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Journal

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PROMOTING ASTRONOMY IN CANADA

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The Best of Monochrome.

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

The California Nebula (NGC 1499) in Perseus reveals its chaotic and turbulent character in this exquisite H-alpha image by James Black from his Light Waves Observatory in Pitt Meadows, B.C. This HII region is illuminated by Xi Persei, the bright star above the nebula in this image. NGC 1499 lies about 1500 light-years away and is approximately 100 light-years in length. James used a Takahashi FSQ 106ED and a Starlight Express SXVR-H36 camera through a 7-nm filter for this image.

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Société Royale d'Astronomie du Canada

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Messier's thirteenth object in his famous catalogue is the Northern Hemisphere's best globular cluster, captured here by the Toronto Centre's Steve McKinney from the Carr Astronomical Observatory near Blue Mountain, Ontario. M13 was discovered by Edmund Halley in 1714, though its 300,000 stars make it just visible to the naked eye at magnitude 5.8. The cluster lies about 25,000 ly from Earth and has a diameter of 145 ly. Steve used an SBIG ST-8300M camera on an AT6RC telescope with an exposure of 6×300 s in RGB and 9×300 s in luminance.

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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Canada

President's Corner

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

There's a certain feeling in the air that BIG things are about to happen. *SkyNews*! More on this in a later *Journal*…

Have you been watching the news about the travails of the Thirty Meter Telescope and the holdup by protesters at Mauna Kea? It doesn't bode well that all the "i"s were dotted and the "t"s crossed many **years** before construction began, and the protests started just recently. Where were the protests when this was being proposed and discussed? It's a very disappointing curveball!

The Board of Directors for the next year is established, since there was no election (once again), and the three applicants were acclaimed to the three vacant positions. They are Heather Laird (Calgary), Robyn Foret (Calgary), and myself. It is troubling that, out of more than 4900 Society members, there are only 9 who will step up and run for Board positions. Where are the members who want to effect change at the national level? Being a Director on the Board is one of the best places to make that happen. We have less than a year before the next election to consider ways to effect a positive change. We need people who take dedication and perseverance seriously. The Board will be considering next steps over the next while, and we all need to spend some time thinking this over. My attitude is, if you're not going to be involved and engaged, then why are you in the Society? And, remember, you always get more out of it than you put in!

This issue of the *Journal* is Jay Anderson's final hurrah—until he starts something new, that is. He has been Editor-in-Chief for ten years and is turning over the reins to incoming Nicole Mortillaro for the October issue. So, make sure you give a great, big "Thank You!" to Jay whenever you have the opportunity, and give a huge welcome to Nicole. She's been here for over a year as Associate Editor-in-Chief, and is now ready to take the solo plunge. "Solo" is really not the word to use, though, as there is a team of over 30 very capable people to help out in every aspect of production. Their names are all listed on the masthead, if you haven't already checked them out.

Warmer weather makes this the best time of year for public outreach, so be sure to get out there with whatever type of instrument you have and show someone the wonders of the night sky. And, while you're at it, order a handful of the *Getting Started in Astronomy* booklets available through your Centre or from the Society Office. They are great to hand out at a sidewalk event or star party.

Clear skies! ✶

Editorial:

Thanks for the Memories

by Jay Anderson, Winnipeg Centre
(jander@cc.umanitoba.ca)

All things must have a dénouement and so, with this issue of the *Journal*, I come to the end of my 10-year tenure as Editor. Life is a succession of experiences and adventures, and this decade-long occupation has certainly been that. It has been a grand education as well.

Being editor means relearning those rules of grammar that you first encountered in Grade 4—rules that seemed tedious and never-ending at the time and probably still are. When put into practice over 60 issues of this *Journal*, however, they are born again, infusing an editor's mind with a sometimes annoying tendency to correct errors wherever they occur in daily life. Tim Hortons forgot the apostrophe (perhaps they should talk to Robin's Donuts), but the Hudson's Bay Company did not; Canadian Tire should probably be Canadian Tires, and don't get me going on compound adjectives, one of my favourites. I think I've become a bit of a pain on that subject.

I don't know if I'm a better writer after overseeing 2500 pages of your compositions, but I know that some of you are. The *Journal* is blessed with many volunteer helpers, some of whom have a monumental knowledge of the English language and its structure, along with an enviable ability to turn a phrase, and they've been my and your instructors, along with the Internet, over the past years. There were a few times where writers may have wondered what happened to their compositions after the editors were done with it. The pictures we published were not always the best we got, though we have shown that some exceptionally skilled and hard-working astrophotographers can be found within the Society. Ultimately, we tried to provide a forum where the beginner could show off: a beginning writer; a beginning photographer; a beginning scientist.

Our philosophy with the *Journal* was to try to capture the nature and personality of the RASC and its adherents—essentially to time-stamp the Society in the years from 2006 to 2015. Would a reader, a century from now, be able to understand the skills, interests, and achievements of the over 4900 members of the RASC from the content of the *Journal*? I hope so.

When I started working with the *Journal*, our biggest problem was content, or more explicitly, the lack of regular content. We advertised for columnists, and very quickly could count on enough pages to ensure a steady and mostly on-time delivery to your door or inbox. We've had some exceptional columns during my 10 years, and I hope that the authors are pleased with what we've done with their work. More than anything else, they made the regular production of the *Journal* possible.

The RASC should be proud of its *Journal*. There are few publications in the world that strive for both popular and professional content as the JRASC does and that are assembled by a cadre of volunteers. When we receive a professional paper, we have to find peers to review, a process that is not always easy, given the demands on a university astronomer's time. I think reviewers regard the JRASC as a little bit unique because of our amateur-professional linkage, and some of the papers you've encountered over the years have been vetted by the top researchers in astronomy. They are always asked to evaluate a submission in terms of its readability for "knowledgeable amateurs," a review question to which the authors respond with good nature. They may view us with a bit of amusement, but we are special and shouldn't lose sight of that distinction.

In recent years, thanks to the encouragement of Jim Hesser, the *Journal* has been able to develop closer links between amateur and professional astronomers. You will see this in the columns that discuss current research and research techniques in a language you can follow. Many years ago, at a General Assembly in Calgary in the 1970s, I suggested that the *Journal* was largely unreadable and should change. I'm comfortable with the steps that have been made. Every paper is judged by whether or not you might learn something interesting from it, even if sections might be obtuse or overly mathematical.

I can't thank everyone—there are more than 60 of you over the last decade who have helped in the background to make the *Journal* work. One person must be singled out however—James Edgar, currently President, but also a tireless inspiration as the Production Manager. Many of the changes that have taken place in the last decade came from his non-stop mind; you need only go back over the changes in layout, the front covers, and the introduction of colour to see them. What you don't see is his quick response to questions and tasks, his insightful decision-making, and the willingness to take on risk.

Your new editor will be Nicole Mortillaro and I can only wish her the same cooperation, opportunity, and satisfaction that I've had in my tenure. I'm sorry to leave and happy to pass it on. ✶

Jay Anderson
Editor-in-Chief (ret)

News Notes / En manchettes

Compiled by Jay Anderson

Early results from the Next Generation Virgo Cluster Survey

Astronomers using the Canada-France-Hawaii Telescope have discovered hundreds of new galaxies in the Virgo cluster, the nearest large cluster of galaxies, roughly 50 million light-years away from us. The discoveries were made as part of the "Next Generation Virgo Cluster Survey" (NGVS) conducted at the CFHT over the past six years, a project designed to provide deep, high-spatial-resolution, contiguous coverage of the Virgo cluster. The research team, consisting of 45 members from universities and institutes across North America and Europe, used the observatory's 340-megapixel "Megacam" camera whose wide-field view stretches across a one-degree-square field. The large coverage, at five wavelengths, allowed the NGVCS team to observe the entire cluster at an unprecedented depth and resolution. The final mosaic is comprised of nearly 40 billion pixels.

Figure 1 — A 100-frame montage of galaxy fields from Megacam, acquired as part of the Next Generation Virgo Cluster Survey. Image NGVS/CFHT/CEA/ NRC

The Virgo cluster appears to be home to far more faint systems than the cluster of galaxies to which the Milky Way belongs, suggesting that galaxy formation on small scales may be more complicated than previously thought, and that our Local Group may not be a typical corner of the Universe. Most of Virgo's new galaxies are extremely faint dwarf galaxies, objects hundreds of thousands of times less massive than the Milky Way. Whereas the Milky Way forms part of a relatively small group of galaxies, Virgo contains dozens of bright galaxies and thousands of fainter ones. In the Local Group, the current theories of galaxy formation suggest that there should be hundreds or thousands of dwarf galaxies, but fewer than 100 have been detected. Clusters such as Virgo were known to be richer hunting grounds for dwarfs, but only recently has the NGVS made it possible to set firm constraints on their numbers.

To exploit the full power of the data, Laura Ferrarese, Lauren McArthur, and Patrick Cote of the National Research Council of Canada developed a sophisticated data-analysis technique that allowed them to discover many times more galaxies than were known previously, including some of the faintest and most diffuse objects ever detected.

To understand the implications of these new discoveries, Jonathan Grossauer and James Taylor at the University of Waterloo ran computer simulations of clusters like Virgo, to see how many bound concentrations of dark matter they should contain at the present day. Comparing the numbers and masses of dark-matter clumps to the population of galaxies discovered by the NGVS, they find a very simple pattern, whereby the ratio of stellar to dark-matter mass changes slowly in going from the smallest to the largest galaxies. It seems that in Virgo there could be a simple relationship between dark-matter mass and galaxy brightness, valid over a factor of 100,000 in stellar mass.

This is not the case in the Local Group: the low-mass, dark-matter clumps that would be occupied by galaxies in Virgo do not seem to have been capable of forming galaxies in the Local Group. A follow-up study with higher-resolution simulations by the NGVS survey team will explore how galaxies are spatially distributed throughout the cluster to seek more clues to the mystery of dwarf-galaxy formation.

The NGVS is an impressive project, comparable to the *Hubble* deep fields in its concentrated focus and potential scientific discoveries. Besides characterizing the dynamic behaviour of the Virgo cluster, the project will be used to study the population of more distant background galaxy clusters, Kuiper-belt objects, and neighbouring star streams in our Milky Way, especially the Virgo Overdensity, a stellar stream thought to be the remnants of a dwarf galaxy. ✶

Compiled from notes provided by the Canada-France-Hawaii Telescope Press Office.

Herschel Space Observatory reveals Milky Way's filamentary nature

Observations with ESA's *Herschel Space Observatory* have revealed that our galaxy is threaded with filamentary structures on every length scale. From nearby clouds hosting tangles of filaments a few light-years long to gigantic structures

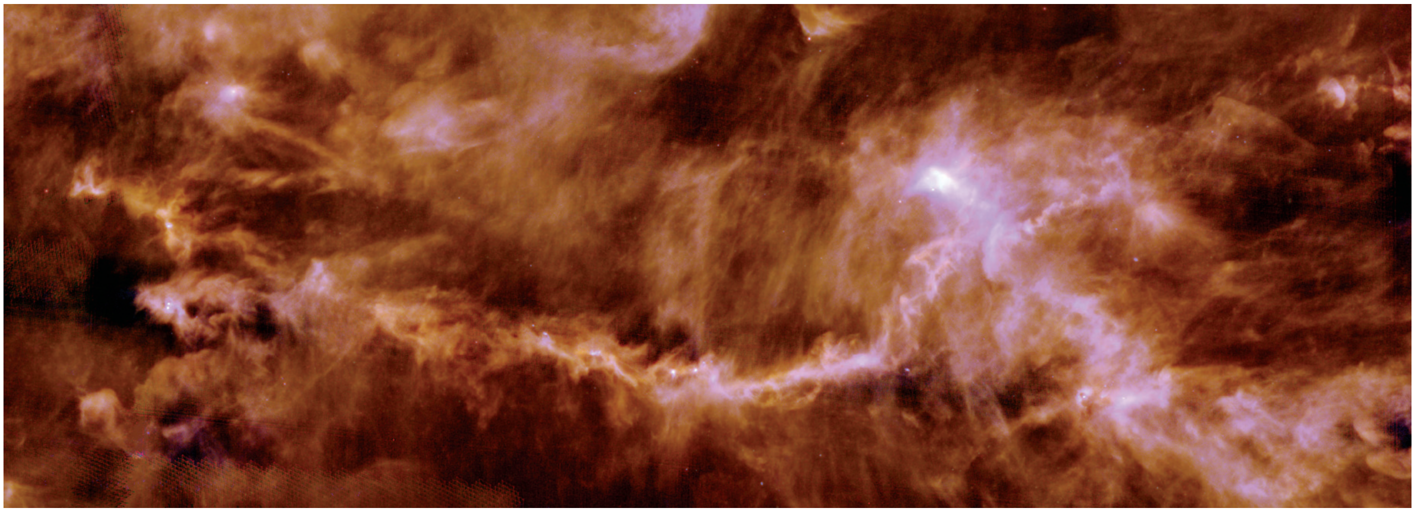

Figure 2 — The B211/B213 filament in the Taurus Molecular Cloud. The image is a composite of the wavelengths of 70 microns (blue), 160 microns (green) and 350 microns (red). Credit: ESA/Herschel/PACS, SPIRE/Gould Belt survey Key Programme/ Palmeirim et al. *2013*

stretching hundreds of light-years across the Milky Way's spiral arms, they appear to be nearly everywhere in the galactic environment. The sensitivity of *Herschel*'s infrared eyes has revealed the ubiquitous reach of the filaments, which were known from only a few examples beforehand.

While dust is only a minor ingredient in this cosmic blend, it shines brightly at the far-infrared and submillimetre wavelengths probed by *Herschel*. With masses of thousands to several tens of thousands times that of our Sun, these are among the most prominent strands ever observed in the galaxy. Longer than 100 light-years, the filaments are at most 10 light-years wide.

"The greatest surprise was the ubiquity of filaments in these nearby clouds and their intimate connection with star formation," explained Philippe André from CEA/IRFU, France, Principal Investigator for the Herschel Gould Belt Survey. "… these observations revealed that filaments, which may extend to several light-years in length, appear to have a universal width of about one third of a light-year. This suggests that something fundamental is lurking underneath."

The filaments are dotted with brighter clumps. These clumps are cosmic incubators, where new generations of stars are taking shape. The blue and violet glow of the fuzzy splotches that embellish the filaments reveals pockets of warmer material, fluorescing in the fierce radiation released by hot, newborn stars embedded within them. Before *Herschel*, only two gigantic filaments like these were known, but astronomers have now used data from the observatory to uncover several new ones weaving their way through the spiral arms of the Milky Way. They believe that these are the first structures to form as interstellar matter starts coming together, eventually leading to the formation of stars. ✶

Compiled from notes provided by the European Space Agency.

New weight for the Milky Way

A team led by Columbia University astronomer Andreas Küpper has used the stars in a tidal stream left behind by the globular cluster Palomar 5 to determine the mass of our galaxy that lies within a radius of 62,000 ly. Palomar 5 is shedding stars because of tidal disruption by the Milky Way—a stream that is 30,000 ly long and has a mass of 5000 Suns.

