bunkmates from a July 4th celebration, I happened to be looking up at the night sky when I saw a shooting star. It was not particularly bright, but it did capture my attention as it raced from the head of Draco, the Dragon, toward the bright star Vega. Right away, I noticed that the stars could be friends. Stars are people, too.

Around the same time, our family got a beagle dog we named Clipper. I spent much time with him as I was growing up, taking him for walks and generally sharing my adventures with him. He was even the subject of my first book, written when I was in the fourth grade. *The Adventures of Clipper* was not a good book, except that I had a wonderful time writing it.

Figure 2 — A meteor, probably belonging to the Omicron Draconid meteor shower, taken by the author on 2005 July 4. The Tempel comet near the centre of the picture had just been struck by the *Deep Impact* spacecraft.

Were I to write it today, I would take Clipper and his owner on many astronomical adventures aboard his rocket ship. The dog would wander past the Moon, sniffing about the site where Armstrong and Aldrin took their first small steps 50 years ago. He would lead on to Mars, whose two tiny moons, Phobos and Deimos, were discovered by Asaph Hall not long after his work was interrupted by a visit from the then-President of the United States, Abraham Lincoln. Clipper the beagle would cruise past Jupiter, skate along the exquisite rings of Saturn, and travel onward through the outer Solar System. He would then roam past the real dog star, Sirius, one of the closest stars to Earth. It might make a better book now than it did in 1956, when one paragraph merely said "Clipper Clipper Clipper."

Figure 3 — A photograph of Clipper, as an older dog, taken by Levy in 1972.

There is one real-life story that never made it to the original book. On a cloudy Friday evening, 1965 December 17, I was walking Clipper toward the summit of a hill near our childhood home. As we walked, the sky began to clear. Clipper did not want to turn back and return home, but after a short tug of war, where Clipper pulled in one direction and I pulled the leash in the opposite, I won out. When I arrived home, my telescope was waiting for me as more clouds were gathering in the west. Around midnight, I began my search for comets, a journey that has so far resulted in the discoveries of 23 comets. It is a project that has given me unparalleled joy, and which continues to this day. And as I look toward Jupiter, I might even detect Clipper's beagle howl as we both recall the collision, a quarter century ago of one of my comets, Shoemaker-Levy 9, with that giant and thrilling world. ✶

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

Observing

The Classic RASC Observing List *The Observers Handbooks* 1943–1980: A Foundation for Deep-sky Observing in Canada

by Chris Beckett, Unattached

Autumn brings cool and hopefully clear nights; it also means the annual edition of the *Observers Handbook* (OH) will soon land in our mailboxes.

Many autumns ago, I attended my first RASC meeting at the Halifax Centre and was given a copy of the *Observers Handbook*. The cover was unceremoniously ripped off before my eyes, something to do with not giving the Milky Way away for free. I read through that copy cover to cover, discovering a few surprising morsels of information, such as nebular filter graphs, exit pupil and binocular charts, as well as observing lists. Fast forward to 2018—as I prepared a talk on “The Styles of RASC Observing Throughout the Years” for a General Assembly history symposium, I found myself perusing the *Observers Handbook*s of yesteryears. In fact, the webmaster had scanned up to 1967 at the time, and now up to 1989. I really didn’t expect to find much, but nonetheless browsed through all the copies, taking note of anything observing related.

The early years brought a surprise with the 1912–17 editions, containing a section called “The Constellations,” a beginners’

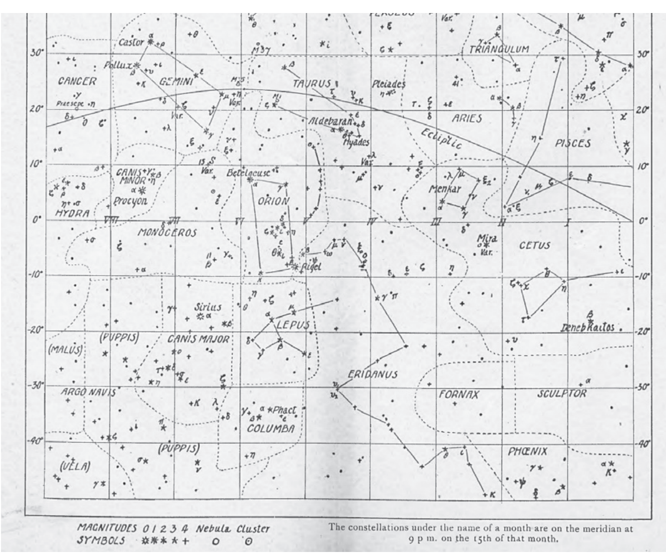


Figure 1 — An example of the star charts as they appear in the 1912–1917 Observer’s Handbook. *According to C.A. Chant, the RASC received numerous requests each year to reprint the charts in the Handbook, but it was cost prohibitive.*

guide to the night sky including four charts down to 5th magnitude, and descriptions of the constellations visible in Canadian skies. Of interest to this observer was seeing many of the Messier objects including M42 and M31, prominent clusters such as the Double Cluster and the Hyades, and many double and variable stars marked throughout the charts, as well as their brief descriptions in the text.

In order to save costs, and perhaps due to wartime paper rationing, this and many other sections were omitted from 1918 forward. Future OH editions would refer observers to more complete texts on the constellations including *Norton’s Star Atlas and Telescopic Handbook* and Olcott’s *A Field-book of the Stars*. While Messier objects and other deep-sky targets were mentioned in subsequent OH until 1937 that an entire list of 103 objects made it into the *Observer’s Handbook*. That same year saw the appearance of the four small seasonal star charts following the Messier List. However, after five years, the Messier objects were replaced with something unexpected and very interesting for deep-sky observers.

The Classic RASC Observing List

In 1943, C.A. Chant was the *Observer’s Handbook* editor, F.S. Hogg was the assistant editor, with Ruth Northcott singled out in Chant’s Preface for her outstanding contributions. Here he also states: “Messier’s catalogue has been replaced by three tables giving more complete information about clusters, galactic nebulae, and extra-galactic nebulae,” so they were going for a more well-rounded list than Messier’s 18th-century offering. Chant was editor of the Handbook for the first 50 editions, 1907–1957, at which point Ruth Northcott became editor.

The three tables each include introductory passages:

Star Clusters: “The star clusters for this observing list have been selected to include the more conspicuous members of the two main classes—open clusters and globular clusters.”

Galactic Nebulae: “The galactic nebulae here listed have been selected to include the most readily observable representatives of planetary nebulae such as the Ring Nebula in Lyra, diffuse bright nebulae like the Orion nebula and dark absorbing nebulosities such as the Coal Sack.”

Extra Galactic Nebulae: “Among the hundreds of thousands of systems far beyond our own galaxy relatively few are readily seen in small telescopes. The following list contains a selection of the closer brighter objects of this kind.”

The 1943 list includes 74 objects in total, broken down as: 25 Star Clusters, 24 Galactic Nebulae (what we call nebulae today) including Dark Nebulae, and 25 Extra Galactic Nebulae (what we call galaxies today). The objects range from easy to extremely challenging, representing all deep-sky

NGC	M	Con	α 1980 δ h m	° ′	Type	Size ′	S mag. sq″	m *	Dist. 10^3 l.y.	Remarks
650/1	76	Per	01 40.9	+51 28	Pl	1.5	20	17	15	
IC348		Per	03 43.2	+32 07	Ref	3	21	8	0.5	Nebulous cluster
1435		Tau	03 46.3	+24 01	Ref	15	20	4	0.4	Merope nebula
1535		Eri	04 13.3	−12 48	Pl	0.5	17	12		
1952	1	Tau	05 33.3	+22 05	SN	5	19	16v	4	"Crab" + pulsar
1976	42	Ori	05 34.3	−05 25	HII	30	18	4	1.5	Orion nebula
1999		Ori	05 35.5	−06 45	PrS	1		10v	1.5	
ζ Ori		Ori	05 39.8	−01 57	Comp	2°			1.5	Incl. "Horsehead"
2068	78	Ori	05 45.8	+00 02	Ref	5	20		1.5	
IC443		Gem	06 16.4	+22 36	SN	40			2	
2244		Mon	06 31.3	+04 53	HII	50	21	7	3	Rosette neb.
2247		Mon	06 32.1	+10 20	PrS	2	20	9	3	
2261		Mon	06 38.0	+08 44	PrS	2		12v	4	Hubble's var. neb.
2392		Gem	07 28.0	+20 57	Pl	0.3	18	10	10	Clown face neb.
3587	97	UMa	11 13.6	+55 08	Pl	3	21	13	12	Owl nebula
ρOph		Oph	16 24.4	−23 24	Comp	4°			0.5	Bright + dark neb.
θOph		Oph	17 20.7	−24 59	Comp	5°				Incl. "S" neb.
6514	20	Sgr	18 01.2	−23 02	HII	15	19		3.5	Trifid nebula
6523	8	Sgr	18 02.4	−24 23	HII	40	18		4.5	Lagoon nebula
6543		Dra	17 58.6	+66 37	Pl	0.4	15	11	3.5	
6611	16	Ser	18 17.8	−13 48	HII	15	19	10	6	
6618	17	Sgr	18 19.7	−16 12	HII	20	19		3	Horseshoe neb.
6720	57	Lyr	18 52.9	+33 01	Pl	1.2	18	15	5	Ring nebula
6826		Cyg	19 44.4	+50 28	Pl	0.7	16	10	3.5	
6853	27	Vul	19 58.6	+22 40	Pl	7	20	13	3.5	Dumb-bell neb.
6888		Cyg	20 11.6	+38 21	HII	15				
γCyg		Cyg	20 21.5	+40 12	Comp	6°				HII + dark neb.
6960/95		Cyg	20 44.8	+30 38	SN	150			2.5	Cygnus loop
7000		Cyg	20 58.2	+44 14	HII	100	22		3.5	N. America neb.
7009		Aqr	21 03.0	−11 28	Pl	0.5	16	12	3	Saturn nebula
7023		Cep	21 01.4	+68 05	Ref	5	21	7	1.3	
7027		Cyg	21 06.4	+42 09	Pl	0.2	15	13		
7129		Cep	21 42.5	+65 00	Ref	3	21	10	2.5	Small cluster
7293		Aqr	22 28.5	−20 54	Pl	13	22	13		Helix nebula
7662		And	23 25.0	+42 25	Pl	0.3	16	12	4	

Figure 2 — The Galactic Nebulae *as they appeared on page 126 for the final time in the 1980 edition of the* Observer's Handbook.

