

The Journal of The Royal Astronomical Society of Canada

Journal

Le Journal de la Société royale d'astronomie du Canada

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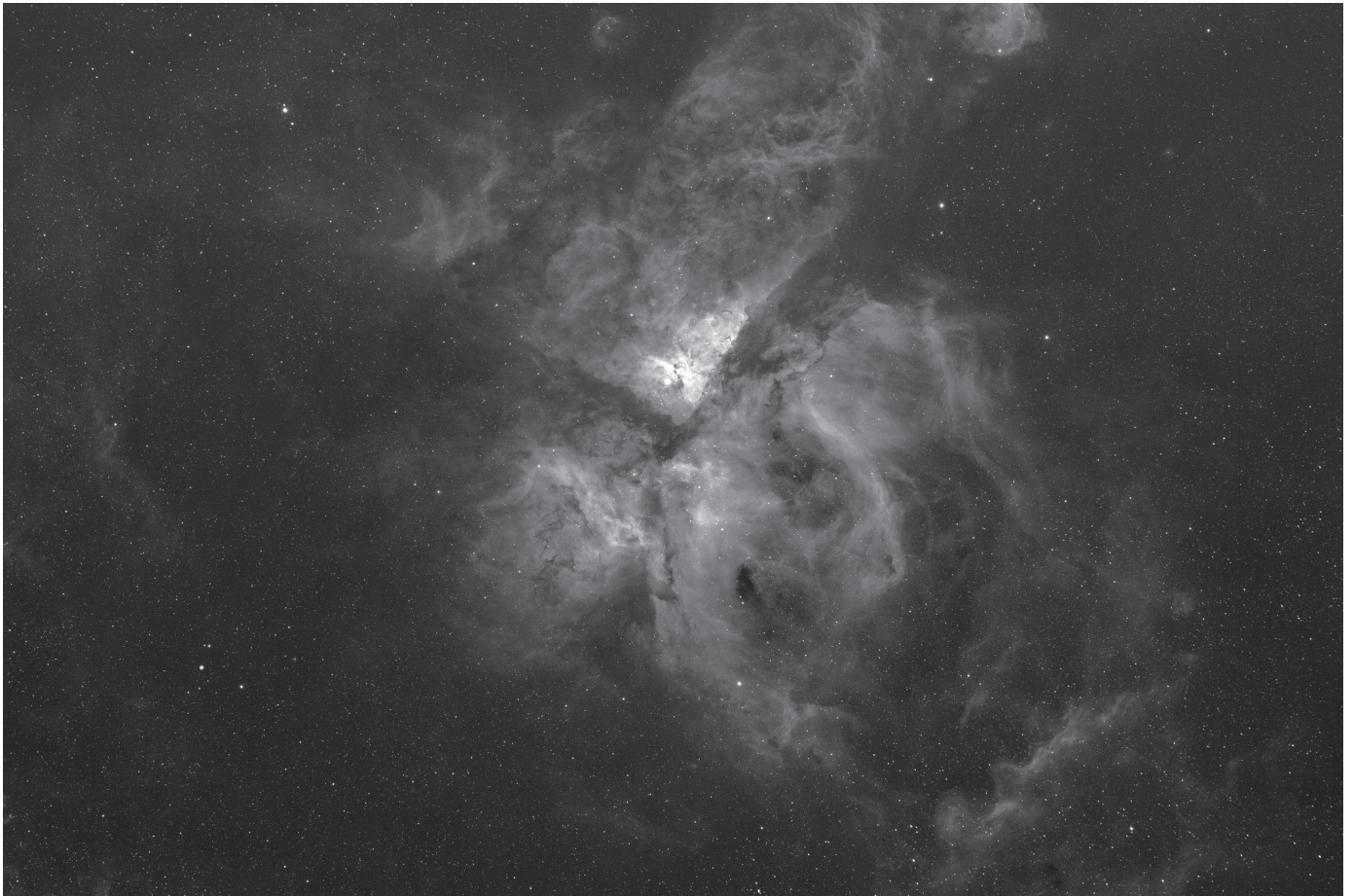
December/décembre 2015
Volume/volume 109
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Sun's Chromosphere
History of Exploring
the Moon

*Sisterly
Grouping*

The Best of Monochrome.

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



This single 300-second H α image of the Carina Nebula, seen from the Southern Hemisphere, was taken by Nicole Mortillaro with iTelescope's remote system in Australia, using a Takahashi FSQ ED, 106mm and an SBIG STL11K.

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This image of the Pleiades was taken by photographer Nigel Ball using a QSI 583 WSG camera on Takahashi FSQ-106 in South Cheshire, England. Total exposure time, Luminance: 160 minutes, Red, Green, and Blue: 30 minutes each.



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

Are we inundated with hype? Yes! Do we like it? No! I question the validity of “super” this and “ultra” that, not to mention the use of “blood” to describe the Moon, red or not! What’s it all about anyway? Where does it end? Here’s what I think—reality is far more exciting than fiction. Just go outside and absorb it all.

Now that we have that off our collective chests, let’s move on.

In the second week of September, I was a guest speaker at the Winnipeg Centre’s Spruce Wood Star Party at the (you guessed it) Spruce Woods Provincial Park, a little bit east of Brandon, Manitoba. Thanks to the gracious invitation by Winnipeg Centre member and organizer par excellence, Silvia Graca, I got to expound on some of my favourite subjects: Woodworking, Genealogy, Chemistry, Astronomy, and Writing. Thanks also to Jay and Judy Anderson for the superb hospitality and evening meal (he’s the Winnipeg Centre President).

Now, that should be a familiar name to *Journal* readers. For first-time readers, Jay was the Editor-in-Chief of this *Journal* for 10 years, recently retired (but not really, because we just put him back into harness for the NewsNotes column). As your Society’s President, I had the extreme pleasure to present to Jay at the SWSP a rare hand-coloured drawing of an 18th-century eclipse, suitably engraved and annotated on the reverse. Our extreme gratitude goes out to Randall Rosenfeld for obtaining the gift and engraved plate, and to Renata Koziol for arranging framing. This is a delightful present, one that touches on many aspects of Jay’s life, and I know he will long cherish it (see Figure 1).

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I don't have to ask how many of our faithful readers got to see the September lunar eclipse—it was splashed all over the social media. And, that's a good thing, because it brings us closer together, allows us to share the excitement about our wonderful hobby, and we get to enjoy each others' numerous talents.

Clear skies! ✨

Figure 1 — Jay Anderson and James Edgar, photo by Bryan Stach



News Notes / En manchettes

Compiled by Jay Anderson

New Discoveries from Rosetta

The European Space Agency has revealed a number of discoveries made by the *Rosetta* spacecraft, in orbit around Comet 67P/Churyumov-Gerasimenko. Prime among these was the announcement that the two-lobed comet was formed by a gentle collision between separate and distinct cometary bodies.

“It is clear from the images that both lobes have an outer envelope of material organised in distinct layers, and we think these extend for several hundred metres below the surface,”

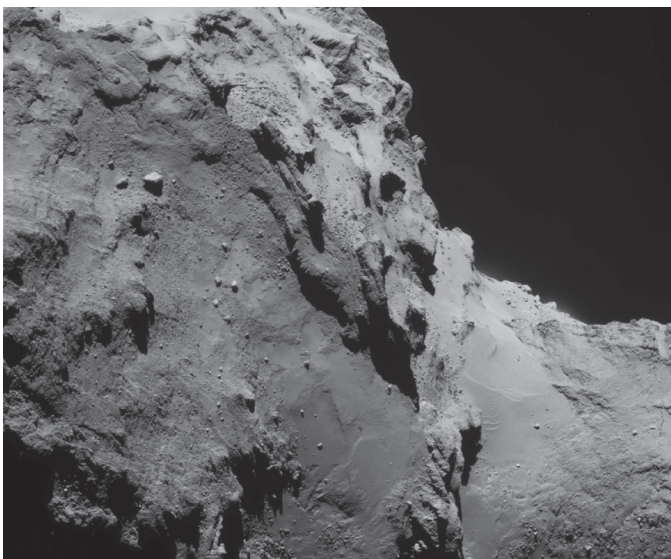


Figure 1 — This Rosetta image shows the smooth Anubis region in the foreground and its stratified contact with the Seth region toward the centre. Image: SA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA.

said Matteo Massironi, lead author from the University of Padova, Italy. “You can imagine the layering a bit like an onion, except in this case, we are considering two separate onions of differing size that have grown independently before fusing together.”

To reach their conclusion, Matteo and his colleagues used *Rosetta* images to identify over 100 terraces and parallel layers (strata) visible in exposed cliff walls and pits on the surface of the comet. A 3-D shape model was then used to determine the directions in which they were sloping and to visualize how they extend into the subsurface. The modelling studies showed that the layers in a comet-like body should lie perpendicular to the local direction of gravity.

When the local direction of gravity was identified in the spacecraft photographs, the terraces and strata were found to be coherently oriented all around the comet's lobes, in some places extending to a depth of about 650 m. The collection of local gravitational vectors converged to outline the presence of two separate bodies, rather than a single body with two lobes.

“This points to the layered envelopes in the comet's head and body forming independently before the two objects merged later,” concludes Matteo. “It must have been a low-speed collision in order to preserve such ordered strata to the depths our data imply.” “In addition, the striking structural similarities between the two lobes imply that despite their initially independent origins, they must have formed through a similar accretion process,” adds co-author Bjorn Davidsson of Uppsala University, Sweden.

Rosetta observations also revealed a diurnal water-ice cycle on the comet. As sunlight heats the frozen nucleus of a comet, the ice in it—mainly water but also other ‘volatiles’ such as carbon monoxide and carbon dioxide—turns directly into a gas. This gas flows away from the comet, carrying dust particles along, building the bright halo and tails that are characteristic of comets.

During the local day, water ice on and a few centimetres below the surface sublimates and escapes; during the local night, the surface rapidly cools while the underlying layers are still warm, so subsurface water ice continues sublimating and finding its way to the surface, where it freezes again. On the next comet day, sublimation starts again, beginning from water ice in the newly formed surface layer. From these data, it is possible to estimate the relative abundance of water ice with respect to other material. Down to a few cm deep over the region of the portion of the comet nucleus that was surveyed, water ice accounts for 10–15 percent of the material and appears to be well-mixed with the other constituents.

“We are now able to show that this cycle is common in several regions of the nucleus, depending on the illumination conditions, and hence further demonstrate that the proposed cycle is a general mechanism of water transport from depth to the surface acting on comets,” said principal investigator Fabrizio Capaccioni.

On another note, scientists analyzing data from ROSINA’s high-resolution Double Focusing Mass Spectrometer (DFMS) identified argon, along with other gases, in the coma spectra of Comet 67P/C-G in October 2014. They identified ^{36}Ar and ^{38}Ar , yielding an isotopic ratio for $^{36}\text{Ar}/^{38}\text{Ar}$ of 5.4 ± 1.4 , which is compatible with Solar System values: for Earth, this isotopic ratio is 5.3, while for the solar wind it is 5.5.

The abundance of argon relative to water vapour was determined to be between 0.1×10^{-5} and 2.3×10^{-5} , the range of values being due to variable solar illumination, which influences the rate of water sublimation on different parts of the comet nucleus. “Even though the argon signal is very low overall, this unambiguous first in-situ detection of a noble gas at the comet demonstrates the impressive sensitivity of our instrument,” says Professor Kathrin Altwegg, principal investigator of the ROSINA instrument at the University of Bern.

“The argon-to-water ratio varied by more than a factor of 20. While the very volatile argon can escape under any conditions, water sublimation depends strongly on the amount of sunlight being received, and so with it the argon-to-water ratio,” explains Professor Hans Balsiger, also from the University of Bern, and lead author of the paper reporting the discovery. “The relatively high argon content of Comet 67P/C-G compared with Earth again argues against a cometary origin for terrestrial water...,” comments Balsiger.

Models can be used to predict how readily highly-volatile gases were incorporated into the icy grains that grew at low temperature in the protosolar nebula. These models show that the high abundance of argon at Comet 67P/C-G and a good correlation with nitrogen are both consistent with the comet forming in the cold outer reaches of the Solar System.

Compiled from notes provided by the European Space Agency

Starbirth Fireworks

Gemini Observatory has released one of the most detailed images ever obtained of emerging gas jets streaming from a region of newborn stars. The region, known as the Herbig-Haro 24 (HH 24) Complex, contains no less than six jets streaming from a small cluster of young stars embedded in a molecular cloud. The region, discovered in 1963 by George Herbig and Len Kuhi, is located in the Orion B cloud at a distance of about 400 parsecs or about 1,300 light-years. This region is rich in young stars and has been extensively studied in all types of light, from radio waves to X-rays.

“This is the highest concentration of jets known anywhere,” says Principal Investigator Bo Reipurth of the University of Hawaii’s Institute for Astronomy (IfA), who adds, “We also think the very dynamic environment causes some of the lowest mass stars in the area to be expelled, and our Gemini data are supporting that idea.” The researchers report that the jet complex emanates from the protostar SSV63, which high-resolution, infrared imaging reveals to have at least five components. More sources are found in this region, but only at longer, submillimetre wavelengths, suggesting that there are even younger and more deeply embedded sources in the region. All of these embedded sources are located within the dense molecular cloud core.

“One jet is highly disturbed, suggesting that the source may be a close binary whose orbit perturbs the jet body,” says Reipurth.

A search for dim optical and infrared young stars has revealed several faint optical stars located well outside the star-forming core, in particular, a halo of five faint Hydrogen-alpha emission stars (which emit large amounts of red light) surrounding the HH 24 Complex. The presence and location of these five very low-mass stars is puzzling, because the gas is far too tenuous for the stars to have formed in their present location. Instead, they are likely orphaned protostars ejected shortly after birth from the nearby star-forming core. Such ejections occur in

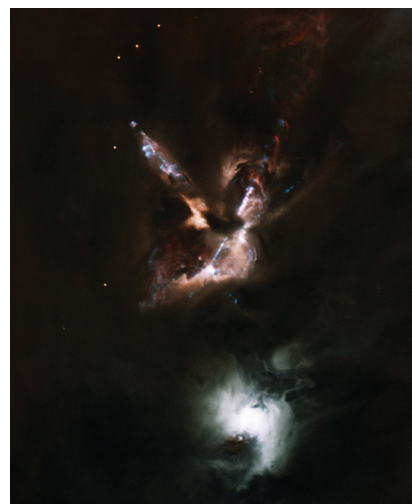


Figure 2 — The HH 24 jet complex emanates from a dense cloud core that hosts a small multiple protostellar system known as SSV63. The jets are the intense blue structures. The nebulous star to the south (bottom) is the visible T Tauri star SSV59. Image: Gemini Observatory/AURA/B. Reipurth, C. Aspin, T. Rector.

situations where many stars are formed closely together within the same cloud core. The chaotic dance of the crowded stars in the complex gravitational field of the cluster ultimately leads to the ejection of the smallest ones.

A consequence of such ejections is that pairs of the remaining stars bind together gravitationally. The dense gas that surrounds the newly formed pairs brakes their motion, so they gradually spiral together to form tight binary systems with highly eccentric orbits. Each time the two components are closest in their orbits, they disturb each other, leading to accretion of gas and an outflow event that we see as supersonic jets. The many knots in the jets thus represent a series of such perturbations.

Compiled from notes provided by the Gemini Observatory

Canadian researchers propose new way to chart the cosmos in 3-D

The Canadian Hydrogen Intensity Mapping Experiment (CHIME) radio telescope could offer the first set of regular data from fast radio bursts. UBC researchers are proposing a new way to calculate distances in the cosmos using mysterious bursts of energy known as fast radio bursts. The method allows researchers to position distant galaxies in three dimensions and map out the cosmos.

Some unknown astrophysical phenomenon is causing these bursts of energy that appear as short flashes of radio waves lasting only a few milliseconds. While only ten fast radio bursts have ever been recorded, scientists believe there could be as many as 10,000 of them a day. As these radio bursts travel toward Earth, they undergo a frequency-dependent dispersion caused by their passage through the ionized plasma of the Universe. The researchers propose using the delay between the arrival times of different frequencies to determine the distance to the source and map the structure of the intervening cosmos. The amount of spread in the signal that arrives on Earth gives scientists a sense of how many electrons, and by extension how much material including stars, gas, and dark matter, lies between Earth and the source of the burst.

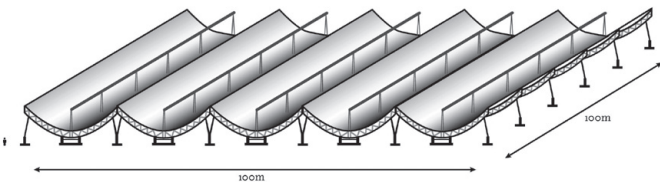



Figure 3 — A model of the proposed CHIME radio-telescope. CHIME is a novel radio telescope consisting of cylindrical reflectors roughly the size and shape of snowboarding half-pipes with an array of radio receivers along the focus. There are no moving parts; CHIME will measure over half the sky each day as the Earth turns. Image: UBC Public Affairs.



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The project is a collaboration between UBC, McGill, and the University of Toronto and is currently under construction at the Dominion Radio Astrophysical Observatory in Penticton, Canada. “CHIME has the potential of seeing tens to hundreds of these events per day so we can build a catalogue of events,” said Kris Sigurdson, associate professor in UBC’s Department of Physics and Astronomy who is also part of the CHIME project. “If they are cosmological, we can use this information to build a catalogue of galaxies.”

This method could be an efficient way to build a three-dimensional image of the cosmos. The tool could also be used to map the distribution of material in the Universe and inform our understanding of how it evolved.

Compiled with notes provided by UBC Public Affairs.

Brightest galaxy cluster discovered

An international team of astronomers has discovered a distant, massive, galaxy cluster containing a core bursting with new stars. The discovery, made with the help of the Maunakea-based W. M. Keck Observatory and Canada-France-Hawaii Telescope, is the first to show that gigantic galaxies at the

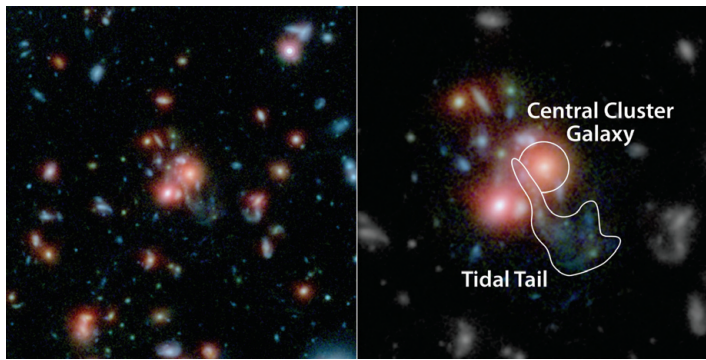


Figure 4 — A massive cluster of galaxies, SpARCS1049+56, can be seen in this two-panel, multi-wavelength view from NASA’s Hubble and Spitzer space telescopes. At the middle of the picture is the largest, central member of the family of galaxies, bursting with the birth of new stars. Scientists say this star birth was triggered by a collision between a smaller galaxy and the giant, central galaxy. The smaller galaxy’s wispy, shredded parts, called a tidal tail, can be seen coming out below the larger galaxy. Throughout this region are features called “beads on a string,” which are areas where gas has clumped to form new stars. This type of “feeding” mechanism for galaxy clusters—where gas from the merging of galaxies is converted to new stars—is rare.

centres of massive clusters can grow significantly by feeding off gas stolen from other galaxies.

“Clusters of galaxies are rare regions of the Universe consisting of hundreds of galaxies containing trillions of stars, as well as hot gas and mysterious dark matter,” said the lead author, Tracy Webb of McGill University. “The galaxies at the centres of clusters, called Brightest Cluster Galaxies, are the most massive galaxies in the Universe. How they become so huge is not well understood.”

What is so unusual about this particular cluster, SpARCS1049+56, is that it is forming stars at a prodigious rate, more than 800 solar masses per year—800 times faster than in our own Milky Way.

This surprising new discovery was the result of collaborative synergy from ground-based observations from Keck Observatory and CFHT as well as space-based observations from NASA’s *Hubble*, *Spitzer*, and *Herschel Space Telescopes*. The Keck Observatory data was gathered by the powerful MOSFIRE infrared spectrograph and was crucial to determining SpARCS1049+56’s distance from Earth as 9.8 billion light-years, that it contains at least 27 galaxies, and that it has a total mass equal to about 400 trillion Suns.

Because *Spitzer* and *Herschel Space Telescopes* detect infrared light—enabling observers to see hidden, dusty regions of star formation—they were able to reveal the full extent of the massive amount of star formation going on in SpARCS1049+56. However, the resolution of the infrared observations was insufficient to pinpoint where all this star formation originated. High-resolution follow-up optical observations were performed by the *Hubble Space Telescope* and revealed “beads on a string” at the centre of SpARCS1049+56, which occur when clumps of new star formation appear strung out like beads on filaments of hydrogen gas. The “beads” are a telltale sign of a process known as a wet merger, which occurs when at least one galaxy in a collision between galaxies is gas rich, and this gas is converted quickly into new stars. The large amount of star formation and the “beads on a string” feature in the core of SpARCS1049+56 are likely the result of the Brightest Cluster Galaxy gobbling up a gas-rich spiral galaxy.

What is particularly interesting is that Brightest Cluster Galaxies closer to the Milky Way are thought to grow by so-called dry mergers: collisions between gas-poor galaxies that do not result in the formation of new stars. The new discovery is one of the only known cases of a wet merger at the core of a galaxy cluster, and the most distant example ever found.

The *Hubble* data in this image show infrared light with a wavelength of 1 micron in blue and 1.6 microns in green. The *Spitzer* data show infrared light of 3.6 microns in red. Image: NASA/STScI/ESA/JPL-Caltech/McGill. ★

Compiled from notes provided by NASA and the W.M. Keck Observatory.

The Sun's Chromosphere

by Dr. Phil Langill

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Introduction

I recall it was a cool, crisp morning, the day of 2006 November 8. Many had gathered at the Rothney Astrophysical Observatory to witness the planet Mercury transit the disk of the Sun. It was a unique outreach event with students and teachers from a local Jr. High school, U of C astrophysics students and faculty, lots of members of the public who dropped in, staff from the (then) Telus World of Science, and of course a keen contingent of Calgary Centre Royal Astronomical Society of Canada members with an amazing array of telescopes.

First contact was shouted out at 12:14:00 p.m. MST, or thereabout. With lots of witnesses with eyes on telescopes, time of ingress depended on who was shouting, and it was not unanimous. Turned out that those watching the event with narrowband hydrogen-alpha filtered telescopes saw Mercury take a bite out of the Sun several seconds before those using regular broad band white-light filtered telescopes. The Sun looks spectacularly different through these two types of telescopes, showing something fundamentally different. And then this delay—very interesting! http://calgary.rasc.ca/transit_of_mercury_2006.htm

I had heard about this phenomenon, but this was the first time I had witnessed it. Naturally there was much discussion as to why there was this very noticeable delay (it has to do with how light gets out of the Sun, which is described in some detail below). But another reason why this event lingers in my memory is because I got an idea how to directly measure the height of the Sun's chromosphere; a precise measurement of the interval between the start of a transit or eclipse, as viewed by these two types of telescopes, coupled with the motion of the objects involved, could be translated into a physical dimension. Always on the lookout for excellent student projects, this one would be primo.

Finally, the opportunity came almost six years later on 2012 June 5 with the transit of Venus. New RAO solar telescopes, H-alpha and white-light, with CCD and video cameras, had been purchased, prepared, and tested. On the actual day of the transit, my Department of Physics and Astronomy was hosting the CASCA AGM, and a big event had been meticulously planned at the RAO. Professional astronomers listened

to the Plaskett Medal talk at the RAO while the transit was unfolding, and RASCals were poised with telescopes ready to show the general public the spectacle, while a live band played music. Despite all the great planning and organizing, Mother Nature had the last say. It poured rain. The only transit viewing done that day from the RAO was via the Internet.

But on 2014 October 23, all the variables came together with a partial solar eclipse. The Moon would make its appearance in the mid-afternoon, leaving plenty of time for the clouds to move in and mess things up. But some sort of high-pressure system kept the intruders on the horizon all day. An eager group of astrophysics 307 students were poised at the remote controls of three solar telescopes 40 km away at the RAO. And while an on-campus public viewing event unfolded with many watching the eclipse with solar glasses and telescopes, finally, an excellent observing run yielded the long sought after data.

www.ucalgary.ca/utoday/issue/2014-11-24/astrophysics-course-gives-undergraduates-hands-experience

www.ucalgary.ca/utoday/issue/2014-10-27/students-take-front-row-seats-watch-solar-system-action

The Sun's photosphere and chromosphere

The light that emanates from the Sun is initially created in its core when protons are fused into helium. Gamma rays of immense energy, far outside what the eye can see (~13 MeV), are the only initial photons made in the Sun. But what the Sun emits into space is vastly different. The Sun is a huge photon conversion machine.