Using data from the Sloan Digital Survey, the researchers studied density waves that they had detected within the Palomar 5 stream. Using a supercomputer, they tested several million models of the stream, comparing the wiggles in the modelled Milky Way to the real thing. By selecting the best-fitting models, they found that the geometry of the stream imposed strong constraints on the mass of the Milky Way and the Earth's position within our galaxy. They

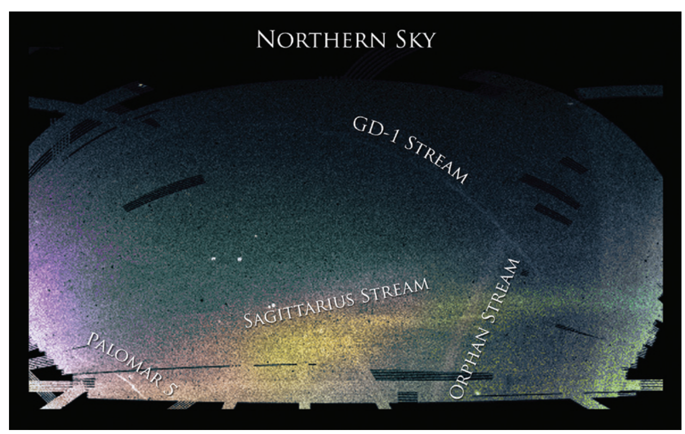

Figure 3 — The Northern Hemisphere of the sky as seen by the Sloan Digital Sky Survey. Stellar streams stick out from the vast number of stars in this view, of which most lie within the Milky Way disk. The Palomar 5 stream is the densest of the stellar streams discovered so far and turned out to be a perfect scale and yardstick for our understanding of the Milky Way. Image: Ana Bonaca, Marla Geha, and Nitya Kallivayalil, with data from the Sloan Digital Sky Survey.

concluded that the distance of the Sun from the galactic centre was 27,000 ly and that the galaxy's mass within the radius defined by the Palomar 5 stream was equivalent to 210 billion suns.

"An important advance in this work was using robust statistical tools—the same ones used to study changes in the genome and employed by Internet search engines to rank websites," explained Ana Bonaca, a co-author from Yale University. "This rigorous approach helped in achieving the high precision in weighing the Milky Way."

"Such measurements have been tried before with different streams, but the results were always quite ambiguous," added Professor Kathryn Johnston, co-author of the study and chair of the Columbia Astronomy Department. "Our new measurement breaks these ambiguities by exploiting the unique density pattern that Palomar 5 created as it orbited around the Milky Way for the past 11 billion years."

The technique also showed that the distance to the Palomar 5 stream was 77,000 ly, somewhat farther than the 61,000 ly that earlier measurements had suggested. ✶

Planetary butterfly emerges in VLT image

The European Southern Observatory (ESO) has released one of the sharpest images ever made with its Very Large Telescope (VLT), showing what appears to be the birth of a butterfly-like planetary nebula. The images are of the red-giant star L2 Puppis, one of the closest such stars to the Earth. The image takes advantage of the VLT's "extreme adaptive optics," which produces images with a resolution more than three times sharper than the *Hubble Space Telescope*.

ESO astronomers found that the disc begins about 6 astronomical units (AU) from the star (about 20 percent greater than Jupiter's distance from the Sun), flaring outward into symmetrical dish- or funnel-shaped wings on each side of the star. The new image also reveals a nearby companion star, thought to be a similar-sized but younger red giant, orbiting about 2 AU distant. The combination of a large amount of dust around an aging red-giant star and a nearby companion exactly fits theoretical ideas about how bipolar planetary nebulae are created.

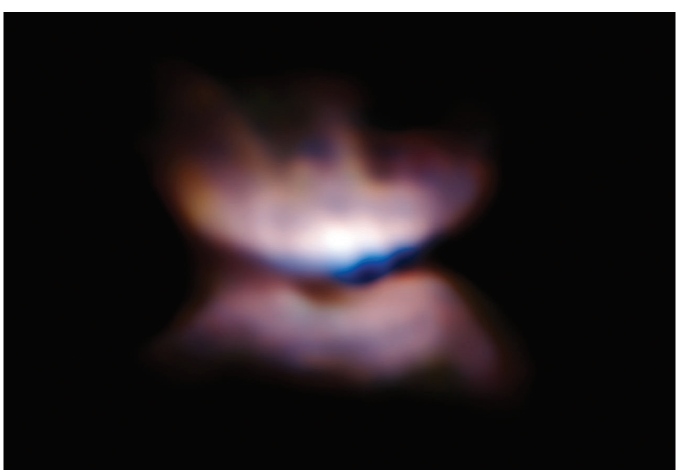

Figure 4 — One of the sharpest images ever made with ESO's Very Large Telescope reveals what appears to be an ageing star in the early stages of forming a butterfly-like planetary nebula. These observations of the red giant star L2 Puppis also reveal a close stellar companion. Image: ESO/P. Kervella

Lead author of the study, Pierre Kervella, explains: "The origin of bipolar planetary nebulae is one of the great classic problems of modern astrophysics, especially the question of how, exactly, stars return their valuable payload of metals back into space—an important process, because it is this material that will be used to produce later generations of planetary systems."

In addition to L2 Puppis's flared disc, the team detected two cones of material rising perpendicularly to the disc. Importantly, within these cones, they found two long, slowly curving plumes of material. Based on the origin points of these plumes, the research team deduces that one is likely to be the product of the interaction between the material from L2 Puppis and the companion star's wind and radiation pressure, while the other is likely to have arisen from a collision between the stellar winds from the two stars, or be the result of an accretion disc around the companion star. The new observations suggest that two theoretical processes in action around L2 Puppis make it very probable that the pair of stars will one day give rise to a butterfly planetary.

The first theory is that the dust produced by the primary, dying star's stellar wind is confined to a ring-like orbit about the star by the stellar winds and radiation pressure produced by the companion star. Any further mass lost from the main star is then funneled, or collimated, by this disc, forcing the material to move outwards in two opposing columns perpendicular to the disc.

The second holds that most of the material being ejected by the dying star is accreted by its nearby companion, which begins to form an accretion disc and a pair of powerful jets. Any remaining material is pushed away by the dying star's stellar winds, forming an encompassing cloud of gas and dust, as would normally occur in a single-star system. The companion star's newly created bipolar jets, moving with much greater force than the stellar winds of the dying star, then carve dual cavities through the surrounding dust, resulting in the characteristic bowl-shaped appearance of a bipolar planetary nebula.

Pierre Kervella concludes: "With the companion star orbiting L2 Puppis only every few years, we expect to see how the companion star shapes the red giant's disc. It will be possible to follow the evolution of the dust features around the star in real time—an extremely rare and exciting prospect." ✶

Compiled from notes provided by the European Southern Observatory.

Featured Articles / Articles de fond

An Amateur Spectroheliograph

by Peter Zetner, Department of Physics and Astronomy, University of Manitoba

The availability of narrowband interference filters designed for sub-Angstrom bandpass at the H-alpha wavelength (6562.8 Å) or ~2 Angstrom bandpass at the calcium K line (3933.7 Å) has allowed many amateur astronomers to produce high-quality images of the Sun in highly monochromatic light. The interest in these two particular wavelengths arises from the fact that light emanating from these spectral lines originates from the solar chromosphere, a layer of the Sun in which the dominating influence of magnetic fields on the gas dynamics produces a wealth of complex structures of great scientific interest and beauty. The narrow bandpass of such filters is an essential requirement to observe these features clearly against the blazing, "white light," continuum emission from the solar photospheric surface. Narrowband filters of this type are commercially available at reasonable prices today, largely because the technology associated with manufacturing optical coatings of precise thickness and high optical quality has advanced to a sufficient level of sophistication. Early efforts to image the Sun in monochromatic light relied on spectrally dispersive optical components: gratings and prisms. To this end, the spectroheliograph (SHG) was developed independently by George Ellery Hale and Henri-Alexandre Deslandres in 1890 (Hearnshaw, 2009 and references therein). This device captures an image of the Sun at a single wavelength of light by utilizing a prism or grating spectroscope for spectral dispersion. An advantage of the SHG, even in the age of readily available narrowband filters, is its spectral selectivity (bandpass). This is determined by the spectroscope and associated optics and can be made (almost) arbitrarily narrow, at least much narrower than the passband of most filters. The wavelength of observation is usually chosen to coincide with a spectral line of one of the solar chemical elements, most frequently, but not exclusively, selected to be a strongly absorbing line of a chromospheric constituent, like the hydrogen or calcium lines mentioned above. In fact, tunability of the SHG to a desired wavelength presents a huge advantage over fixed-wavelength filters.

As an introductory description of the operation of the device, I've chosen to quote an early paper by Hale:

> *The principle of the spectroheliograph is exceedingly simple. Imagine a direct-vision spectroscope in which the eyepiece ordinarily employed is replaced by a (second) slit. If an image of the Sun is formed on the first slit of this spectroscope, the second slit will permit the passage of only a narrow region of the spectrum corresponding in width to this slit. If the (second) slit is now moved until it coincides with the H beta line, for example, only hydrogen light will pass through the instrument. If, then, a photographic plate is placed behind and almost in contact with the second slit, and the spectroscope is moved at right angles to its optical axis, an image of the Sun, in monochromatic hydrogen light, will be built up on the plate from the successive images of the slit. If the exposure is suitable, the chromosphere and prominences will be shown surrounding this image. Such is the spectroheliograph in its simplest form. It is obviously immaterial whether the motion be given to the spectroscope, on the one hand, or to the solar image and photographic plate, on the other. It is only necessary that the relative motion of the solar image and first slit be such that light from all parts of the solar disk shall pass successively through the slit, while the photographic plate and second slit experience a corresponding relative motion. The second slit serves simply to isolate any desired line in the spectrum; hence its width must be such as exactly to include this line, and to exclude all light from other parts of the spectrum. (Hale, 1903*)

A point worth emphasizing is the required relative motion of solar image with respect to the first slit and synchronized relative motion of the second slit and photographic plate. In the Rumford spectroheliograph, set up by Hale at Yerkes Observatory and operating by 1903, scanning of the Sun's image across the primary slit was accomplished by a uniform motion of the telescope tube in right ascension while the photographic plate was being moved at the same time and rate across the secondary slit. Another example is an improved instrument set up at the Royal Observatory, South Kensington, England, in 1905 and used extensively by William Lockyer. This instrument made use of a scheme in which both the solar image in the focal plane and the photographic plate remained fixed in position while a moving platform

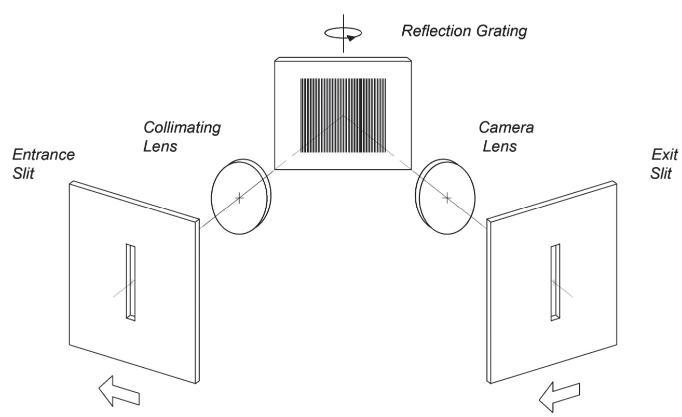

Figure 1 — Generic diagram of a spectroscope with reflection grating as the dispersive element. The axis above the grating, with circular sense defined, indicates the method of tuning the spectroscope. The arrows show scanning directions used in the early SHG instruments of Hale, Deslandres, and others.

housing the spectrograph, comprising entrance slit, exit slit, and dispersing optics, was translated laterally with a precisely controlled hydraulic piston (Lockyer, 1905).

Figure 1 presents a schematic diagram of a typical spectroscope lying at the heart of these early instruments. The dispersive element in this case is a reflection grating whose direction of dispersion is perpendicular to the long dimension of the slits. In the early days, prisms were preferable to gratings, at least until grating manufacturing technology improved. By locating the (narrow) entrance slit at the telescope focal plane, a sharp solar image falls on the slit. The entrance slit also lies in the focal plane of the collimator lens, such that rays emanating from any given source point in the entrance slit are transformed by this lens, into a parallel bundle of rays incident on the grating at a direction determined by the location of the source point. This parallel bundle of rays is reflected by the grating, in the dispersion direction, by an amount dependent on the wavelength of the light. For some particular wavelength, these reflected parallel rays intercept the camera lens and are brought to a focus at the (narrow) exit slit. The particular wavelength of light at which this happens can be selected by rotating the grating about the indicated axis, allowing the device to be "tuned." Any source point in the entrance slit is brought to a corresponding image point at the exit slit but with wavelength-selected light. Since the solar disk is imaged at the entrance slit, a corresponding monochromatic image of the portion of the disk occupying the entrance slit is generated at the exit slit. The exit slit image can be magnified or de-magnified by adjusting the ratio of camera lens to collimator lens focal lengths. The "spectral purity" of the light transmitted through the exit slit is determined by the entrance and exit slit widths, the focal lengths of collimator and camera lens, and the grating dispersion (determined by the number of grooves per unit length). The spectral purity increases (*i.e.* the spectral bandpass narrows) with decreasing slit width, increasing focal lengths, and more grooves per unit length. The arrows drawn below the entrance and exit slits in Figure 1 indicate the direction in which the scanning takes place, the solar image scanned across the entrance slit in synchronism with the photographic plate scanned across the exit slit.

Strictly speaking, the device described in the preceding lines is a "monochromator." Multi-wavelength (polychromatic) light passes the entrance slit and (nearly) monochromatic light emerges from the exit slit. By removing the exit slit and replacing it with a camera film or sensor plane, a "spectro-

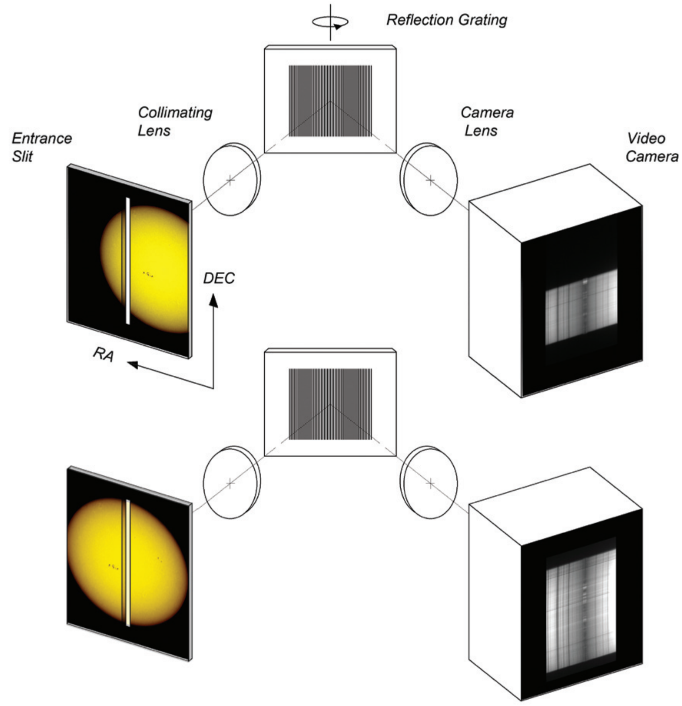

Figure 2 — Operating principle of a modern spectroheliograph. The solar disk at two possible positions on the entrance slit during its drift is shown along with the two corresponding video frames. In any given video frame, spectral information is encoded along the dispersion direction (roughly horizontal in the figure) and spatial (image) information is encoded perpendicular to the dispersion direction (vertical in the figure) contained in the corresponding slice of the solar disk present at the entrance slit.

graph" is configured. The wavelength-dependent directions of reflected light from the grating transform, via the camera lens, into wavelength-dependent positions on the sensor plane such that a spectrum is generated. This arrangement doesn't lend itself well to image generation, as desired with a SHG, because the narrow "slice" of solar disk passing the entrance slit is dispersed into a wide area on the camera sensor (film). Nevertheless, Henri Deslandres brought into operation, in 1910, the "spectral velocity recorder," where the single entrance slit was replaced by multiple (200) slits and the exit slit was widened. Although not strictly an imaging device, the film plane comprised multiple spectra (with width determined by the exit slit) covering the entire solar disk (divided into 200 slices). The Doppler-effect relation between line-of-sight velocity and spectral-line shift was used to velocity analyze the visible structures (Hearnshaw, 2009).