The move away from the Messier Catalogue, which had been included in the OH for the editions from 1937 to 1942, was an effort to provide better representation of the nebular class of objects. As Dr. Racine put it "to illustrate the different types of interactions between stars and interstellar matter in our galaxy," this really appeals to me as I have also long felt the Messier list, created with small, narrow-field instruments, limits the contextual understanding of the nebula story. In fact, he also made the addition of *extended complexes*, wide-field regions including Rho Ophiuchus and Delta Ophiuchus, a dark-nebula region now commonly referred to as the Pipe Bowl. Both these extended complex objects are included in the Wide-Field Wonders list I authored for the *Observer's Handbook.*

objects, and covering the entire sky so you'd need to pack your bags and head south to see them all.

While many of the clusters and galaxies were from Messier's list, the nebula list contained selections from a variety of catalogues, including Barnard's dark nebulae.

So which nebulae did they include? I was surprised to find many objects we consider challenging today, such as the Horsehead (B33) and Snake (B72 "S") dark nebulae, Hubble's Variable Nebula, as well as the North America Nebula. While the Messier list would again make its appearance and finally become an official observing program, this "Classic" list would be refined over nearly four decades. Among the updates was the 1967 OH addition of Star Clusters table authorship by T. Schmidt-Kaler, who wrote a more complete introduction and introduced Coma Berenices and many non-Messier objects to the cluster table, including objects below Canadian horizons, such as NGC 4755 the "Jewel Box." The 1967 edition also saw Sidney van den Bergh take authorship of the External Galaxies table, who split the table into The Brightest Galaxies and The Nearest Galaxies, a change that persists today. After Ruth Northcott's death in 1969, the Galactic Nebulae list was rewritten by René Racine, who would remain its author till 1981, when it totalled over 35 objects, by this time the cluster list had jumped to 62, and the Brightest and Nearest Galaxies totalled 49.

All the objects in this Classic list now find homes in one list or another, however the three tables for Clusters, Nebulae, and Galaxies is an original list of 146 objects and foundational to visual observing in Canada, and would make a fulfilling observational experience for observers seeking a different sort of challenge. To locate the Handbooks referenced in this article, including the three tables from 1943 to 1980, visit the Handbook History page at www.rasc.ca/handbook-history ✶

Chris Beckett is a past chair and now a regular member of the Observing Committee, a long-time binocular and small telescope observer and author of the RASC Observer's Handbook WIDE-FIELD WONDERS. *Since 2012, he has been the Continuing Education Astronomy Instructor at the University of Regina and enjoys observing under the dark skies of Grasslands National Park in the desert environment of southwestern Saskatchewan.*

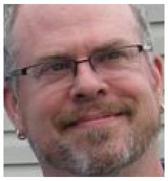
The December *Journal* deadline for submissions is 2019 October 1.

See the published schedule at

www.rasc.ca/sites/default/files/jrascschedule2019.pdf

Binary Universe

To Catch the Stars



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

A planar astrolabe

For centuries, astronomers used astrolabes to identify stars and planets and to predict events. These mechanical devices were calculators for the early astronomers. Astrolabes are also used by mariners. Today we have powerful computing devices in our purses or pockets.

https://itunes.apple.com/ca/app/astrolabe-clock/id421777015

There is a fun and free iOS app that you can use to identify stars and planets, know the Sun and Moon rise and set times along with the Moon's phase, and predict events including solar and lunar eclipses. Appropriately, it is called Astrolabe Clock.

The digital astrolabe

I first started using this small and elegant app on my iPod Touch many years ago. My first blog entry mentioning the tool is dated 2012 March 16 when Grace Horvatin and I—inside the bright light dome of Toronto—used it to find Mars in the evening sky. Having the easy-to-use app in my pocket, I was able to confirm a morning naked-eye sighting of Mercury while heading to work on 2014 October 27. On a bus no less. Many times, I found the software very useful for identifying planets seen before sunrise or after sunset. I often consulted it to check the Moon phase and twilight times for an upcoming weekend. I made good use of Astrolabe Clock (AC) version 1.04 copyrighted 2011 but then stopped using it.

Recently, I downloaded the version 1.11, which was last revised in 2015. It was good to be back, and I enjoyed the handful of improvements.

On launching AC, the display shows a circle, which is a 24-hour clock with high noon at the top (see Figure 1). The green arrow with the Sun indicates the current time. The colours within the outer band allude to daylight and nighttime, blue and grey respectively.

The red arc is the ecliptic, of course, with all the planets shown (yes, Nicole, even Pluto). You should be able to tag each planet with its colourful symbol. One can easily see which planets are leading the Sun, that will be up before dawn, and the ones following our local star, your evening targets. The Moon also appears with the phase represented.

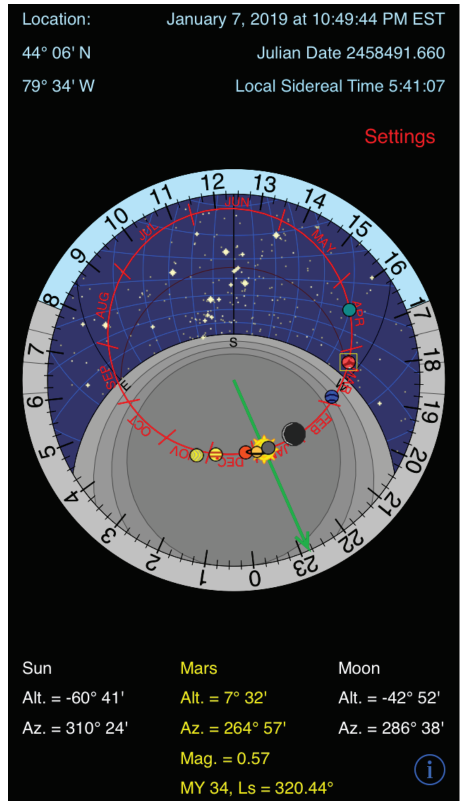


Figure 1 — Astrolabe showing the sky at 10:49 p.m., with Orion on the meridian and Mars setting.

By default, this circle states the months, so the two-dimensional astrolabe can immediately be read for time *and* date information. There's an option in the Settings that allows you to switch to a zodiacal mode (with symbols).

Assuming you start the app at night, the phone background will be black and the simulated sky violet. You'll see dim-through-bright stars plotted and, while small, you should be able to make out familiar patterns. If you run AC during the day (Figure 2) or you change the time to midday, the phone background changes to grey, the sky will turn pale blue, and the stars will disappear.

Twilight is handled in clever ways. The grey circles show the horizon and various elevations below. The increasingly darker circles indicate civil, nautical, and astronomical twilight. Also, the grey radial lines in the outer dial show the twilight time transitions.

Azimuthal gridlines appear in the sky. There are lines at the cardinal points with the south vertical line highlighting the meridian. The celestial equator is shown as the arc running between the east and west markings.

When the Moon is full, a small circle will be drawn in the sky showing the Earth's shadow (Figure 3). If close to or touching the Moon, you can anticipate a lunar eclipse.

The display can be zoomed in (Figure 4) or out, or panned with normal pinch and swipe gestures.

Simultaneously, I find this single display remarkably helpful and informative, rich in detail and content, but not overwhelming. The clockwork-like movement really is evocative of the finely crafted metal instruments. It also reminds me of the beautiful astronomical clock Orloj in Prague's old town square.

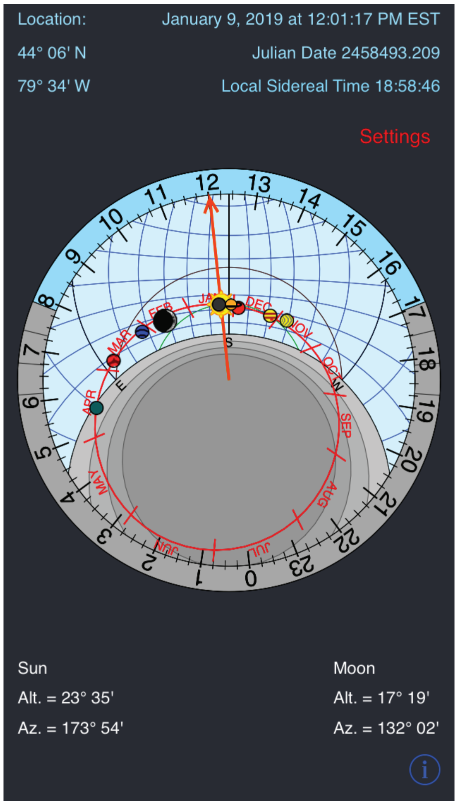


Figure 2 — The time was manually set to 12 noon. Uranus rising. The Moon is young.