The gamma rays are made in an environment that's hard to imagine; pressures and temperatures and densities far outside our human experience. But because photons are electromagnetic in construction, their interaction with each other and the thick plasma of charged particles they travel through can be understood. The distance they travel before interacting with something, on average, can be calculated. It's called the photon mean free path (often designated λ in the literature), and it is very small in the centre of the Sun—on the order of a micron. With every interaction, the direction of travel is changed.

Although λ grows as the photons eventually move away from the core into regions of lower density, with a ~2/3 of a million-kilometre journey (the radius of the Sun) to travel before exiting into space, those photons experience bazillions of interactions. And over the hundreds of thousands of years it takes to complete this journey, an initial gamma-ray photon is ground down into hundreds of thousands of lower energy photons that span the electromagnetic spectrum.

If the Sun had a solid surface like a planet, to a very good approximation its entire spectrum could be calculated by one equation; the blackbody emission formula derived by Max

Planck. But because the Sun is a ball of gas, the “exit strategy” for photons is a little more involved, especially for some photons. If you’re a photon with energy such that you have a low probability of interacting with your surroundings, then as you approach the upper atmosphere of the Sun from below, the probability of making that one last scatter and then finally leaping into space approaches certainty.

The vast majority of photons, at least in the visible part of the spectrum, all make that last scatter from a layer just a few hundred km thick in the Sun’s upper gaseous atmosphere. If you image the Sun in the visible part of the spectrum, using a broadband filter (or a very dark pair of sunglasses, if your imager is your eye) you capture the light coming from that relatively thin layer—giving the impression that the Sun has a surface. This “surface” is commonly referred to as the Sun’s photosphere.

There are some photons that have a tougher time getting away from the Sun, however. Such photons are the ones whose energy is readily absorbed by bound electrons. These are not electrons freely roaming about the solar plasma. They are electrons that have been captured by a positively charged nucleus, and are now part of an atom. In the upper, cooler, and less dense, layers of the Sun’s atmosphere, neutral atoms and ions of hydrogen, helium, sodium, calcium, and the like, can persist.

Unlike free electrons that can interact with photons of a whole continuum of energies via scattering, bound electrons can only absorb a photon if the energy of that photon can push the electron to one of its allowed higher-energy states. The photon is no longer, but its energy persists in the excited electron. And as bound electrons would much rather be in their ground state, they very quickly drop down to a lower-energy state, releasing their excess energy, in the form of a photon, in some random direction. This electron/photon absorption/emission excitation/de-excitation “dance” happens many times before these photons make their final leap into space.

If you image the Sun using a very narrow (~0.05 nm) transmission filter, with the centre wavelength corresponding to a prominent bound electron transition, you capture light primarily coming from this lower-density layer above the photosphere. This layer is called the chromosphere and is readily observable this way in the blue-violet part of the spectrum at 393.4 nm, corresponding to a bound electron transition of singly ionized calcium. Instrumentation more commonly available these days operates at 656.28 nm, the wavelength corresponding to the $n = 3$ to $n = 2$ electron transition in atomic hydrogen. This deep-red photon corresponds to the lowest energy, or “alpha,” transition in the famous Balmer Series of Hydrogen. Hence, this wavelength is referred to as the “H α ” line.

It is the chromosphere’s elusive nature that makes it challenging to observe. It wasn’t even known to exist until a

“flash spectrum” of the Sun was taken by Charles Augustus Young during the eclipse of 1879 December 22. www.britannica.com/topic/flash-spectrum. Thanks to the work of William Wollaston (1802) and Joseph von Fraunhofer (1814), the Sun was known to have a complex absorption-line spectrum. https://en.wikipedia.org/wiki/Fraunhofer_lines. But it suddenly changes to an emission line spectrum when the Moon covers the Sun’s photosphere during a total solar eclipse. The most intense flash-spectrum emission line corresponds to H α . <http://apod.nasa.gov/apod/ap131115.html>.

Data collection and analysis

To capture the moment the chromosphere was touched by the limb of the Moon, an H α PST Coronado telescope, and a Celestron 8-inch scope with a DayStar Quantum SE H α filter, were used. The Coronado was paired with an SBIG ST2000 CCD camera using an achromat Barlow lens. A red-glass pre-filter covered the front of the PST. The front of the C8 was masked using a metal cover with a circular 8-cm opening holding a red-glass pre-filter. An Astrovid eyepiece video camera was mounted at the back end of the Daystar filter.

To capture the moment the photosphere was touched by the Moon, a Kendrick white-light filter over a Meade LX200 8-inch telescope was used. The filter was masked using a



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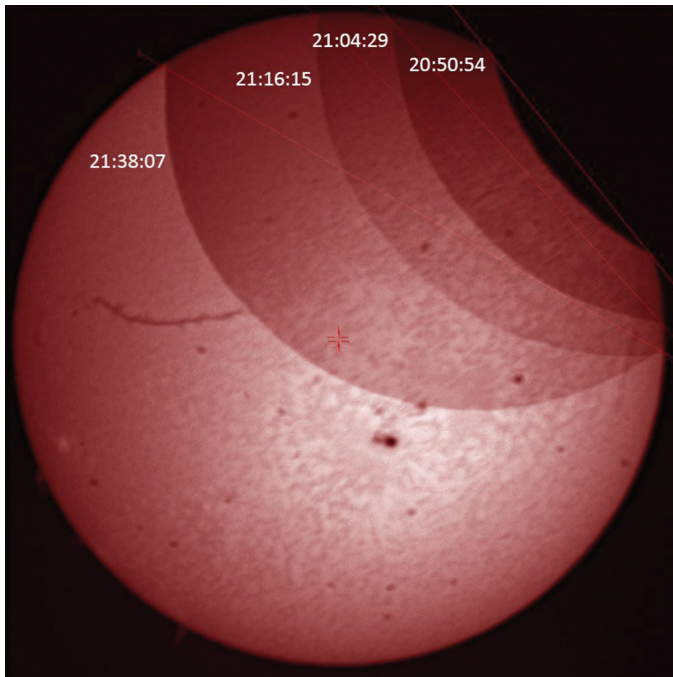


Figure 1 – Coronado H α PST images of the partially eclipsed Sun at four different times in UTC. A very long filament is seen, along with the immense sunspot region AR2192 (most of the smaller dark spots are dust specs in the optics). The red straight lines are made in software to create intensity slices, from which cusp separations are measured.

cardboard cover with an 8-centimetre circular opening. A Meade Deep Sky Imager CCD camera was mounted at the back end of the telescope via an f/6 focal reducer.

It might seem a bit odd to use a DSI to image the brightest object in the sky, but the nice aspect of using that camera was its very fast exposure time and readout. Tests showed that an exposure time of 0.0006 sec was optimal, and individual images could be read out in $\sim 2/3$ sec. The field of view of this white-light telescope and imager was \sim half the diameter of the Sun.

The entire disk of the Sun could be imaged with the Coronado H α telescope and SBIG camera with exposure times of 0.0010 sec. The down side to this setup was the fairly large vignetting that could potentially complicate the image analysis, and the fairly slow image readout of ~ 8 sec. Conversely, the video camera on the C8 was capturing H α images at 30 frames a second. However, its field of view was quite small at $\sim 1/5$ the Sun's diameter.

All three solar telescopes were mutually piggyback mounted to the RAO's remotely operational Baker-Nunn Telescope. After a final focus check, everything was ready. If all went well, the time interval over which the Moon would traverse the Sun's chromosphere could be measured with small error. For what follows, this time interval will be referred to as ΔT_c .

The only thing that was needed now was good weather, and a practice run. The former came to be, but as this was a one-chance-only endeavour, the latter wasn't available. The

various telescopic images came through different optical configurations, so the directions of north and east weren't all the same. And the different fields of view and slight possible misalignments made the task of capturing ingress in all three telescopes challenging. By group consensus, the anticipated point of contact on the edge of the Sun was chosen and the optimal pointing was set. The cameras were given the command to start taking images, and we waited with great anticipation.

And suddenly the Moon appeared in the wide-field Coronado. A short time later in the Meade! But as luck would have it (or the lack of it), the moment of ingress as viewed in the H α video was missed. The C8's pointing was just slightly off. Alas, as the data was being collected, we knew the objective of measuring the height of the Sun's chromosphere could still be reached but not with the hoped timing accuracy in H α .

When the white-light images were later critiqued, another problem was discovered. In a little more than half of the DSI images there was an odd readout problem introducing some sort of pixel shifting error giving images that looked scrambled and blurred. The cadence of the error was quite random, and rarely were two consecutive DSI images unaffected. So depending how the camera readout was behaving at the moment of ingress, the timing accuracy in white-light might also be diminished.

The moments of ingress in H α and white-light were carefully determined using "by eye consensus." That is, with everyone gathered around the computer, the sequence of images was scrolled through. By meticulously scanning both forward and backward repeatedly, consensus was reached about in which image the Moon's edge first appeared. In the SBIG H α images, the timestamp of that image was 20:43:05 UTC. In the image immediately prior to this, some people thought they saw the Moon's edge, but the effects of seeing might have been at play, and it was not unanimous. In the image immediately after, an even more prominent signature was observed by everyone.

With an 8-sec gap between consecutive images, this analysis indicates that the time of initial contact was between 20:42:57 UTC and 20:43:05 UTC. The conclusion, therefore, is that the Moon's edge contacted the chromosphere at 20:43:01 (± 4 sec) UTC.

In the white-light DSI images, consensus was reached, and the timestamp of the image corresponding to when the Moon's edge contacted the photosphere was 20:43:15 UTC. The uncertainty would be half of the $\sim 2/3$ -sec gap between consecutive images, but unfortunately the uncertainty estimate was worsened by the readout error problem. The estimate of the uncertainty in this ingress time was estimated to be ± 0.6 sec.

Shortly after the eclipse had ended, the clocks on the computers controlling the cameras were inspected. Twenty

seconds of video at 30 frames per second was screen captured using Snagit showing simultaneously the computer clocks corresponding to the SBIG H α and the DSI white-light images. This was a critical step because the timestamp on the images was used to determine the sequence of events. A timestamp in the header of a FITS image corresponds to the start time of the exposure, and those timestamps come from the computer clocks. Careful inspection showed that the H α clock was ahead of the white-light clock by 1.5 +/- 0.2 seconds. This offset introduces a constant artificial time delay in the start of the eclipse in the two cameras, and needs to be subtracted in the final analysis.

The uncertainty here is unfortunate and unexpected. It came from the fact that one computer was connected to via VNC, and the other computer was connected to that computer via VNC. So it was a “chained” video connection, not two separate straight-through video connections to the two computers. Consequently the two clocks did not run constantly in step with each other in the Snagit captured video, and the video “jitter” caused the uncertainty in the clock offset.

This offset analysis is rather critical so an additional clock-check exercise was done. The computers running the H α SBIG and white-light DSI cameras were ~10-year-old WinXP and ~1-year-old Win7 machines, respectively. Their clocks were initially synchronized using the same Internet time service. Four hours later, their clocks were happily ticking in step, but six days later, the H α WinXP clock was 13 seconds behind the white-light Win7 clock. The older computer’s clock runs a bit slower than the newer, but over the few-hour duration of the eclipse the clocks ran at essentially same rate, and the time offset can safely be assumed to be constant.

So, with all things considered, the time interval between the two first contact times is $\Delta T_c = 12.5 \pm 4.8$ sec. Despite the ~40% error, students were very relieved to have been able to make the measurement, and went on to estimate the height of the Sun’s chromosphere and write an excellent report. Their Asph 307 mission was accomplished!

Where two circles intersect

The enormous uncertainty in the determined height of the chromosphere was quite dismaying. Despite the great observing run, the prolonged readout of the H α images was the culprit. I was lamenting about this with friend and colleague Dr. Jeroen Stil, and an interesting idea arose. The Sun and Moon are essentially circles, and in a partial eclipse, those circles cross each other in the sky. As the Moon bites off more and more of the Sun, what appears is a distorted looking Sun with two “horns” or “cusps.” As time progresses to mid-eclipse, the cusps get taller and sharper and further apart. This effect is shown in Figure 1.

Could the H α images be analyzed and the cusp separations measured? And if the cusp separation increase with time could

be compared to a model of two circles passing each other, might it be possible to extrapolate backward in time to the moment the two circles just touched? It was an intriguing idea worth giving a try! So I started by deriving the equations for the intersection points of two circles, and after much work, a time-evolving model of the partial solar eclipse of 2014 October 23 was built using MS Excel.

The mathematical grid of spatial coordinates, and incremental shifts between circles, had to be translated to actual angular sizes and real-time steps matching the actual event unfolding in the sky. To do this, values were extracted from two popular desk-top planetarium programs. Starry Night was the primary source, with verification using Stellarium. These programs provided key information, such as: the distance from the RAO to the Sun and Moon during the eclipse (to calculate angular sizes), the duration of the eclipse (to translate incremental steps into time steps), and the angular separation between the Sun and Moon at mid-eclipse (to determine the minimum offset between the passing circles).

The cusp separations had to be carefully measured in the wide-field H α PST SBIG images. This was skilfully done by RS using MIRA Pro 8 UE. A handy line-profile tool was employed as Figures 1 and 2 show. By trial and error, in a given image, a line is drawn symmetrically across both cusps. The first step is to make sure the line clips each cusp to the same extent. If this is done correctly, the intensity plot would show two symmetrically shaped cusps with similar heights and widths. In Figure 2, the blue and brown lines are like this. The red and black lines are as symmetric as possible, but vignetting had slightly reduced the brightness of one side of the Sun making the cusps a bit different in brightness.

In the final step the line is dragged laterally so that it clips the very tips of the cusps. The goal here is to get as close as possible to the tip of the cusps without just measuring a noisy intensity profile of the dark Moon. In determining the best line position, it was decided that the peak values of the cusps be no less than 20 times larger than the range in the background scatter in the darkness between the cusps.

Cusp separations were measured 36 times, from as early on as possible until the Sun and Moon’s decreasing altitude in the sky forced the end of observations. The timestamp of the corresponding images were recorded. An initial time had to be chosen for both the model and the observations, and for convenience 20:40:00 UTC was used. Uncertainties in cusp separation were estimated to be between 2 and 3 pixels early in the eclipse (for the first ~1000 seconds), and between 1 and 2 pixels thereafter.

The data was in hand, and the model fitting could commence. By adding or subtracting a second or two to the start time in the model, the calculated cusp separations could be matched with the observed. Or at least, that was the plan. Unfortunately,

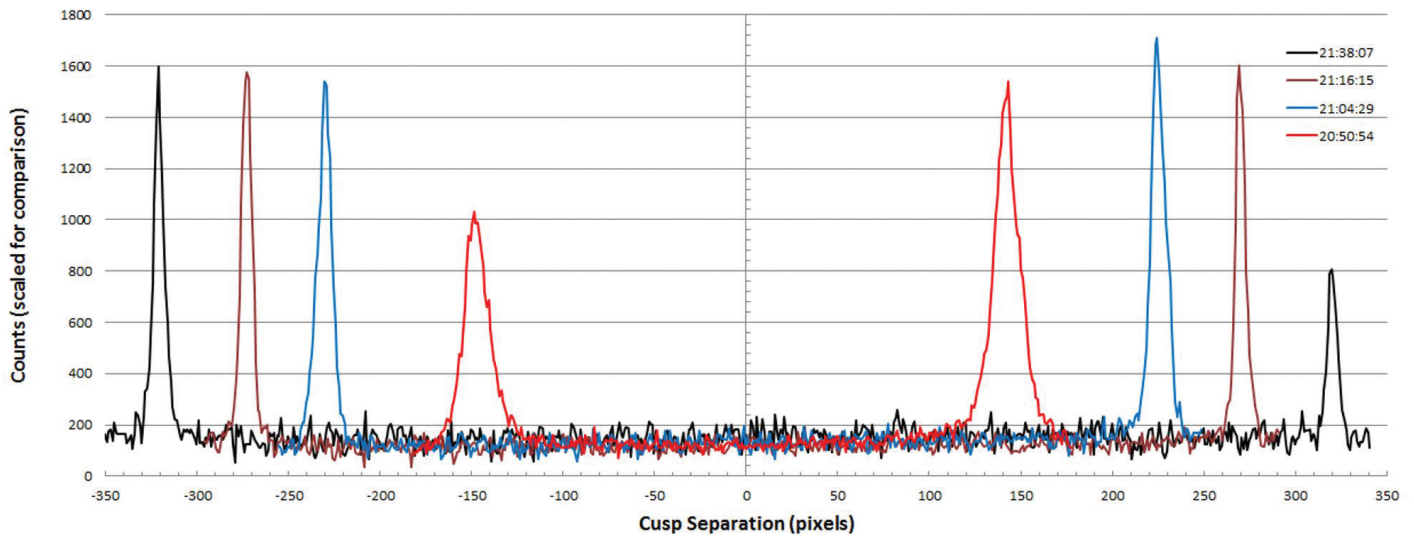


Figure 2 — The intensity slices corresponding to Figure 1. The positions of the individual peaks can be measured and the distance between pairs of corresponding peaks can be calculated. Note how widths of the peaks decrease as the separation between the peaks increase.

two rather important pieces of information were still unknown. The first was the CCD plate scale (the number of pixels in the images that correspond to 1 arcminute on the sky). The second was the angular size of the circle representing the Sun in the H α images. The desktop planetarium software provides the white-light photospheric solar radius, but the model is for the Moon passing in front of the chromospheric Sun. So these two unknowns had to be treated as free parameters, and initially it was doubtful if this approach would bear fruit.

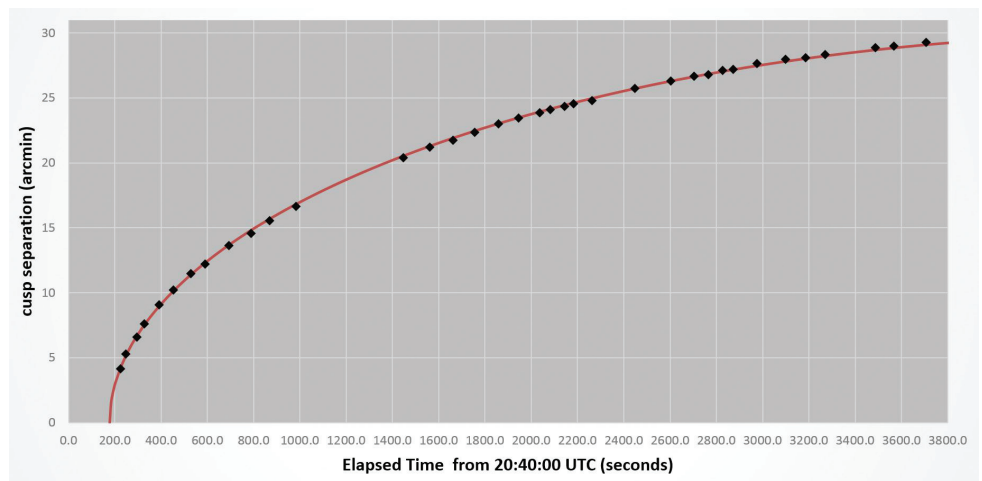
Analyzing Residuals

Given all the variables, many different models can be calculated. But the best model will be the one that reproduces the data most closely. The accuracy of this fit is quantified by calculating residuals. A residual is simply the difference between the measured cusp separation at the time of the images' timestamp, and the corresponding calculated cusp separation at that same time in the model. Combining the 36 residuals gives a number that provides a basis of comparison,

and provides guidance as to which model is doing the better job of matching the data. Some residuals might be positive and others negative, so adding all the residuals isn't best. By squaring the residuals first, before adding them, ensures that only positive numbers go into the sum. Of course, it helps to be able to plot a graph to see visually how well the calculated values match the data, so that was done too. But when it is close and you're trying to make fine determinations, you need to compare the sum of the squared residuals.

So with regard to the angular size of the H α Sun to be used in the model, a quick literature search of the size of the chromosphere (the very thing all this work is ultimately intended to determine, but better than ever before, hopefully) was done. The literature values have a wide range, but in terms of the gargantuan radius of the Sun, the chromosphere adds a few tenths of a percent. So the model was run five times, with the first using a solar radius 0.1% larger than the photospheric Sun, and the last using a solar radius 0.5% larger.

Figure 3 — The cusp separation model is the red curve and the measured cusp separations are the diamond-shaped data points. The model can be shifted in time, moving the curve to the left or right. As explained in the text, the time corresponding to this best-fit model to the data is determined. This result shows that moment the Moon's edge touched the Sun's chromosphere was 20:42:58.5 (+/- 0.4 sec) UTC.



Chromospheric solar radius (% larger than photospheric solar radius)	Best time of initial contact from residual analysis (UTC)	Corresponding minimal Σ (residual ²)	Corresponding best plate scale from residual analysis (pixels/arcmin)
0.1	20:42:58	0.457	22.21
0.2	20:42:58	0.460	22.20
0.3	20:42:58	0.463	22.19
0.4	20:42:58	0.466	22.18
0.5	20:42:58	0.470	22.17

Table 1. Intersecting circles model fit results.

And with regard to the plate scale it was quite easy to find optimal values for each of the five models. This is because the images available went far into the eclipse (almost 4000 seconds) when the cusp separations were large. Since the plate scale is simply a multiplicative factor, large cusp separations are changed markedly by even small changes in plate scale, so trial and error was relatively painless. The residual analysis easily pointed to the plate scale values that gave the best model fits.

The best-fit model is shown in Figure 3. How this particular model was determined to be the best one is described in the following paragraphs. As for error bars in the data points, the uncertainty in the measured cusp separations is at worst 3 pixels, and when converted to angular separations, gives values smaller than the height of the diamond data points. There is essentially no error bar in time as the timestamps in the image headers correspond to the start of the exposure, and the exposure times are a fraction of a second. There is a timing error between the computers running the two different cameras, but that is taken care of later in the analysis.

A summary of the results of the five models are shown in Table 1. The first thing to note is the column of initial contact times. Rather unexpectedly, all models gave the same result of 20:42:58 UTC (178 seconds after 20:40:00 UTC), which is consistent with the by-eye consensus range of 20:42:57 UTC and 20:43:05 UTC. To assess the error bar in this result the

models have to be examined more closely. The sum of squared residual analysis suggests that the first model with the smallest chromospheric radius fits the data the best. However, an improvement to the models can be made.

Also in Table 1 are the values of the plate scale that gave the smallest sum of squared residuals for each model. Because this value is not known a priori, it is treated as a parameter. But from these results its actual value can be ascertained. Note that the values are nearly the same, to two decimal places. Also, there is a linear trend in plate scale, with the value decreasing as the chromospheric Sun radius increases. It would be reasonable to assume that the true value of the plate scale lies somewhere within the range of values in Table 1. Taking a simple average would be a good estimate, but a slightly better estimate would be a weighted average with the weights determined by the values of the sum of squared residuals. This analysis gives 22.1903 pixels/arcmin.

An additional analysis, which included another 20 models that use initial contact times off by just a second or two from optimal, gives an average plate scale of 22.1881 pixels/arcmin. All this together strongly supports a plate scale for the H α images of 22.19 pixels/arcmin. So an unexpected result of the modelling process is that the plate scale of the PST-SBIG optical system was determined.

Chromospheric solar radius (% larger than photospheric solar radius)	Time span over which the resulting Σ (residual ²) value was a minimum (in seconds after 20:40:00 UTC)	Corresponding minimal Σ (residual ²) using derived plate scale of 22.19 pixels/ arcmin
0.1	177.4 – 177.9	0.473
0.2	177.7 – 178.3	0.464
0.3	178.1 – 178.9	0.462
0.4	178.3 – 179.1	0.469
0.5	178.8 – 179.3	0.482

Table 2. Two-intersecting circles model fit results, using the derived plate scale.

The five models were then redone, but instead of treating the plate scale as a parameter, it was fixed at 22.19 pixels/arcmin. The results are shown in Table 2. The span in times over which the absolute minimal sum of squared residuals of each model is given, along with the corresponding sum.

The sum of squared residual values in Table 2 now show a minimum corresponding to the third model, suggesting this model best fits the data. And correspondingly, the time that Moon first touched the Sun's chromosphere in the sky was 20:42:58.5 (+/- 0.4 sec) UTC. This result is consistent with the by-eye analysis, but with a much smaller error bar.