If we now take the spectrograph camera and replace it with a video camera, we have configured the modern SHG. The scanning required to produce images with the SHG is inherent in the video camera and can be almost trivially simple to implement. The telescope is pointed in a fixed direction along the Sun's path and the solar image allowed to drift across the entrance slit, which is oriented such that the dispersion direction corresponds to right ascension (RA). Video is acquired at the camera frame rate, each video frame capturing a spectrum associated with the particular slice of solar disk present at the entrance slit at the moment the frame is exposed. The general scheme is shown in Figure 2 with the solar disk at two possible positions on the entrance slit and the two corresponding video frames. In any given video frame, spectral information contained in the corresponding slice of the solar disk present at the entrance slit is encoded along the dispersion direction (roughly horizontal in the figure) and spatial (image) information is encoded perpendicular to the dispersion direction (vertical in the figure).

At this point it is tempting to imagine that the camera frame rate (in frames/second: fps) should be carefully matched to the solar drift rate in order to achieve the required synchronization. However, there is no stringent requirement whatsoever on the frame rate, aside from ensuring it is greater than a minimum value. The minimum frame rate, fps_min is determined by the solar disk diameter, D, at the entrance slit, the entrance slit width, w, and the transit time of the complete disk across the slit, T (127.6 seconds). The required calculation is: fps_min = (D/w)/T. The minimum frame rate ensures that no portion of the solar image is lost to the imaging process in the dead time between video frames. The instrument described below comprises a 1000-mm focal-length telescope and, most commonly, an entrance slit of 25 microns. The minimum frame rate for this configuration would be 2.9 fps. A 15-fps video capture is generally used, "oversampling" the spatial information at the entrance slit by a factor of 5.

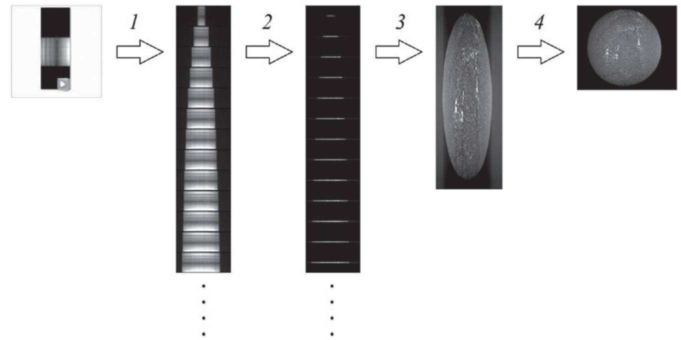

Figure 3 — Illustration of the procedure required to form an image from the video file acquired during a solar-disk drift scan. Images from left to right represent: the video file, the sequence of video frames ready for editing, the sequence of cropped video frames, the concatenated assembly of cropped video frames, and the final spectroheliogram. Steps 1 through 4 are described in the text.

The procedure required to form an image from the video file acquired during a solar-disk drift scan is represented in Figure 3. The video file is loaded into video editing software in step 1. My preference is the *VirtualDub* program, freely available and versatile, although somewhat outdated. In step 1, a rotation of the video of 90 degrees (CW) is shown, not necessary for image processing but convenient for the purpose of drawing the figure! Keep in mind that, with the indicated rotation, the dispersion direction in Figure 3 is vertical (as opposed to, roughly, horizontal in Figure 2). Close inspection of the second image (from the left) in Figure 3 shows that each video frame covers the same spectral region, in this particular example, near 393 nm, chosen by tuning the grating appropriately. Dark bands running horizontally are the various spectral absorption lines present in this region of the solar spectrum. The rather wide, fuzzy spectral line in the centre of each frame is the strong CaII K absorption line at 393.37 nm. The variation in intensity along the CaII K line, from left to right in any given frame, contains the spatial (image) information in this particular slice of the solar disk due to the intensity variation of the CaII K absorption across the slice. The visible bright spots, for example, are generally associated with regions of chromospheric plage. Note the presence of thin vertical lines in the spectra. These lines ("transversalium") are associated with dust and irregularities on the entrance slit.

In step 2, each frame of the video is cropped to isolate a single spectral line of interest, the CaII K line in the example. In a sense, this step introduces a "digital" exit slit such that the final image will represent the solar disk viewed at a single wavelength. It must be noted that the spectra shown in Figure 3 are somewhat idealized. In most instruments, the recorded spectral "lines" have some curvature associated with them ("smile") and may be rotated somewhat in the frame. Step 2, therefore, generally involves video-frame image processing in addition to the cropping. Fortunately, *VirtualDub* has a number of video filters available that can be used to remove smile and rotation from each video frame. I have found the "General Quadrilateral Transform," "Barrel Distortion," and "Rotate2" filters to be especially useful. Once the spectral lines have been straightened by filtering, the cropping can be applied. The location of the crop (*i.e.* the vertical height of the crop within the frame, in Figure 3) will determine the wavelength at which the final image is constructed and the width of the crop will determine the spectral bandwidth. For reasons discussed below, I generally choose the cropping to isolate a strip of 2 pixels width in order to minimize the bandwidth. In some cases, enlarging the crop width is useful, especially in the imaging of solar prominences.

Once each frame has been suitably cropped, the cropped frames need to be assembled (concatenated) to produce the solar-disk image. This is represented by step 3 in the figure. In my processing workflow, step 3 involves exporting the cropped frames, as a sequence of separate images, to a folder using the *VirtualDub* "Export" command. Assembly of these individual images into a single image is carried out with *ImageJ*, another freely available image-processing package that is well known to many astronomers. The commands "Import > Image Sequence" followed by "Image > Stacks > Make Montage" achieve the (nearly!) desired result (4th image from the left in Figure 3). The image resulting from concatenation of the cropped video frames in step 3 is, invariably, elongated by an amount dependent on the camera frame rate and the chosen pixel width of the crop. The elongation can be easily corrected by adjusting the aspect ratio in any image processing software. This adjustment alleviates the need to enforce a stringent synchronization between camera frame rate and solar-image drift rate since it, essentially, takes an average over-redundant, oversampled frames. The tremendous simplification afforded by this image-processing correction is a luxury that early spectroheliographers like Hale and Deslandres were unable to enjoy. Step 4 represents this correction along with other image enhancements like contrast and sharpness adjustments. At this point, it is also desirable to remove the transversalium lines mentioned above. This can be painstaking and difficult, depending on the severity of the problem, but can be accomplished by various filtering actions. I use *Adobe Photoshop* and *ImageJ* to finalize the image.

The names of a number of amateur astronomers, who have pioneered the development of the modern SHG as described above, come to mind: Andre and Sylvain Rondi, Phillipe Rousselle, and Daniel Defourneau. Information about their work is available online and they, along with others, will be profiled in a forthcoming book (Harrison, 2015). A photograph and schematic diagram of the SHG I have constructed is given in Figure 4. The instrument is built around a surplus Czerny-Turner spectrograph housing that was modified by introducing a hole and flange to accept incident light from the direction shown. The basic design philosophy was to incorporate M42 camera lenses (readily available on eBay) to provide the collimation and focusing. These lenses are often well-corrected for aberrations (notably Pentax Takumars) and come in a large variety of focal lengths, giving some versatility to the design. Coupling between the various lenses is accomplished with combinations of step adapter rings as well as T-mount adapters. In the interest of keeping the device relatively small and maneuverable, an "Astro Rubinar" *f*/10 lens (100-mm aperture), of catadioptric (Maksutov) design, is used as the telescope. To protect the cemented achromats located near the focal plane of the catadioptric telescope, a uv-ir blocking filter (Schneider True-cut, 100mm x 100mm) has been mounted in front of the telescope objective.

The telescope produces a solar image of approximately 9.3 mm in diameter that is focused onto a 25 micron × 18 mm-long slit held in place by a modified version of the original spectrograph slit holder. A collimator focal length ranging from 300 mm to 750 mm has been used in various versions of the instrument. Longer focal lengths of collimator are desirable as they give a smaller angular magnification of the solar disk (less vignetting at the grating) and an increase in the spectral

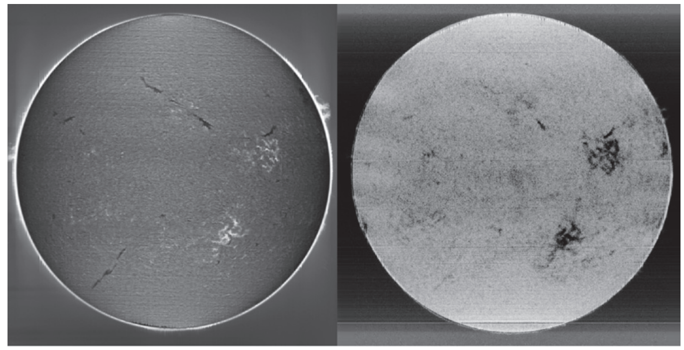

Figure 5 — Solar disks imaged in H-alpha light (left) and He D3 light (right) on 2014 July 15. The spectral bandwidth is approximately 0.025-nm.

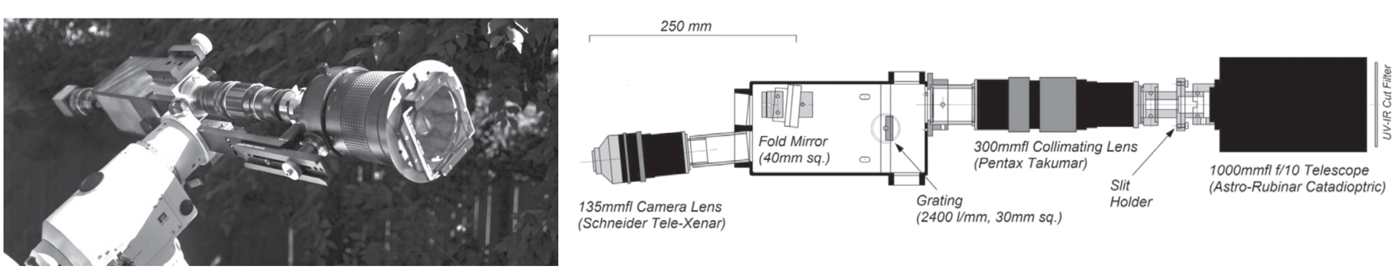

Figure 4 — Schematic diagram and photograph of the instrument. It is shown attached to an NEQ-6 mount.

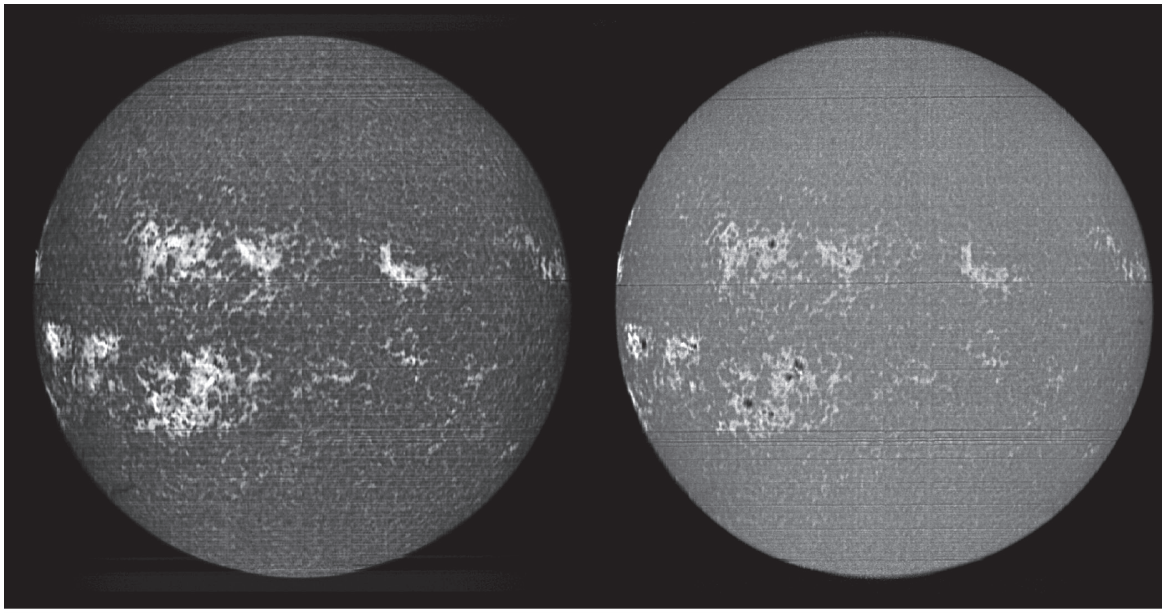

Figure 6 — Solar disks imaged 2014 July 3 at the centre of the CaII H absorption line (left) and 0.05 nm to the blue (right). The spectral bandwidth is approximately 0.015 nm.

resolving power. On the other hand, the longer the collimator focal length, the slower the optical speed (f-ratio) of the system. At 300-mm, the collimator gives an angular magnification of 3.3× in combination with the 1000 mm focal-length telescope, corresponding to a 1.7-degree angular divergence of the beam illuminating the grating and an optical speed of *f*/10 (30 mm-square grating) at the spectrometer input. This is an ideal match to the *f*/10 telescope lens and fixes the overall system speed at *f*/10. Also, for this collimator focal length, a spectral resolving power of approximately 20,000 is achieved with a 25-micron slit and 2400 l/mm grating.

The final diameter of the solar image at the camera is related to the solar-image diameter at the entrance slit by a magnification factor, m, determined by the ratio of camera to collimator focal length; $m = f_{cam} / f_{coll}$. For the configuration shown in Figure 4 (f_{coll} = 300 mm, f_{cam} = 135 mm), m = 0.45 and the solar-image size at the camera is 4.2 mm. This is a reasonable match to the 1/3-inch CCD sensor size (5.80 mm × 4.92 mm) of the Imaging Source DMK31AU03 camera used in my first imaging efforts. The same magnification factor, m, determines the image slit width at the camera sensor. For m = 0.45 and a slit width of 25 microns, the image-slit width is 11.3 microns (2.4 pixels for the DMK31AU03). This image-slit width of 2.4 pixels underlies the rationale for cropping slices of 2-pixel width out of the video frames as discussed above. It is also consistent with the Nyquist criterion for digital sampling applied to the spatial information contained within each slice.