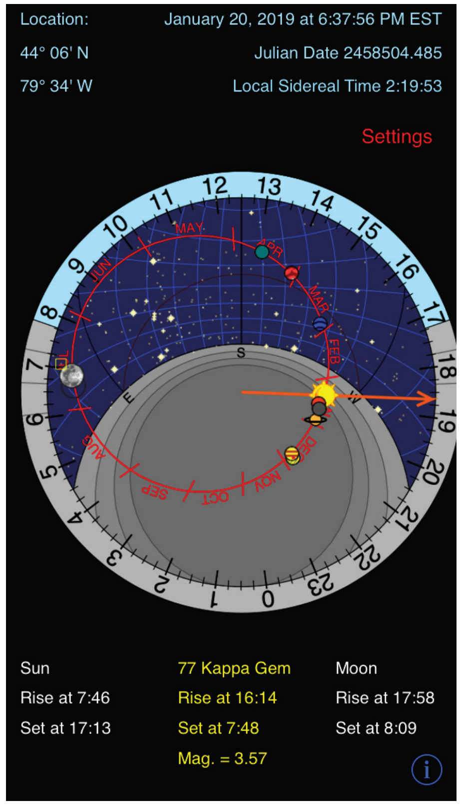


Figure 3 — The faint circle near the full Moon alludes to the impending lunar eclipse.

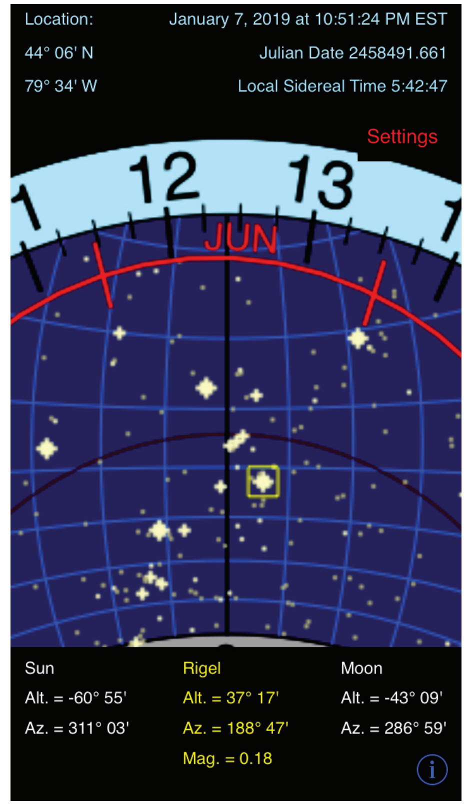


Figure 4 — Zoomed into the Hunter constellation with Rigel selected.

Making motion look simple

Facts and figures are relayed at the edges of the screen. Along with the local civilian date and time, the app shows the Julian date. In 2012, the app did not have this, but the current version notes the local sidereal time (joining the LST apps I described in the December 2018 *Journal*). Details of the Sun and Moon are shown. Tapping on a planet or a star reveals details like its magnitude.

By default, you will see the coordinates of the Sun, Moon, and planet or star using altitude and azimuth numbers. This can be changed to RA and Dec in the Settings panel. Tapping the bottom of the screen will switch the display between the coordinates and the rise/set times.

Tuning

Want to see what the sky will look like at a particular time, say later in the evening, or at sunrise a few hours later? Or which daytime planets will be visible? First, tap on the Sun. When the green arrow turns orange, you may swipe around the circle.

The display will interactively adjust as you drag the Sun above or below the horizon. Tap on the arrow's head to advance one day; tap the arrow's base to back up.

To get to a date or time far into the future or past, use the Settings button.

In the configuration panels, there are a dozen options you can toggle on or off or change to suit your preferences (Figure 5). For example, you can show the stars even in the daytime, set the location to something other than your current, you can suppress the display of the distant Solar System bodies, or you can change the astrolabe projection to aim north.

More info

I found the AC app very easy to use. If you need assistance you can tap the blue information button for the onboard help. The developer's website also includes explanations and tips.

www.twonineeightsoftware.com

I chatted with the friendly developer. He said he continues to support the app and is willing to entertain product idea suggestions. Of course, I asked about red-light mode. He helped me sort and resolve a minor display issue.

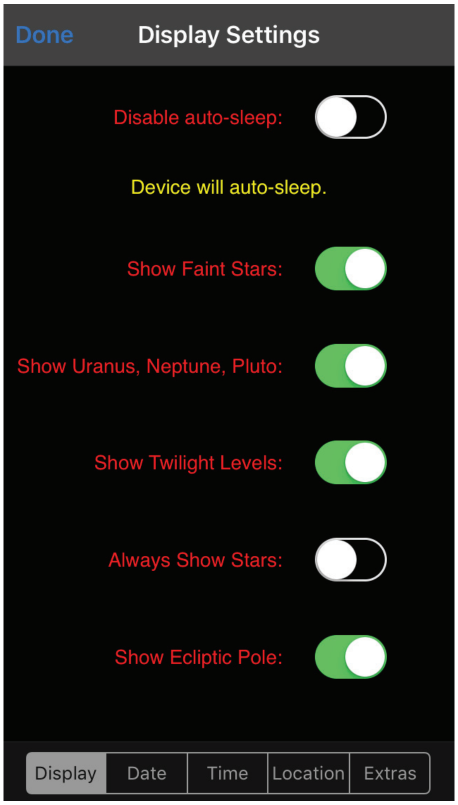


Figure 5 — The Astrolabe Display Settings panel with toggle switches.

Astrolabe Clock is tiny (for a change) and downloads very quickly. I tested the app on a modern iPhone and it worked well. All the screen shots are from the 5S. I did not test on an iPad, but it should perform nicely, taking advantage of the additional display real estate and also allow landscape orientation.

So, if you have left your antique astrolabe at home or you're not standing in front of Prague Orloj, you can still easily identify stars and planets, predict rise and set and twilight times, predict lunar and solar eclipses, all with your attractive digital Astrolabe Clock.

Bits and bytes

There's a neat trick for iPhone users with iOS 11 (or higher) installed, whereby you can configure your device to quickly switch into red-light mode. Via the Display Accommodations settings, in the Accessibility menu, adjust the "Color Filters" option, select "Color Tint" as your filter, and use the Intensity and Hue sliders to make a deep red colour. Finally, to rapidly enable the red mode, set up an Accessibility Shortcut such as triple-clicking the Home or Side button. ✶

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 Toronto Centre Carr Astronomical Observatory, sits on the David Dunlap Observatory committee, and is a member of the national Observing Committee. In daylight, Blake works in the IT industry.

CFHT Chronicles

Odds and Ends from Hawaii

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

Rarely do I write from a first-person perspective, but I feel as though I should start this column off with an update from Hawaii. As I write this, the Maunakea Observatories have not taken scientific data in 24 days. It is the longest pause in observations in the 50-year history of Hawaii astronomy. By the time this column is read in October, I do not know where we will be. I assume back on the sky, taking data, and making discoveries, the work that we want to do.

The time delay between writing and publishing provides me a unique opportunity to make a request of my readers. I do not know what the situation will be in October, but I ask that everyone take a deep breath before charging into assumptions about the situation, especially on social media. The protests are about more than the Thirty Metre Telescope, and very few people in Hawaii fit into a neat box of science or culture. Especially on Hawaii Island. We are a small community. Waimea, where CFHT's offices are located, is a town of maybe 12,000. Because of that, almost everyone who works at an observatory knows someone who is opposed to the TMT, if not directly protesting. At the moment, my husband's friend is storing his camping supplies in our garage to use while protesting. To say times are complicated is an understatement.

Namakanui

I usually just write about CFHT, but this is clearly a column of firsts, so I'm going to talk a little bit about the James Clerk Maxwell Telescope.

For those not familiar with JCMT, it is the largest astronomical telescope in the world designed specifically to operate in the submillimetre wavelength region (think far-infrared-microwave) of the spectrum. The JCMT is used to study our Solar System, interstellar and circumstellar dust and gas, and distant galaxies. It's located just down the hill from CFHT on Maunakea and is operated by the non-profit organization, the East Asian Observatory (EAO).

The EAO is formed by East Asian Core Observatories Association (EAOC) for the purpose of pursuing joint projects in astronomy within the East Asian region. In the era of very large-scale astronomical instruments, East Asia will be competitive internationally by combining their funding resources, their technical expertise, and their manpower. The intention of EAO is to build and operate facilities, which will enhance and leverage existing and planned regional facilities.

JCMT was one of the eight telescopes whose powers combined to form the Event Horizon Telescope and image the black hole at the centre of M87. In a previous column, I wrote about the origins of the name given to the black hole (at least here in Hawaii)—Powehi. Professor Larry Kimura worked with the JCMT and SMA teams to create a name that poetically described the black hole.

After that collaboration, Dr. Jessica Dempsey, the deputy director of EAO and JCMT, reached out to Kimura again. This time, she asked him to name JCMT's newest instrument. Again, he met with Dempsey and the instrument team to learn more about the instrument before he settled on a name.

The instrument was built by ASIAA (Taiwan) in concert with EAO. It has three different detector elements, collecting light at 0.8 mm, 1.2 mm, and 3.5 mm. It is cooled down to just a few degrees above absolute zero in order to be sensitive to the faint radiation emitted from cold, star-forming gases such as carbon monoxide and other complex molecules that coalesce in our galaxy and beyond. It works essentially like your radio receiver: astronomers can tune into the frequency of the element or molecules they want to study.

After learning about the instrument, Kimura named it Namakanui, which translates to "big-eyed fish." Each of the three detectors have their own species names, U'u (1.2-mm detector), Aweoweo (0.8-mm) and Ala'ihi (3.5-mm).