So the effort of doing this modelling work has paid off. Applying this analysis to the white-light images was also considered. However, with the smaller field of view of the Meade 8-inch and DSI, the two cusps were only captured in images for less than the first 1000 seconds of the eclipse. This is not far enough into the eclipse to be able to nail down the unknown plate scale, as was done with the H α images. Additionally, the fast exposure and readout times of the camera has already provided a very good estimate of the time of contact of the Moon on the Sun's photosphere; 20:43:15 (+/- 0.6 sec) UTC.

The conclusion, finally, including the offset time in the computer clocks, is that the time taken for the Moon to cross the Sun's chromosphere as measured during the partial eclipse of 2014 October 23 has been determined to be $\Delta T_C = 15.0 \pm 1.2$ sec. The final step is to use this time interval to determine the height of the Sun's chromosphere.

Some fabulous time-lapse video of the partial solar eclipse of 2014 October 23, taken by RASC Calgary Centre's Larry McNish, can be seen here:

www.youtube.com/watch?v=Wy6Dks3RGgo

www.youtube.com/watch?v=fLLdyQgiINo

A Little Geometry

The moment that the Moon contacted the chromospheric Sun is shown in Figure 4. The coordinates of the contact point is derived from the best-fit model described above. The green line that connects the centres of the Sun and Moon, and passes through the contact point, is perpendicular to the Sun's surface. The height of the chromosphere, the quantity being sought here, is measured along that green line.

The precise motion of the Moon relative to the Sun, as viewed from the RAO, is also shown in Figure 4. The offset of 8.983 arcmin was found using Starry Night. The distance indicated by the dotted orange line is how far the Moon has to travel for the eclipse to reach its halfway point. That distance can be calculated by taking the radius of the Sun and multiplying by the cosine of the angle θ , and doubling that result. With

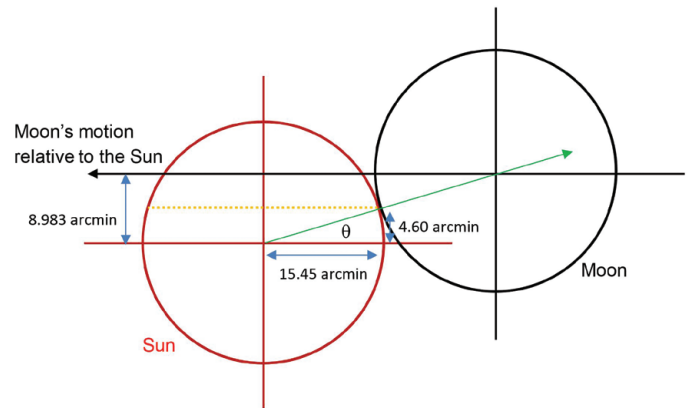


Figure 4 — Details of the Partial Eclipse of 2014 October 23. The coordinates of the initial contact point between the Moon and Sun are given by the cusp separation model shown in Figure 3.

$\theta = 16.6^\circ$, this calculation gives 1,337,966 km. According to Starry Night, the entire eclipse took 9440 sec, so the eclipse was halfway over after 4720 sec. This distance divided by this time gives 283.5 km/s. This is the projected speed of the Moon as it crossed the disk of the chromospheric Sun during the eclipse.

The amount of time it took the limb of the Moon to traverse the chromosphere was $\Delta T_C = 15.0 \pm 1.2$ sec. At this speed, the Moon travelled 4252.5 +/- 340.2 km in the direction of the dotted orange line. To find the component of this distance in the direction of the green line, the height of the chromosphere, we multiply by the cosine of θ . That calculation gives $H_C = 4075 \pm 325$ km. Happily, the error bar is just 8%, but this was a surprising result.

Other Results

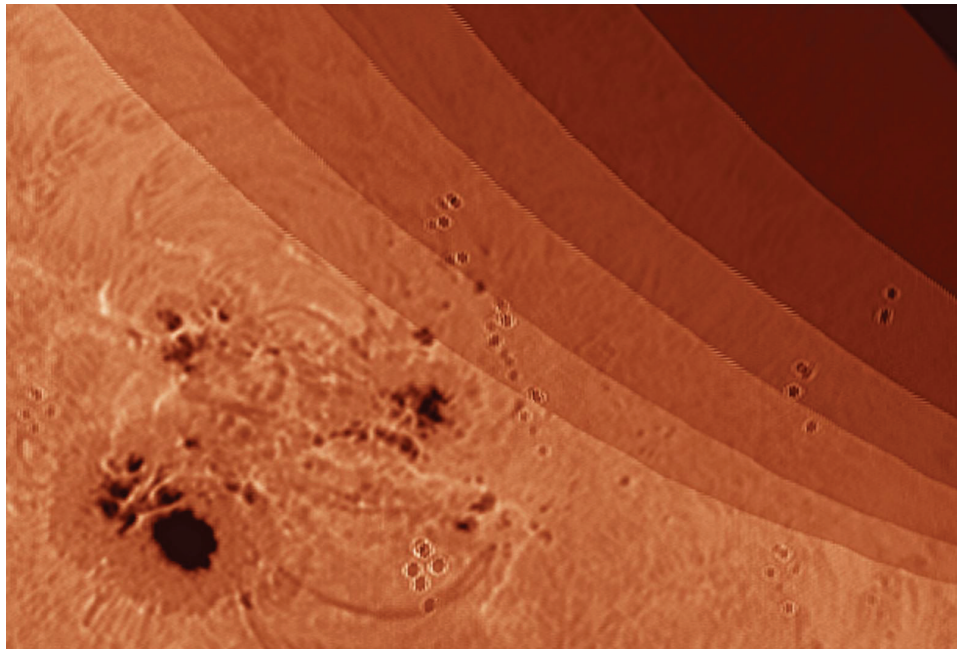
A quick scan of general Internet sources gives values for the height of the Sun's chromosphere ranging from 2000 km to 3000 km, with a bias toward the lower end. The value found in this work seems anomalously high, so the first thing to check is the references cited in the online articles. Unfortunately, in most cases, they are nonexistent. So it's possible that "history is at work" and the newer websites copy "quick facts" from older websites. Perhaps the same old values get recycled.

With a more in-depth Internet search, two interesting papers were found. The first comes from Modh. Zambri Zainuddin of the University of Malaya. On 2006 November 9 in Malaysia, he and a team measured the thickness of the Sun's chromosphere using data collected during the transit of Mercury.

www.academia.edu/340667/Determination_Of_The_Sun_Chromosphere_Thickness_Using_The_Transit_Of_Planet_Mercury

This was the very day described in the introduction of this paper (it was November 8 in Canada), and the day that this

Figure 5 — One of the largest sunspot groups to appear on the Sun in decades was in prominent view during the partial solar eclipse of 2014 October 23. This sequence shows the Moon creeping eastward toward AR2192 as viewed in H α with the Daystar Quantum SE filter and Astrovid video camera. The Sun was well into its maximum sunspot cycle.



time-delay measurement idea came to me. It was a surprise to discover, therefore, that this very method was already being employed by Zainuddin *et al.* in 2006.

The chromosphere height found in that study was between 2450 km and 3715 km. Not knowing the precise orbital speed of Mercury during the transit, this range of heights spans the possible range of the planet's speed. So although it was disappointing to learn that this method was already in use in 2006, it was reassuring to see their upper-limit result was close to the result found here.

Another interesting paper is by A.G. Voulgaris *et al.* <http://arxiv.org/abs/1202.1535>. This team of researchers repeated the 1870 work of Charles Young by capturing the spectrum of the Sun during the total solar eclipse of 2010 July 11, except with much better equipment and a vastly deeper understanding of the physics of the interaction of photons with atoms (fundamental concepts in astrophysics known as radiative transfer). They were able to study both the chromosphere and the corona, with amazing detail.

Using a timing method that involves the motion of the Moon and observing emission line intensity, they find a chromosphere height of 9400 km when looking at the lines of H and He. And in the lines of the heavier elements of Na, Mg, and Fe, they find a height of 3300 km. They refer to the latter as the lower chromosphere. Also interesting to note, the projected speed of the Moon across the disk of the Sun in that spectroscopic study is 285 km/s, essentially the value found here. Figure 8 in that paper actually complements the results found here very well.

Conclusions

The result found here of $H_c = 4075 \pm 325$ km might seem anomalously high, but the spectroscopic study of the chromosphere and corona by Voulgaris *et al.* found a value over twice as large. Additionally, their analysis suggests the chromosphere might be portioned into lower and upper regions, and this result certainly points to the middle chromosphere. But why

is this result so much different than other results found using H α filters? A closer look at Figures 1 and 5 lent a clue.

The huge active region AR2192 doesn't look the same in those two H α images. Its structure appears quite different and it is not just due to the difference in spatial resolution. Also, in the Coronado PST image in Figure 1, a huge, dark filament stretches across the Sun like a big scar. In the Daystar H α images, this filament was barely noticeable.

A prominence is a thin curtain of cool gas held suspended high into the Sun's chromosphere and corona by magnetic field lines. Filaments are prominences seen from above looking down. Since the Coronado was showing the filament and the Daystar hardly at all, these two telescopes were not showing the same part of the chromosphere. The Daystar was imaging structure lower down, and the Coronado was imaging structure higher up. And it was the Coronado images that were used in this timing delay analysis.

So different H α telescopes show different regions of the chromosphere—how is that possible? The Daystar H α filter has a thermally controlled bandpass. That is, with a built in regulated heater, its default setting only lets light exactly centred at 656.28 nm to pass through. The Coronado has a tuning ring that adjusts the bandpass, and is set at the discretion of the user. Also, the Coronado's bandpass is about twice as wide as the Daystar's (~0.10 nm vs. ~0.05 nm). So the Coronado PST isn't as discriminating when it comes to what layer in the chromosphere it reveals, and on October 23, it was set to the middle chromosphere.

Finally, I would encourage all RASC solar enthusiasts to try to repeat this measurement. The equipment is already in the hands of most, so all that's required is a reliable and accurate timing measurement—just make sure to synchronize your computer clocks first! ★

A Brief History of Lunar Exploration: Part I

by Klaus Brasch

*And if she faintly glimmers here,
And paled is her light,
Yet alway in her proper sphere
She's mistress of the night.*

From The Moon Poem by Henry David Thoreau

Introduction

An advantage of reaching one's 75th birthday is the realization that you are now part of history. To that end, I count myself fortunate to have experienced a time when night skies were still quite dark even in big cities. I was ten years old in 1951, when my father led me to the roof of my grandparents' house in Rome, Italy, and showed me the Moon through an old brass telescope. Seeing craters, mountains, and dull grey features termed Maria, all in sharp contrast, jolted me into the realization that I was seeing another world in space and engendered an awareness of the beauty of the cosmos that has lasted a lifetime. Later, I was given a book titled *La Luna* (Fresa, 1943), which I still have, filled with drawings, facts, and photographs about and of the Moon. While mostly beyond my comprehension at the time, this book showed that studying the natural world was a legitimate and fun thing to do, and set me on my course of becoming a scientist.

The history of lunar explorations through the ages has been documented by a number of authors (see e.g. Kopal and Carder, 1974; Moore, 1963; Sheehan and Dobbins, 2001), most of these works are dated, very technical or deeply scholarly, and not really aimed at today's amateur observer. This essay will hopefully meet that need.

From Antiquity to the Telescope

It's safe to say that besides the Sun, the Moon has been the most influential celestial object in human affairs. Wikipedia (2015a) lists no less than 70 lunar deities, spanning various continents, cultures, and mythologies. Not surprisingly, the monthly lunar cycle has been linked with human menses and

fecundity in many cultures and consequently associated with female deities like Selene in Greco-Roman mythology and the Chinese goddess Chang'e (Figure 1). Others, however, favoured male lunar deities, including Sin in Mesopotamia and Tsukuyomi in Shintoism.

The Moon has given rise to many myths and superstitions, as well as some positive omens, in both ancient and modern times. Lunar eclipses have been particularly maligned, conjuring visions of demons and ravenous animals. The Incas, for example, believed that an eclipse was due to a jaguar devouring the Moon and then crashing to Earth to feast on humans (Lee, 2014). In ancient China, the Moon was perceived as a mirror and that dragons swallowed it during an eclipse. People would beat on mirrors during such events, causing the dragon to release the Moon once again. In western history, the term lunatic, from the Latin *Luna* or moon, has been widely associated with aberrant human and animal behaviour. Madness and werewolves—among other myths—were linked by ancient Greeks to the phases of the Moon because, they reasoned, since our orb influences ocean tides, it was likely to affect the human brain as well. These ideas persisted well into the 17th and 18th centuries in European folklore and elsewhere. Indeed, even today, it is still commonly believed that the Moon influences the weather, the times for crop planting and harvesting, and recently the so-called super Moon, an astrological rather than astronomical term, regularly appears on Internet sites. For more *The Moon in our Imagination*, see Hockey (1986).

The Moon also plays a pivotal role in Judaism (Wikipedia, 2015b). Rosh Chodesh or *Beginning of the Month*; lit. *Head of the Month*, is the name for the first day of every month in the Hebrew calendar, and is marked by the new Moon. Based on the book of Exodus, this established the beginning of the Hebrew calendar and in Psalm 81:4 both the new and full Moon are mentioned as a time of awareness.

While the Quran clearly emphasizes that the Moon is a sign of God, not a deity itself, it plays a significant role in Islamic religion, which also uses a lunar calendar. The crescent Moon, called Hilal, defines the start and end of the Islamic month, and determining the precise time of Hilal is crucial to specifying the date of Ramadan, a most important time of atonement. This was one of the reasons early Muslim scholars studied astronomy (Wikipedia, 2015c).



Figure 1 — From left:
Selene, Chang'e, and Sin
(All wikicommons)



Figure 2 — Top: Hans Lippershey (1570–1610); Thomas Harriot (1560–1621) & his Moon chart. Bottom: Galileo Galilei (1564–1642) (Justus Susterman); Galileo's sketch of the Moon with comparable photograph (All images wikicommons)

The realization that the Moon might be another world or planet like the Earth can be traced back to earliest literature in both western and eastern cultures. In the 2nd century AD, for example, Lucian of Samosata wrote a parody titled *True Story* about travel to another world with alien inhabitants. Likewise a 10th-century Japanese folk tale titled *The Tale of the Bamboo Cutter*, also involves travel to the Moon, which is inhabited. After invention of the telescope in the early 1600s, speculation as to the nature and composition of the Moon reached a more Earth-centred perspective with references to Maria or seas to the large dark lunar features and to mountains like the lunar Alps and Apennines. Belief in the possibility that our nearest neighbour might be inhabited also reached a new high, as exemplified in the 1638 book by English astronomer John Wilkins titled: *The Discovery of a World in the Moone or, a discourse tending to prove that 'tis probable there may be another habitable world in that planet*.

By the 19th century, when our understanding of the Moon as a planetary-sized body with its own distinct geology and orbital characteristics had advanced significantly, “hard” science fiction stories began to appear, instead of just fantasy voyages involving magic or gods. Notable among these are *From the Earth to the Moon* (1865) and its sequel, *Around the Moon* (1870), both by the remarkably futuristic French author Jules Verne. This was followed in 1901 by the H.G. Wells classic, *First Men in the Moon*, in which travel to our satellite, inhabited by insect-like *Selenites*, is accomplished via an anti-gravity machine. With advances in rocket science during the early 20th century, more hard science fiction followed, including the remarkably realistic 1950 movie, *Destination Moon*, a fitting prelude to the soon-to-follow space race, and

culminating in 1968 with the Arthur C. Clark novel and Stanley Kubrick classic movie, *2001: A Space Odyssey*. This epic saga coincided with the Apollo missions and provided not only a credible backdrop to manned exploration of the Solar System, but also a tantalizing prologue to the real possibility that intelligent life might exist elsewhere in the Universe.

First Light

While it is clear that Galileo Galilei did not invent the telescope, a device largely attributed to Dutchman Hans Lippershey, who tried to patent it, nor was Galileo the first to use one to examine and sketch the Moon. Englishman Thomas Harriot most likely did, but the great Italian astronomer was the first to formally publish his findings (Figure 2). His *Sidereus Nuncius* (*The Starry Messenger*), published in 1610, was a testament to his scientific prowess, and placed Galileo in a pre-eminent position in the annals of cosmology (Figure 3). As astrophysicist Richard Learner puts it: “*The Starry Messenger*... is more a symptom of his greatness than one of its causes. His achievements rest on his immense intellectual confidence, even arrogance. He was confident enough to accept that in eight months he had accumulated sufficient evidence to reject the picture of the universe that had been built up by 2000 years of endeavor by pre-telescopic astronomers: the Book of Genesis was wrong, the philosopher Aristotle was wrong, the great Greek astronomer Ptolemy was wrong, even St Thomas Aquinas was wrong, but Galileo was not” (Learner, 1981).

Galileo’s epic discoveries and their cosmological and theological implications at the time, inevitably led him into conflict with the Catholic Church and other authorities. His defence of Heliocentrism as advocated by Copernicus, coupled with his clearly strong intellectual arrogance did not help things either. This is so diplomatically and lovingly alluded to in a letter by his daughter, Sister Maria Celeste on 1633 April 20, while Galileo was facing judgement by the Holy Office of the Inquisition (Sobel, 1999). The letter states in part “The only thing for you to do now is to guard your good spirits, taking care not to jeopardize your health with excessive worry, but to direct your thoughts and hopes to God, Who, like a tender, loving father, never abandons those who confide in Him and appeal to Him for help in time of need.”

Galileo, of course, was not the only prominent astronomer at the time to run into trouble with religious authorities. His contemporaries, Johannes Kepler, a Protestant, ran into religious persecution, and Thomas Harriot was accused of atheism even before starting his astronomical observations (Learner, 1981).

Nonetheless, with news about the telescope, word spread quickly across Europe that the device had considerable military, commercial, and scientific uses. Although Lippershey claimed first rights, other lens makers, including Dutchman

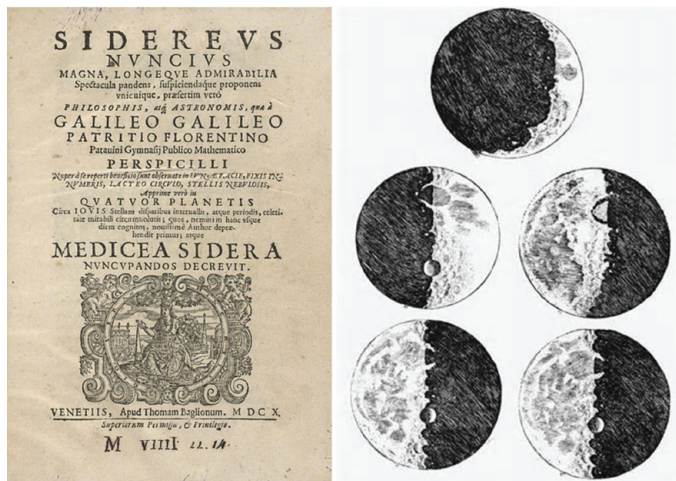


Figure 3 — Sidereus Nuncius (The Starry Messenger), published in 1610

Jacob Metius and Italian Giambattista della Porta in Naples made similar claims. In all probability, once the concept of a telescope and reasonable quality lenses became available, many people no doubt put two of them together and realized their potential. Because of this, and despite objections by clergy, philosophers, and other adherents of the Ptolemaic model of the Universe, observational astronomy had opened Pandora's Box. The Moon, Jupiter's satellites, the phases of Venus, sunspots, and endless vistas of stars in the Milky Way, as described by Galileo, Harriot, Kepler, and many other contemporaries, gradually shook the foundations of the prevailing concepts of cosmology in favour of the Copernican model.

Although Galileo's telescopes were probably among the best available at the time and his observing skills equal to the task, his intellectual fortitude was at the root of his many achievements (Sheehan and Dobbins, 2001). Despite the fact that some have criticized his published lunar drawings as poorly executed, lunar-mapping expert Ewen Whitaker points out that Galileo's sketches of the Moon's surface features at different phase angles were remarkably accurate, especially given the optical limits and extremely narrow field of view of his instruments (Whitaker, 1989). Take Figures 2 and 3 for example. As an experienced lunar observer for many decades, I have often wondered as to the precise identity of the prominent round feature depicted by Galileo in the south-central portion of the lunar disk bisected by the terminator at both first and last quarter. The dark northern oval is clearly Mare Imbrium, but the conspicuous southern feature seems disproportionately large in size to correspond to any obvious crater or basin.

A few years ago, I was fortunate enough to observe the Moon just past first quarter through replicas of Galileo's famous two parallel-mounted telescopes at the annual Riverside Telescope Makers conference in Big Bear, California. Their maker, a very skilled craftsman, had visited the museum in Florence, Italy, where the originals are housed and was given all specifications as

to glass type, magnifications, lengths, and focal lengths of the historic instruments by the museum's archivist. Upon returning to the US, he fashioned as exact a replica as possible of both telescopes and their mount.

It took but one glance at the first-quarter Moon through the 20-power telescope to solve the mystery of the large crater; it was most likely the great walled plain, Albategnius, as suggested by Whitaker (1989). How did we know? For one thing, the field of view of Galileo's refractor was so narrow as to not fully encompass the entire lunar disk at once. Consequently, what is depicted as the lunar limb in some of his sketches is most likely the edge of the field of view, making Albategnius appear disproportionately large in his rendition, especially under low angles of illumination. Second, as pointed out before (Whitaker, 1989), many second-tier publications of his bestselling *Sidereus Nuncius* were illustrated with vastly inferior woodcut copies of his drawings and most likely not faithfully.

We also observed Jupiter that night with the replica telescopes and were astonished to see that while the Jovian disk was just a dazzling, multi-colored blob; the Galilean moons were clearly visible. I think all who looked through those telescopes that evening came away with a new sense that Galileo's observations some four centuries ago were not only remarkable in themselves, but that his essentially correct interpretations of what he saw are among the most astute in the history of science.

Early Telescopic Studies

Like many advances in astronomy, the study of the Moon progressed in parallel with improvement in telescope and eyepiece designs. The extremely narrow field of view and optical aberrations of the Galilean design were improved considerably in 1611 through modifications introduced by Johannes Kepler. This design used a convex lens as eyepiece in place of a concave one, allowing for a much wider field of view and greater eye relief (Figure 4). Although the resulting image is inverted, this combination provided considerably higher magnification as well (Wikipedia, 2015d). Severe chromatic aberration was still a problem though, which could be minimized by using simple objective lenses of very high f-ratios (Learner, 1981); an approach carried to extremes by Johannes Hevelius's 150-foot-long "aerial" or "tubeless telescope," and even longer designs by others (Figure 4).

Despite the many limitations of both Galilean and Keplerian type telescopes, a number of observers produced remarkably good early lunar maps. This can be attributed to several factors. The rapid proliferation of optical devices, coupled with curiosity about the true nature of our satellite, likely led to a competition to be the first to make new discoveries and attach names to lunar features; the equivalent of the first Moon-race (Sheehan and Dobbins, 2001). For instance, between 1609 and 1679, at least a dozen known Moon maps were produced of varying degrees of accuracy and with a plethora of different

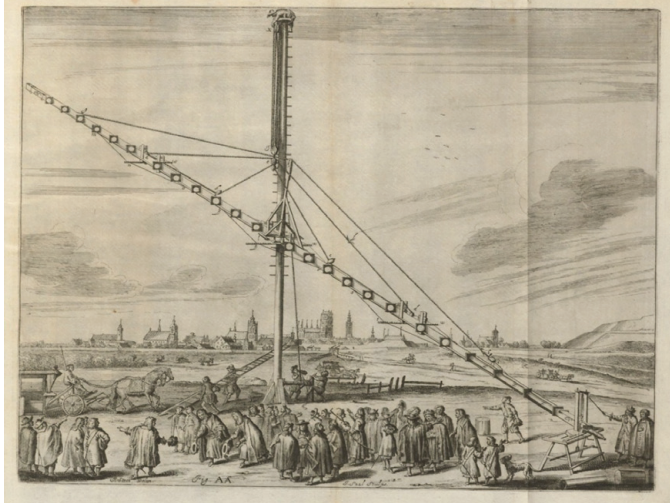
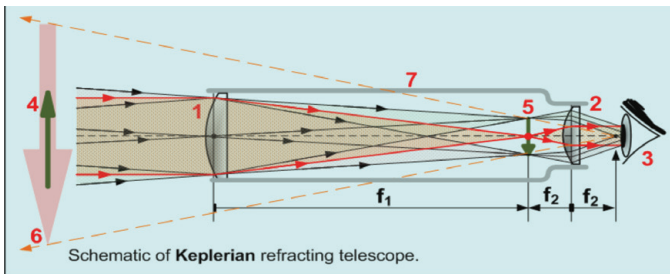


Figure 4 — Top: Keplerian modification of the Galilean telescope, providing better eye relief, higher magnification, wider field of view, and an inverted image. Bottom: Woodcut of Johannes Hevelius's unwieldy "aerial telescope" in Danzig ca. 1667.

feature names. For complete coverage of this period of lunar cartography see: Kopal and Carder (1981); Chapter 1, and Whitaker (1989).