Some sample images produced by this instrument are shown in Figures 5 and 6. The beauty of the technique lies in the ability to capture an image of the Sun in almost any wavelength of interest, at high spectral resolution, during a single observing session. Figure 5 shows a comparison of disks imaged in H-alpha (656.3 nm) and He D3 (587.6 nm) on 2014 July 15. Entirely different aspects of the solar atmosphere are visible. For example, active regions in H-alpha show bright plage features that correlate directly with absorbing regions ("black plage") in He D3. Filaments in H-alpha correlate with features in He D3, in both cases visible as (dark) absorption features. The He D3 line is extremely weak in absorption and generally invisible on the solar disk, hence difficult to image. However, enhancement techniques (like subtraction of the nearby continuum) can be easily applied to the spectroheliogram to bring out the slightly enhanced absorption in regions of plage and filaments. As illustrated in Figure 6, smaller differences in wavelength can also make large differences in the appearance of the solar disk. The figure shows comparison images taken (2014 July 3) only 0.05 nm apart in the broad CaII H line near 396.8 nm. At the centre of the CaII H line

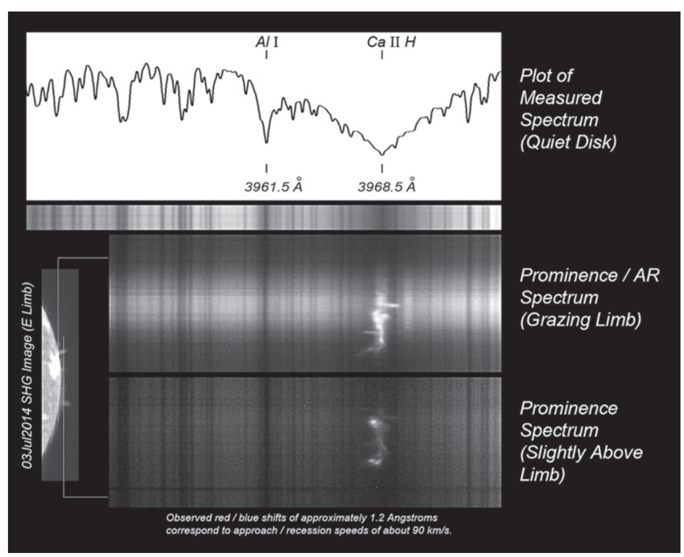

Figure 7 — Spectra recorded near the Sun's limb in the vicinity of an active region and prominence (2014 July 3). These spectra are associated with solar-disk locations indicated by the yellow guide lines overlain on the spectroheliogram to the left. The dispersion direction is horizontal and two prominent absorption-line identifications are made in the plotted spectrum at the top.

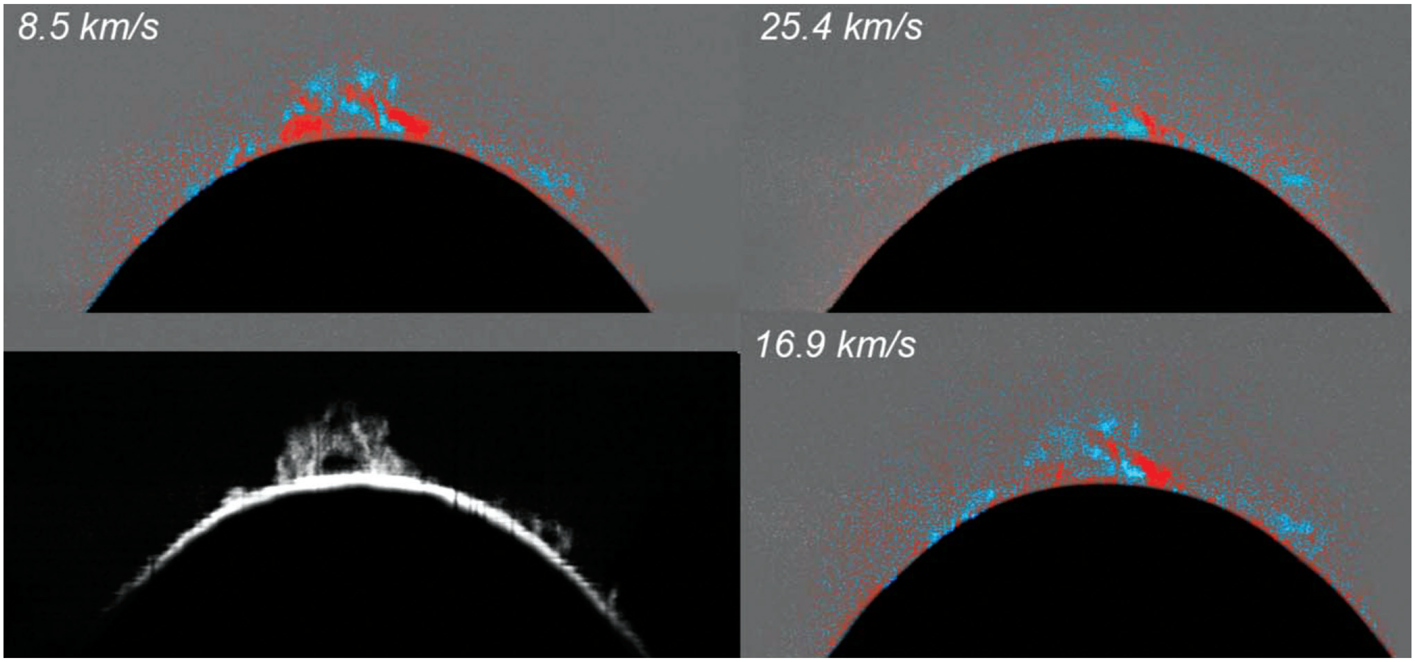

Figure 8 — A dopplergram showing the velocity characteristics of a prominence imaged in CaII H light (2014 June 21). The basic image (lower left) is resolved into velocity maps of receding (red) and approaching (blue) regions of the prominence with the indicated gas velocities.

(CaII H3), one is essentially looking at the upper regions of the chromosphere exclusively while 0.05 nm away (CaII H1) lower, photospheric features (sunspots) become more visible. For the images in Figure 6, f_{coll} = 500 mm, f_{cam} = 270 mm and a 3600 l/mm grating was used (0.014 nm spectral bandwidth). Image capture was done with a Point Grey Grasshopper Express camera (2/3-inch CCD).

Other than wavelength-diverse imaging, the SHG allows detailed study of velocities of solar features, magnetic field effects, and more, making for an extremely interesting technique accessible to the amateur. For example, Figure 7 shows two spectra recorded near the Sun's limb in the vicinity of an active region and prominence. These spectra are, in fact, the cropped video frames associated with solar-disk locations indicated by the yellow guide lines. The dispersion direction is horizontal and the vertical direction conveys spatial (solar-disk image) information. The bright plage and the prominences stand out as emission features within the otherwise dark CaII H absorption line. What is fascinating about these spectra is the pronounced "zig-zag" nature of the emission spectra. The zig-zag is indicative of regions of rapidly receding and approaching plasma closely spaced to each other in line of sight. The red and blue shifts are associated with speeds of up to 90 km/s and the "spiky" nature of the spectrum reveals that there are well-defined streams of gas heading toward and away from us—likely surges. Further out in the prominences (two are mainly visible), the lower spectrum shows gas that seems to be largely blue shifted (approaching). This information can be re-processed in a form that vividly demonstrates the distribution of velocities in the solar plasma. Such a "dopplergram" of a prominence on the eastern solar limb (2014 June 21), captured in CaII H light, is presented in Figure 8. The three colour images show a velocity map of the prominence, delineating regions of prominence plasma moving toward us (blue colouring) or away from us (red colouring) at the indicated velocities (with respect to the CaII H "line centre"). Such maps are relatively easy to construct by producing spectroheliograms at wavelengths offset to the blue and red sides of a spectral line centre by fixed increments and subtracting the corresponding images in pairs.

The SHG described here is in a, more or less, continual state of flux! The modularity inherent in the design allows for straightforward re-configuring of the optics. A planned measurement of magnetic fields, for example, will require the introduction of polarizers that is relatively easy to accomplish. In addition to the fascination of imaging the Sun in light of high spectral purity, there is additional enjoyment in this ability to modify the instrument itself. ✶

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The Town of Aylmer LED Streetlight and Sports-Field Lighting

by Arthur Oslach
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In February 2013, CRU Solutions Inc. provided a presentation to Aylmer Town Council explaining the financial and energy-saving benefits of implementing a full-cut-off LED streetlight upgrade project for the Town. Council endorsed the project concept and included financial provisions in the 2013 Budget. October 2013 tenders closed for the project and the LED Streetlight Upgrade project bid provided by CRU Solutions Inc. (ERTH Corp.) was accepted and awarded to CRU by the Town of Aylmer and Council. In December 2013, the Town of Aylmer & ERTH Corp. (CRU Solutions Inc.) entered into an agreement for the provision of services to upgrade all of the town's streetlights to more-efficient LED. The Town of Aylmer Council accepted RFPs (Request For Proposal) for both the LED Streetlights & Sports-field Lighting Upgrades Projects in late 2013 and all works were completed in 2014. In April–July 2014, the LED Streetlight Upgrade Project was completed; in total, 732 more-efficient LED lights were replaced and installed.

The town is financing the 100 percent of the cost of both projects through a 15-year loan attained through Infrastructure Ontario. Based on the costing model provided by CRU Solutions, all financing costs are expected to be paid for through the hydro savings and lower annual projected maintenance costs achieved from the LED Street-lighting Project. The town had an inventory of 712 lights prior to the upgrade.

Average monthly usage prior to
LED Streetlight Project .... 38,722 kWh

Average monthly usage after
LED Streetlight Project .... 15,565 kWh

There has been a 23,157 kWh (59.80 percent) decrease in average monthly power consumption, which constitutes to an average of $4,287.03 (HST included) decrease in monthly hydro billing in 2015 compared to 2014 for the town's streetlights. The projected annual savings in streetlight hydro invoicing for 2015 is $51,444.36 (HST included).

The projected annual streetlight power consumption reduction is 277,884 kWh. As a result, there the annual average reduction in greenhouse gas emissions achieved from the Streetlight LED Conversion Project comes to 192 tons of carbon dioxide equivalent.

The conversion to LED lighting is an integral component in the Municipality's "5 Year Energy Conservation & Demand Management Plan" which complies with legislation under the Province's "Green Energy Act, 2009." Considering the overall cost savings attained now and in the foreseeable future, in addition to the extremely positive impact this green initiative has had on the environment, the overall project should be considered a huge success for the Town of Aylmer. ✶

Great Images

by Ian Wheelband

Ian took this image from Toronto Centre's Carr Astronomical Observatory in Thornbury, Ontario, using a 12.5″ reflector. Total exposure time was three-and-a-half hours.

The largest galaxy in the image is NGC 5566, also known as ARP 286, located in the constellation of Virgo. It and its neighbour to the lower right, NGC 5560 are about 65 million light-years distant. The light left the galaxies about the same time that the dinosaurs became extinct. The smaller and considerably dimmer galaxy to upper right is NGC 5569. At 83 million light-years away, it is just a chance alignment.

An Ideal Getaway for the Discerning Astrophotographer in Rodeo, New Mexico

by George Cavanaugh, Calgary Centre
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If you drive along the Interstates heading east out of Arizona into New Mexico, you could easily miss the hidden and more-remote places in that desert climate that are perfect for a serious astronomer. Whether you enjoy the simple pleasures of viewing or have a vehicle full of equipment ready for imaging, there are several places to set up telescopes and enjoy nights of clear skies and pleasant temperatures.

One of these is in the vast open area between two mountain ranges in the very deep southwest corner of New Mexico—a perfect place for clear skies. In your visit to this area, you are likely to come across others who are looking for the same things: zero light pollution, gentle weather, and pristine skies (on average, 340 days per year of cloudless skies). Scan the surrounding properties from the driver's seat and you will spot the tell-tale signs of amateur astronomy in the numerous white domes sprouting from the back yards of distant homesteads. This part of New Mexico and adjacent Arizona is becoming a favoured vacation spot for those who seek ideal conditions from which to hone their astronomy skills.

Astronomy and dark skies are not all this area has to offer. The region has a rich Apache culture and western history. Panoramic views and spectacular vistas are only part of Hidalgo County's appeal. It boasts two ghost towns, ranch and hiking tours, bird-watching trips, and horseback-riding tours. A day-trip excursion can take visitors to Tombstone, the historic town where the showdown at the OK corral occurred, to Kartchner Caverns, the only living cave system still open to the public (though very restricted), or to Mexico for a lunch date serenaded by a mariachi band. The wild terrain of the Chiricahua Mountains lies only a half-hour drive away, part of the reason for the dark skies and dry terrain of this section of New Mexico.

For the avid camper, Rusty's RV ranch is the perfect spot to set up your camper or fifth-wheel. It is not unusual to come across others from Canada and the U.S. hauling their telescope equipment over great distances to take advantage of everything that this area has to offer. Some visitors come with a widespread reputation for their skills and experience, and regulars to Rusty's are often delighted to be in residence at the same time as astrophotographer Dalton Wilson. Nearby Arizona Sky Village, just across the state line from Rusty's, offers an opportunity to meet Canadians who have elected for a semi-permanent presence in the valley.

In the last five years Ken and Bev From have organized an annual star party at the Painted Pony Resort, gathering a now-familiar and repeating set of attendees from Canada for a week of astronomy viewing and imaging. Just like going to music or space camp when you were young, a group of adults and a few of their children of all ages take part in the Froms'

Figure 1 — The dark skies along the New Mexico-Arizona border allowed the author to capture this wide-angle view of Orion and Barnard's Loop beneath a slice of the Milky Way. This area is one of the richest in the northern sky. The author captured this detail using a modified Canon 5D Mark II with a 24-mm lens. Exposure was 5 × 5 minutes with internal darks.

"Astronomy Camp." It has become a sought-after adventure for many of us, and is usually fully booked every year. Those who come to this event go home having learned a great deal from other like-minded people and frequently many magazine- worthy pictures that they can hang in prominent spots around their home. Over the years, the astronomers who have come to this spot have developed ongoing friendships, sharing knowledge and rejoicing in each other's successes. ✶

George Cavanaugh is the 2nd Vice-President of the Calgary Centre.

Figure 2 — Tim Hortons's mugs salute the photographer in this image from the courtyard of the Painted Pony Resort.

Figure 3 — IC 1805 (left), the core of the Heart Nebula, and the Orion Nebula reward the photographer in the southwest skies. The author took these images using a C11 Hyperstar telescope and an Atik 428ex colour camera.