"Dr Kimura chose the names to describe the many species of fish in Hawaiian waters that come out in the darkness of night to hunt with their large sensitive eyes," says Dr. Jessica Dempsey, deputy director of the East Asian Observatory. "The names are perfect because the instrument will peer into the darkest and coldest regions of space to help astronomers hunt for objects we currently are unable to see."

The EAO team plans to use Namakanui next year for the next experiment with the Event Horizon Telescope as the world-wide collection of telescopes hunt for the next image of a black hole. EAO and its neighbour on the summit of Maunakea, the Submillimeter Array, participated in the last Event Horizon Telescope experiment, which led to the immense achievement of imaging Pōwehi, the black hole at the centre of the massive M87 galaxy, announced earlier this year.

In the next hunt, Namakanui's detectors will bring to the experiment measurements that are four times more sensitive, giving us an even greater chance of imaging these mysterious monsters at the centre of our galaxy and beyond.

Namakanui arrived in Hilo during the first days of the July protests, intended for delivery and installation at the summit immediately after. The ongoing protests and access challenges meant this was not possible. Instead, the creative staff at EAO and ASIAA cooled the instrument down in the EAO labs, to start testing and learning about the instrument. At the writing of this, Namakanui is still in Hilo. The challenge will remain in getting the instrument installed and commissioned in time for the Event Horizon Telescope tests later this year and early next year.

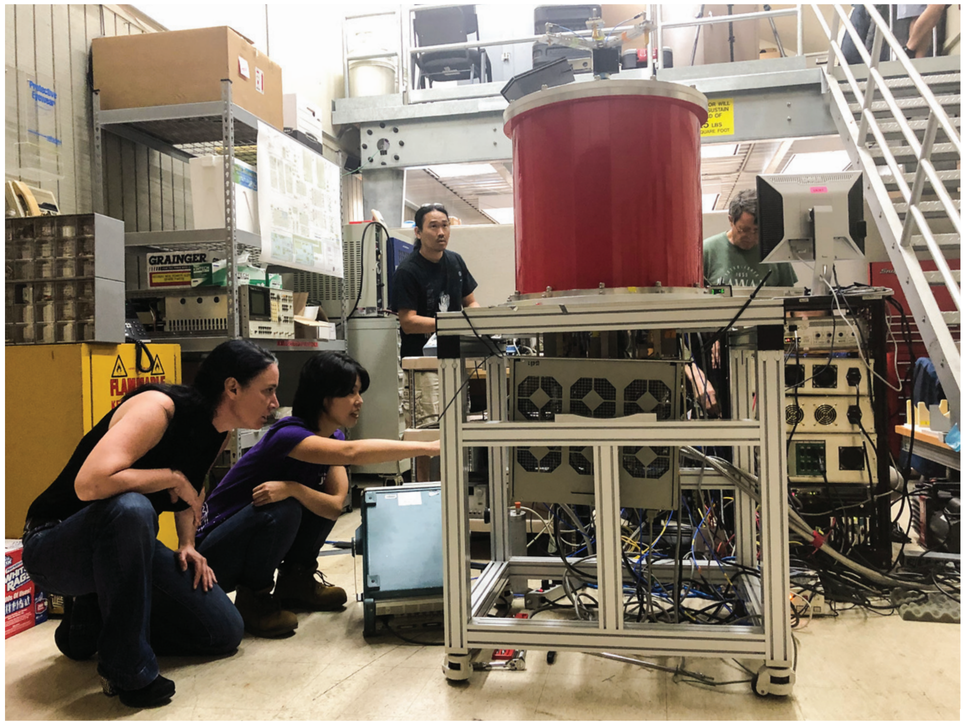


Figure 1 — JCMT deputy director Dr. Jessica Dempsey and instrument scientist Dr. Izumi Mizuno inspect Namakanui at the EAO offices in Hilo before it departs for the summit.

Unique Outreach Experience

In early June, I joined our resident Canadian astronomer Laurie Rousseau-Nepton in an incredibly rewarding outreach experience in Québec. We participated in the Astronomy for Canadian Indigenous People (ACIP) project spearheaded by Ismael Moumen from Université Laval. The IAU's Office of Astronomy Development, CASCA, and the Centre for Research in Astrophysics of Québec (CRAQ) funded the project.

For the description of this project, I am liberally borrowing from the poster Ismael Moumen, Laurie Rousseau-Nepton, Julie Bolduc-Duval from Discover the Universe, and I submitted for the 2019 CASCA meeting in June.

Summer 2019 is the pilot year for the project where we operated on building connections into the First Nations communities we worked with. Laurie, Ismael, and I visited the school Wahta' on the reserve Wendake and the Centre d'Amitié Autochtone de Trois-Rivières in the city of Trois-Rivières. We wanted to create a connection between First Nation communities and resources in the astronomy community. Through these visits, we reached members of the Atikamekw, Hurons-Wendat, and Innus communities.

Figure 2 — Dr. Laurie Rousseau-Nepton talks to students at school Wahta'.

While the evening programs were open to families and the boarder community, we aim to reach students aged 8–14 years old. The project has three components:

1. Visiting schools in the Indian reserve(s) to reach young Indigenous students;
2. Facilitate a visit for those students to Observatoire du Mont-Mégantic during the Popular Astronomy Festival of Mont-Mégantic;
3. Organizing a special webinar for teaching astronomy.

A key and unique component of the project is the deeply personal connection between the Reserves visited and Dr. Laurie Rousseu-Nepton, the primary presenter during the school and community visits. Dr. Rousseau-Nepton is the first First Nations woman to earn a Ph.D. in astronomy. More importantly for these communities, she lived on the Wendake Reserve as a teenager and her extended family is connected to several Reserves across Québec.

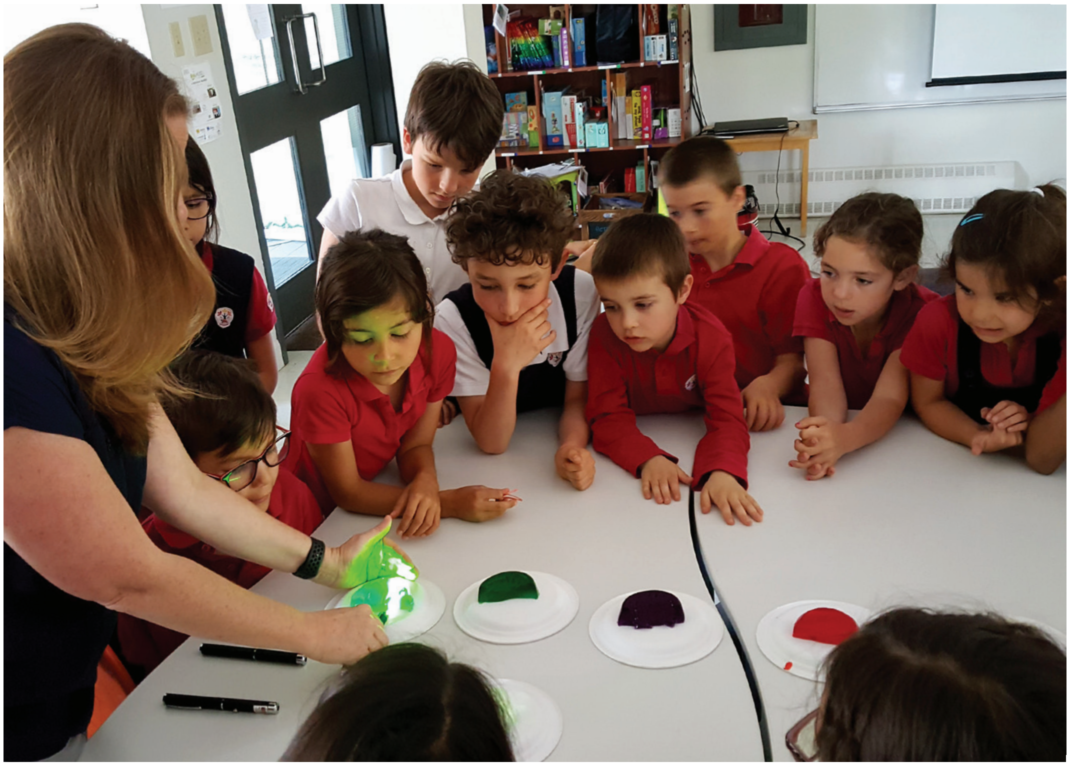


Figure 3 — Laser Jell-O optics

For the school visits, Laurie talked about her experiences growing up down the street, her job at CFHT, and the work that she does now. After her presentation, we broke the group into two. Half asked Laurie questions, and the other participated in a science demonstration with Ismael and me. We showed the students how astronomical filters work by shining lasers through Jell-O. It is a favourite demonstration of mine. It is a lot easier to explain optical depth when the students can see the absorption of a red laser pointer in green Jell-O. After ten minutes or so we switched, allowing both groups to experience the activity and time with Laurie.

During the evening sessions, Laurie spoke more broadly about her background and her science. She focused on molecules found in star-formation regions. We paired her talk with another activity, this time the kids in the audience made sample molecules out of gummies, marshmallows, and pasta. We had examples of simple molecules and a more complex sugar molecule. Surprisingly, several students attempted to make the sugar molecule.