The developmental history of lunar exploration can be grouped into several phases (Ré, 2014). The pre-telescopic era most likely began in 450 BC with the speculations by the remarkable Greek philosopher Democritus, that the Moon contained mountains and valleys, and ended in 1603 with English physician William Gilbert's discovery of lunar libration and his quite accurate naked-eye map of the full Moon. The birth of selenography, however, the detailed study of the surface and physical features of the Moon, began with the invention of the telescope. The first mapping efforts by Galileo and Harriot were quickly followed by more systematic attempts by Michel van Langren (better known as Langrenus) in 1645, Johannes Hevelius in 1647, and Giovanni Riccioli in 1651, with a little help from his Jesuit colleague Francesco Grimaldi (Figure 5). All three of these early maps included nomenclatures of various lunar features, many honouring prominent Catholic figures in the Langrenus map and terrestrial land features by Hevelius. Many of these names were subsequently abandoned except those assigned by Riccioli, most of which gained gradual acceptance and survive to this day.

Two other major players to enter the astronomical scene in the mid to late 1600s were Dutchman Christiaan Huygens

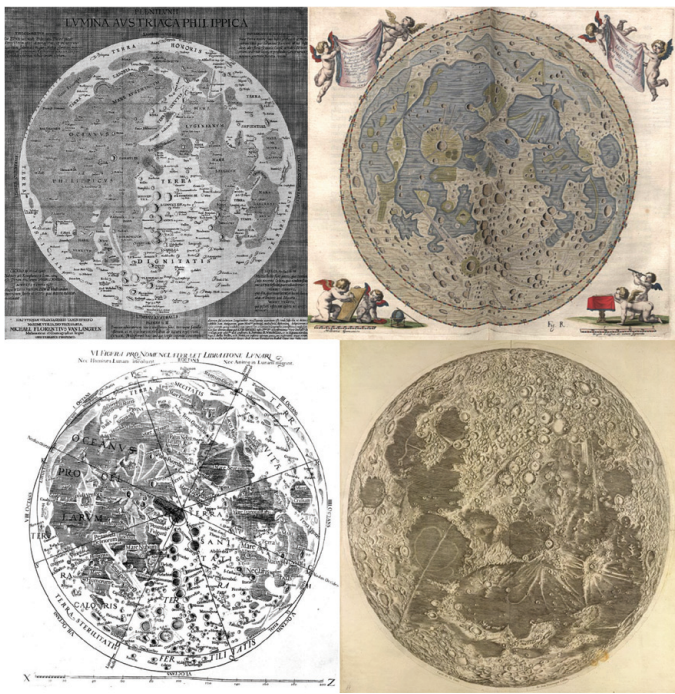


Figure 5 — Top left: Langrenus (1645), right: Hevelius (1647) Bottom left: Riccioli & Grimaldi, right: Cassini (ca. 1680)

(1629-1690) and Italian Giovanni Cassini (1625-1712) (Figure 6). Equipped with much improved Keplerian-style telescopes, these two giants of observational astronomy made some seminal discoveries, both in their respective native countries and in France at the invitation of King Louis XIV.

Huygens optimized telescope design in two important ways. He and his brother Constantijn improved lens grinding and polishing methods, and by combining two plano-convex lenses, produced the first compound eyepiece with superior eye-relief and well suited to the very long focal-length-telescopes of the times (Learner, 1981; Wikipedia, 2015e). In addition, the Huygens brothers tried to better control these unwieldy instruments and accommodate their very long focal-length objectives by eliminating the tube altogether. In these "aerial" instruments, the objective lens was mounted inside a short iron tube, which in turn was mounted on a swivelling ball-joint on top of an adjustable mast. The eyepiece was placed in another shorter tube and the two were kept in alignment via a taut connecting string (digiplanet.com).

With such much-improved optics, Christiaan Huygens went on to discover the true shape of Saturn's rings, as well as its main satellite Titan around 1655. He also made some of the earliest observations and sketches of the Orion Nebula. Though not principally a lunar observer, he nonetheless left his mark there too, by being first to record such features as the Straight Wall, the Huyginus Cleft, and the later-named Schroeter's Valley (Sheehan and Dobbins, 2001).

Huygens's contemporary, Giovanni Cassini, began his prodigious astronomical career in 1650 at the University of



Figure 6 — From left: C. Huygens, G. Cassini, replica of Newton's telescope (all wikicommons and public domain)

Bologna, where he determined the rotational period of Mars as 24 hrs 40 min, very close to the modern value of 24 hrs 37 min, and generated accurate tables of Jupiter's moons. Based on this work, he was subsequently recruited to Paris Observatory in 1669, where he spent the remainder of his life (Sci.ESA, 1999) [Ed. Giovanni Domenico Cassini became Jean-Dominique Cassini after he moved to Paris]. Also using the improved very long telescopes, he accumulated an impressive list of discoveries. These included surface markings on Mars, the rotation period of Jupiter, and the main division in Saturn's rings that still bears his name. Between 1671 and 1684, he furthermore discovered four more Saturnian moons, Iapetus, Rhea, Tethys, and Dione (Learner, 1981; Wikipedia 2015f).

Cassini was also a very accomplished lunar observer. At Paris Observatory, he established new standards in lunar cartography, stemming no doubt from his interest in terrestrial longitude determinations and map making. He made many drawings of lunar features in different phases, which he then combined into a 12-foot diameter chart (Ré) (Figure 5). This map overshadowed essentially all previous efforts with respect to details and positional accuracy (Kopal and Carder, 1971). However, as was the case with most lunar observers then, there was much personal interpretation and poetic license in the depiction of individual features, particularly due to the notion that the large dark regions of the Moon were actual seas. A good example of that is Cassini's portrayal of the Heracleides Promontorium at the southern tip of Sinus Iridium, which to him looked like a lady's head and the surface of the Sinus itself as almost wave-like (Sheehan and Dobbins, 2001, p. 31). The ultimate result of that is that many of the early lunar maps lacked accuracy and favoured artistic or aesthetic qualities over precision (Whitaker, 1989).

Most early lunar charts also lacked positional accuracy due to the vagaries of our satellite's orbital characteristics, most notably longitudinal and latitudinal libration. It was known from the observations by Gilbert in 1603 that the Moon appeared to rock slightly both from side to side and up and down as it circled the Earth, thereby revealing peripheral detail to terrestrial observers. This was fully illustrated on the charts by both Hevelius and Riccioli, making it very difficult to establish accurate selenographical coordinates. That in turn, proved problematic in early attempts by French scientist Pierre

Gassendi (1592-1655) and others to calculate terrestrial longitudes by timing passage of major lunar structures through the Earth's shadow during eclipses. Finally in 1693, after decades of effort by several observers, including Hevelius, Langrenus, French mathematician Philippe de la Hire (1640-1718), and even Isaac Newton (1642-1727), to explain lunar libration, Cassini revealed the exact laws of the Moon's rotation (Sheehan and Dobbins, 2001).

The era of long and aerial telescopes probably reached its peak with the work of Philippe de La Hire, artist, mathematician, and astronomer. He became part of a circle of French scientists and intellectuals that included Cassini, Huygens, René Descartes, and others (Wikipedia, 2015g). Among many astronomical achievements, he published an artistically superior map of the Moon, and calculated accurate tables of the movements of the Sun, Moon, and planets, as well as determining coordinates of the French coastline and the Paris meridian.

Although nearly a half-century would pass before it came into its own, the reflecting telescope was invented by Isaac Newton, with a working model unveiled in 1668 (Figure 6). It had many advantages over the very long and cumbersome non-achromatic refractors of the era (Learner, 1981). These included: colour-free optics, much shorter and compact design, and a generally wider field of view. However, Newton's design suffered from spherical aberration and his speculum (tin and copper alloy) mirrors were subject to rapid tarnishing. Although John Hadley greatly improved optical performance of Newtonian reflectors in 1721 through use of parabolic mirrors, the limitations of speculum remained.

Scientific Lunar Cartography

After a long hiatus, the next significant phase in lunar map making began in the mid-18th century with Johann Tobias Mayer (1723-1762) (Figure 7), and with development of the achromatic refractor and the filar micrometer (Kopal and Carder, 1974; Learner, 1981). In many ways, Mayer was the father of scientific lunar cartography, since, like Langren a century before him, he was determined to establish accurate lunar longitudes using the times of entry of different features into the Earth's shadow during a total eclipse. By using the crater Manilius as central point of his system of coordinates, Mayer used a glass micrometer to measure the positions of several other lunar features (Sheehan and Dobbins, 2001). In this fashion, he generated two maps in orthographic projection (Figure 7). This remarkable work, as Apollo-era Moon experts

Kopal and Carder (1974) observed, places him in a unique position in lunar cartography: “...Tobias Mayer became not only the first modern selenographer of the world, but also the founder of the German school of selenography which in the century to come “took” the Moon away from the French and Italians, and which included Schröter, Lohrmann, Mädler, Schmidt, and Fauth.”

In addition to establishing a system of lunar coordinates still in use today, Mayer also made important contributions to studies of the Moon’s libration and motion, and correctly concluded that our satellite had little or no atmosphere based on his observations of instant extinction of stars when occulted by the Moon. In short, during his unfortunately short life, Mayer’s work marked the effective end of the era of early telescopic studies of the Moon and the beginning of the modern phase of lunar cartography that extends to the present day, now with manned exploration and mapping by spacecraft.

Following closely in Mayer’s footsteps, Johann Hieronymus Schröter (1745–1816) would soon become the true father of modern selenography (Figure 7). Despite his training as a theologian and later lawyer, like many amateur astronomers, Schröter was probably inspired by a seminal event, in this case William Herschel’s discovery of Uranus in 1781. He managed to get an appointment as magistrate in the small German town of Lilienthal where, with ample means and time, he was able to pursue his true passion (Moore, 1963). There he established an elaborate private observatory in 1778, equipped with several of Herschel’s excellent telescopes, and later instruments as large as 18.5 inches aperture, making Lilienthal Observatory the largest in the world at that time. Although Schröter’s plans for a detailed 46.5-inch map of the Moon were never realized, some 75 of his plates were published in two volumes in 1791 and 1802. Sadly, however, most of his original papers and observatory were destroyed during the Napoleonic wars in 1813 and he never recovered. Nevertheless, his contributions to selenography were substantial, involving detailed scrutiny of selected features under varying degrees of illumination, determining the altitude of lunar mountains, and developing a special projection machine to insure positional accuracy not before attained (Sheehan and Dobbins, 2001).

Although Schröter held many unorthodox beliefs (see below) and was not a particularly good draftsman, his contributions to lunar cartography, and indeed several other aspects of astronomy, were major (Baum, 2007). He was a completely honest observer and rarely made mistakes; nor did he draw anything unless sure he had actually seen it (Moore, 1963). His micrometer-aided measures of lunar mountain heights were better than anything up to that point, and he independently rediscovered many features including the Huyginus Cleft, the Straight Wall, and Schröter’s Valley. He also coined the term *rilles* for crack-like features.

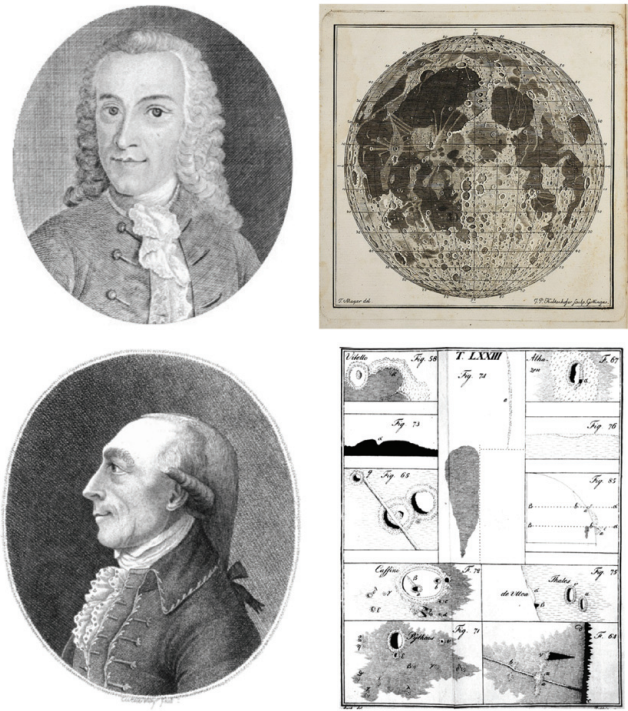


Figure 7 — Top row: J. T. Mayer and his orthographic lunar map, Bottom row: J.H. Schröter and lunar drawing example (all wikimedia)

Much the same applies to his planetary and solar work. These included his firm establishment that Venus has a dense atmosphere, and detection of the phase anomaly on Venus, known as the Schröter effect, referring to the discrepancy between the predicted and observed dates of dichotomy, as well as his efforts to determine the rotation period of both Mercury and Venus, and his discovery of solar granulation and details of sunspot umbrae (Darling, 2015b). Schröter’s pioneering efforts at comparative studies of the Moon and major planets preceded what would later become the sub-discipline of *planetology* as endeavoured a century later by Percival Lowell.

Volcanism and Selenites

In common with many of his contemporaries, Schröter became deeply interested, one might say obsessed, with the question of whether lunar craters were formed through volcanism, and whether the Moon had an atmosphere and might indeed be inhabited. The question of the origins of lunar craters no doubt began as soon as Galileo first observed them and adapted the term from the Greek name for vessel. Over the centuries at least three competing theories were advanced for the origin of craters: volcanic eruptions, meteoric impacts, and a most unlikely notion suggesting glacial action of sorts. In the 17th and 18th centuries, astronomers were fiercely divided over the issue of volcanic versus impact origins, as well as whether there was water and air on the Moon (Sheehan and Dobbins, 2001,

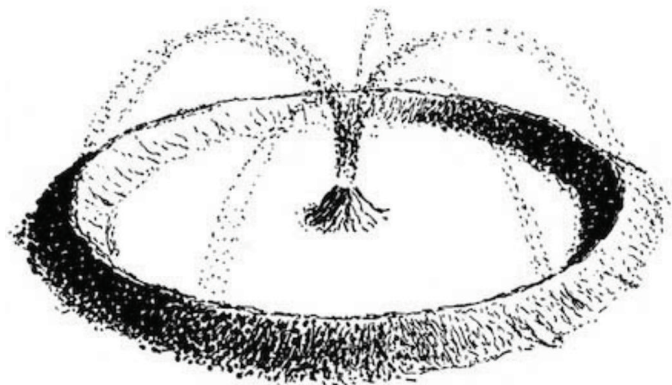
Darling, 2015a). The latter two, of course, would have implications with respect to possible lunar life.

None others than such luminaries as Hevelius, William Herschel, and Isaac Newton before him, were convinced that not only the Moon but also the Sun and other planets were inhabited by intelligent beings (Baum, 2007, Darling, 2015a). Although such notions were by no means universally shared, Schröter most certainly entertained them. As David Darling (2015b) put it, “Schröter was an enthusiastic pluralist who wrote that he was fully convinced that every celestial body may be so arranged physically by the Almighty as to be filled with living creature....”

He also claimed to have detected an atmosphere on other planets he thought were inhabited, and attributed what he perceived as colour changes on the Moon to cultivated lands. It is perhaps important at this point to emphasize that most scientists and scholars of that era had strong religious convictions and were sure that the Almighty would not have created anything in the Universe without purpose. As a result, belief in pluralism or conviction in multiplicity of inhabited worlds was almost universal among Schröter and his contemporaries (Darling 2015c; Sheehan and Baum, 1995). Once again, a parallel can be drawn here and a century later, when enthusiasm, indeed conviction, for the plurality of inhabited worlds reached a peak of sorts with Percival Lowell, Camille Flammarion, Giovanni Schiaparelli, Richard Proctor, and other Mars enthusiasts of the Victorian era, only to be defused again by scientific reality in the 20th century (Teitel, 2011).

It is noteworthy that both ideas, namely that most craters are volcanic in origin and that, despite its all-but-nonexistent atmosphere, the Moon might still harbour some form of life, persisted into the 1960s. The volcanic origin of craters, so eloquently proposed by English amateurs James Nasmyth (1808-1890) and James Carpenter (1840-1899) in 1874, held sway for nearly a century (Nasmyth and Carpenter, 1874). Their “fountain model” of volcanic eruption, adapted to the largely airless Moon and its lower-than-Earth gravity, had great appeal (Koeberl, 2001) as it seemingly explained both lunar crater walls and central peaks (Figure 8). Since the art of high-resolution astronomical photography was not yet perfected, Nasmyth and Carpenter made stunning plaster-of-Paris models of lunar features based on detailed visual observations (Figure 8). Although by mid-20th century the pendulum had largely swung in favour of the impact hypothesis, several noted authors, including V.A. Firsoff (1912–1981) (Firsoff, 1959, p. 61), Sir Patrick Moore (1923–2012) (Moore, 1963, p. 106), and even some professional scientists (Simpson, 1966), still favoured a largely volcanic origin of lunar craters.

Likewise, and no doubt inspired by Percival Lowell’s notions about Mars and William H. Pickering’s (1858–1938) rather outlandish theories about plant and insect life on the Moon (Darling, 2015C), Firsoff concludes as late as 1959: “To sum



Nasmyth and Carpenter’s volcanic fountain creating a crater by ejecting material from a central cone.

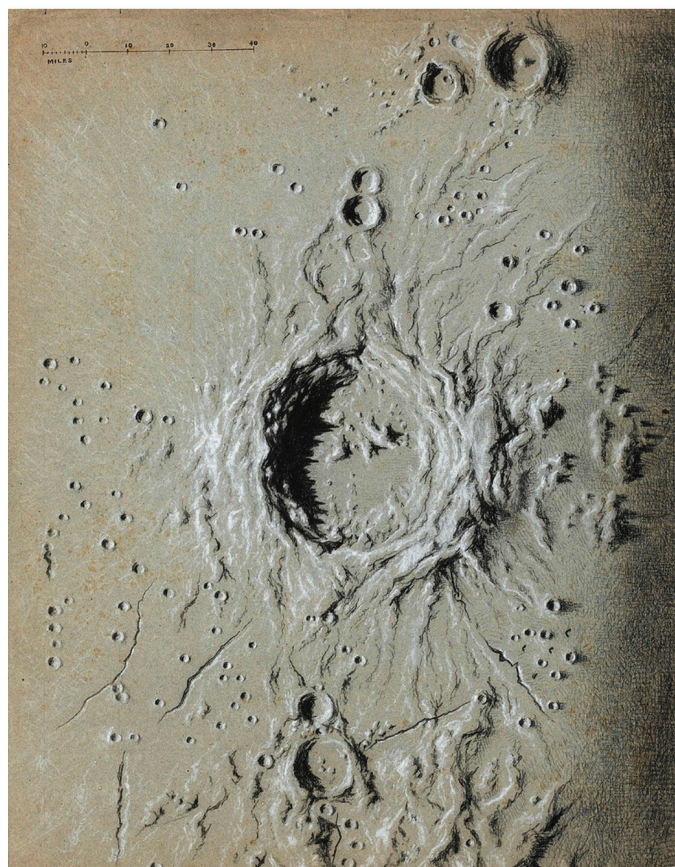


Figure 8 — Top: Nasmyth and Carpenter fountain model of lunar crater formation (Coventry and Warwickshire Astronomical Society, 1993). Bottom: Rendition of the crater Copernicus by James Carpenter (1874)

up, there does not seem to be any sufficient reason why plants, even of a highly organized type, should be unable to exist on the Moon, though probably only in isolated oases of life, the highlands being almost entirely barren, as they appear to be on Mars” (Firsoff, 1959, p.178).

Perhaps the most notorious 19th-century advocate for intelligent life on the Moon, as well as on other planets including Venus, was Bavarian Franz von Paula Gruithuisen (1774–1852) (Baum, 2007). An ardent admirer of Schröter’s,

Gruithuisen acquired several of Fraunhofer's superbly crafted achromatic refractors ideally suited for lunar and planetary observations. Fascinated by Schröter's observations of several rilles (grooves or clefts) in certain regions of the Moon, he proceeded to study them in great detail, believing them to be cities or great monuments built by intelligent Selenites! As a result of such claims and notwithstanding the fact that he was an astute observer of both the Moon and the planets, Gruithuisen is given little credit for his original work and findings. Among other things, he was one of the first to suggest that lunar craters are impact features and to note the bright regions at the poles of Venus, which he thought were polar caps as on Mars. As noted historian of astronomy Richard Baum describes him: "...Gruithuisen was an obsessive pluralist... [and] carried his interest into practice and went in search of life on other worlds" (Baum, 2007, p. 170). After observing the illusive Ashen Light on Venus, his imaginings went beyond the pale, attributing the phenomenon to a celebratory festival by the planet's inhabitants (Sheehan and Brasch, 2013). *

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Abstract

Most discussions of astronomical images as sources for scientific data or aesthetic pleasure concern representations judged to be quantitatively, or qualitatively “good.” An image that is not “good” would seem to offer little in return for any effort spent on analysis. Can anything be learned from looking more closely at less than optimal images? A 19th-century transit of Mercury drawing by prominent Society member Sir Adam Wilson provides a test case.

The good, the bad, and the ugly

Most astronomical images that merit inclusion in curated exhibitions (e.g., Canadian Astronomical Images [IYA2009]), art books devoted to astronomical imagery (e.g., Benson 2014), or introductory astronomy texts are usually technically accomplished representations possessing “photogenic” qualities, high aesthetic appeal, and verisimilitude. The “goodness,” or quality of such astronomical images is assessed in a manner no different from that used to judge the quality of Paul Kane’s (1810-1871) portrait of Superintendent J.H. Lefroy (1817-1890) of the Toronto Magnetic and Meteorological Observatory (ca. 1845; AGO, Paul Kane). Art is art.

When it comes to science, astronomical images in research or review papers have usually been captured by systems that have been carefully and thoroughly characterized, and from which data can be reliably and consistently reduced through quantitative protocols. Here “goodness” is attributed according to the quality of the science the images can deliver. It is possible, and frequent, for astronomical images to have both high scientific value and middlebrow aesthetic appeal (e.g., the various Hubble Deep Fields; Illingworth et al., 2013 exemplifying the science potential; Kessler 2012, the art).

Qualitative assessments of the aesthetic fitness of an image, however balanced, have elements of the subjective about them, as do quantitatively based assessments of their research value, however logically systematic, or data based. Science is an art, and art involves science, and without the exercise of judgement neither is particularly achievable. It is something we are stuck with, and it’s best to be honest about it. We should also be

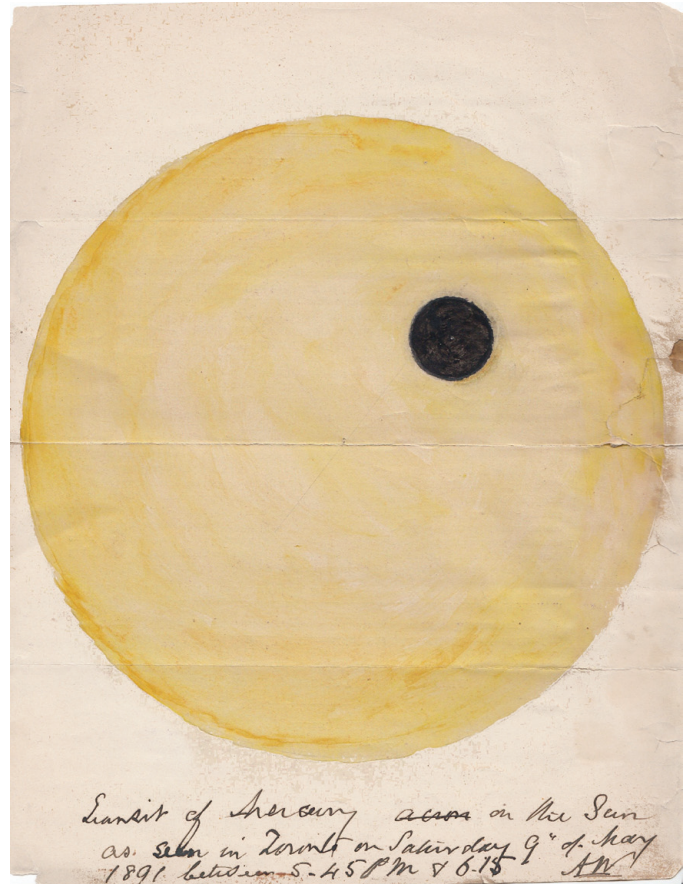


Figure 1 — Sir Adam Wilson’s drawing of the transit of Mercury 1891 May 10, as seen from somewhere in Toronto. Sir Adam used the reverse of a legal document for his record. Reproduced courtesy of the RASC Archives.

aware that judgements of the fitness of an image can vary with time. In 1856, pioneering astrophotographer Warren De La Rue (1815-1889) “created a drawing of Jupiter of such artistry and (apparent) attention to detail that it was used as the closest thing to a standard visual reference in written discussions of the planet’s features until the end of the century” (Hockey 1999, 78-81). To our post-*Voyageur* eyes, it looks like a poor attempt to render details of the Jovian atmosphere. To modern observers, there were other Victorian-era astronomers who produced much more accurate records of the appearance of Jupiter (e.g., Rosenfeld & Sheehan 2011, 55, although the case is complex).