RASC Vancouver Centre Heralds the Opening of Trottier Observatory

by Suzanna Nagy, Vice-President and Event Coordinator, RASC Vancouver Centre

I first met Dr. Howard Trottier in 2007, when he had just moved to the Vancouver area to accept a position as Professor of Physics at Simon Fraser University (SFU). Dr. Trottier's love of astronomy and particularly astrophotography drew him to join the Vancouver Centre almost immediately. I was introduced to Dr. Trottier by our President at that time, Mr. Ron Jerome. By 2008, Dr. Trottier was asked to join the Vancouver Centre Council. His enthusiasm and interest in public outreach was a perfect fit for us.

At that time, Vancouver Centre was having difficulties, as we had lost our long-time home at the Planetarium. We were nomadic with no place to hold lectures and meetings. Dr. Trottier quickly stepped up to the plate and made introductions to the Dean of Science at SFU, with the end result that Vancouver Centre was given meeting space and lecture theatres with all fees waived.

Dr. Trottier also started a public outreach program at SFU that he called "Starry Nights." With the assistance of SFU astronomy students and RASC Vancouver Centre volunteers, Dr. Trottier began hosting star parties on campus, which quickly became a huge hit. The Starry Nights program brought thousands of children and youth to campus to learn about astronomy and to observe the night skies. Dr. Trottier quickly became known as "Mr. Starry Nights."

It wasn't long before Dr. Trottier's aspirations expanded to dreams of building an observatory on the SFU campus.

I now have to digress and introduce you to the Trottier Family Foundation. Lorne Trottier (brother to Howard Trottier) is an electronic engineer and co-founder of Matrox, a company making specialized computer graphics and video products. Lorne Trottier's financial success with Matrox allowed him and his wife, Louise, to create the Trottier Family Foundation and over the years have generously donated to various universities in Canada to enhance scientific development. One of Lorne and Louise Trottier's goals is science outreach to young people.

Through a very generous donation of $2.7 million by the Trottier Family Foundation (Lorne Trottier, Louise Trottier, and their daughters, Claire and Sylvia), Dr. Howard Trottier was able to see his dream of an observatory at SFU come to fruition. On 2014 January 9, SFU announced the construction of the Trottier Observatory. Building started later that year, on September 9.

Photos and videos of the construction can be found at www.sfu.ca/science/trottierobservatory.html.

The Trottier Observatory is located at the east end of the SFU campus near the famous Academic Quadrangle and features a 6-metre-diameter dome housing a 0.7-metre-aperture telescope on a fully robotic alt-azimuth mount built by PlaneWave Instruments. Accessories include a 16-megapixel high-resolution camera built by Finger Lakes Instruments, which is complemented by a complete set of high-quality broad- and narrow-band filters supplied by Astrodon. Soon to come is a high-resolution echelle spectrograph on order from Shelyak Instruments.

The Science Courtyard was then built adjacent to the Trottier Observatory on public space provided by SFU. The Courtyard is filled with architectural features including two huge concrete walls that are meant to represent an ancient observatory with a fixed slit view of the heavens such as existed in Mesoamerica thousands of years ago. The walls are adorned with large lighted seasonal star charts. The Science Courtyard also includes space for telescopes next to the dome and features landscaping that reflects the outline of our galaxy.

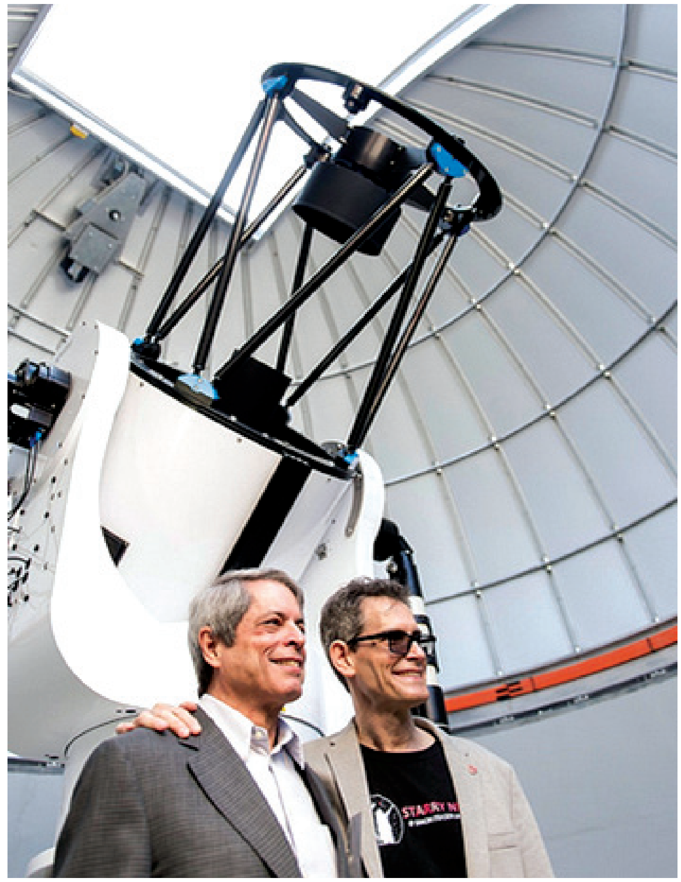

Figure 1 — Lorne (left) and Howard (right) Trottier in front of the 0.7 metre PlaneWave telescope. Photo courtesy of SFU.

Figure 2 — The interior of the observatory, showing the 0.7-m PlaneWave telescope. Vancouver RASC member Alan Jones is speaking with the young visitor. Photo: SFU Creative Services.

On 2015 April 17, the Trottier Observatory was revealed to the public with much fanfare and media attention. The ribbon-cutting ceremony was hosted by SFU's President, Andrew Petter, with many members of the Trottier family in attendance. That same evening, a Gala Star Party was hosted by SFU with the assistance of Vancouver Centre, at which there were almost 2000 people in attendance.

Both the Trottier Observatory and the Science Courtyard are now prominent features at the campus and are visible landmarks of the importance of science to society.

The purpose of the Trottier Observatory is three-fold: to be used as a teaching tool for SFU students; to be available for schools across British Columbia to access remotely for teaching at elementary and high school levels; and finally as a focal point for SFU's and Dr. Trottier's Starry Night outreach program.

However, hosting regular star parties and ensuring the Trottier Observatory can be regularly opened to the public is a huge endeavour and was beyond what SFU could manage alone.

Figure 3 — The Trottier Observatory in the SFU Science Courtyard. Photo: SFU Creative Services.

Dr. Howard Trottier suggested a partnership between the Faculty of Science at SFU and the Vancouver Centre. In exchange for RASC volunteers bringing their telescopes to star parties as well as staffing the observatory for public events, SFU would continue to offer the Vancouver Centre meeting rooms and lecture halls for free, as well as share a percentage of the observatory time for use by members of the Vancouver Centre.

The Vancouver Centre is thrilled to be invited as an active partner in SFU's public outreach observatory program. We are looking forward to many years of great star parties and other public events. Currently, our annual International Astronomy Day activities are hosted at SFU. In May this year, 8000 people attended the Astronomy Day event, which was held in conjunction with SFU's Science Rendezvous festival. ✶

RASC and *Star Trek*—A Match Made for the Heavens

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They say 1965 was a good year, and even though I made my debut then, I just had to look back and see just what made it so special. Being stuck to the crib for some time afterward, I had to trust reliable folk and historical records from years later. To my delight, I found out my favourite sci-fi TV show launched that year. Yes, *Star Trek*—that phenomenon known worldwide as one of the greatest space stories—had its unveiling on Burbank Street in Los Angeles that summer. The brain child of producer Gene Rodenberry, it was initially rejected by NBC for airing that year. It eventually reached the airwaves in 1966 with the first regular episode, *The Man Trap*, broadcast on Thursday, 1966 September 8, from 8:30–9:30 as part of an NBC "sneak preview" block. While the original series managed to linger for three years, it had none of the fanfare of today.

After lying dormant for 10 years (though with reruns on syndicate TV and cartoons), the next production with the original cast came in 1979 with *Star Trek: The Motion Picture*. Experts seem to believe that this not only reignited interest among diehards but sparked curiosity within a new generation, eventually leading to 11 more movies and 6 more TV series. It's still going, with a new movie, *Star Trek Beyond*, set to launch in August 2016. Today the *Star Trek* business is a multi-billion entity with paraphernalia for sale all over the globe. Were Rodenberry alive today, he would not have believed its success. Now, having lived through all of it myself, I can attest that 1965 was indeed a great time to enter the Earth.

Fast forward to today. For the past 17 years, I've been a resident near the town of Vulcan, Alberta. Before Vulcan, I'd lived in Toronto (Rexdale to be specific), Ontario, and had only heard of Vulcan through the Saturn commercials of about 20 years ago; I never would have imagined then that I'd land up here. However, in August 1998, the farm I live on today, just outside of town, became my home. Coincidentally, it was the opening ceremony of the *Star Trek* Museum. It was a grand event for the under-2000 population of Vulcan. As the most up-to-date building in this agriculture town, it got a lot

Figure 1 — (Clockwise from upper left) The Trek Station at night under a waxing Moon. Courtesy of Vulcan Tourism; Inside the Trek Station where a presentation by Calgary's Roland Dechesne is made to a standing-room-only audience; Global TV Calgary interviews the author; Leonard Nimoy remembered by one of many millions of fans. This bust is on permanent display in downtown Vulcan; author Neel Roberts (left), astronomy co-ordinator Karl Ivarson Jr. (centre), and Calgary member Roland Dechesne (right) ready to participate in the annual Spock Days parade with the 20-inch telescope on their float.

of attention. I still remember as a newcomer in my '74 Ford farm truck, wearing a cowboy hat, saying to myself "I'm going to be involved in this" with no idea how and for what.

I have a love for the stars—that's why I moved out of the big city and bought a farm. Even though I had no telescope, star chart, or idea what was up there in the sky, I had a passion to learn and to help others along the way. Technology at that time was starting to move in the direction of the Internet and portable devices, but they were still pricey and nowhere near as developed as today. In 2003, I was introduced to *Starry Night*,a program way ahead of the times, that allowed me to travel virtually to other planets, galaxies, and more. It let me look at the cosmos from different time periods and land on places like Saturn, under the rings.

I decided to take a chance and share *Starry Night* with the local newspaper and a tour co-ordinator at the Trek Station. They absolutely fell in love with it and wanted more. Simon Ducatel, reporter for the *Vulcan Advocate*, later ask me to write a monthly column called *Sky's the Limit*, which still runs today. That was followed more recently by a column called *Your Universe* in the *Prairie Post*.

Organized stargazing in Vulcan began in 2003, but it had trouble getting off the ground because it was missing one thing—experts on the subject. In 2009, I joined the Calgary Centre. I had heard of the club but, after joining, sure wished I had hooked up earlier. They were such a natural fit to what I had hoped for Vulcan and for the hunger to learn the sky that people seemed to have. Regular meetings in Vulcan were launched officially with the total lunar eclipse of 2010 December 21. Participants came from as far as Australia for a look through an 11-inch Celestron telescope. Unknown to the facilitators, the event was broadcast by several news stations, including CBC Calgary. Later, after an afternoon interview with Global TV, I knew for sure I was onto something.

Since that eclipse, the Calgary Centre has planted firm roots in Vulcan with permanent displays at the telescope, astronomy materials, and about 1000 pictures of their events, including the famous "Spock Days" that is the town's main annual celebration—a (much) smaller cousin of the Calgary Stampede. Stars from Hollywood such as Walter Koenig (Pavel Chekov from the original series), Marina Sirtis (Deanna Troi from *Star Trek Next Generation*), and Garrett Wang (Ensign Harry Kim from *Star Trek Voyager*) have visited Vulcan. The RASC has a float and a mobile 20-inch telescope that they bring for the parades. Riders dress up as their favourite characters, led by the RASC banner on the vehicles.

The Trek Station has been in business for over 17 years now with a present annual visitation of 14,000 patrons. The RASC Calgary Centre recognized the centre and the citizens of Vulcan by a corporate award. Robyn Foret, President of the Calgary Centre, explained that the awards committee "was honoured to recognize the efforts you and the other "Vulcans" put forth. We don't give out that award every year and it sometimes is difficult to find a good corporate citizen and proponent of light-pollution abatement. You guys made it an easy pick for us this year." Tour Manager Devan Daniels has praised the work done by the Calgary Centre and wants to try to expand the program. Shannon Clark and Karen Haller are the regular Vulcan Tourism employees present on Friday nights to assist with the presentations and leave excellent, lasting impressions to all visitors.

The RASC recently promoted the idea of astrophotography with smartphones. Started as an experiment by Alycia Ivarson three years ago with her iPhone, it has caught on like a Prairie wildfire, challenging Vulcan members to turn it into an easy-to-use pastime. RASC members Norm Baum from Carmangay and his wife Rose Marie are regular participants and avid astrophotographers. Norm does a "show and tell" using images captured from his sky over the month and shows others the basics on how they can get going. Apps such as *Sky Safari Pro 4* and *Pocket Universe*, computer programs like *Starry Night*, and GPS-enabled telescopes have made the astronomy game much friendlier for the beginner. In fact, the average amateur can sound like an astrophysics professor in a short time!

Astrophotographer Alan Dyer was the guest speaker at the 2015 Spock Days and drew a large crowd. Dyer is an accomplished speaker, writer, and presenter on the subject, and a household name in astronomy. He may be retired on paper but is busier than ever. With an ever-growing demand to get to know the skies, his new projects include marketing an e-book on nightscapes, teaching Northern Lights sessions in Churchill, Manitoba, and partnering with All-Star Telescopes (www.all-startelescopes.com) near Didsbury, Alberta on specialty *Photoshop* astrophotography seminars. The Trek Station hopes to evolve into a permanent resource centre for astronomy enthusiasts, encompassing fellowships with other keen observers, a variety of equipment, and guidance by RASC heavy hitters like Dyer.

Vulcan made international headlines in 2009 when it attempted to host the premier of *Star Trek 1*. Though not successful, the effort was rewarded when Leonard Nimoy contacted the tourism centre and offered a compromise to then-tour co-ordinator Dayna Dickens. He arranged to have much of the town bused for a special pre-viewing courtesy of Paramount Pictures. As one of the participants, it was the treat of a lifetime. How many times will one be in a movie house where the whole village knows you? Nimoy visited the town personally a year later in April 2010. Media from around the world came to see the event, and he spoke those famous words

> *I've been a Vulcan for 44 years. It's about time I came home. In all these experiences I've never had an experience quite as touching as I'm having here today and I appreciate it, thank you. May all of you live long and prosper.*

Nimoy passed away in February this year, 50 years after the launch of *Star Trek*. The legacy he left behind is unsurpassed, but in addition, he gave a magnificent boost to all that had been done in Vulcan since its inception in 1903. Rumor has it they may still use cameos of Nimoy for future movies, but ordinary folks here remember him for all his personal appearances. Nimoy really liked the town and wanted to be more involved before taking sick. His last tweet stamped Monday, 2015 February 23 at 12:36 a.m. read "A life is like a garden. Perfect moments can be had, but not preserved, except in memory. LLAP" Couldn't be put better.