Laurie's leading of the classroom and evening sessions was critical. When students and the community see themselves in the presenter, the message of their own capabilities and unlimited possibilities resonates deeper

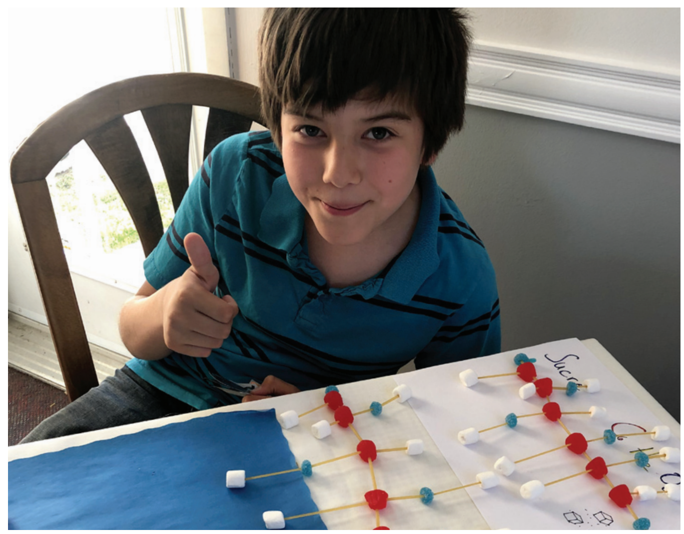


Figure 4 — Students building molecules

A month after our visits, the group visited Mont-Mégantic overnight. I have not had the opportunity to touch base with Ismael on how the visit went, but I am confident that the kids had a great time.

Julie Bolduc-Duval scheduled a special webinar for teachers involved in the program through Discover the Universe. The webinar will highlight activities and resources for teachers to teach astronomy in their community. ✶

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 Program Manager; the CFHT is located on the summit of Maunakea on the Big Island of Hawaii.

John Percy's Universe

Reflections on the 2019 RASC–AAVSO General Assembly

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

In June 2019, the RASC and the American Association of Variable Star Observers (AAVSO) held a stimulating and enjoyable joint General Assembly (GA) at York University in Toronto—one of several that they have held over the years. The theme of the conference was education and public outreach which, along with variable stars, is my favourite topic! I have been a member of the RASC for 58 years, and the AAVSO for 42 years, and have happily served both organizations in many roles. Since I am slowly ramping down my active involvement with both, and very slowly "riding off into the sunset," this meeting was a bittersweet one for me. But it was exciting. The program of lectures, papers, workshops, meetings, and informal discussions was diverse and thought-provoking. It has caused me to reflect on the present and future of these two illustrious organizations that I know and love.

The Breadth of Astronomy

The invited talks at this GA were reflective of the many and diverse facets of astronomy, including interdisciplinary connections: music, art, literature, poetry, history, heritage, and biography—as well as science and education, of course. My two favourite International Year of Astronomy (IYA) projects involved the arts (Percy 2014a) and heritage (Percy 2014b). There was a wonderful presentation at the GA about my late colleague and mentor Helen Sawyer Hogg, Canada's best-known and most beloved astronomer, by her biographer Maria Cahill. Don Morton vividly recalled life at the Dunlap Observatory in the decade before I started there in 1961. Jan Cami's talk on the revitalization of Western University's Cronyn Observatory was an inspiration to all of us who are working to preserve and revitalize our astronomical heritage. David Levy's presence and presentations were highlights for everyone.

Citizen Science

The first invited lecture was by Dr. Cliff Johnson, on *The Zooniverse* (zooniverse.org) This is an outstanding example of "citizen science"—non-professionals voluntarily supporting scientific research. I've been thinking about this topic and wrote my current Editorial in the *Journal of the AAVSO* on this topic (Percy 2019). It was prompted in part by a very creative undergraduate student's senior thesis project, working with me—her background spanned the sciences and the social sciences—and by reading the entry on the topic in *Wikipedia.* All of these emphasized the s*ocial* as well as *scientific* aspects of citizen science. How can science attract and engage people of all ages, genders, and backgrounds? And what are the benefits of citizen science, above and beyond its contribution to scientific research? How can it serve citizens, as well as science?

That's relevant to a topic that the AAVSO is wrestling with: how to attract and retain new variable-star observers of all ages and backgrounds. The answer is: the AAVSO and similar organizations must create and support a gentle and engaging introduction to their science—variable-star observing in the case of the AAVSO. The AAVSO is often perceived as being the preserve of greying white males (like me) with high-tech backgrounds and interests. Galaxy Zoo, the original project in The Zooniverse, is simple to begin, and enticing to continue. The learning curve is shallow. The RASC too could benefit by providing new members with a gentle introduction to astronomy. The NOVA (New Observers to Visual Astronomy) courses are a good start. But it's complicated by the fact that astronomy, with its diverse connections, means different things to different people.

Citizen Education

If citizen science enables volunteers to contribute to science research, then surely, when volunteers contribute to science education and outreach, they should pride themselves on being "citizen educators." In astronomy, their role is particularly important at the school level, because very few schoolteachers have any background in astronomy, or astronomy teaching. Amateur astronomers have a passion for astronomy and sufficient knowledge to help. Let's not forget that the RASC received the prestigious Michael Smith Award in 2003 for exemplary outreach in science in Canada and continued its outstanding work through IYA.

But knowing astronomy doesn't necessarily imply knowing how to teach it. This was the theme of one of my previous columns (Percy 2014c), which applied some of Professor Derek Hodson's principles to astronomy outreach.

At the GA, I was impressed and engaged by the workshop on Astronomy Education and Outreach Best Practices, in which some of our best "citizen educators" shared their passion and creativity with the participants. I was equally impressed by the greatly enhanced education and outreach page (1) on the RASC website. It's unfortunate that so many of the resources come from the US, but that merely reflects the higher priority and funding for STEM education south of the border.

And, in 2019, the GA included outreach activities for the public. Excellent!

Equity and Diversity in Astronomy

I could not help but notice that the audience at the AAVSO sessions was almost entirely graying white males like me. This may have been partly a "selection effect"; graying white males

Figure 1 — Jessica Vaughan is a member of the RASC Youth Committee, and of the RASC Niagara Centre, where she does lots of event planning and outreach. At the 2019 GA, she enthusiastically demonstrated how to make Jupiter bottles, both for the GA participants and the public. She is clearly an exemplary ambassador for the RASC. Photo by Maria Kalsatos.

may have had more time, resources, and interest in travelling to a conference than beginners at variable-star observing. Note, though, that the present Director of the AAVSO, its past president, and my forthcoming successor as Editor of the *Journal of the AAVSO* are all women.

Women were better represented in the RASC sessions, though the governance of the RASC is mainly male. In the last three decades, the RASC has had only one female (national) president. The AAVSO has had five.

Both organizations are rightly concerned with expanding their diversity. They have also been developing values statements—as they should—to help deal with issues of discrimination and harassment that may unfortunately occur.

Best Practices

University professors like me receive little or no training in teaching, even though it's half our job. If we take on administrative roles, as I did, we receive little or no training in that either. It is therefore not surprising that, when RASC or AAVSO members take on administrative roles, they may feel ill-prepared, so I was pleased that RASC Director Randy Attwood offered a workshop on running a Centre, based on the RASC's manual on that topic. Likewise, those of us who serve on RASC or AAVSO committees could use some guidance from "on high"—a job description, basic preparation, and yearly evaluation—formal or otherwise. This is the essence of "best practices."

In universities like mine, every department is comprehensively reviewed every few years—its undergraduate and graduate programs, research, outreach, facilities, and administration. It's important for organizations like the RASC and AAVSO to review their programs, publications, and governance regularly and objectively, and use the results to make themselves even better—even though this can be a time-consuming process.

Last Words

As banquet speaker, I had "the last word" at this GA. My presentation was an updated version of my Qilak Award Lecture of a few years ago. You can find a published version in this *Journal* (Percy 2012) and the presentation version on my website (2). I highlighted the outreach work of the Dunlap Institute of Astronomy and Astrophysics, which was in its infancy when I gave my Qilak Lecture. I mentioned the teachers and role models who fostered my interest in education and outreach, the many colleagues and students who have helped me, and the many organizations through which we have done it.

I especially praised the work of the RASC and AAVSO, and their partner organizations, almost all of which are run by volunteers. My advice was contained in several words: partnership, collaboration, cooperation, coordination, enthusiasm—all leading to high reach, leverage, and impact, and to effectiveness through "best practices." And fun! At this GA, I was reminded of the dozens of RASC and AAVSO conferences that I have attended over five decades, the memorable people and places, and the sheer joy of contributing to astronomy education and research alongside fertile minds of all ages.

Acknowledgements

My sincere thanks go out to all the GA organizers, presenters, and volunteers for making this such an enjoyable and memorable experience, and for their ongoing work in the advancement of astronomy. Special thanks to Randy Attwood for inviting me to be the banquet speaker. Thanks also to Jenna Hinds and Jessica Vaughan for making Figure 1 available.

Websites

1 www.rasc.ca/education-public-outreach
2 www.astro.utoronto.ca/~percy/qilak2019.pdf

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Dish on the Cosmos

Wobbly Jets and Bursty Black Holes

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

Like the previous column in this space, this dispatch from the long end of the electromagnetic spectrum focuses on high-resolution observations of black holes. The recent imaging of the supermassive black hole in M87 relied on very-long-baseline interferometry, where a network of telescopes spanning the Earth combined their signals to provide the first image indicating an event horizon for a black hole. This massive technical feat presented breakthrough physics, conclusively demonstrating the nature of black holes, but the image was just a relatively simple donut of emission. Here, we look at what we learn from making a movie of the emission around a different black hole.

The black hole in question comes from the black-hole binary system V404 Cygni, where a stellar mass black hole (nine solar masses) is in orbit with a low-mass star (0.7 solar masses). Once, this system was a binary star system with one star having a mass of more than 30 solar masses. One of the rules of stellar evolution is that high-mass stars run through their lives faster than low-mass stars. The massive star goes through its supergiant phases and ends its life in a supernova explosion, blasting off its outer layers and leaving behind a black hole. This particular supernova explosion did not disrupt the binary system, leaving instead the slightly disturbed smaller star in orbit with the black hole.