It is rare to encounter images that are considered visually unappealing, or are visually challenging, or conceptually disturbing, or inadvertently comical, in collections of astronomical images curated for public middlebrow “art” contexts, unless the theme is purposely radicalized. Likewise, astronomical images from which good data cannot be reliably harvested are usually not used for datasets when better-quality images are available (a sane strategy for normal science, but one needing to be questioned in art).

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Figure 1 — Malcolm Park took three different images on three different nights with three different OTAs to capture this beautiful final of M31, M33, and the star Mirach. For Mirach and M31, Park used a Nikon D810A camera on an Orion ED80 600 mm with a focal length of $f/7.5$. M33 was imaged using a QSI 683WSG CCD camera on a TEC 140 refractor. Mirach is a stack of nine 180-second subs at $f/2.8$ at ISO 800 on an Astrophysics Mach-1 mount. M31 is a stack of six 180-second images at ISO 2500. All images were guided with a KW Kwiq Guider and stacked in Photoshop.



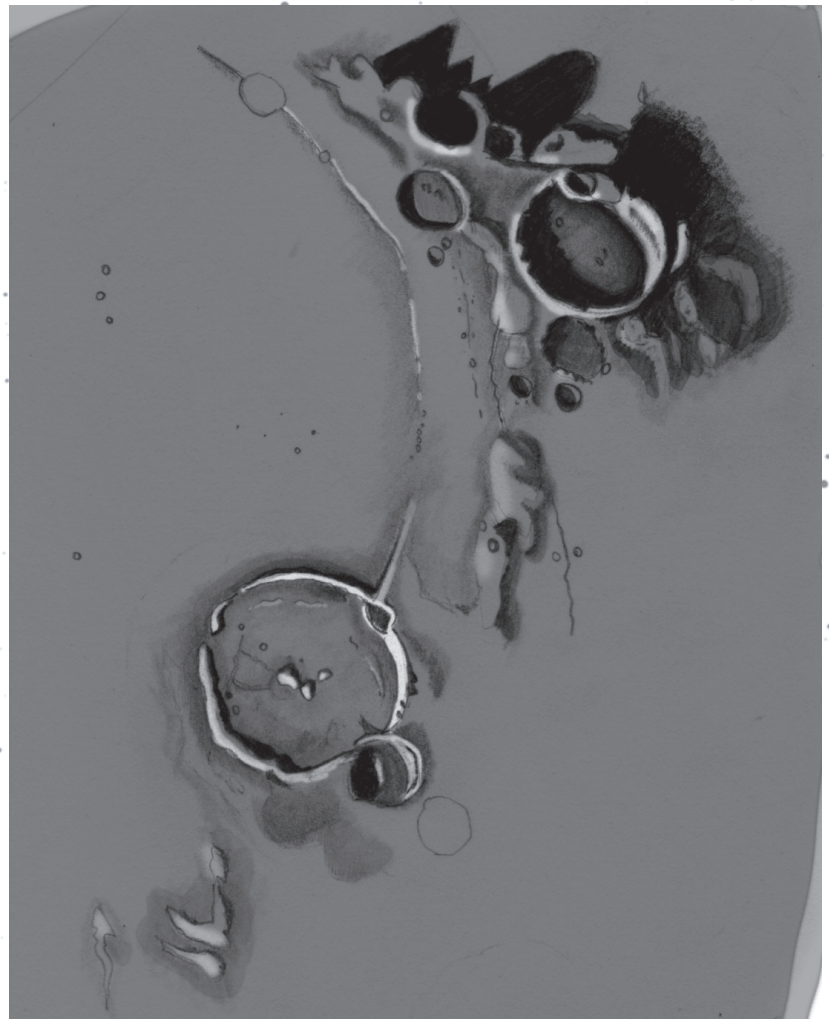
Figure 2 — The northern lights dazzle in this stunning image by Tenho Tuomi, who took this from the Tuomi Observatory, 17 miles north-northwest of Lucky Lake, Saskatchewan, on 2015 March 17. The 10-second exposure was captured using a Canon T5i/700D camera at ISO 1600 with a Canon XT/350D 18-55 lens at $f/3.5$, set at 18 mm. No processing software was used.

Pen & Pixel



Figure 3 — This collage of the total lunar eclipse of 2015 September 27 was taken in Clarke's Beach, Newfoundland and Labrador. Robert Denney used his Celestron Nexstar 127slt and a Nikon D5000 camera. No Photoshop was used in processing, but the collage was created using Picasa.

Figure 4 — On 2015 September 29, Halifax Centre's Michael Gatto took advantage of excellent seeing conditions to sketch this image of craters Mersenius (top), and Gassendi (bottom). He used an 8" f/7.5 reflector with magnifications of 120 and 200X, hand-tracked with an Alt-Az mount. It was sketched at the eyepiece in pencil, then scanned, with grey tones and highlights added in Photoshop.



When “good” images are the prevalent expectation in art and science, is there any use for aesthetically “ugly,” and scientifically “bad” images?

The virtues of the bad

The aim *should* be to obtain the best images possible to answer the research question(s) for which they are sought. What is available, however, may not meet the modern standard for a good image, or even an older standard contemporary with the image’s creation.

Imperfect images may be the sole scientific record of a transient event if there were few observers, and technical failure has occurred in the apparatus, or the record as published is incomplete, or the rare original images have suffered serious degradation. In such cases, bad images can have high scientific value because they are the *only* images. For a hypothetical but easily comprehensible example, if Johannes Hevelius’s (1611–1687) imperfect retrospective image illustrating Jeremiah Horrocks’s (1618–1641) observation of the 1639 transit of Venus was the sole surviving account of Horrocks’s observation, it would assume a greater significance than it enjoys (for the image, see Horrocks 2012, xxiii, 122).

If a long series is necessary for a particular branch of time-domain astronomy, it may be necessary to turn to old (sometimes *very* old) records stemming from “scientific” cultures with markedly different graphic conventions from ours, which we may only imperfectly understand. Good data cannot be easily or even reliably harvested from such images, yet there may be no choice but to extract the imperfect data (e.g. Rosenfeld 2014).

A bad image may be significant for historical reasons. It may be from the hand of a figure sanctified by the scientific canon, a figure who has made real contributions to science. There were prominent astronomers who could extract useable data from the visual shorthand of their images (although others could not), or who illustrated their papers with observational drawings employing overly formulaic depictions of phenomena, approaching at times the stiff formalism of cartographic conventions. Unlike his son Sir John (1792–1871), William Herschel (1738–1822) was not an accomplished astronomical artist (Herschel 1912, I 159, 294, 295, 311, 378, 443, pl. XIII; II, 152, 158, 333, 409, pls. II, III, IV). Some of Sir William Huggins’s (1824–1910) planetary drawings were passable with caution, but none could be called outstanding. The fruit of his early years with the RAS, it is fortunate that he turned his attention to other astronomical fields (Huggins 1909, 361, 363, 365, 367, 373).

An unskilful observational drawing with minimal scientific value may, however, provide information on the state of

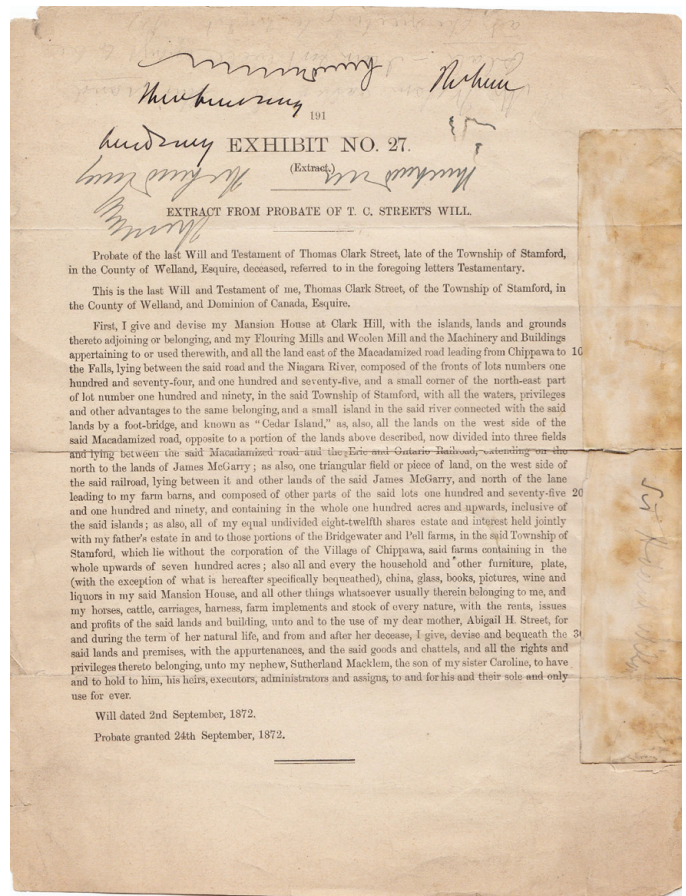


Figure 2 — The obverse of Sir Adam’s Mercury transit drawing. Reproduced courtesy of the RASC Archives.

development of a particular observer’s ability to see at the period the drawing was executed, as well as evidence of the state of his or her technique for recording the observation (in reading these images it is important not to confuse artistic limitations with perceptual ones). Information for his or her ability can be compared to that of others in his or her observing circle, as well as with contemporary observers in other places. If gathered in sufficient quantity, such material might be useful in writing the history of the average observer. The information might even be amenable to statistical treatment. Average observers have a history, and it tends not to be told at the expense of telling the history of exceptional observers.

Sir Adam Wilson’s Mercury transit drawing

Sir Adam Wilson (1814–1891) was a socially prominent member and benefactor of the Astronomical and Physical Society of Toronto (Rosenfeld 2009; 2011). Created QC in 1850, he was the first mayor of Toronto elected by popular vote (1859–1860); in the early 1860s he served as solicitor general for Upper Canada. As a moderate reformer, he clashed with John A. Macdonald and George Brown. The zenith of his legal career was reached as Chief Justice of the Court of Common



Figure 3 — Detail from a photograph of a Society “star party” ca. 1900, showing an amateur reflector contemporary with Sir Adam’s now lost instrument (the instrument shown here probably had a 10.8-127 cm primary mirror, whereas Sir Adam’s was equipped with a 15.2 cm mirror). Reproduced courtesy of the RASC Archives.



Figure 4 — Diagram of an amateur reflector on a parallactic mount. Sir Adam’s reflector was said to be similarly supported. From John Browning, *A Plea for Reflectors* (London: John Browning, 1876), p. 15, figure 4.

Pleas (1878), followed by Chief Justice of the Queen’s Bench (1884–1887; DCB, Wilson, Parker).

Sir Adam seems to have discovered astronomy in his later years. After his retirement from the bench (Anon. 1891, 70–71). He was proposed for membership in the Society on 1890 October 7 (the year of its revival), and was duly elected on the 21st, at the age of 76 years (APST Minute Book, 44, 46). He had acquired a 6-inch speculum-mirror reflector, of which he was both proud, and anxious, hosting members at his house to display his acquisition and to solicit their opinion of its worth (Anon. 1890, 21). He contributed to the meetings, chiefly in moving and seconding motions, and was elected a life member on 1891 July 14 (this was then a species of honour; Anon. 1891, 24). His time within organized astronomy was short; he died on 1891 December 28, a little over a year after having been elected (Anon. 1891, 70). He’d foreseen this eventuality, and left his telescope and a celestial globe to the Society (Rosenfeld 2009; 2011).

Eight months before he died, Sir Adam did manage to observe the transit of Mercury on 1891 May 10, from Toronto. He sent a brief report to the Society, which appeared in the *Transactions*: “Observations respecting the transit of Mercury were made by Sir Adam Wilson, who sent a large drawing, and reported that he had been very successful” (Anon. 1891, 12). The drawing does survive (Figure 1), and shows if anything that Sir Adam was a man too easily pleased by his own efforts. The first thing one notices is that Mercury is depicted much too large in relation to the solar disc, a common error of beginners. Sir Adam has misrepresented the true size of Mercury’s disc against the Sun by 450 percent. Another problem is that he gives a figure for the duration of his transit observations, but not for the precise time of his drawing. The inscription across the bottom reads: “Transit of Mercury across on the Sun/ as seen in Toronto on Saturday 9th of May/ 1891 between 5.45 PM & 6.15 AW.” In fact, only the first and second contacts would have been visible from Toronto, with the Sun a mere 5 degrees or so above the horizon at first contact. The transit would have commenced around 18:57, so clearly the information inscribed on the drawing is unreliable.

The image has been drawn on the back of a probate will extract dating from 1872, a not inappropriate act of recycling for a legal professional (Figure 2). The materials used are pencil, compass, straightedge, pen & India ink, and brush & yellow wash. The sequence of work appears to have been to draw the solar disk with compass and pencil first, then a line through the Sun's centre with pencil & straightedge, followed by the disk of Mercury with compass & pencil, next the solar disk was filled with the yellow wash, and finally Mercury was filled in with India ink. The inscription with signature was then added. Some attempt has been made to show the limb darkening. An examination of the solar limb reveals that Sir Adam experienced difficulty keeping the yellow wash within the confines of the pencil outline.

The scientific value of Sir Adam's transit image is less than negligible, and it is hard to conceive of anyone turning to it for aesthetic enjoyment, other than perhaps Sir Adam himself. "Bad," and "ugly," the image is a good witness of the materials chosen by an amateur of the period. Its crude inaccuracies hint at the state of Sir Adam's observational abilities, and the errors in drawing and annotation suggest the state of his understanding, or lack of understanding, of what would make his drawing useful. It is the work of an amateur at the beginning of his observational career. There is something naively touching in Sir Adam's lack of sophistication when he reports his observation a success, and sends his poor drawing to the Society as proof!

It is pleasant to think of an elderly man, discovering astronomy in his 70s, and in the last year of his life, taking the time to enthusiastically record an observation. His transit drawing for all its faults may have been an improvement on his earlier efforts at creating observational records. It seems he received support from the Society, for he left his astronomy hardware to his astronomical friends in that organization. It is to be hoped that they offered advice and example to enable him to become a better observer, which he might have, had he lived longer.

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A Virtual Moon



by Blake Nancarrow, Toronto Centre
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If you love the Moon, you'll love Virtual Moon Atlas. VMA is a free application downloaded from Patrick Chevalley and

Christian Legrand. The software is offered for the Windows, Macintosh, Linux, and PocketPC platforms. Chevalley may sound familiar: he also wrote Cartes du Ciel.

Virtual Moon Atlas shows realistic views of our nearest celestial neighbour to assist the astronomer, particularly one using binoculars, telescope, or camera, in identifying or locating lunar features. It can simulate the Moon phase, varying distance, and libration for any date and time. It is easy to use but contains an astounding array of charts, maps, and

overlays, as well as a wealth of detailed textual information to satisfy the serious Moon observer. It is not just an atlas—consider it a lunar encyclopaedia.

I have used the product periodically over the years. It is installed on my netbook and desktop Windows computers. The current version is 6.1 (with update applied). The product has expanded a lot over the last couple of years and now offers a number of components including AtLun, DatLun, and PhotLun.

AtLun is a lunar atlas that shows detailed maps. The DatLun allows one to search databases and extract content. And the PhotLun component permits one to search and view Moon photos. The AtLun feature, the main attraction, is the one I use and the focus of this article.

After installing the app, you will be prompted to indicate your location. On Earth, of course. It is sensitive to topocentric and geocentric positioning. You'll also need to set the date, time, and zone. A rather realistic simulated view of the Moon will

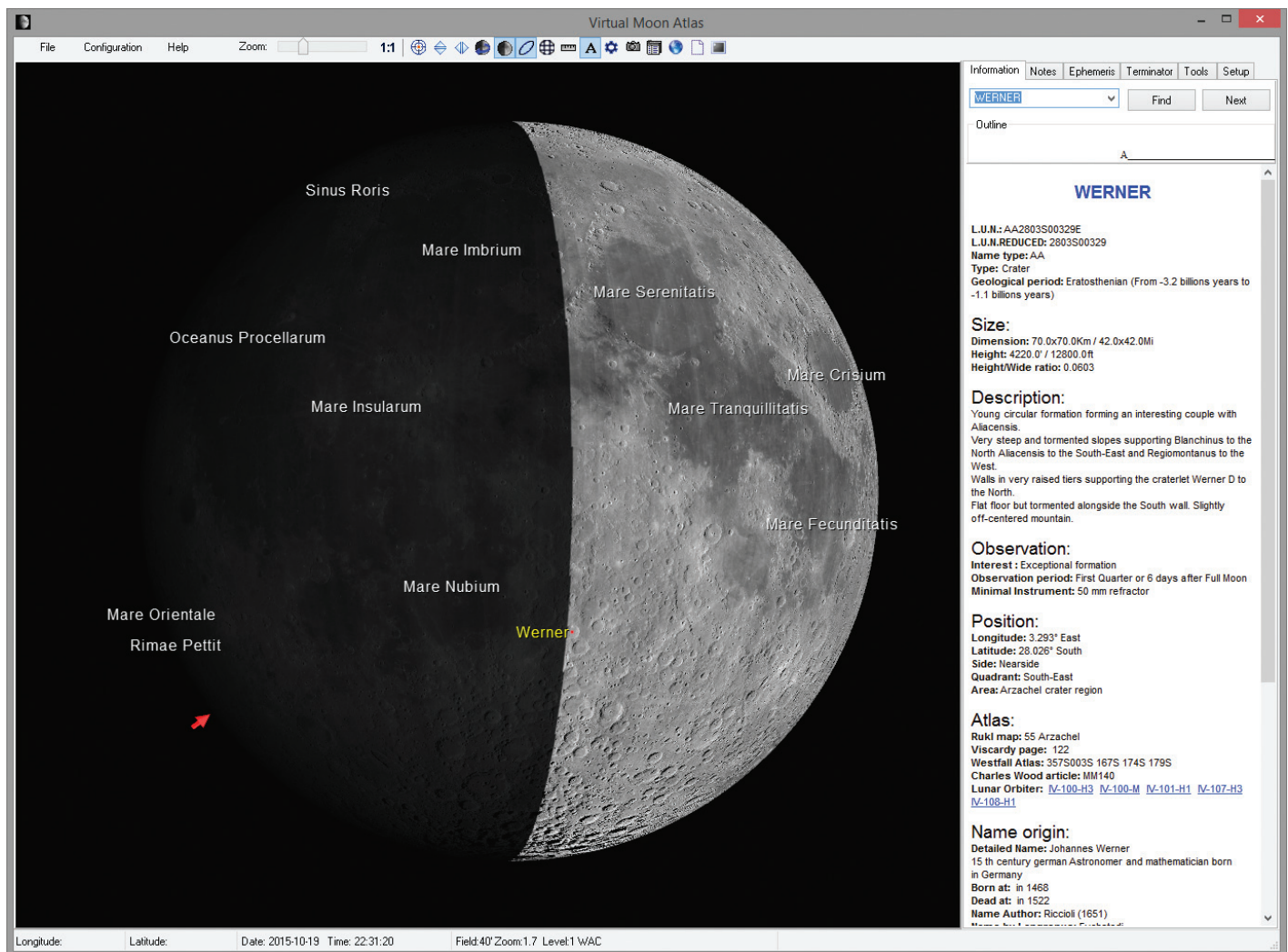


Figure 1 — The VMA program in the atlas mode showing the Moon's phase on 2015 October 20, major features including maria, and the maximum libration point (red arrow). Crater Werner was selected (shown in yellow).

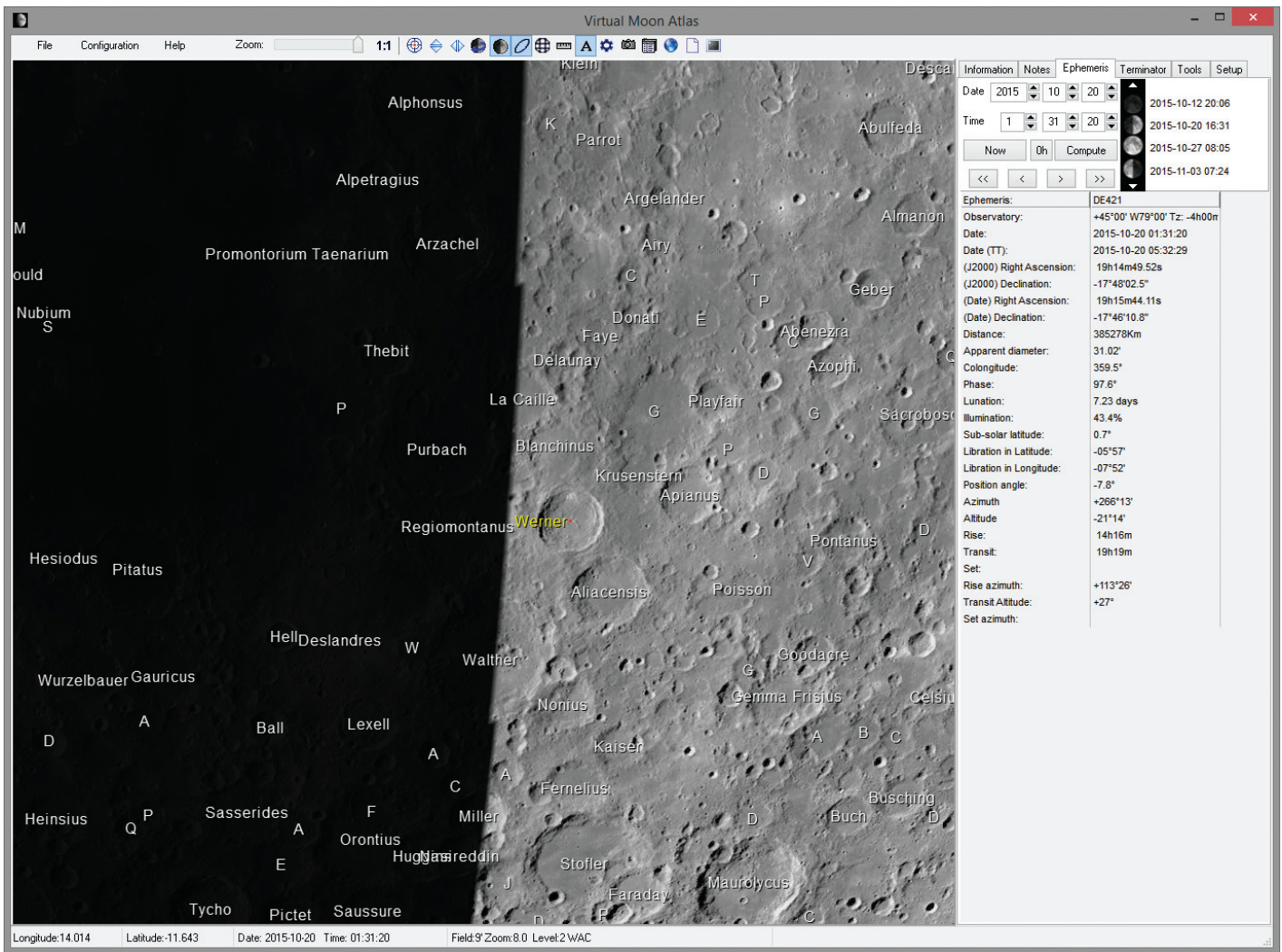


Figure 2 — Zoomed into an area in the southern hemisphere. The Ephemeris tab shows date/time controls and detailed information about the Moon phase.

appear. The topocentric option is preferred as it will rotate and tilt the Moon image for your specific position on the planet.

VMA creates a fairly realistic presentation of the lunar surface. That said, you can turn off the display of the phase so to view the entire surface. You can darken or brighten the shadowed part of the Moon (to perhaps simulate Earthshine).