While the Calgary Centre and Vulcan tourism always seek better ways to serve, what matters is it all started with an idea and now has grown into a magnificent adventure. No one encouraged me but it would not have been possible if people were not willing to take a risk and explore the possibilities. The Village of Vulcan started a little over 100 years ago by the Canadian Pacific Railway as a station. No doubt it was very lonely, and the men at the time had big dreams. Vulcan today has a bright future thanks to the Calgary Centre and to Vulcan Tourism's efforts. Some of those visions the men of old dreamed are coming true. If Leonard Nimoy could have sent one more tweet when asked about all this, I'm sure he would have found it "Fascinating!" ✶

Neel Roberts is a tax professional by day and the Astronomy Co-ordinator at the Star Trek Station in Vulcan, Alberta. An RASC Calgary Centre member since 2009, Neel loves the great outdoors like quading, boating, and snowmobiling with friends on his farm or across remote areas of Western Canada. Neel welcomes your questions and comments. You can find out more about Vulcan and RASC participation at http://calgary.rasc.ca/vulcan2015.htm.

The Observer as the "Centre of the World": Jean-Sylvain Bailly and the Sounds of the Observatory

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Abstract

Jean-Sylvain Bailly was a French astronomer of the Enlightenment who contributed to the astronomical practice of his time. He is best remembered today for his voluminous works on the history of astronomy, and as an influential and ultimately tragic figure on the political scene in the early years of the French Revolution. His *History of Modern Astronomy* contains a brief but memorable passage on the ideal astronomer of his day, and the astronomer's observing space. It has never before been translated into English.

The Astronomer

Jean-Sylvain Bailly (1736-1793) was a notable astronomical figure in a place that seems to have conceived, allured, and harboured memorable astronomical characters in abundance, at least when viewed across time through a retrospective optic tinged with nostalgia (Figure 1). Less performatively eccentric than his colleague Jérôme Lalande (1732-1807), less politically powerful than Pierre-Simon, Marquis de Laplace (1749-1827), and lacking the lucky relative longevity of either, he made his lasting mark on French science, public life, and the history of astronomy (on Lalande, see Dumont 2007; for Laplace, see Hahn 2005). His story was of such intrinsic interest that it captivated Helen Hogg at one point (Hogg 1949).

Born in the Louvre to a family secure in the aura of respectable royal office, he came to mathematics relatively late at age 20, but showed flair enough to be fostered by the Abbé de La Caille (1713-1762), and attract the attention of Alexis Claude Clairaut (1713-1765), among others (Smith 1954; Glass 2013; Luminet 2014). Bailly played a part in the celebrated—and controversial—campaign to recover Halley's Comet in 1758-1759, and manned one of the 1761 transit of Venus stations with de La Caille. He was elected to the *Académie royale des Sciences* a mere six years after commencing the study of mixed mathematics (and would eventually be elected to the *Académie française* in 1783, and the *Académie des inscriptions et belles-lettres* in 1785, one of only two *savants* to be so honoured—the other was also an astronomer, Fontenelle). His chief lasting contribution to astronomical research was his observational and theoretical efforts to refine the ephemera for the satellites of Jupiter, although they were superceded in his lifetime.

More massive by volume than the fruits of his observational and theoretical research were his writings on the history of astronomy; *Histoire de l'astronomie ancienne, depuis son origine jusqu'à l'établissement de l'école d'Alexandrie* (*History of Ancient Astronomy Since Its Origin Up to the Establishment of the School of Alexandria* 1775; 1781 2nd ed.), *Lettres sur l'origine des sciences* (*Letters on the Origin of Science* 1777), *Historie de l'astronomie moderne depuis la fondation de l'*école d'*Alexandrie jusqu'à l'époque de 1730 (History of Modern Astronomy Since the*

Figure 1 – Portrait medal of Jean-Sylvain Bailly by F. Montagny, 1821, copper-alloy. Reproduced by permission of the Specula astronomica minima.

Foundation of the School of Alexandria Up to the Epoch of 1730, 2 vols., 1779, with a third in 1782 extending the story to that year), and *Traité de l'astronomie indienne et orientale, ouvrage qui peut servir de suite à l'histoire de l'astronomie ancienne* (*Treatise on Indian and Oriental Astronomy, Which Serves as a Continuation of the History of Ancient Astronomy* 1787). The RASC Archives Rare Book Collection has all of them, six imposing quarto volumes, but they do not represent the sum total of Bailly's writings on history, for there are his contributions to the periodical literature to weigh as well.

Bailly's history of astronomy is very much a product of its time and a child of its author, but so is every history of astronomy. It received wide notice in its day, and some of its statements elicited criticism, indicating that it was indeed read. As history, the work has not worn as well as Delambre's slightly later works, but it is precisely because of its limits as an 18th-century work that it can be read with profit now. One reads Bailly not for his insights into ancient or non-western astronomies, but for insights into 18th-century attitudes towards the astronomical past.

He also wrote more directly about the astronomical present. Particularly striking to this author is an extended passage in the second volume of his *History of Modern Astronomy*, which offers an image of the ideal late 18th-century astronomer and his work space. It is given in translation below. It is hard to imagine an astronomer with professional training now writing of personifications of astronomy, the night, and nature, but such was the literary idiom of the time. It is not without its charms. The passage brings out the "ideal" dedication expected of one entering on the serious pursuit of astronomy. That the ideal reflects to a real extent 18th-century experience, particularly in the professionally imposed isolation of some practising astronomers, can be seen in later 18th-century accounts of the assistants of the Astronomer Royal in Greenwich (Higgit 2014). Also notable is Bailly's description of being subject to the unpredictable vagaries of weather. Parallels can also be read between his description of the ideal astronomer's devotion to observing and unremitting zeal for astronomy, and descriptions of Charles Messier's (1730-1817) observational lifestyle, published upon his death:

> *Messier was eminently an observer; he would see nothing, he would hear nothing of which he did not take note...for he was good, although his laborious life imparted a somewhat severe character. He was a faithful friend, eschewing intrigue, always punctual—as when going to his telescope to observe a phenomenon.*[1]

Bailly's description of the aural environment of the observatory is arresting; there are no manmade noises extraneous to the activity of doing astronomy. This is in contrast to those modern amateurs (and professionals) who prefer to impose their musical tastes electronically on their immediate observing or imaging environment. One cannot be prescriptive about this, but there is an attraction to observing in silence, so that one can hear the natural world of the night (it is hard to imagine Leslie Peltier with a radio blaring in his dome or out in the field). And then there is Bailly's description of the physical hardships of doing visual astronomy, and the motivation necessary to survive doing it—this will strike a chord of recognition among contemporary visual observers, as well as those astrophotographers who prefer not to image remotely.

After successfully serving on important scientific commissions dealing with hospital reform and aspects of sanitation in Paris, Bailly was elected first President of the newly created National Assembly (1789), and the same year, was unanimously proclaimed First Mayor of Paris. The period from the early French Revolution to the Second Republic in 1848 was an interesting one for French astronomers, for they wielded more secular authority and occupied more elevated positions in the corridors of power than in any modern representative state since. And it is probable that more astronomers were executed in that place and time than in any society since (perhaps the Stalinist purges effected a similar grisly harvest). For the most part, Bailly's political career was reasonably successful. Until it wasn't, and he was guillotined, a victim of the Terror.

The Text

> *The edifice of the observatory is a monument which partakes more of grandeur than of utility. Astronomy has no need of this luxury, but it is useful as a mark of the interest and encouragement of kings.*[2] *Astronomy requires no more than a round tower, sufficiently elevated to afford sight of the entire horizon, and sufficiently spacious to allow the placement of the necessary instruments, and the unrestricted activity of the astronomer... It is there the astronomer stands, watchful for all phenomena. He becomes the centre of the world, the sky turns around him, and nature unfolds herself before his eyes...We hope that the young men who destine themselves for astronomy discover there the setting for their duty, and employment for their wakefulness. Those not destined for astronomy are better advised to leave off amazement, and to begin to believe in the replies Nature furnishes, judging for themselves the manner in which she is queried.*
>
> *Those who enter into this sanctuary ought to be devoted without reserve to the service of Urania* [Rosenfeld 2009]. *She is the goddess for whom the astronomer is the priest, and for whom he produces "oracles"—but the "oracles" are earned, wrought by his perseverance. He enjoys no respite but days sombre and sad, the moments when Nature adds to all his shadows that of clouds. His day is interrupted, sectioned by different observations. The Sun occupies the morning, midday, and evening. When that star disappears, the other planets and stars reveal themselves, heralding other work. Astronomers often share the work amongst themselves, but those who would embrace all astronomical duties require an iron constitution. It is necessary that the zeal for science awakens at the moments indicated in the night. It is*

necessary that the zeal for science wards off sleep, so that the astronomer is awake for the duration of the night. It is necessary that those watches recur, and that the astronomer sacrifice himself to the work following observing, and still observe the stars every night. It is necessary that the eye be attached to the refractor, and the ear to the clock, whether the body be upright, bent, or, as frequently happens, supine to observe the zenith. The cold of the night, winters, fatigue, and the dangers of insomnia matter not!

Behold the nearly nocturnal existence of the astronomers! This was the life of Tycho, of Hevelius, and of Flamsteed. These rigours sped the death and premature loss of the Abbé de La Caille, a master whom we still lament, and whom Science, Virtue, and Friendship lament with us. These rigours are greatest in the parts of Europe where astronomy is often especially cultivated, such as at Copenhagen, Gdańsk, London, Paris, where celebrated observers have lived, where the skies are as changeable as men. Beautiful nights are rare, and only occur in brief intervals of the year. The remainder of the nights are characterized by intermittent darkness. It is necessary, therefore, to keep intense watch for those moments favouring the observer which the fickle sky grants. Most observations are "stolen" from the jaws of these adverse circumstances. It is the observer's constancy, and zeal, but above all the cooperation of the weather that permit the building up of a body of observations leading to theory...[3]

Entering the observatory, the night commences, following the procedures of the observer, imitating his silence. One ought to hear nothing but the soft sound of the clock, there ought to be no motion other than that of the stars. One contemplates the details of things, to be prepared to seize the fleeting observational moment, which is never to return. The faculty of thought ought to be stilled, and the soul tied to the organ of sight. The shape, size, position, movement, the distance of the stars, here is what Astronomy sets to discover, and here are the means; (Bailly 1785, II, 279-283.)

Appendix

Bailly's French text is provided here:

Le bâtiment de l'observatoire est un monument plutôt de grandeur que d'utilité. L'astronomie n'a pas besoin de ce luxe, mais il est utile en ce qu'il marque l'attention & l'encouragement des Rois. Il ne faut à l'aftronomie qu'une tour ronde, assez élevée pour découvrir le contour entier de l'horizon, assez spacieuse pour y placer, pour y faire mouvoir sans gêne les instrumens nécessaires... C'est là que l'astronôme est debout, attentif à tous les phénomènes; il devient le centre du monde, le ciel roule autour de lui, & la nature est en mouvement pour se développer à ses regards...nous souhaitons que les jeunes gens, qui se destinent à l'astronomie, trouvent ici le tableau de leurs devoirs & l'emploi de leurs veilles; ceux qui ne s'y destinent pas, mieux instruits, cesseront de s'étonner, & commenceront à croire aux réponses de la nature, en jugeant eux-mêmes la manière dont on l'interroge.

Celui qui entre dans ce sanctuaire, doit être dévoué sans réserve au service d'Uranie. C'est la déesse dont il est le prêtre, & dont il rend les oracles; mais ces oracles sont obtenus, arrachés par son assiduité; il n'a de relâche que les jours sombres & tristes, les momens où la nature ajoute à tous ses voiles celui des nuages; sa journée est interrompue, coupée par différentes observations; le soleil l'occupe le matin, à midi, le soir; & lorsque cet astre disparoît, les autres planètes, les étoiles se découvrent pour amener d'autres travaux. Les astronômes souvent se les partagent, mais celui qui les embrasse tous doit avoir un corps de fer: il faut que le zele de la science l'éveille à des momens marqués dans la nuit; il faut que ce zele le défende du sommeil , s'il doit veiller pendant la nuit entière; il faut que ces veilles soient répétées, s'il se consacre au travail suivi & renouvelé toutes les nuits de l'observation des étoiles; & cela l'œil attaché à la lunette, l'oreille à la pendule, debout, ou le corps plié, souvent couché, regardant le zénith, malgré le froid des nuits & des hivers, malgré la fatigue & les dangers de l'insomnie! Voilà la vie presque nocturne des astronômes; ce fut la vie de Tycho, d'Hévélius, de Flamsteed; c'est celle qui a pressé la mort & la perte prématurée de M. l'abbé de la Caille, d'un maître que nous pleurons encore, & que la science , la vertu & l'amitié regrettent avec nous. Ces fatigues sont les plus grandes dans la partie de l'Europe, où l'astronomie a été le plus particulièrement cultivée. Coppenhague, Dantzick, Londres, Paris, où ont vécu ces observateurs célèbres, ont un ciel changeant comme les hommes. Les belles nuits sont souvent isolées, & ne *se suivent que dans quelques intervalles assez courts de l'année; le reste des nuits est couvert d'un crêpe, ou n'a que des momens. Il faut donc épier ces momens, & l'inconstance du ciel, qui devient favorable à l'observateur. La plupart des observations sont ainsi dérobées; c'est la constance, le zele, & fur-tout le tems qui les assemble pour fonder un corps de doctrine...*

Entrons dans l'observatoire, la nuit est commencée, suivons les opérations de l'observateur, imitons son silence. On ne doit entendre que le foible bruit de la pendule, il ne faut d'autre mouvement que celui des astres: on contemple les détails des choses, on veut saisir l'instant qui va s'échapper pour ne jamais revenir; la pensée doit être immobile, & l'ame attachée à l'organe de la vue. La figure, la grandeur, le lieu, le mouvement, la distance des astres, voilà ce que l'astronôme se propose de découvrir, voici ses moyens;" (Bailly 1785, II, 279-283.)

Acknowledgements

This article is dedicated to Jay Anderson, in appreciation of his successful tenure as Editor-in-Chief of this *Journal*. The translations from the French are by the author, and any errors remaining are due to his agency. This research has made use of NASA's Astrophysics Data System. RASC members who wish to consult the 18th-century volumes of Bailly's histories in the Archives may arrange to do so through contacting the Society's Archivist. ✶

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Endnotes

1 "Messier était éminemment observateur; il ne voyait rien, n'entendait rien dont il ne prît note...car il était bon, quoique sa vie laborieuse lui eût fait contracter une humeur un peu sévère; fidèle ami, sans intrigue, ponctuel en tout, comme il l'était à se présenter à sa lunette pour l'observation d'un phénomène." Delambre 1818, xcij.

2 Bailly does not have in mind modest, functional observatories, but rather grand structures erected at state expense, which also function as symbols of royal prestige, magnificence, and patronage, such as the bâtiment Perrault (1667) of the Paris Observatory (1667), or Flamsteed House at the Royal Observatory, Greenwich (1675); Wolf 1902; Howse 1975.

3 The passage from "He enjoys no respite" to "a body of observations leading to theory" is closely paralleled in spirit by the account of Bailly's training in Arago (1859, 98-100). Arago attributes the attitude to La Caille, Bailly's teacher. Amusingly enough, the 19th-century British translators of Arago objected to this austere depiction of the astronomical craft; perhaps they feared they themselves fell somewhat short of the mark."