In the present day, the remaining star has run out of the hydrogen in its core that sustained it for its life on the main sequence. Now, the outer layers of the star are starting to expand in the red-giant phase. As gas gets pushed out from the core of the star, it passes over the tipping point where the gravity from the black hole is stronger than the gravity from the original star, so the gas flows down the gravity well toward the black hole. Because of the orbital motion of the system, the gas carries angular momentum and cannot directly fall into the black hole. Instead, this gas goes into orbit. The friction within this orbiting gas disk dissipates the random motions, organizing the material into a stable, relatively thin disk around the black hole. As the gas grinds against itself in the disk, it experiences friction (or technically, viscosity), heating up and losing orbital energy. The heated material gives off light that we see in ultraviolet and X-ray emission. The gas then orbits progressively lower toward the black hole. This gas structure is called the accretion disk, which acts as an engine to remove the angular momentum from accreting material and channel it onto the black hole.

The accretion disk is ionized gas near the black hole, and the relative motions of electrons and positive ions creates currents that thread the gas with magnetic fields. As the disk spins, with material near the black hole moving faster than material in the outskirts, it winds up the magnetic field around the rotation axis of the disk. This twisted field drives fast (relativistic) jets of particles outward from the black hole at significant fractions of the speed of light. We can see the emission from these jets with radio telescopes.

The picture so far describes the state of an X-ray binary system most of the time: material falls off a donor star and is processed through the accretion disk onto the black hole. The picture is not completely steady: the gas can slowly build up in the accretion disk, with the disk gaining more matter than it can drain onto the black hole. As gas builds up, the disk itself becomes unstable and efficiently dumps material onto the black hole. The instability is speculated to be the result of a runaway process where the cooler material in the outer part of the disk heats up: heating produces friction that produces more heating, etc. This jump in viscosity dissipates energy rapidly, dumping material into the centre of the system. When more material accretes onto the black hole, the inner disk and jets brighten dramatically sending the system into an "outburst."

Outbursts are opportunities to study how black holes interact with the matter immediately around them. Since black holes themselves give off no radiation, we need to infer their behaviour from their influence on the surrounding gas. In 2015, the V404 Cygni system went into a bright outburst and it is relatively nearby (only 2400 pc away), giving an unprecedented chance to observe the system with a diverse set of telescopes. The system was even bright enough to be observed with the Very Long Baseline Array (VLBA), a set of radio telescopes spanning the United States and territories, from Hawaii to the Virgin Islands. While not quite as large as the Event Horizon Telescope that recently observed the M87 black hole, the VLBA was a perfect system for targeting V404 Cygni at milliarcsecond resolution. At this distance of the source, it means the telescope can see emission at roughly 1 AU scales.

What makes these high-resolution observations so interesting is that better resolution means we can watch how the black-hole system is changing over shorter timescales. Since the speed of light is the limit for how fast things can move, we can only watch things evolve on minute or hour timescales if we have the resolution to observe light-minutes or light-hours. In the case of the 1 AU resolution, this is about eight light-

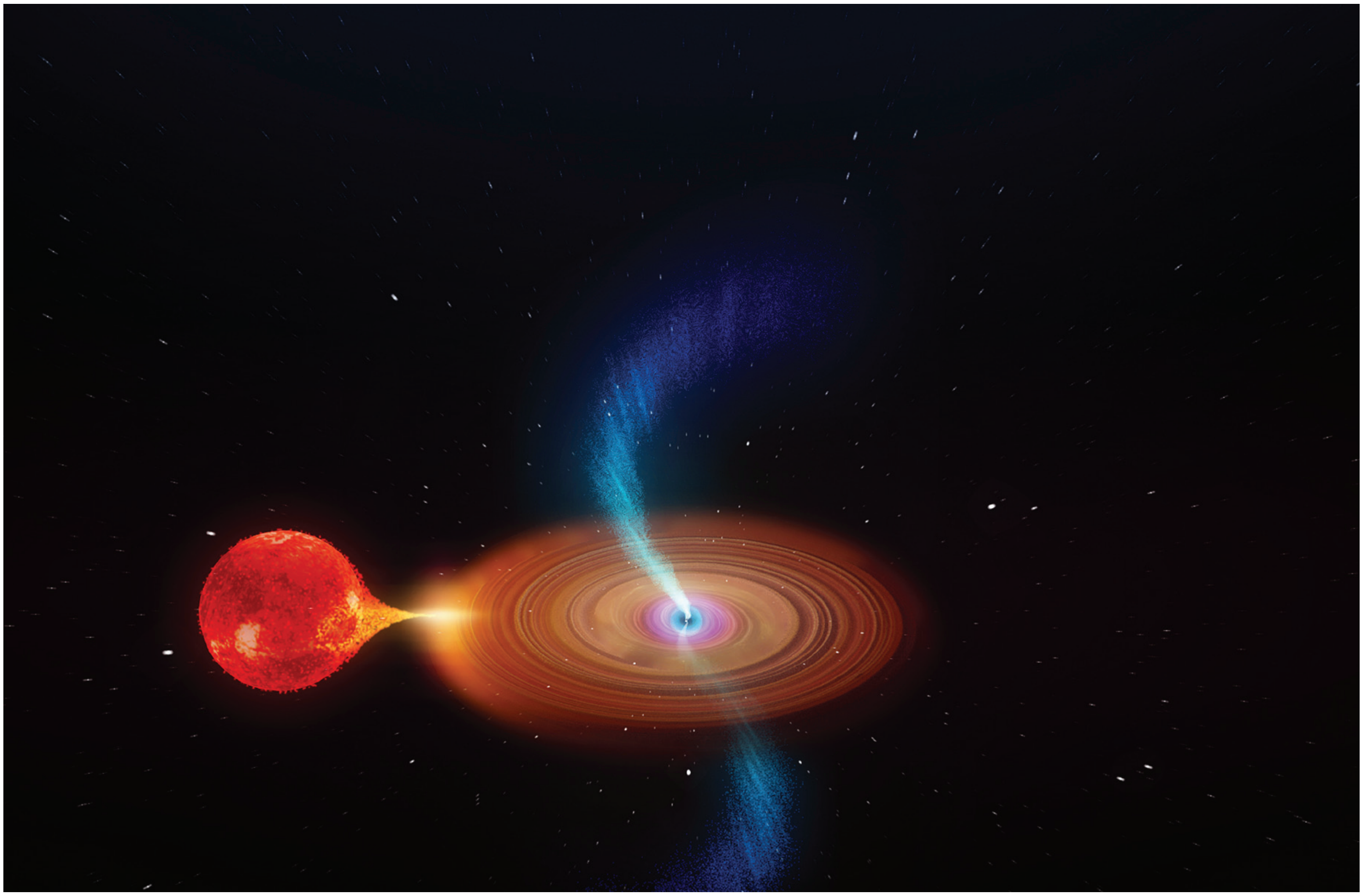


Figure 1: An artist's rendition of the V404 Cygni system, showing the low-mass donor star (left) contributing mass to the accretion disk around the black hole (right). The misalignment of the black hole spin with the accretion disk prompts the accretion-induced jet to precess. Credit: ICRAR.

minutes, so with the VLBA observations, we can watch the area near the black hole evolve a few times an hour, making a truly interstellar movie.

When astronomers made this movie, they watched small clouds of plasma being shot out along the jets at roughly 0.5*c*, half the speed of light. Several of these blobs were symmetric, watching one cloud of plasma being shot in each direction. The movie also revealed that the jets were wobbling around, likely undergoing precession around an axis every hour, much like the Earth's rotation axis slowly precesses to point at different pole stars over a 26,000-year period. While observing the actual clouds of plasma being launched in the jet was novel, the wobbling was unexpected. After consideration, the team concluded that the jets are wobbling because the spin of the black hole is tilted with respect to the orbital plane of the binary system, and thus tilted with respect to the accretion disk. As material falls down onto the black hole, it undergoes precession due to the distortions in spacetime created by the tilted, spinning black hole. This effect may seem like a novelty, but the X-ray binary systems serve as tiny scale models of the central black holes in galaxies, which drive jets spanning intergalactic scales. These scales take millions of years to undergo any evolution, so the small-scale models give clues as to how galactic jets work, and whether these jets shape the evolution of all the galaxies in the Universe.

This particular story is close to me: one of the lead researchers on the team, Gregory Sivakoff, is in the office next door to mine. Another main team member, Alexandra Tetarenko, was a graduate student here at the University of Alberta group and presented this work at her thesis defence. I've been able to hear about how this project has been puzzled out, from the rush to get telescopes pointed toward the V404 Cygni back in 2015, through all the headaches with data and thinking about the physics, to finally developing a clean, novel result. Some new discoveries take just a moment but work like this is a careful labour over many years.

Watch the movie: https://vimeo.com/332194993 ✶

Erik Rosolowsky is a professor of astronomy 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.

Imager's Corner

CGX-L Review

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

In this edition I'll be taking a short break from image processing to offer an equipment review. Unfortunately, for me, my trusty Celestron CGE Pro mount finally suffered a failure that I couldn't repair, and I had to go mount shopping. My requirements were that it be portable, capable of handling 35 to 40 pounds of my gear, and have Celestron's all-star polar alignment software so you know what that meant— a new Celestron mount.

Features

Close to 10 years ago, I bought my first decent mount for astrophotography, a Celestron CGE Pro. After many years of great service, something finally broke that I couldn't fix. The RA motor started to chatter, and the pointing accuracy headed into the toilet. In its day, the mount was a trailblazer, and features like all-star polar alignment were worth the price of admission. The ability to set up and be polar aligned and ready to start imaging in under 10 minutes was a big change from having to spend close to 40 minutes drift aligning each time I drove to my favourite dark-sky site, so I was anxious to keep that kind of simplicity in whatever mount I purchased to replace my trusty workhorse.