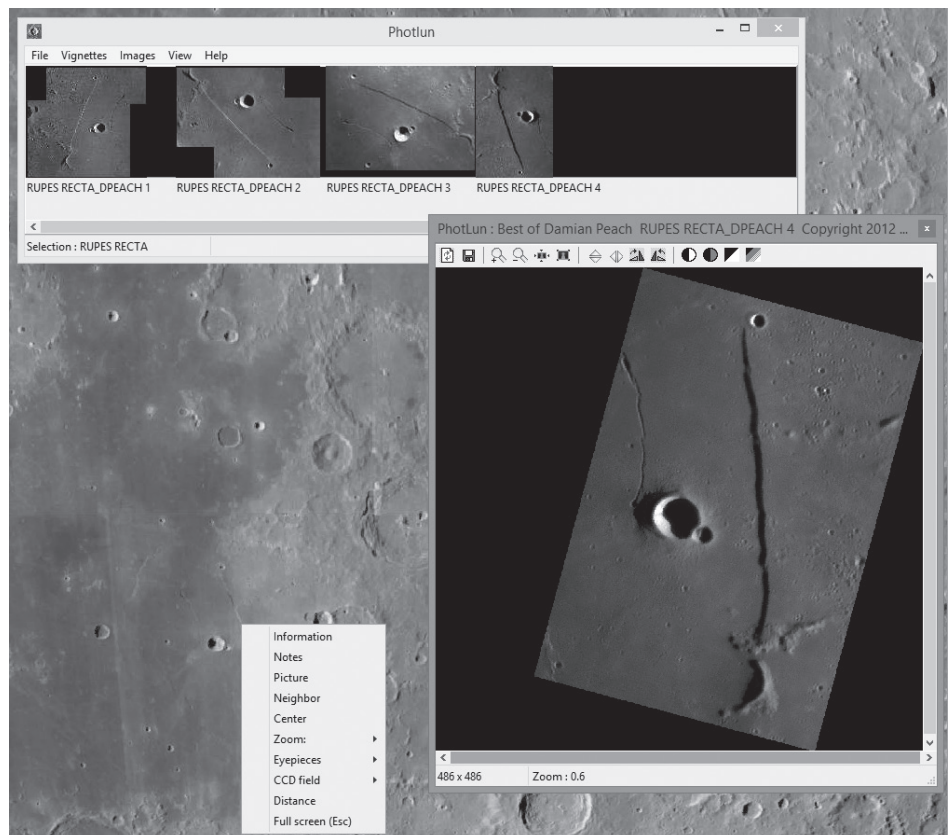


Figure 3 — Photographs can be selected and viewed easily via the shortcut menu.

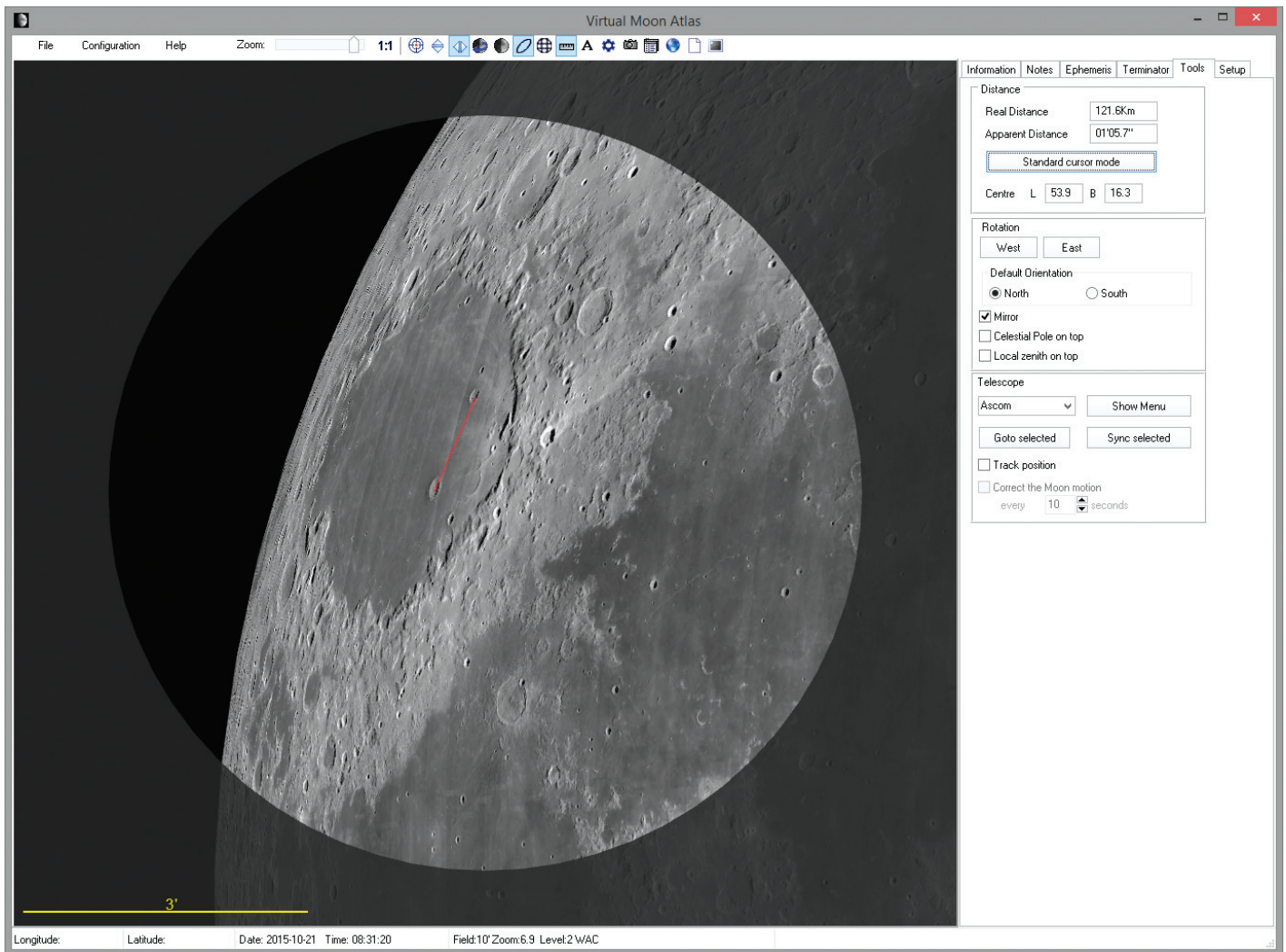


Figure 4 — Simulated telescopic view, mirror-reversed or flipped horizontally. The measurement feature, from the Tools tab, was used to determine distance between craters Picard and Peirce. Angular scale shown (in yellow).

Zoom and panning is easy with the mouse. The toolbar offers a Zoom slider and Center button. Labels are toggled on or off easily, once again, from the toolbar. The label display is dynamic, meaning more labels appear as you zoom in. The label density can be controlled in the Configuration settings.

Clicking on the image of the Moon places a small red bullet near or on the target. The Information tab leaps to life with many facts about the selected item. Hyperlinks take the user to websites with photographs and more detailed information.

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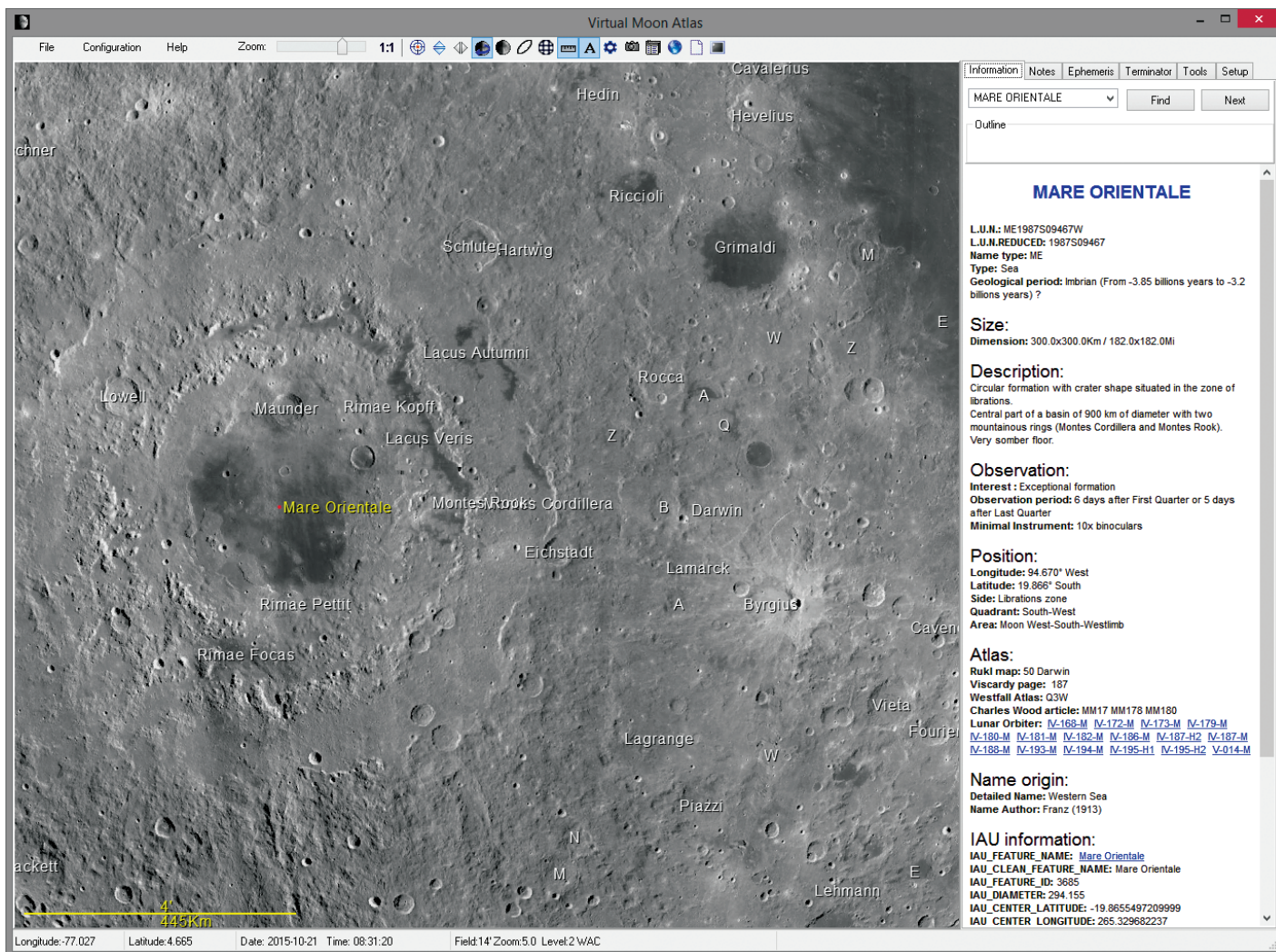


Figure 5 — We are hovering directly over Mare Orientale using Full Globe mode, a view not possible with the backyard telescope.

VMA provides extraordinary detail about features. For example, with craters, the outline or profile elevation is shown symbolically, the dimensions and height noted along with a verbose description, when it was discovered, and the page number where you might find an illustration in a popular paper atlas.

One can search for a feature by typing its name in the Information tab although proper names are generally required. Wildcard searching is permitted.

Once image libraries are downloaded and installed, one can view photographs from space agencies, professional observatories, and others. The PhotLun tool can be used directly or can be triggered by right-clicking on a target. Images can be flipped and rotated, brightened or darkened, to simulate the view in ocular. Catalogue and link to your own photos, if inclined.

The Ephemeris tab allows a user to change the date and time, jump ahead or backward one hour or one day, or jump to a preferred phase. Details shown below include apparent size,

longitude, illumination, phase angle, along with rise and set times.

The Terminator tab helps one review a sortable list of targets lying along the intriguing line between light and dark. Also, the list can be filtered by interest value and size of observing instrument. Selecting a feature highlights it on the Moon image.

The software tool permits logging or note-taking via the Notes tab. Telescope and camera views can be simulated. In fact, you can drive a mount with VMA (and appropriate ASCOM drivers). There is a measurement tool for gauging distances and sizes.

There are a number of additional interesting and advanced features in VMA. For example, one can do far-side viewing. Using Full Globe mode, you can simulate being in orbit. A variety of scientific overlays may be shown to emphasize, for example, iron content, feature elevations, gravity fluctuations, etc.

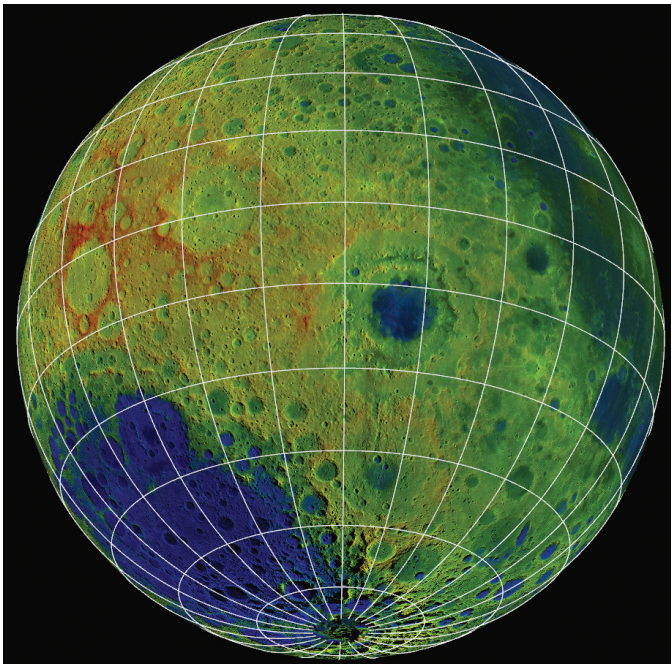


Figure 6 — Elevations on the Moon. A Kaguya Altimetric overlay is shown with grid (set at 15° intervals).

There is extensive documentation for Virtual Moon Atlas provided across four user manuals. The tutorial is worth reviewing immediately after installation. There is a

Yahoo!Group in the event one has questions or challenges with the tool.

The software itself can be operated in different languages.

In a rare approach, the developers consider the platform a user might have. While OpenGL is recommended, VMA works on many types of computers, old or new, slow or fast, with or without high-end graphics capabilities. It works just fine on my netbook with lowly Atom processor and integrated graphics under Windows XP; I can get much better detail and response on my quad-core home computer with more RAM and dedicated video board running Windows 8.1. The Performance slider on the Setup tab can be easily adjusted to balance resolution and speed. That's a refreshing take from a programmer.

Visit <http://ap-i.net/avl/en/start> to learn more about and to download Virtual Moon Atlas. Assuming you like looking at the Moon ... ★

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 EPO, co-manages the Carr Astronomical Observatory, and is a councillor for the Toronto Centre. In daylight, Blake works in the IT industry.

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John Percy's Universe

Joseph Miller Barr Revisited

by John R. Percy
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Every generation or so, we need to remind the readers of this *Journal* of the remarkable achievements of Joseph Miller Barr (1856–1911), an enigmatic Canadian amateur astronomer and early RASC member. Although he may have been disabled in some way, he made important contributions to astronomy. His 1908 paper on “The Orbits and ‘Velocity Curves’ of Spectroscopic Binaries” (Barr 1908) appears on a list of the top ten astronomy-related papers of the year by citation, along with three by a gentleman by the name of Einstein¹. Clarence Chant (1911) published a short obituary of Barr, and Jack Heard (1974ab) and Alan Batten (1983), among others, have written about him and his work.

The Story in Brief

Joseph Miller Barr was born on 1856 March 14 (according to his death certificate) in St. Catharines, Ontario, the son of a merchant. He lived his entire life in that city. Evidence suggests that he was disabled and/or chronically ill. He lived with his family, did not marry, or own property. He was described as being exceedingly studious, and having an interest in astronomy from his earliest years. It is not clear whether he ever went to school; he may have been tutored at home. Between 1887 and 1910, he published over a dozen professional-quality papers in respected journals, including *JRASC*. But, he never—for some reason—attended an RASC or other meeting to present them personally. He also wrote letters to his local newspaper, and at least one to the *Toronto Globe*, on scientific topics. He died on 1911 July 9.

Barr's Scientific Work

Barr's primary astronomical interests were in spectroscopic and other binary stars, and in variable stars—topics that were closely related. His name is immortalized in the Barr effect. When Jack Heard (1974a) wrote his article, he said that, to the best of his knowledge, Barr was the only astronomer who had an “effect” named after him. Now, there are several.

The Barr Effect is a spurious non-random distribution of the orientations of spectroscopic binary orbits. Spectroscopic binaries are stars in which the spectral absorption lines of one or both stars are observed to vary periodically in wavelength because of the star's orbital motion, and the Doppler effect. Careful measurement of the changing wavelengths over time gives the orbital “elements”: the period, size, and orientation of the orbit. Barr noted, from the published orbits of 30 spectroscopic binaries, that the orientations were such



Figure 1 — Joseph Miller Barr (1856–1911). His age in this photo is uncertain. From Chant (1911).

that there was an apparent excess (up to 90 percent, as opposed to the expected 50 percent) in one direction; such that their periastron points were nearly always farther from us than their apastron points (Batten 1983). This apparent effect was partly because, at the time, pulsating stars such as Cepheids were erroneously believed to be spectroscopic binaries with eccentric orbits but, even when these were omitted, the effect persisted.

Helmut Abt (2009) has published the most recent discussion of the Barr Effect. He notes that, as the number of spectroscopic binaries increased—from 30 in Barr's time, to 275 in 1935, to 2801 in 2004—the effect has persisted. It is real. Otto Struve, Alan Batten, and others have shown that it is caused by the distortion of the spectral absorption lines by gas streams passing between the components. In some stars (e.g. U Cep), the spectroscopic eccentricity of the orbit is actually spurious, and caused by the gas streams; the eclipse light curve shows convincingly that the orbit is circular. Abt (2009) studied 570 spectroscopic binaries, which had reliable, non-circular orbits. The Barr Effect is definitely present, and most pronounced in B0–B3 V–III stars, i.e. hot stars.

Barr's other interest was in variable stars (my favourite kind). He wrote a 12-page article on “The Study of Variable Stars” in the very first edition of what is now the RASC *Observer's Handbook* (then called *The Canadian Astronomical Handbook for 1907*), and contributed a table of interesting variables to the 1908 edition. Chant was the editor, and he describes Barr's paper as “admirable.” The Astrophysics Data System (ADS) lists 13 research papers by Barr, in journals such as *The Observatory*, *Nature*, *Astrophysical Journal*, *Astronomical Journal*, *Popular Astronomy*, and this *Journal*. Some of these are duplicates; he published three papers in both RASC publica-

tions and in *Popular Astronomy*. He also published some papers in the *Transactions of the RASC*, which is not included in ADS, and perhaps others. As a 17-year-old, he wrote a short, important (but overlooked) letter to *Scientific American* magazine about the possibility of confirming the binary nature of the eclipsing variable Algol, using the newly-developed spectroscopic technique (Barr 1873).

Barr, the Enigma

Jack Heard (1974b) devoted the second of his articles to the question of what manner of person Barr was. For this, he enlisted the help of a knowledgeable St. Catharines' librarian, consulted Barr's obituary in the local newspaper, checked available city directories, and even visited the local cemetery (Barr was apparently buried elsewhere). On the basis of Barr's "decidedly retiring nature" (Chant 1911), his long illness and private funeral (obituary), his lack of an occupation, independent residence, or wife and family (city directories), Heard concluded that Barr was "severely handicapped physically." Heard even comments on the one existing photograph of Barr (Figure 1, from Chant 1911, page 449) as being that of a "plump-faced young woman or rather pretty boy." He also points out that Barr's hair and clothing in the photo appear to have been retouched (or "severely tampered with" (Heard 1974b)). All very mysterious. Was Barr embarrassed about his appearance? Was this photo actually of Barr's sister Mary? Could Joseph actually have been a Josephine? Could he have had a genetic and/or hormonal syndrome that gives a male feminine characteristics? Later, I shall suggest that he was afflicted with some chronic illness; this may explain his appearance in the photograph. Or, if he had a deformity, that might explain the retouching.

I could not overcome the feeling that not all had been said about Barr, and I still feel that way. Len Chester, of the Ontario Genealogical Society, kindly sent me a copy of his death certificate. It states that he was born on 1856 March 14, and died on 1910 July 9 (clearly a typo for 1911). He was therefore 54 years old—not a bad age. His occupation was listed as "astronomer." The general cause of death was what we would call arteriosclerosis, and the immediate cause was given as gangrene. In the 1901 Canada Census, he was listed as living with two lodgers. His birthdate was given as 1856 July 12. So there is some confusion here.

Whatever schooling and disability Barr may or may not have had, he writes very professionally, even at the age of 17. Randall Rosenfeld has kindly provided me with copies, from the RASC Archives, of some of his letters to J.R. Collins, RASC Secretary at the time. Barr's handwriting is strong, and the letters are those of a well-read, literate person. His excuses for not attending RASC meetings and social events are rather vague—"I greatly regret that, under present conditions, I shall be unable to attend the Society's 'At Home' on Thursday next"; and (re: the 'At Home'): "I greatly regret

that I cannot be present on that evening"; and (re: a paper submitted to the Society): "It is not probable that I can be present at any meeting of the Society at which this paper may (Barr's underlining) be read or discussed." The tone of these remarks suggests, to me, that he may have had some chronic or recurring illness. It's also possible that he had some deformity, which did not affect his ability to function, but made him reluctant to appear in public.

He must have had some access to the astronomical research literature, since his publications are appropriately referenced, including to North American and European journals, and observatory publications. Perhaps he induced authors to send him copies of their papers; this was apparently done regularly at the time, including when the recipient was an advanced amateur. It is clear from his letters that he corresponded with leading astronomers of the time, such as H.H. Turner, V.M. Slipher, and F. Schlesinger. Today, such assistance might be noted in Acknowledgements at the end of the paper; in Barr's time, acknowledgements do not seem to be common. Barr also observed variable stars regularly, so he could presumably go outside.

Whatever his disability, deformity, or disease, he was a remarkable person. The "Barr Effect" keeps his name alive today. ★

Acknowledgements

I am grateful to Ontario Genealogical Society researcher (and RASC stalwart) Len Chester, biomedical scientist Maire Percy, RASC Archivist Randall Rosenfeld, and astronomy historian Tom Williams for their comments, and especially to Len and Randall for providing crucial documents as mentioned above. Special thanks to Randall for scanning and sharpening Figure 1.

- 1 [www.stsci.edu/~kgordon/papers/LitFun/top ten papers by year.html](http://www.stsci.edu/~kgordon/papers/LitFun/top%20ten%20papers%20by%20year.html)

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Introducing your Canadian Astronomers

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

CFHT's staff of ~45 includes astronomers, engineers, IT, computer programmers, accountants, machinists, and our own mechanic and electrician. Our staff is a mix of people from around the world. Within the astronomy group, we have resident astronomers from Canada, France, the University of Hawaii, and Taiwan. CFHT resident astronomers carry out their own research, support the nighttime observations of CFHT, develop instruments, support our users, and many, many other things. The resident astronomers also act as points of contact for astronomers from the country they represent.

Canada has three resident astronomers at CFHT: Daniel Devost, Lison Malo, and Nadine Manset. I interviewed each of them to give readers the chance to get to know them and understand the diverse research interests that astronomers have.

Dr. Lison Malo, resident Canadian astronomer at CFHT.

Dr. Lison Malo is CFHT's newest resident Canadian astronomer. She started at CFHT in 2014 and formally graduated with her Ph.D. from the Université de Montréal in June 2015. Lison's interests in astronomy were piqued like many people—by a comet. When Comet Hale-Bopp appeared in the sky in 1997, it was visible from Montréal. Lison was impressed to see the comet with her own eyes and wanted to learn more about it. As her interests in astronomy grew, she found role models in Canadian astronauts Julie Payette and Marc Garneau.

Lison attended the Université de Montréal, receiving both her B.Sc. in physics, and ultimately Ph.D. in physics from the school. During the summers of her undergraduate degree, Lison worked at ASTROLab du Parc National du Mont-Mégantic. She credits the training she received there as critical to her understanding and development of a broad knowledge in science and astronomy. Lison maintains very close ties to the ASTROLab and is still involved with their programming, remotely attending their summer astronomy festival from the CFHT control room.