Pen & Pixel

Figure 1 — Victoria Centre's Dan Posey collected photons for nearly five-and-a-half hours to produce this image of Messier 51 (the Whirlpool Galaxy). Dan combined 3h25m of exposure this year with 1h20m of exposure in 2013. The latest images were taken with a Canon 6D; the 2013 images were compiled using a QSI583c camera. All exposures were 5 minutes, but the total allows for a very deep look into space: Dan notes that one of the galaxies in the field has a magnitude of 21.8.

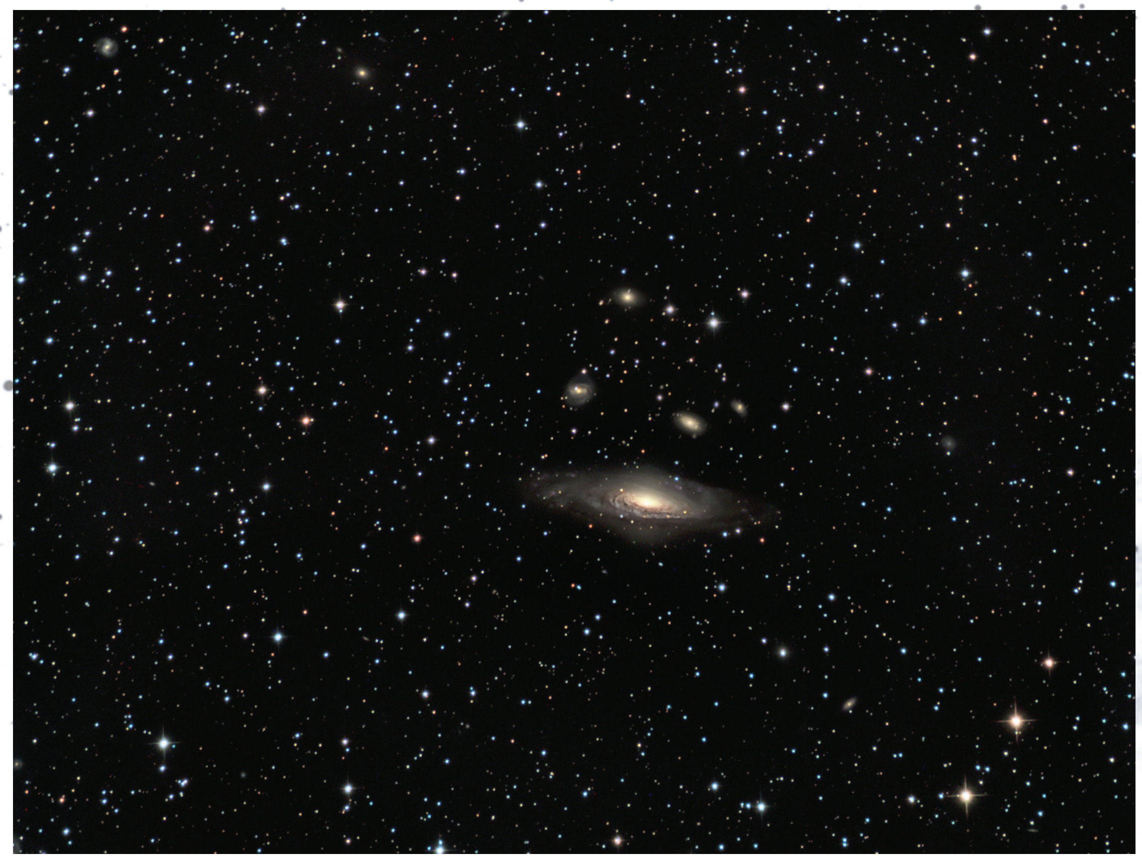

Figure 2 — Brian McGaffney of the Kingston Centre sends along this image of the Deer Lick Group in Pegasus, one of the prettiest of the sky's selection of galaxy assemblages. The bright foreground galaxy is NGC 7331, lying at a distance of about 46 Mly. The smaller galaxies lie about 10 times farther way. NGC 7331 was discovered by William Herschel; its structure is similar to the Milky Way. Brian took this image over three nights from his observatory in Bancroft, Ontario, using a 14-inch astrograph and with a modified Apogee U16m camera. A total of 28 hours of exposure in LLRGB were combined to produce the image.

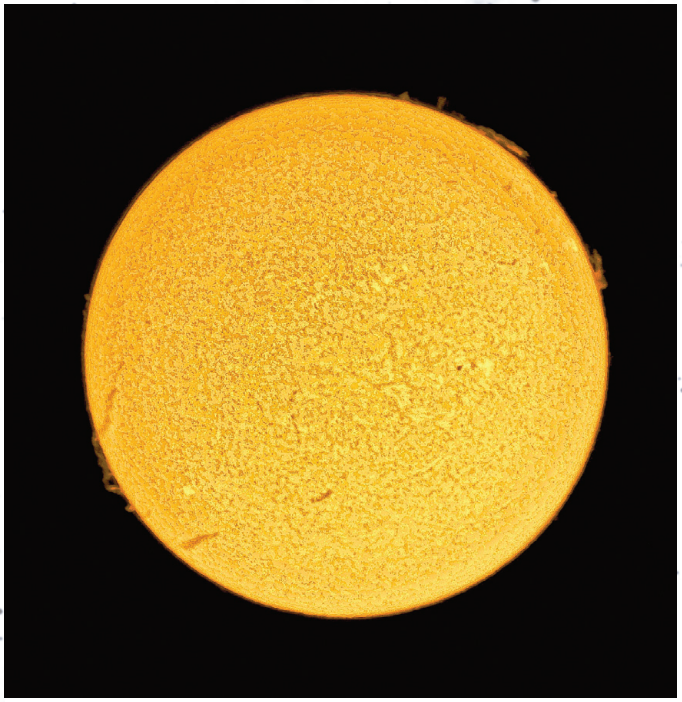

Figure 3 — Not all amateur astronomy is done at night. Winnipeg's Sheila Wiwchar borrowed a Lunt 60-mm pressure-tuned, single-stack telescope and attached a Canon 60D to trap this H-alpha image of the solar disk on May 30.

Figure 4 — Dan Meek focused on NGC 4725 and NGC 4712 in April and provides us with this deep image of the galaxy pairing. The unique one-arm spiral of NGC 4725 is visible as a ghostly arc surrounding the top and left side of the galaxy. Dan used an 11-inch EDGE SCT and a QSI583wsg camera for an exposure totalling 660 minutes.

Dan notes that "during two of the three nights, for about an hour and a half or so each night, the aurora was dazzling in the night sky. During these times, I would just shut off the camera, make a cup of hot chocolate and sit back in my chair and enjoy the show...priceless."

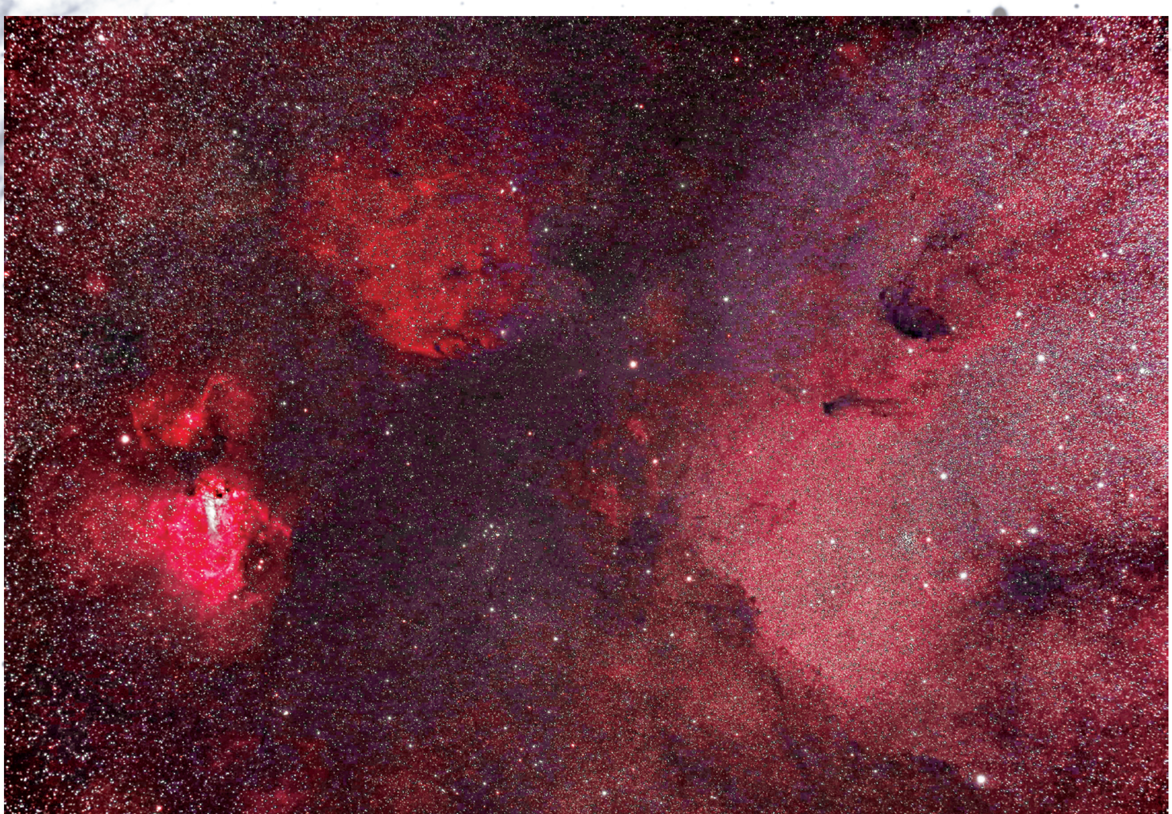

Figure 5 — Klaus Brasch took this revealing image of the central Milky Way under very clear skies using a TMB-92 telescope on a Canon 60D at ISO 3200 through an H-alpha filter. The scene includes M17, IC 4701, and M24 along with dense star fields and dark dust lanes.

Orbital Oddities

Bloody Supermoon!

by Bruce McCurdy, Edmonton Centre
(bmccurdy@shaw.ca)

> *And in my darkest moment, fetal and weeping*
> *The moon tells me a secret – my confidant*
> *As full and bright as I am*
> *This light is not my own and*
> *A million light reflections pass over me*
>
> *Its source is bright and endless*
> *She resuscitates the hopeless*
> *Without her, we are lifeless satellites drifting*
>
> *Tool – Reflections*

I'm an astronomer not an astrologer, so I'm much more about looking into the past than envisioning the future. The predictions of value to me rely on established cycles and the known laws of physics that "predict"—with extreme accuracy, I might add—upcoming astronomical events like the cycles of the Moon or the next eclipse. I'm generally not one for horoscopes, but I'm about to go outside of my usual comfort zone and predict an unusually strong public reaction to one such event, the upcoming total lunar eclipse of 2015 September 27-28.

The pending event is the focal point of several different lunar cycles that are coming together in a remarkable confluence. That night's full Moon will be:

- In total eclipse, the so-called "Blood Moon" of popular lore
- At perigee, the so-called "Super Moon" of popular lore
- The "Harvest Moon," the most famous of the named Moons of popular lore

That's a lot of popular lore. It stands to reason that somebody in the popular press might put all these things together, and if the wind is blowing a certain way, it might really take off. If social media gets hold of this thing, as I think it might, astronomy clubs and science centres planning to offer public observing of the eclipse had better be prepared to, uhh, "supersize."

The eclipse is also the final one of a tetrad of total lunar eclipses (TLEs), all visible from parts of North America. The last of these is both the longest at 1 hour 12 minutes, and at an optimum time—in the evening hours on a Sunday. The previous eclipses of this quartet occurred in the overnight or predawn hours, mostly on weeknights. While TLEs have been relatively common in recent times, they haven't been very accessible. This one is different.

Now I well understand that there's a certain amount of disdain if not resentment within the astronomical community for some of these "popular lore" types of things, especially that pesky supermoon that has become something of a social phenomenon in recent years. When I call it "recent," what I really mean is that it is about as old as the Moon itself, but only recently has it grabbed the public imagination with some snappy New Age terminology—coined, appropriately enough, by an astrologer for *Horoscope* magazine. Take it away, Wikipedia:

> *The name SuperMoon was coined by astrologer Richard Nolle in 1979, arbitrarily defined as:*
>
> *…a new or full moon which occurs with the Moon at or near (within 90 percent of) its closest approach to Earth in a given orbit (perigee). In short, Earth, Moon, and Sun are all in a line, with Moon in its nearest approach to Earth.*
>
> *Nolle also claimed that the moon causes "geophysical stress" during the time of a supermoon. Nolle never outlined why the 90 percent was chosen.*

First of all, let's dismiss out of hand the claims of "geophysical stress," which are tightly constrained and amount to so much nonsense. Let's also take a moment to ridicule the contrived threshold of 90 percent, which is not easily calculated. (90 percent of *what*, exactly? And why?) According to one source, the magic number is 361,836 km—any full Moon closer than that is "super." So it turns out we don't just get one supermoon that's closest to perigee, we get the one before and the one after as a bonus. Not exactly scientific—imagine if we marked three full Moons on our calendars on the basis that the night before and the night after the official full Moon, it is still *nearly* full, so close enough! The definitions are lax enough that there are supposedly SIX supermoons in 2015, three at new phase early in the year, three at full phase in August to October.

Underneath all that bafflegab, though, lies a fundamental astronomical principle, that of the varying distance between Earth and Moon and of the strictly regular cycle that governs it. Predict the next supermoon and impress your friends!

For our purposes, I will focus on just the perigean full Moon, and at that, just the single event in the cycle that represents its true peak and ignore those on the shoulders. We'll also ignore entirely the perigean new Moon—a "dark supermoon"—which as a visual phenomenon is a non-event except in those cases where our satellite clips a piece out of the Sun.

Full Moon supermoons, on the other hand, are as visible as astronomical phenomena can get, that don't absolutely require the use of some sort of filter. The lunar orbit is famously elliptical with a variance of about 12 percent; the extremes of that variance occur at syzygy, when the major axis of the Moon's orbit points at both Earth and Sun. Thus extreme perigees always occur when the Moon is either new or full. The Moon is closer to the observer and appears physically bigger in the sky, and at full phase is pretty much as bright as it can get. There are secondary influences from other factors that smudge the margins a bit, but a perigean full Moon is invariably big and bright.

Exceptionally so? Depends on one's point of view. While the full Moon's distance can vary on the order of 50,000 km from one extreme to the other and varies in brightness by as much as 30 percent, this variation is as regular as clockwork. The relationship between the "lunation" or synodic month (full Moon to full Moon = 29.53 days) and the anomalistic month (perigee to perigee = 27.55 days) is extremely close to a 15:14 ratio, so every 14 lunations the cycle largely repeats (Figure 1), with relatively minor variations due to secondary factors like the Earth–Sun distance.

To research the matter further, I corresponded with RASC Honorary Member Jean Meeus, a top expert in astronomical calculations. At my request, Jean graciously provided a customized table detailing the Earth–Moon distance at the moment of each full Moon for the period 2000-2020. This data forms the underpinnings for Figures 1–3.