The CGX-L is Celestron's highest capacity mount, with a claimed capacity of 75 pounds not including counterweights, although like all mounts, I wouldn't load it past ¾ of its rated capacity for astrophotography. The mount comes well packed in three boxes, one for the tripod, one for the counterweight, and one for the equatorial head. Courtesy of the shipping company, the boxes did not arrive together, so I decided to check if the equatorial head would fit on my CGE Pro tripod. This was when I discovered that the hole pattern lines up very nicely, except Celestron purposely made the holes a little too low to get the bolts in to attach the head on the tripod. The difference was well less than 0.5 mm, but just enough that you would have to buy a new tripod, or drill and tap new holes in the aluminum collar at the top of the old one (not a good plan to put steel bolts into tapped aluminum). Now, I know that Celestron claims that the new tripod is lower and wider for increased stability (all true), but to move the holes just enough to prevent using your old tripod with the new mount seems a little chintzy to me.

The next day, the tripod arrived, and I set about assembling the new system. There are lots of nice touches, like a clip inside one of the carrying handles to hold the Allen wrench used to put the thing together. Better still would have been some proper knobs that did not require any tools, but that would have probably interfered with the azimuth adjustment knobs, so all-in-all the clip is a nice solution for those of us who need the mount to be portable.

At 52.6 pounds, the equatorial head is more than 20 pounds lighter than the head of the CGE Pro, a very welcome change in a portable system. Gone is the electronics pier of the older design, which makes for an easier lift when putting the thing together, another welcome change for those of us who travel to dark skies.

With the mount and tripod assembled, I popped the scope in the dovetail saddle and immediately noticed the dual saddle design that accepts both Vixen and Losmandy style dovetail plates. It has newly designed knobs for clamping things in place, and compared to the knuckle busters that were used on the CGE Pro, they are a welcome improvement. The next thing I noticed was the wonderful altitude adjustment that actively drives the altitude both when raising and lowering the mount. Gone is that awkward altitude bolt of the CGE Pro. Celestron claims the new system is much easier to adjust, and having tried it, I believe them: it is simply a joy to adjust with no jumping or sticking when raising or lowering the scope.

Figure 1 — CGX-L Equatorial Head

Celestron has done away with the external motor cables of the CGE Pro in favour of a through-the-mount wiring arrangement. They have even put a couple of auxiliary ports and an ST4 type autoguider port on the saddle to simplify cable routing. The arrangement works very well if you only use Celestron accessories, another chintzy aspect of the design—would it have killed them to run a single USB port and 12-volt power up to the saddle?

For use in automated applications like a remote observatory, the mount has limit and home switches built in so the user does not have to align anything at start-up, and for the most part, nothing will hit the tripod during the evening. Another nice feature is that the mount will track for an hour and 20 minutes past the meridian, assuming your scope is short enough not to hit the tripod.

The design includes two carrying handles cast into the mount. These make it very easy to carry the equatorial head and are great points to tie down USB and dew heater cables that need to be run up to the scope. It is relatively easy to find a cable routing that will avoid any cable drag issues as the mount moves around the sky.

Figure 2 — My setup, note the cabling tied off the carrying handles with a loop to allow for motion of the declination axis.

Mount and CPWI software

This is an area where the CGX-L really shines. The hand controller is simple to navigate and has lots of useful features. Using two alignment stars and a minimum of three calibration stars, the pointing accuracy is usually less than 5 arcminutes anywhere in the sky and you can sync to a star in a given area to improve pointing substantially in a small section of the sky. The system comes with the usual features like backlash compensation, variable guide and tracking rates, extensive object databases, and a nice identify function that will let you know the name of whatever you are pointing at any given time. The pointing accuracy is good enough to make the all-star polar alignment very usable, and this feature is the chief reason I decided to purchase another Celestron mount. This proprietary polar alignment system is fast, simple, and more accurate than most polar scopes. On my CGE Pro, polar alignment usually took about two minutes and I was ready for a night of imaging. The software also includes a permanent periodic-error-correction system where the corrections are stored in non-volatile memory and are ready to be used at any time.

Celestron has partnered with Planewave to create CPWI, a software package running on a PC that includes a TPoint-like modelling system that improves overall pointing substantially. The user interface is a little hokey, but the pointing accuracy is spectacular! After just four alignment stars, I was unable to find the desired star in my camera's field of view in each of four all-sky slews. After a little head scratching it turned out that I couldn't see the stars in the display because they were under the crosshairs! Aside from a slightly clunky planetarium interface, the pointing accuracy of this software coupled to the CGX-L is simply amazing.

CPWI also includes an ASCOM interface that allows other software to make use of the improved pointing accuracy. On note of caution here is that the ASCOM driver uses the current epoch (Jnow) for coordinates while the planetarium interface of CPWI and a lot of other software uses J2000. If you are using the CPWI ASCOM interface to control your scope you will have to precess all coordinates to the current epoch in order to have the target properly centred.

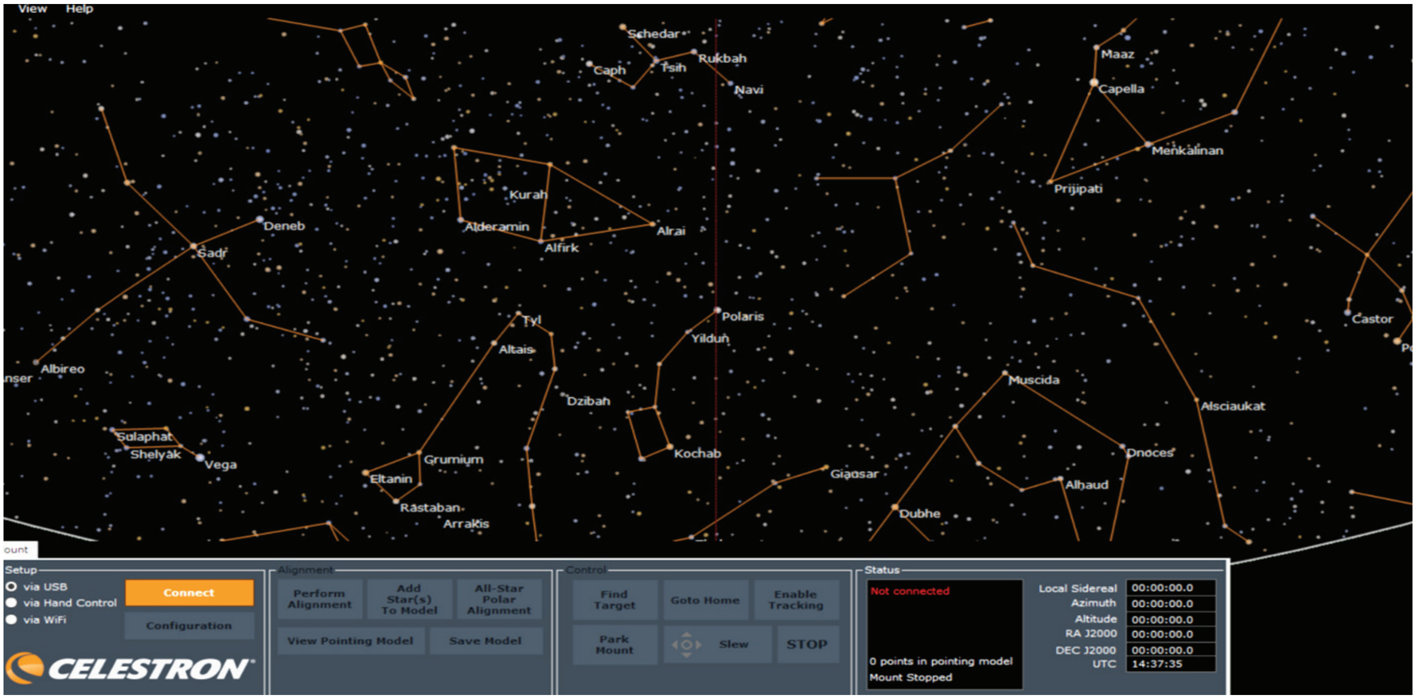


Figure 3 — CPWI interface

Tracking

This is where the rubber meets the road for any mount. Periodic error was reasonably smooth with little in the way of large abrupt transitions. Overall, the peak error was about 9 arcseconds as shown in the PHD log plot below and quite slow. Not too bad for a mid-priced mount.

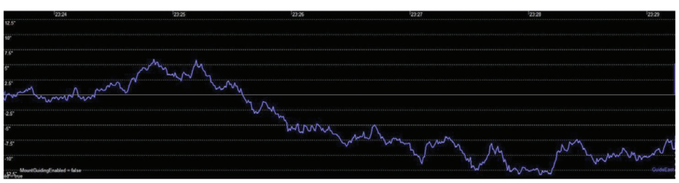


Figure 4 — Uncorrected periodic error

Even without PEC enabled, this was very easy to guide out as the slow periodic error was easy for my Orion SSAG to remove as shown in the M5 image below.

Figure 5 — M5 guided without PEC

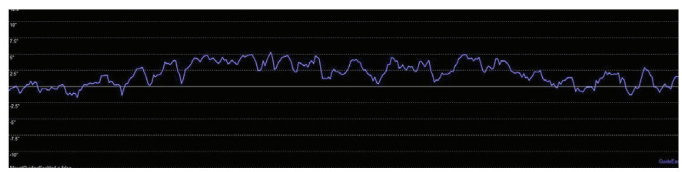


Figure 6 — Periodic error with PEC enabled

After PEC training, the error was essentially random with about 2 arcseconds peak amplitude. I suspect I could get this down to the arcsecond level if I was careful, but since my setup is portable and not in an observatory it simply wasn't worth it.