Lison's primary research interests lie in a better understanding of the evolution of young (10-120-My-old), low-mass ($<1M_{\text{sun}}$) stars and a complete census of the young stars found in our solar neighbourhood. The main objective of her



Figure 1 — Dr. Lison Malo

thesis research, under the supervision of René Doyon and in collaboration with David Lafrenière and Étienne Artigau, was searching for and characterizing these young, low-mass stars. Her research led to the development of a tool called BANYAN, a Bayesian analysis tool to determine the probability of membership of candidate stars to nearby young kinematic groups. Lison is also interested in determining the fundamental parameters of a star to determine its exact age. To do so, she compares the parameters with the theoretical stellar evolutionary models, including processing the magnetic field of the stars.

She is a member of the Matysse team that recently published an article entitled “Magnetic Activity and hot Jupiters of young Suns: the weak-line T Tauri stars V819 Tau and V830 Tau.” This paper, using ESPaDOnS data, announced the preliminary discovery of a Hot Jupiter orbiting the hot, young star V830 Tau. The star is very young, ~2 million years old. It is difficult to discover planets around such young stars because the magnetic field of the star combined with star spots generate perturbations in the spectra of the star larger than those created by planets, even Hot Jupiters. By monitoring the stars and using tomographic techniques inspired by medical research, the Matysse team mapped the star's surface, which allowed them to compensate for the perturbations caused by the star's age and uncover a $1.4-M_{\text{Jupiter}}$ exoplanet orbiting 20 times closer to the star than the Earth orbits the Sun. According to Lison “this modelling allows us to compensate for the perturbations that the spots generate in the spectra of young stars and thus regain the power of diagnosing the presence of close-in giant planets.”

In addition to her active research, Lison's work at CFHT includes supporting ESPaDOnS and SITELLE users, CFHT science contact for GRACES, the project scientist for OPERA, and she is an active member of the SPIRou science team. I have covered ESPaDOnS and SITELLE before, so let

us skip over to GRACES. GRACES is a joint CFHT-Gemini project to connect ESPaDOnS with Gemini. Engineers connected the two facilities with a 1000-ft fibre-optic cable taking the light from Gemini's 8-metre mirror and feeding it into ESPaDOnS inside CFHT. Gemini users now have access to the high-resolution spectroscopy features of ESPaDOnS, but not the spectropolimeter features. I'll be writing a separate article about GRACES in an upcoming column. OPERA is CFHT's open-source data-reduction software for ESPaDOnS and GRACES. As the project scientist, Lison oversees the development of the code and works with the programmer to ensure it reduces the data correctly. SPIRou is an infrared spectrograph/spectropolimeter currently in development. We anticipate it arriving at CFHT in 2017. Like GRACES, SPIRou deserves its own dedicated column in the near future.

Lison's favourite part of her job is the fact that each day she's part of the actual research interests of international researchers. From extragalactic Universe research to a better understanding of the planets in our Solar System, she helps these researchers receive the most powerful images to reach their scientific goals. Her advice to students is to always be passionate and curious about physics and astronomy. Don't be self-conscious to ask about internships in worldwide observatories, even if there are no internships published on their websites. She also recommends getting involved in outreach activities about science and astronomy.

Dr. Nadine Manet, resident Canadian astronomer and QSO team manager at CFHT.

Dr. Nadine Manset is CFHT's longest-tenured Canadian resident astronomer, starting at CFHT in 1999. I asked when she first became interested in astronomy. Her response was that the first "big book" she ever read as a kid was a fantasy/sci-fi novel. She liked the story and started to read more books in the same genre, learning words like "galaxy," "nebula," and "black hole." She realized those words belonged to a science called astronomy and she started to read books and magazines about space exploration and astronomy. In her teens, she learned that a job existed where she could do astronomy, study the Universe, and get paid to do it. So teenage Nadine decided to become an astronomer. Much of her inspiration to this day comes from *Star Trek* and other sci-fi novels, movies, and TV shows.

Like Lison, Nadine attended the Université de Montréal for all her post-secondary schooling, receiving her B.Sc., M.Sc., and Ph.D. in physics. During her studies at Montréal, Nadine spent the equivalent of a year at the Observatoire du Mont-Mégantic working on an instrument, taking data, observing, and training other students and astronomers.

Nadine's research interests include polarimetry of young T Tauri stars, astrobiology, spectroscopy of hot Be stars with



Figure 2 — Dr. Nadine Manset

dust, and optical/IR imaging to find new young stars of the Herbig Ae/Be type. Her most recent paper "Toward Understanding the B[e] Phenomenon: V. Nature and Spectral Variations of the MWC 728 Binary System" reported on the long-term monitoring of a binary star system. The binary pair is comprised of B5 and G8 stars. Spectroscopic analysis of the system pointed to a variable stellar wind coming off the larger B5 star and the presence of a gaseous disk around the same star. As a result of the analysis, the team concluded that the binary pair matches the models of a close binary system that has undergone a non-conservative mass-transfer. In simpler terms, the B5 star is losing material via its stellar wind at a rate faster than the G8 star can accrete. Therefore, the excess material is temporarily stored in an accretion disk surrounding the larger star.

It is not all research for Nadine. She serves as the manager of CFHT's Astronomy Group and the Queued Service Observations (QSO) team. As the Astro Group manager, Nadine proposes and implements the overall planning and operations of the group. She coordinates scientific operations according to the priorities of the executive director and oversees the budget and management commitments of the staff and scientific operations. In her role as QSO team manager, Nadine works with astronomers to explain the capabilities of CFHT's instrumentation suite and ensures that the data collected each night meet the requirements of their research projects. Nadine is very active in public outreach, serving as the chair of the Maunakea Astronomy Outreach Committee, made up of representatives from each of the Maunakea Observatories.

Much like Lison, Nadine's favourite part of her job is to help astronomers from around the world do scientific research and make incredible discoveries. She thinks it is exciting when a big article or press release comes out that mentions data taken at CFHT. Without those data, without CFHT, our instruments, our team, and our support, those discoveries probably would not happen.

The cons of being a manager at a CFHT are the cons of being a manager anywhere: the dreaded paperwork. Nadine deals with timesheets, travel requests, expenses, budget, evaluations, safety recording, meeting organization, etc. It is vital to keep CFHT running, but I think it is safe to say no one becomes an astronomer to do paperwork.

Nadine encourages students to get interested in astronomy in the same way she did: reading books, blogs, and websites about astronomy. She says be active in astronomy, if you do not have a telescope, get a pair of binoculars and a sky chart and study the night sky that way or participate in science fairs with an astronomy-themed project. Visit planetaria and science centres. Take plenty of science courses, and not just in astronomy, but in physics, chemistry, biology, and computer programming. And, like Lison, she encourages students to get out there and try to get an internship so they observe, write papers, and do the work of an astronomer.

Dr. Daniel Devost, resident Canadian astronomer and CFHT's director of science operations.

Our third Canadian astronomer is Daniel Devost, CFHT's director of science operations and a resident Canadian astronomer since 2007. Like Lison and Nadine, Daniel discovered astronomy at a young age growing up in the dark skies of Québec City. He had the opportunity to see many, many stars at night including the Milky Way arching across the sky and he was fascinated by what he saw. His amazement grew as he began to understand that astronomers were able to understand the stars from just a beam of light. And he wanted to find out more. Fortunately for Daniel, Carl Sagan and the *Cosmos* series provided even more information and a source of inspiration.

Daniel went to the Université Laval where he got his Ph.D. After completing his schooling, Daniel worked at the Space Telescope Science Institute in Baltimore and then on the *Spitzer Space Telescope* at Cornell University. Fun fact, Daniel is

CFHT's only Canadian resident astronomer to work anywhere other than CFHT; Lison and Nadine have spent their entire careers here.

Daniel's primary area of research is on the abundance of metals in the Universe. For astronomers the periodic table is very simple: hydrogen, helium, and everything else. Astronomers call "everything else" metals, with the percentage of non-hydrogen and helium components referred to as the metallicity of an object. If you think about it, it makes a certain amount of sense. Hydrogen comprises ~74% of the known Universe, helium ~24%, and the remaining 2% is everything else, i.e. metals. However, one could say the devil is in the details; the 2% greatly influences astronomical phenomena and makes up almost everything we see around us on the Earth, including ourselves. Daniel's research focuses on finding out the metallicity of our Milky Way and other galaxies.

As director of science operations, Daniel's time is taken up by many administrative tasks. For astronomers to get data at CFHT (and any telescope for that matter), they have to submit a proposal. Part of that proposal requires requesting a specific amount of telescope time. For example, someone from the University of Hawaii may ask for 6 hours of time to identify asteroids within our Solar System while a Canadian astronomer requests 40 hours to study a distant galaxy. Canada, France, and the University of Hawaii are not the only astronomical communities that CFHT serves; we work with astronomers from Brazil, China, and Taiwan as well. At every call for proposals, CFHT receives 80-100 proposals with astronomers requesting twice as much time as we have available. That is actually a great thing for CFHT, a healthy telescope should receive more time requests than is available; it is referred to as the oversubscription rate. Each proposal must be reviewed and classified by scientific merit. Overseeing that process and the overall data collection at CFHT is Daniel's responsibility.



Figure 3 — Dr. Daniel Devost

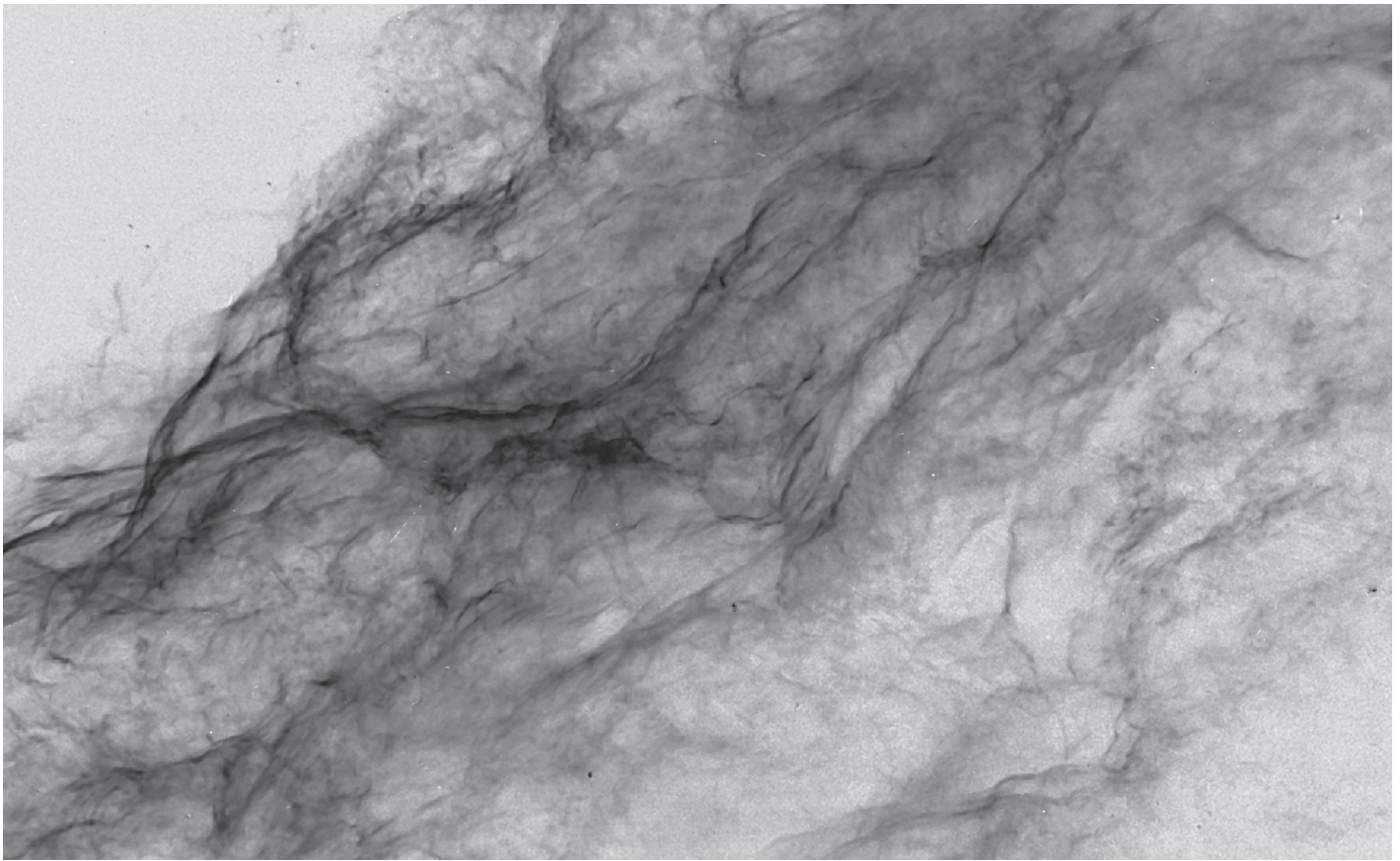


Figure 4 — Veil Nebula as imaged by SITELLE. Image was taken in the OII filter. SITELLE is an imaging Fourier Transform Spectrograph, so a spectra is created for each pixel in the image. We will show a SITELLE image/spectra in a future column.

Once the proposals are written, data is collected and analyzed, astronomers write papers and publish their results. Tracking CFHT's publication rate falls under Daniel's responsibilities as well, as does representing CFHT in all of our constituent countries and important meetings. Daniel travels extensively. At the writing of this article, he is flying to Brazil to meet with the Brazilian astronomical community and attend one of their meetings. Daniel is a huge advocate for public outreach. He frequently gives summit tours and talks about astronomy and CFHT.

Daniel's favourite part of his job is when news comes out about a new discovery. He loves to see how CFHT contributed to the discovery process. It makes him feel proud about the work that he and the entire CFHT team does. Closer to home, Daniel enjoys learning about all the interesting technologies in use at CFHT and seeing them in action. Working at an observatory can make you feel like a kid in a candy store, if you are interested in cutting-edge technology and science.

Much like with Nadine, Daniel's biggest con is paperwork. I think that could be said about most jobs. Paperwork aside, Daniel told me that working at CFHT is his dream job.

His advice to students is to stay in school and study hard. Having a career in astronomy involves mastering several fields of science like physics, math, and chemistry (do not try to use the astronomer's definition of a metal there). Students also need to develop their reading and writing skills.

Rest assured Canadians, your CFHT resident astronomers are working hard for Canada and astronomers around the world. And being from Québec is not a requirement, just the way things worked out this time.

SITELLE update:

With last issue's article dedicated to SITELLE, I wanted to provide a quick update. The August commissioning run went very well. The results from the science team are very positive and we are providing regular updates on our Facebook page (Canada-France-Hawaii Telescope Corporation). In our 2016 call for proposals, SITELLE appears as an option. We look forward to SITELLE on the schedule again soon! ★

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

AstroCHEMISTRY



by Erik Rosolowsky, Department of Physics,
University of Alberta

For centuries, the study of space has been the domain of physics. Isaac Newton first stated the basic laws of classical physics using planetary motion as an inspiration. Experiments on the Earth were fraught with friction and air resistance, which obscured how mass interacts with forces. Astronomical systems were immune to these effects. This allowed Newton to fathom what the true physical laws were and to conjecture that the laws were universal. Astronomy also inspired revolutions in modern physics, including Einstein's theory of relativity, and provided some of the basic observations of quantum mechanics. Over that time, astronomy has become synonymous with astrophysics, and the observations of space have become tightly linked to understanding how they work using the study of physics. When I'm on an airplane and someone asks what I do, I can truthfully say either I'm an "astronomer" or an "astrophysicist." Both would be true, but saying I'm an astrophysicist will almost always quench conversation for the rest of the flight (though once I said that I'm an astronomer and was asked to cast a horoscope). However, the narrow link between physics and astronomy has been broadening slowly for decades.

With the discoveries of the first molecules in space in the 1940s, the questions of chemistry in space began to be asked. Even so, the questions were easy enough that even simple physicists like me could answer them. Physicists often joke that chemistry is just applied physics, and to some degree that is true. All of the ways that atoms interact are indeed governed by physics, but many chemistry problems cannot be solved with the traditional tools of physics. Instead, chemists have developed their own methods that make these problems tractable. When the known molecules were simple enough that their behaviour could be understood through physics, astrophysics happily included the study of these newly discovered molecules. However, observatories like ALMA that operate at millimetre wavelengths are changing this field, identifying progressively more new species. There are well over 100 known molecules in space with more being discovered each year. Recently, the tools of physics have become inadequate and a new field of astrochemistry has emerged at the interface between astronomy, physics, and chemistry.

ALMA, in particular, is changing this field because it easily observes where complex molecules give off most of their light. When ALMA sees a molecule, what it really is seeing is the unique energy jump associated with changes in that molecule's

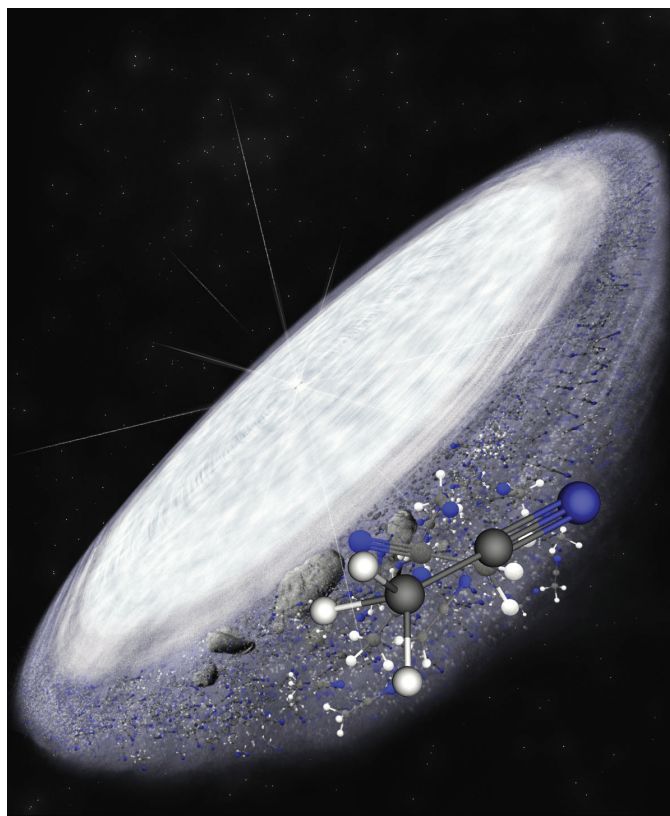


Figure 1 — Artist's rendition of the molecular material found in a protostellar disk. The figure depicts ethyl cyanide and several other molecules that were recently found nearby a forming star. Image credit: B. Saxton (NRAO/AUI/NSF)

molecule's internal structure. Single atoms have specific energy levels for their electrons that are associated with unique spectral lines. These emission lines usually occur in the visible part of the spectrum and have specific colours. For example, a deep-sky telescope filter emphasizes the spectral lines associated with hydrogen and oxygen emission seen in emission nebulae. These transitions are from the electrons jumping between levels inside the atom. While molecules also have electron jumps, the light that ALMA sees is the molecular structure of the molecule vibrating or rotating. These motions are also "quantized" like the electron energy levels and they, thus, show up as unique spectral signatures. One complication is that the number of these vibration and rotation transitions is vastly larger than just electronic transitions. Molecular spectra are thus complicated, giving off energy at many different "colours" of radio-wave light. Methanol (wood alcohol) is common in space and has over 2000 different spectral lines scattered through the frequency range where ALMA observes. Ethanol, the alcohol in liquor, is also found in space and has over 12,000 spectral lines. The mass of ethanol in the nearby Orion star-forming region is larger than all the mass in Jupiter!

This rich chemistry in molecular gas is particularly interesting because these are the locations where new planetary systems

are being formed. The molecular diversity of these forming systems implies that planetary systems start out with a reservoir of complex molecules, which may provide an environment where life could emerge more easily. One of the big questions in how life could have emerged on the surface of the Earth is to ask where the complex molecules needed for things like primitive cell walls could come from. The surface of a just-formed Earth would be constantly bombarded by the debris left over from planet formation. This would heat and sterilize the surface of the planet, destroying any complex molecules. However, these same impactors, namely comets that fell on Earth in a gentle comet rain late in the formation period, could also carry complex molecules onto the surface of Earth. Comets in our own Solar System do indeed carry complex molecules that we use in our bodies, like the amino acid glycine. Some meteorite samples also carry the same nucleic acids that we use in our DNA. These are excellent pieces of evidence that complex molecules formed before the Solar System and were later incorporated into our planet's biosphere. However, this is not conclusive and we are uncertain as to whether this was the central mechanism in the formation of life. Our vision thus turns further from home where we explore the chemistry of forming systems to understand how reliable this chemistry source could be.

ALMA is making a series of observations of currently forming star systems, trying to unravel the processes that are at work. For example, Nami Sakai and her team at the University of Tokyo recently found that forming systems have evidence

for a chemical boundary right at the edge of their proto-planetary disks. They found that material being channeled into the planetary disk undergoes sudden heating and compression to high density, initiating complex networks of chemical reactions. Other teams, such as that led by Karin Öberg, follow molecules from coldest, densest clouds showing that they can be formed in dark clouds and be carried into proto-stellar disks intact (Figure 1). In these cold, dark clouds, molecules form on interstellar grains, which are like small pieces of soot. These grains provide a catalytic surface where atoms can be collected and complex molecules slowly built up under the processes of surface chemistry. We still wonder if molecules such as amino acids are formed in the hot conditions of an accretion shock or are they the colder product of surface chemistry? ALMA will help resolve this by measuring where these molecules are found and the conditions that produce them. This work points to a better understanding of whether our Solar System was seeded with complex molecules formed during Solar System formation. Or do these chemicals owe their heritage to chemistry playing out farther afield in the gloomiest, cold depths of space? Expanding astronomy to include chemistry and soon also biology brings new ways to see the Universe. ★

Erik Rosolowsky is a professor of physics at the University of Alberta where he researches how star formation influences nearby galaxies. He completes this work using radio and millimetre-wave telescopes, computer simulations, and dangerous amounts of coffee.

A National Fundraising Committee

*by Randy Attwood FRASC,
Society Executive Director*

The Royal Astronomical Society of Canada solicits donations from its members to support various projects that pertain to its mandate of promoting astronomy and allied sciences to the people of Canada. Our members are very generous. Last year the Society received over \$18,000 from members.

To expand these programs and generate new activities, we need to increase our revenues through donations and grants. To do this, at a recent meeting of the Board of Directors, we have formed a Fundraising Committee. The chair is Heather Laird with members Craig Levine and Julia Neeser, President James Edgar (ex-officio), and Executive Director Randy Attwood (ex-officio).

It is important in a not-for-profit organization such as the RASC for the Board, the Staff, and volunteers to work

together in finding these funds. First, we would have to determine for which areas we need to generate funding. To support our mandate, funding could pay for education and public outreach projects, publications, or materials to support various programs being run at Centres across the country. The Society needs extra funds to expand its office space to support any additional projects or activities that may require bringing in new fulltime or part-time staff.

The new committee will identify donors, make contact and start discussions with them, ask for contributions, and recognize donor generosity.

We are looking to add a couple more members to the committee. We need members who have a strong background in fundraising. We have seen tremendous interest in RASC public outreach activities in the past. With your help, we can reach out to various donors who would like to see us continue to expand these activities.

If you would like to serve on the Fundraising Committee, please contact the Chair, Heather Laird (hlaird@rasc.ca), or email me at the Society Office (execdir@rasc.ca) ★

Second Light

Three New Looks at Comet 67P/Churyumov-Gerasimenko

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



The *Rosetta* mission reached Comet 67P/Churyumov-Gerasimenko in May of last year, and has been sending back data since then. A series of three recent *Nature* papers reveal some very interesting aspects. For a body composed largely of water ice, there is a striking lack of evidence for surface ice on 67P (and other comets). Maria Cristina De Sanctis of the Astrophysics Institute in Rome and her colleagues have now found small amounts of water ice on the surface, where it appears to go through a daily cycle of sublimation and freezing out, according to the local illumination by the Sun (see the September 24 issue). Matteo Massironi of the University of Padua, and his colleagues, have determined that the two lobes of the comet formed independently before they became stuck together at some point in the past (see the October 15 issue). Finally, André Bieler of the University of Michigan and his colleagues find that molecular oxygen exists in the coma of the comet, with an abundance of 1–10 percent (see the October 29 issue).

De Sanctis found the water ice near the “neck” of the comet, between the two lobes. There are jets in the area, and the water possibly originates in those jets, freezes out as the region rotates into darkness, and then sublimates the following day, leading to a diurnal cycle. Or, the water could come from sublimation of sub-surface ice as the overlying few centimetres of material is warmed by the Sun. If the latter process, then this water could be related to the pits seen on parts of the surface, about which I wrote last month.

Massironi studied the strata on the surface of the comet, and modelled the gravity field. They find that the two lobes of the comet are distinct, with their own sets of onion-like layers. Both lobes show extensive stratification, but those features are missing near the “neck,” where the lobes are joined. The gravity-field vectors they have calculated for the lobes separately are essentially perpendicular to the stratification. They conclude that the two lobes formed independently of each other, but in the same general region of space because the layers of stratification are very similar, and became attached through a low-velocity collision. They suggest that this might in fact be quite common for comets.

To me, the most interesting result is the finding of relatively abundant molecular oxygen by Bieler et al. There are no

efficient processes acting at the comet that could break down water molecules and have the oxygen formed in place. The only conclusion is that the oxygen predates the formation of the Solar System, and was incorporated into the comet when it formed.

The Solar System formed from a core of dense material in a molecular cloud, and so most of what is in it predates the formation. As the core collapses to a proto-star, and an accretion disk forms around the star, the gas goes through a phase where it is relatively dense, at least compared to the average for a molecular cloud. Molecular oxygen is very reactive, and it seems surprising that it could have survived this phase. Oxygen has been found in the interstellar medium in just a very few places. Most chemical reactions in the interstellar medium would tend to drive the oxygen to bond with carbon, forming carbon monoxide, which is the most abundant molecule in the Milky Way Galaxy (and presumably elsewhere) after molecular hydrogen. CO is very stable, once formed. Oxygen also reacts rapidly with hydrogen on dust grains.

Spatially, the O₂ in the coma of the comet is correlated with the presence of water. This suggests that the oxygen could have been incorporated into grains of ice in the early Solar System. While this conjecture could work, with some very special conditions, there is no current model of the Solar System formation that actually envisages such conditions. Every other idea considered by Bieler and his colleagues is even more unlikely.

This situation arises often in astronomy, where new instruments reveal unexpected results that force us to reconsider what we think we know. That’s what makes it fun to be an astronomer! I suspect that I will be writing again about 67P, but next month I will probably have something to say about Ceres. ★

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

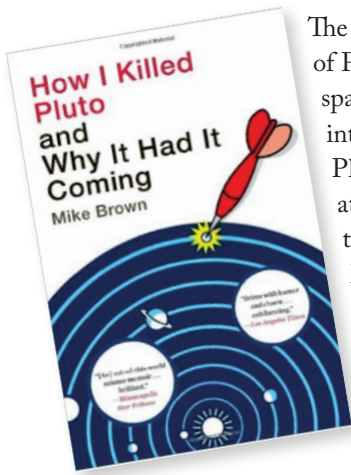
The February *Journal* deadline for submissions is 2015 December 1.

See the published schedule at

www.rasc.ca/sites/default/files/jrascschedule2016.pdf

Reviews / Critiques

How I Killed Pluto and Why It Had It Coming, by Mike Brown, pages 273; 13 cm × 20 cm, Spiegel & Grau, 2012, price \$19.00 CAD, paperback (ISBN 978-0-385-53110-8).



The fast flyby this past summer of Pluto by the *New Horizons* spacecraft boosted the public's interest in the former "Ninth Planet" and re-ignited the debate, at least in the media, about the enigmatic body's pedigree. Mike Brown's book, originally published in hardcover in 2010, provides all the details needed for non-specialist readers to make their own decision about Pluto's planetary status. It is an

open-and-shut case: Pluto is currently

the largest known member of the Kuiper Belt objects, the third category of Sun-orbiters after the four rocky, inner planets and the four gas giants. The book explains how and why it is now classified as a "dwarf planet."

How I Killed Pluto is written chronologically, with a few flashbacks along the way. Brown describes his evolution as a scientist from graduate student through to planetary astronomy professor at the California Institute of Technology. His memoir is honest, funny, and moving, particularly when he describes his courtship with his wife Diane and the changes to their lives that came with the birth of their daughter Lilah. His self-deprecating humour shows up in sentences such as this one, selected at random: "And then Diane's water broke, perhaps changing astronomical history."

If this were mostly an autobiography, it would be a very good book. What makes it great is the thread of new discoveries that runs through it. Brown describes his interest in the outer Solar System, and how that interest turned into a research proposal, and then an obsession. The highs and lows of observational astronomy, the logistics of working at a large observatory, the twists of fate that combine with flashes of insight to yield new attacks on an old problem, all are described vividly and candidly. Along the way, Brown details his discoveries of the Kuiper Belt objects Quaoar, Sedna, Haumea, Eris, and Makemake. Some of them even have moons, and Brown had given all of them unofficial names, including Santa, Easterbunny, and Xena.

The sequence of discovery, confirmation, and announcement for each object turns out to be complex, and for Santa (Haumea) also fraught with intrigue. A rival astronomer claimed prior discovery, perhaps obtained through unethical

means, and the International Astronomical Union had to stickhandle the process of naming and assigning credit. We are given an inside look at astronomers' egos, and the view is not pretty. Brown describes in great detail the workings of the IAU through the Prague meeting of August 2006, when he was online half a world away in Pasadena. Resolutions, sub-resolutions, amendments, comments, and finally votes led to Pluto no longer being considered a planet. Brown's insightful comments on that meeting are a few of the many highlights of the book for me. I recommend it to all readers interested in Pluto, in how astronomical research is done (by some) and in how to write first-class books about science.

Michael Attas

Michael Attas is an Unattached Member and JRASC Associate Editor living in the dark skies of Pinawa, Manitoba. He has retired from Atomic Energy of Canada Limited, where he worked for many years.

Les carnets d'un astrophysicien, à l'écoute des étoiles, par Jean-René Roy, pages 417, 23 cm × 16 cm, Éditions MultiMondes, Sainte-Foy, 2013. Prix: papier 34,95\$, Epub ou pdf 24,99\$ (ISBN: 978-2-89544-464-0).



À prime abord j'ai un peu de difficulté à catégoriser ce livre parce que c'est plus qu'un ouvrage touchant la science, c'est également le résultat d'une expérience de vie qui exprime une inquiétude sur l'avenir de l'Homo sapiens qui a peine à appliquer les leçons du passé. L'auteur relate les principales étapes de sa vie en tant que scientifique, mais chaque chapitre est entrecoupé de sujets qui peuvent paraître étrange dans cet ouvrage mais qui

démontrent son intérêt. À l'occasion il n'hésite pas à prendre position, que ce soit par exemple sur la politique (qui conduit trop souvent à la guerre), la défense du droit des femmes, de l'épuisement des ressources, etc ...

Il évoque plusieurs des points marquants de l'évolution de la science ainsi que les personnalités impliquées. Pour reprendre l'expression du géologue et historien américain Martin J. S. Rudwick, Galilée défonça les limites de l'espace et Darwin celle du temps. Par ailleurs, la découverte de l'expansion de l'univers par Edwin Hubble suggère qu'elle a eu un commencement. À un autre moment il relate le contexte de la course à la lune entre Soviétiques et Américains, avec les retombées techniques et scientifiques qui en jaillirent. Pour nous situer dans le temps, il nous ramène aussi à la mémoire des faits politiques important comme par exemple la guerre du

Vietnam et la crise des missiles de Cuba. Les planètes et leurs satellites ne sont pas en reste, nous apprenant par exemple que si tout le gaz carbonique séquestré dans les roches calcaires de la Terre était libéré on se retrouverait avec une densité de ce gaz égale au 2/3 de celle de Vénus.

L'histoire de sa vie

Enfant, personne autour de lui pouvant fournir les explications attendues, Jean-René décida de devenir un savant (quelqu'un qui a beaucoup de connaissance au sens large) et en cela le vulgarisateur passionné qu'était Fernand Seguin l'a influencé grandement.

Une première étape de vie à l'extérieur de la maison familiale, pensionnat où il a subi la pression des Robes noires pour devenir un des leurs et entendu tous les discours du temps contre la sexualité. Nous étions alors avant la débâcle des communautés religieuses des années 60.

Étudiant, pendant l'été il a travaillé dans le domaine minier à la SOQUEM, plus précisément à marquer des claims. Une de ses réflexions est que les minéraux et les roches sont les produits de l'évolution du système solaire.

En 1970, alors qu'il est à l'Université Western en Ontario, une première expérience à l'étranger l'amène à l'observatoire solaire tout neuf de Sacramento Peak au Nouveau-Mexique. Il y obtiendra les données pour sa thèse de maîtrise. On l'a invité à revenir l'année suivante, cette fois-ci ça l'a conduit au doctorat. Ensuite, chercheur post-doctoral à Caltech où il a cotoyé le fameux physicien Richard Feynman.

Visite surprise à Moscou en décembre 1973 pour rencontrer des physiciens dissidents. Voyage d'émerveillement mêlé de crainte, il en revint soulagé avec en plus un manuscrit pour publication d'un auteur captif de l'URSS.

Après la Californie il se retrouve en Hollande en 1974 où l'expérience acquise avec le soleil est mise à l'œuvre pour définir les caractéristiques physique d'une caméra pour l'observation

du soleil, la dite caméra étant destinée au satellite Solar Max lancé en 1980.

En 1975, retour au Canada, plus précisément à l'Institut Herzberg et en 1977 des offres attrayantes pour des postes permanents en Californie, Herzberg, et U. Laval. Il choisit cette dernière où un nouveau département d'astronomie est à mettre en place, d'autant plus attrayant avec le nouvel Observatoire du Mt-Mégantic opéré conjointement avec l'U. de Montréal.

Puis en l'an 2000 c'est dix années dans le Pacifique qui commencent lorsqu'il déménage à Hawaï pour y travailler à la direction du Télescope Gemini Nord, lequel a entre autre été utilisé en 2008 par David Lafrenière et Christian Marois pour imager les premières exoplanètes.

En 2006 c'est l'appel des Andes, plus précisément l'observatoire Gemini Sud au Chili

Revirement en 2009, il se retrouve à Washington pour la National Science Fondation (NSF) des Etats-Unis en tant que conseiller en gestion des grandes installations scientifiques supportés par la NSF. C'est un extraordinaire survol du monde complexe de la politique scientifique à ses plus hauts échelons.

2011 Space Telescope Science Institute à l'Université Johns Hopkins à Baltimore, où son expérience de gestionnaire de grande installation scientifique est mise à profit.

Quelques phrases type à retenir: se départir de l'idée d'un «statut particulier» de l'humain dans l'univers ou accepter que l'univers n'est pas fait pour nous ont été des pas difficiles (245); nous sommes poussières d'étoiles et enfants fortuits de la loterie galactique (261); Grand nombre (de planètes) = immense variété (possibilités de vie). Après les humains, la vie continuera l'aventure de l'ADN (361).

Autres

À titre professionnel il a œuvré en astronomie, mais son intérêt diversifié l'a amené à acquérir des connaissances sur nombre de sujets, incluant la nature humaine. Il a appris des langues: russe, néerlandais, espagnol, et portugais, en plus évidemment du français et anglais.

Il relate la progression de la puissance des télescopes rendus possibles grâce à plusieurs innovations technologiques tels que miroir mince ou segmenté, contrôle par ordinateur, détecteur CCD, optique adaptative, etc ...

La politique y passe aussi, se ralliant à plusieurs auteurs engagés. Il n'hésite pas à critiquer la politique qui mène à des guerres injustifiées comme en Afghanistan et Irak.

Il aborde l'émancipation féminine qui a fait un bond en avant dans les années 60-70, la pilule contraceptive étant le



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moteur principal de cette révolution. Il reprend les paroles du biologiste allemand Ludwig Haberlandt qui écrivit en 1931 «En théorie un des grands triomphes de l'humanité serait l'élévation de la procréation à un acte volontaire et délibéré». Malgré nombre d'hésitation et de résistances de différent pouvoirs, surtout religieux, la pilule fut finalement adopté et mise en marché avec grand succès au début des années 1960.

L'humain vit sur la croute terrestre hors des océans, mais ses activités perturbent tous les milieux. Il est la cause du réchauffement climatique et de la disparition accéléré des espèces.

L'auteur a t'il atteint son objectif de devenir un savant? La conclusion s'impose, OUI il est devenu un scientifique d'envergure internationale. Pour plus d'information, lisez ce livre édifiant et stimulant.

Damien Lemay

Damien Lemay is a former National President of the RASC, and President of the FAAQ. He is a recipient of the Society's Chant Medal and Ken Chilton Prize. He trained as a physicist, and worked in the telecommunications industry in Québec. He is a notable astrophotographer, and was an active member of the NRC's Associate Committee on Meteorites.

How to Fake a Moon Landing: Exposing the Myths of Science Denial, by Darryl Cunningham, pages 176; 14.5 cm × 21.5 cm, Abrams ComicArts, New York, 2013, price \$18.95 CAD, paperback (ISBN 978-1-4197-0689-9).



How to Fake a Moon Landing is a graphic novel, something we used to refer to as a hard-covered comic book, that discusses the many misunderstandings and myths held by the general public about a selection of scientific themes. Those tackled are not restricted to astronomical topics, but include homeopathy, the chiropractic practice, vaccinations, evolution, hydraulic fracking, climate change, and

science denial, as well as the lead-in theme surrounding the Moon hoax, which is what initially attracted my interest.

Despite the cartoon nature of the contents of *How to Fake a Moon Landing*, illustrated and written by Darryl Cunningham, it is not a book to be taken lightly. With a lovely introduction by Andrew Revkin and a textual preface by the author, the book discusses many of the controversial topics of the current era in a straightforward and educational manner, drawing heavily upon a variety of published and on-line sources to

refute the many myths associated with each topic. I was familiar with the controversies surrounding most of the book's contents, yet still found the discussions to be an educational treat.

Readers may be disappointed to find that *The Moon Hoax* is only a brief 15-page entry at the beginning, but I found that the other topics discussed were often more important to one's everyday life. Hydraulic fracking, in particular, is currently a highly inflammatory issue for which every person seeking a career in politics should read *How to Fake a Moon Landing* prior to taking a stand on the matter. It is a theme that has made headlines nationally, as evidenced by a recent news note in *National Geographic* magazine commenting upon the sudden increase of earthquakes in Oklahoma, previously a tremor-free region of North America, and attributed to fracking.

As for *The Moon Hoax*, the book tackles the usual points raised by some as "evidence" that there were no Moon landings: the lack of stars in photos from the Moon's surface, the flapping American flag seen in images from the lunar surface, the lack of a crater created by the lunar lander on touching down, the lack of flames from the lander rockets, and the curious walking movements of lunar astronauts. Much is made of the connections to conspiracy theories, although in my opinion it was the Hollywood movie *Capricorn One* that may have spawned much of the nonsense.

It occurred to me as I read through *How to Fake a Moon Landing* that there are possible analogies in the topics to other controversies in astronomy, although current "newspeak" is to refer to them as divergences, or other polite terms. The power of the petroleum industry to downplay concerns about hydraulic fracking, for example, has similarities to the manner in which some large, well-funded, ground-based or space-based astronomical missions dismiss criticism of their findings out-of-hand, without the usual scientific rationalization. I know of many victims of such behaviour in the astronomical community.

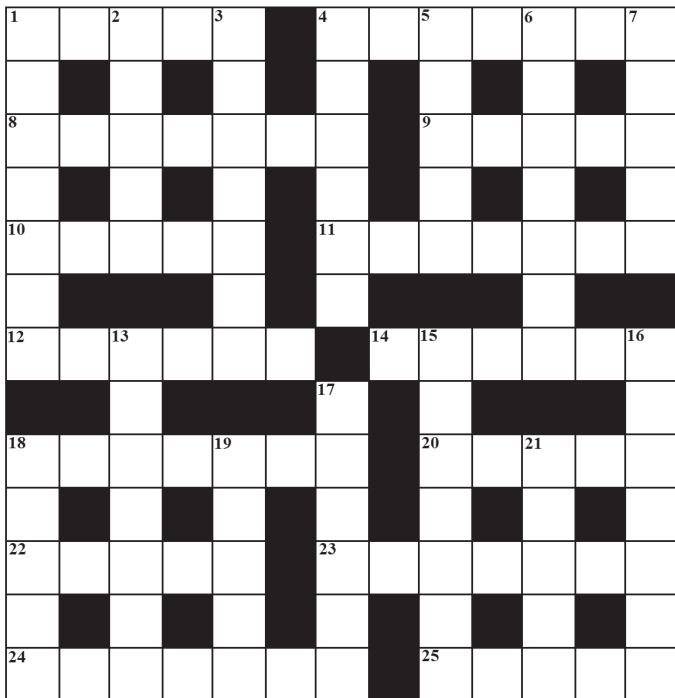
Perhaps it is because of such insights that I am happy to recommend *How to Fake a Moon Landing* to others who may be interested in reading light-hearted discussions of some highly controversial scientific topics. A full knowledge of astronomy, biology, physiology, geology, atmospheric physics, chemistry, medical physics, epidemiology, or psychology is not necessary to enjoy its contents.

David Turner

David G. Turner is a life member of the RASC, review editor for JRASC, and Professor Emeritus of Astronomy and Physics at Saint Mary's University. He is always interested in new ideas for educating the public (and scientists) about interesting scientific topics.

Astrocryptic

by Curt Nason



ACROSS

1. Cute, variable star Mira is seen here (5)
4. Santa's family held six in a lunar base (7)
8. They sang a rare lunar tune; long single after breakup of Cream (7)
9. Meteor remnant brings precipitation from a thunderhead (5)
10. X-ray satellite once seen in crossing the Moon (5)
11. Lunar rock seen playing violin at eastern limb (7)
12. Scattered blue within North America, for example (6)
14. To eat French food in M44 (6)
18. Train wreck among spectacles seen in RASC office address (7)
20. Literary tribute within poles of orbital points (5)
22. Crater identification an issue of Venus (5)
23. French astronomer modified LED to get around artificial light at night (7)
24. Carbon monoxide detected in X-rays around Uranus (7)
25. Sign of Pegasus as a source of gas (5)

DOWN

1. Wild romance shows the way to Pluto each year (7)
2. Like M57 but in Taurus, I hear (5)
3. Space bent around one before Lorentz's initial theory of relativity (7)
4. Prime Gem sent to RASC in error (6)
5. Lunar range crossing basalt Airy crater (5)

6. Imagine making, e.g., astrophotos with a CCD (7)
7. Atmospheric probe ends badly, holding nothing (5)
13. Wager a photo includes a star with a dusty disc (4,3)
15. Reconfigure a Mallin camera to image Orion's middle (7)
16. Porter finally led us to sell his telescopes in Springfield (7)
17. Twin hockey sticks put us first in disease (6)
18. Endless course changes for Kuiper Belt orbiter (5)
19. Right ascension, declination and rotation first measured by it (5)
21. A bright star in Bode Nebula (5)

Answers to October's Astrocryptic

ACROSS

- 1 PROCTOR (2 def); 5 ATLAS (2 def); 8 LIBRA (li + bra);
 9 PALOMAR (pal + anag); 10 STRANGE (2 def);
 11 RADII (radi (o=i)); 12 ALPHER (an(LP)ag);
 13 TAURUS (tau + (t)rus(t)); 16 TERRA (arret (rev));
 18 IMAGERS (I + anag); 20 RUDOLPH (2 def);
 21 EZINE (EZ + in + E); 22 SAXON (2 def); 23 PERIGEE (per + I + gee)

DOWN

- 1 PALUS (anag); 2 OLBERS' PARADOX (anag);
 3 TRAINEE (train + EE); 4 RAPIER (RA + pier); 5 ALLER (all + ER); 6 LIMB DARKENING (2 def, tan); 7 SERVISS (hom); 12 ANTARES (ant(are)s); 14 AMATEUR (an(e)ag);
 15 BISHOP (2 def, chess); 17 ALLEN (hid);
 19 STERE (anag)

It's Not All Sirius

by Ted Dunphy



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 Heart of Darkness, Unraveling the Mysteries of the Invisible Universe, *Jeremiah P. Ostriker & Simon Mitton*, 2013, pages 299, reviewed by James Edgar, Jun., 140
 How I Killed Pluto and Why It Had It Coming, 2010, 273 pages, reviewed by David Turner, Dec. 2015
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 Les carnets d'un astrophysicien, à l'écoute des étoiles, par Jean-RenéÂL Roy, pages 417, reviewed
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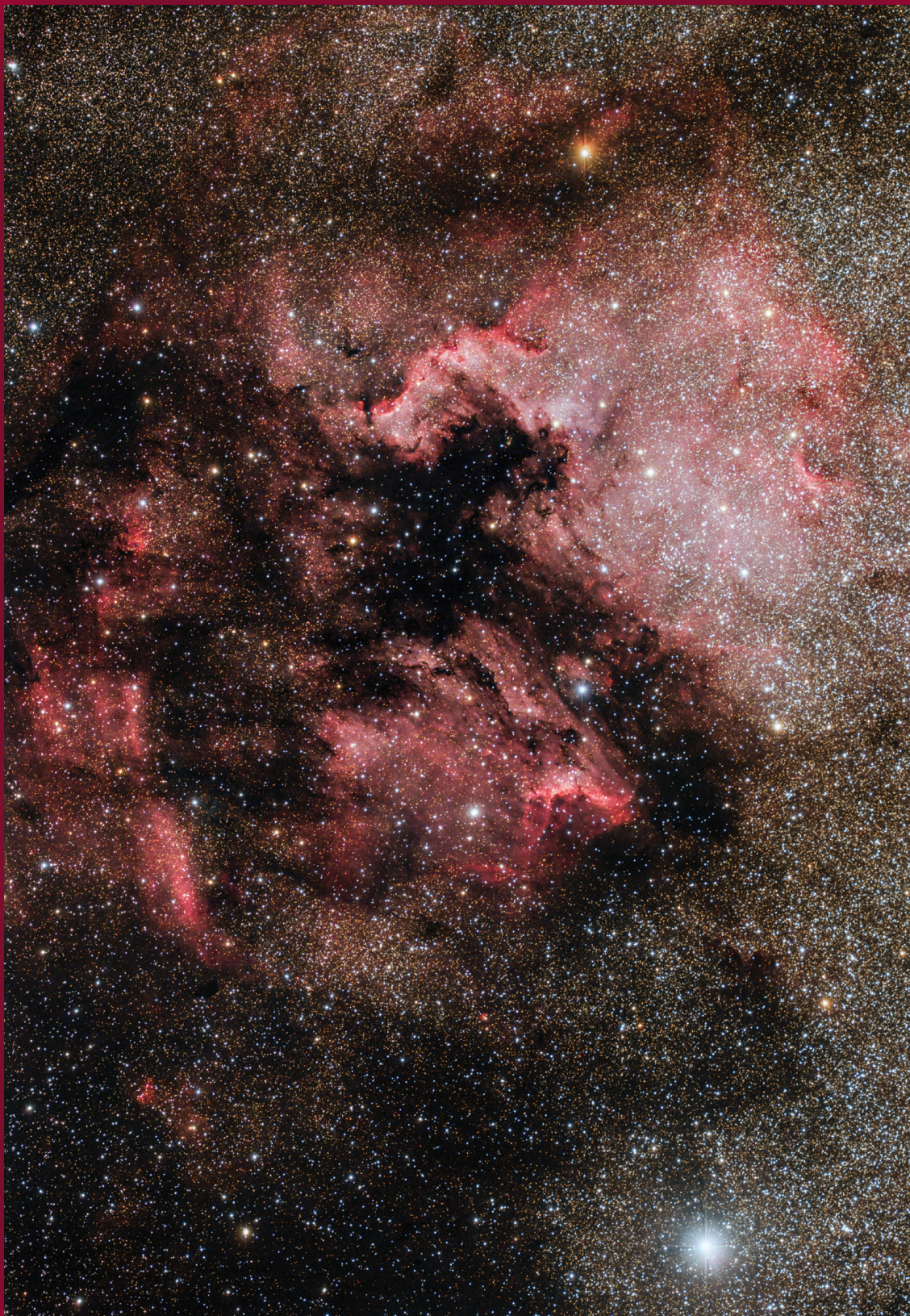
Observer's Calendar

Paul Gray, Halifax

Great Images



This image of Comet Lovejoy and Messier 76 was taken by RASC Toronto Centre President Paul Mortfield from his remote observatory in Auberry, California, on 2015 February 20. This single 120-second exposure was taken using an RCOS 16-inch telescope $f/8.9$ with a field of view of approximately 34 arcminutes.



Journal

Great Images

Lynn Hilborn took this image of the Pelican Nebula using a Canon 6d modified camera and Teleskop Services 71 telescope at $f/5$. The final image was produced using 21 600-second frames at 1600 ISO for a total of 3.5 hours. Hilborn took the images at from his WhistleStop Observatory in Grafton, Ontario.