Shooting from my urban light-polluted driveway for an hour produced 20 guided 180-second exposures with perfectly round stars. The guiding was done on a dim star so the guider exposure could be increased to 10 seconds. With PEC enabled the system produced the image in Figure 7.

Figure 7 — Guided exposure with PEC enabled

Figure 8 — 100-percent crop of the Crescent Nebula image. Note the nice round stars.

Even at a 100-percent crop, the stars are nice and round. The mount was loaded with about 30 pounds of equipment, including a Sky-Watcher Esprit 120, Orion 80-mm guide scope, Canon 60Da, Orion SSAG, USB hub, and cables (Figure 8).

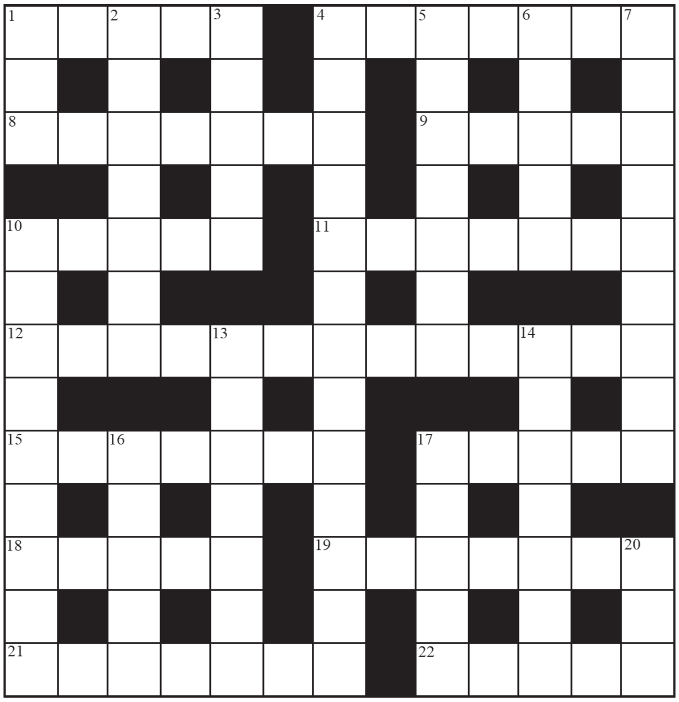
All in all the CGX-L is an excellent mid-priced mount for either permanent or portable applications offering good tracking and with the addition of CPWI, spectacular pointing accuracy. For those needing a portable setup, the heavy duty tripod is rock solid and even has a holder for tablets or cell phones. Aside from the lack of a USB connection on the dovetail saddle, just about every required feature is included.

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

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

Astrocryptic

by Curt Nason



ACROSS

1. Space key leads to it in Orion's shield (5)
4. No skier tumbles around this lunatic (7)
8. Astronomer searched for Pluto, lost time in Greenwich but was healthy (1,6)
9. Turning edges of lenses with a grassy plant (5)
10. Variable G proponent within periodic Kepler equation (5)
11. Variable type rarely changes after the end of October (1,1,5)
12. Give any friend time to start a star party (6,7)
15. Shower source disperses at nadir (7)
17. Curiosity peaks at this mount (5)
18. Renew relative age of a crater inside another (5)
19. Oddly, it never rains on this mare (7)
21. Lost in confusion around Toronto museum, ended up on a mount near Canberra (7)
22. Not dark matter – photons! (5)

DOWN

1. Occasional Moon event initially seen by Herschel (3)
2. Astronomer perhaps clustered in a closet (7)
3. Bethe took a spin around Jupiter (5)
4. Former flux discrepancy solved by Tories on lunar excursion (5,8)
5. Become determined to observe the Pup (7)
6. See Randi amazingly at his lowest (5)
7. Carina turned grape into Saturn's outer space (6,3)
10. Put off nest building for Ptolemaic circles (9)
13. What stray moon is to astronomy (7)
14. Wise men in gin joints doing astrophotography (7)
16. Cryostat made to prevent moisture on lenses with argon (5)
17. Longitude author hasn't written about lobes (5)
20. Moment without one acronym for a sectional telescope (3

Answers to August's puzzle

ACROSS

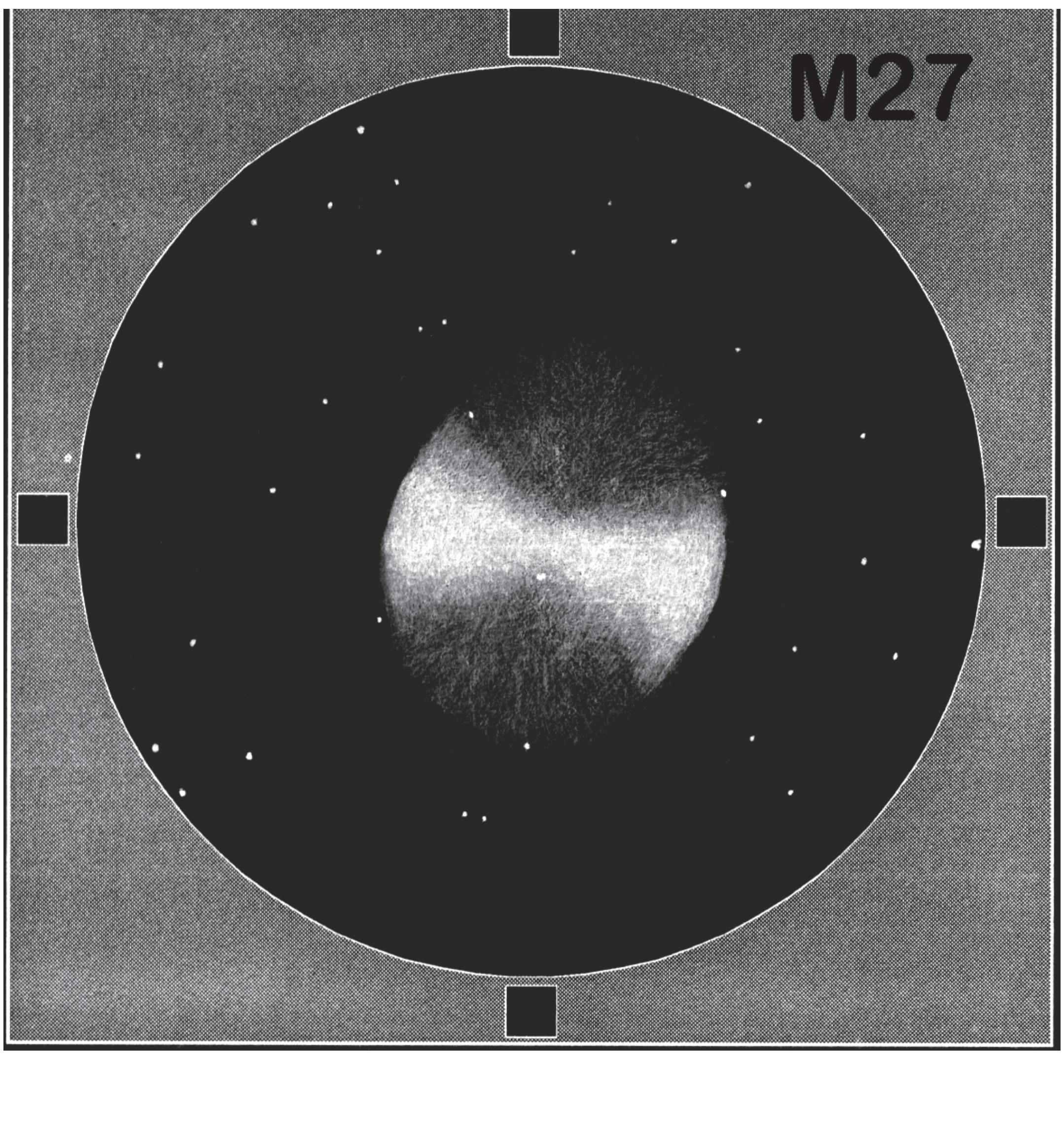
1 HOYLE (2 def); **4** FOCUSER (2 def); **8** MURCHIE (2 def); **9** PALUS (anag); **10** ROOKS (2 def); **11** COLUMBA (anag); **13** MUSCAT (Musca+T); **15** PALLAS (p(all)as); **18** TAYGETE (2 def); **19** STOIC (hid); **20** ROAST (anag); **22** KAPTEYN (k(apt)ey+N); **23** SCHEDAR (anag); **24** ATENS (anag)

DOWN

1 HUMORUM (humor+um); **2** YARKOVSKY (2 def); **3** ETHOS (anag); **4** FRENCH (2 def); **5** CAPELLA (anag); **6** SOL (Solo-o); **7** RASTA (anag); **12** MELPOMENE (Mel+Po(men)e); **14** AVERTED (2 def); **16** SECONDS (se(con)ds) **17** MENKAR (anag); **18** TORUS (hom); **19** SEPIA (anag); **21** ASH (anag)

Great Images

by Stuart McNair



Stuart McNair sketched M27 using graphite on photocopy paper (Messier program forms), scanned and inverted.

Journal

Cygnus the Swan was photographed by Michael Watson from Algonquin Provincial Park, Ontario. Michael used a Sigma 50 mm ƒ/1.4 DG HSM ART lens on Nikon D810a camera body, mounted on an Astrophysics 1100GTO equatorial mount with a Kirk Enterprises ball head for a total exposure time of 12 minutes (ISO 2000; 2 minutes exposure at ƒ/4; unguided).

Subframes were registered in RegiStar and then stacked and processed in Photoshop CS6.