It is worth noting that the 15:14 ratio is not quite perfect, though certainly close enough to confidently predict the next "supermoon." The true period of the alignment of Earth with the apsides of the lunar orbit is about 13.94 lunations, so very slowly, over a period of a couple of decades, the peak itself phases in and out. The famous Saros cycle consists of near-integer values of 239 anomalistic months and 223 synodic months, which could be parsed as 15 cycles of 15:14 and one "correction" of 14:13.

This brings us to the realm of eclipses. They too follow a rhythm, albeit a significantly more complex one. In the current instance, I focused on total eclipses only and ignored the rest. In the current era, total eclipses are common, typically three

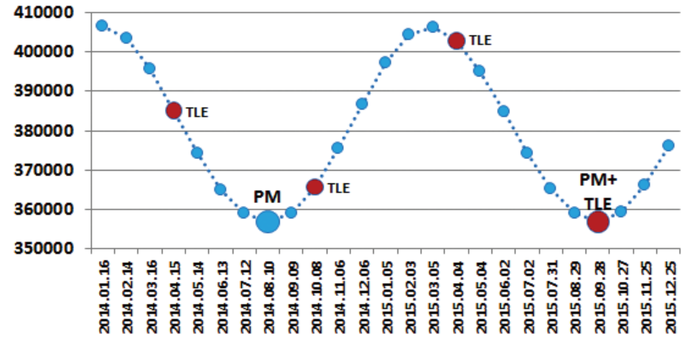

Figure 1 — The Earth–Moon distance at successive iterations of full Moon, 2014–15 adheres to a 14-lunation cycle, with the closest approaches (PM = Perigean Moon) separated by exactly that interval. The four TLEs, marked by darker circles, occur at six-month intervals with the last of them happening to fall on a perigean Moon. All data to create this and subsequent figures courtesy of RASC Honorary Member Dr. Jean Meeus, whose assistance is gratefully acknowledged.

or even four in a row at intervals of six months, followed by a fallow period (typically 29 lunations) after which they pick up again. Any short-term combination of eclipses features an interval that is relatively prime to the perigean Moon cycle of 14 lunations. This means that the distribution of eclipses seems randomly scattered across the regular in-and-out "breathing" of the perigee-apogee cycle, as Figure 2 reveals, but it is inevitable that occasionally one will land exactly on a peak, as we will experience in September.

In the 21-year period under review, there are 20 TLEs, about one a year. With a 1-in-14 chance that a TLE might fall on a perigean full Moon, we might expect to see one or two perigean eclipses in that span. In this particular period, there is one.

Similar arithmetic applies to the Harvest Moon, which occurs at the rate of exactly one a year. There is a 1-in-14 chance that it will correspond with a perigean full Moon. In the studied period this too happens just the once, with a very near miss in 2006.

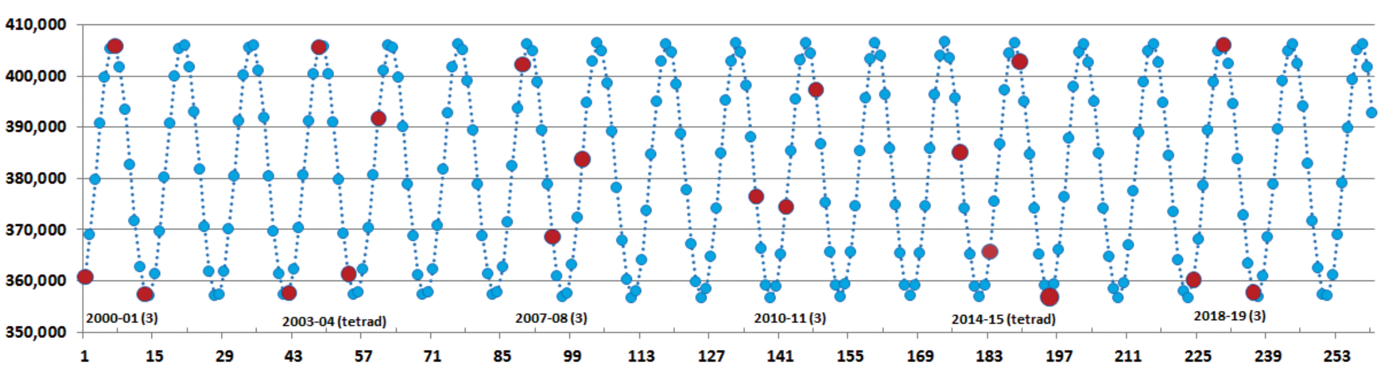

Figure 2 — The Earth–Moon distance at successive iterations of full Moon, over the longer period 2000–2020 reveals the regularity of the perigee-apogee Moon cycle. Of the 260 full Moons in the 21-year period, 20 will be totally eclipsed (larger, darker circles). Only the upcoming TLE of 2015 September 28(27) occurs at the closest approach of a given cycle, though those of 2001 January 09 and 2003 May 16 were very nearly so, as will be those of 2018 January 31 and 2019 January 21, and would qualify under the dubious category of "eclipsed supermoons." Note that a diagram for new Moons would look virtually identical (other than those eclipses), but would be flipped peak to valley; or if you prefer, offset by seven lunations.

Bottom line: none of these things are "rare." What is unusual is the confluence of three different phenomena that each occur on average about once every 12–14 months. Simple probability suggests that "Bloody Supermoons" should occur, on average, every 1½ to 2 decades, depending on the frequency of eclipses during the era in question. Throw in the additional wrinkle of the Harvest Moon and that expectation becomes closer to once every couple of centuries.

Sounds like a "once-in-a-lifetime" event, doesn't it? Not at all. The last confluence of totally eclipsed Harvest Moon at perigee occurred just one Saros ago, on 1997 September 16. A cycle caught up in a supercycle, although a third of a world away on that occasion and totally unavailable to the western hemisphere. One Saros from now, on 2033 October 08, the Moon will again be at perigee and in eclipse, but the date is too far removed from the autumnal equinox for it to be a Harvest Moon. The next such triple coincidence might not occur for several centuries into the future, though I did not explore the matter. ✶

Dedication: *This column is dedicated to Jay Anderson, outgoing JRASC Editor after ten years of volunteer service to the Society at this position. Jay has provided guidance, column ideas, encouragement, and timely kicks in the butt in equal measure. I thank him especially for his patience with a columnist who is both a detail-obsessed perfectionist and perpetually tardy.*

Bruce McCurdy is marking his 30th year as a member of RASC's Edmonton Centre, and his 29th as a volunteer at the Public Observatory of Telus World of Science – Edmonton. He has contributed Orbital Oddities to JRASC since 2000, with the above representing the 50th iteration of this column.

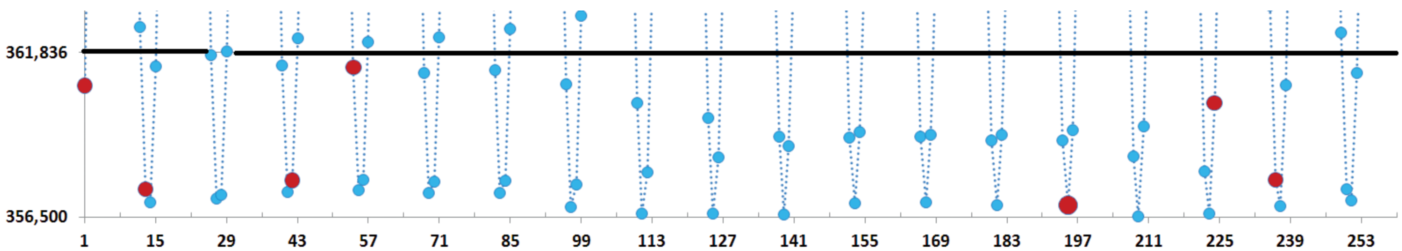

Figure 3 — A close-up of just those full Moons in the period 2000–2020 that achieved "supermoon" status, an arbitrary designation covering any full Moon closer than 361,836 km. This loose definition yields three successive "events" every 14 lunations. Note the slow evolution of the placement of the data points, as the 14-month cycle is not quite perfect. TLEs, which follow different cycles, are randomly scattered throughout.

Second Light

Hot Jupiters and Atmospheric Evaporation

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

The term "hot Jupiters" was coined for planets like 51 Peg b that orbit very close to their parent stars—sometimes within ten stellar radii of the star. This close orbit raises the possibility that they could lose some of their atmospheres because of the extreme irradiation. In fact, this was quite a worry for me when the paper by Mayor & Queloz reporting the discovery of 51 Peg b was submitted to *Nature*—would such an atmosphere be stable over the lifetime of the star? (The answer is yes.) In 2003, Alfred Vidal-Madjar and his colleagues reported the detection of an extended atmosphere around a hot Jupiter (*Nature* volume 422, p. 143), although part of that interpretation was later challenged, with a controversy extending to today. Comparable "Hot Neptunes" are much smaller planets, meaning that the atmosphere is less tightly bound by gravity, and there was a theoretical prediction that the loss of atmosphere could be seen in ultraviolet observations of transits. David Ehrenreich of the Geneva Observatory, and his colleagues (including Vidal-Madjar) made the observation of the transit of GJ 436b, a hot Neptune-type planet, and found the signal of the occultation to be far stronger than expected (see * June/July issue of *Nature volume 522, p. 459*). The "depth" of the transit was an astonishing 56 percent, compared to ~0.7 percent in the optical, and it lasted at least five hours, against one hour in the optical. They actually are not sure how big the cloud is, as they have not yet seen the end of the transit.

The story begins back in 2003, when Vidal-Madjar and his colleagues were observing the transit of the planet HD 209458b in the ultraviolet and saw an absorption signal in their spectra. In order to determine where the absorption was

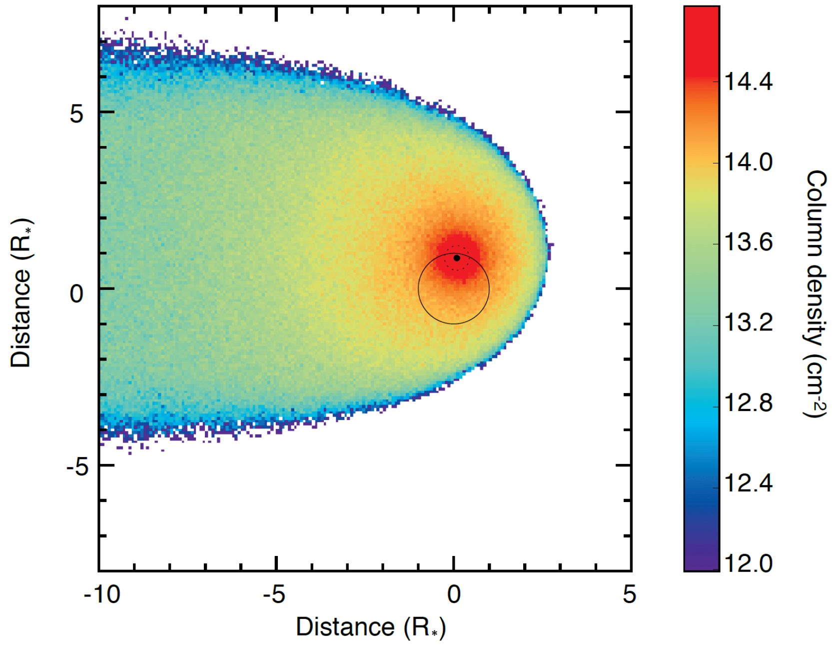

Figure 1 — A simulation showing the cloud and planet transiting the star, as seen from Earth (which is to the top of the figure). The star is indicated by the large black circle, with the planet as a small dot at 0.85 stellar radii at mid transit. Figure courtesy of David Ehrenreich and Nature.

taking place, they had to subtract stellar geocoronal emission (they used the *Hubble Space Telescope*, so no atmospheric corrections were necessary). The resulting analysis led them to conclude that some of the absorption was taking place beyond the point where hydrogen atoms are gravitationally bound to the planet, meaning that the atmosphere was both extended and escaping. They concluded that the puffing up and loss was being driven by radiation from the star. The loss rate, however, was sufficiently low that the planet would lose only a small fraction of its atmosphere over the main-sequence lifetime of the star.

The dispute arises from the fact that the hydrogen atoms seen by Vidal-Madjar were travelling at high velocity relative to the planet. In 2008, Mats Holmström argued that the high-velocity atoms could be explained by a phenomenon known as "energetic neutral atoms" (*Nature* vol. 451, p. 970). The stellar wind is mainly ionized hydrogen (protons), moving outward from the star at ~100-150 km/s, and when those protons interact with the planet's "exosphere" (the very diffuse extension of the atmosphere that exists around all planets with atmospheres), a charge exchange reaction happens whereby the protons pick up electrons, and are slowed down. Holmström further argued that the stellar radiation was insufficient to make the planet's atmosphere so extended.

There was a criticism of Holmström's paper from Vidal-Madjar's group in Paris (*Nature* 2008, vol 456, E1), to which Holmström replied (same reference), and a further criticism of Holmström by Ehrenreich (*Astronomy & Astrophysics* 2008, vol 483, 933). The controversy has continued. Science in action can be messy.

GJ436 is an M dwarf star with a radius just under half that of the Sun. The planet's orbital radius is ~0.03 AU. It is about four times bigger than Earth, and quite cool, with a temperature of just ~700 K (contrast this with a temperature of ~1100 K for HD 209458). The planet transits the star every 2.64 days, with a transit time of (as I said earlier) about one hour in the optical. Its orbit is quite eccentric, such that it grazes the stellar disk at closest approach.

Ehrenreich and his collaborators used the *Hubble Space Telescope* and observed three transits. Setting up the observations is tricky, because the HST's orbit is 96 minutes, only 56 minutes of which can be used for the transit before the star is occulted by Earth. During the transit, they found that over half of the stellar disk is covered. The ultraviolet transit starts two hours before the optical one, and ends at least three hours later. They conclude that the planet is surrounded by a comet-like cloud of neutral hydrogen. Because the radiation from the M star is much less than for hot Jupiters around solar-type stars, the associated radiation pressure does not strongly confine the atmosphere, and so the planet has come to be surrounded by a "coma" and "tail" of escaping atoms that are moving together with the planet, but not gravitationally bound.

The authors calculated the loss rate, and found that the planet loses ~0.1 percent of its atmosphere every billion years. If the M star was more active in the past, then the planet might have lost up to ~10 percent of its atmosphere over its lifetime till now. Ehrenreich then concludes that hot Neptunes that are closer to their parent stars could lose most or all of their atmospheres, perhaps turning them into bodies similar to the super-Earths that have been seen.

Ehrenreich's results are so striking that there can be no doubt that the planet is surrounded by a huge cloud of gas. Whether that settles the controversy around HD 209458b is not so clear. However it turns out, it's fun to watch science in action. ✶

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

Binary Universe

SkySafari Plus

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

With the recent announcement of the Ocumetics bionic lens, along with other wearable optical technologies, augmented views of the night sky might soon be commonplace. In turn, memorizing constellations and bright stars may become a thing of the past. Imagine being able to just look up and see patterns highlighted with the names of stars and planets hovering in our field of vision. Over there, look, a new bright comet!—and if you get the telescopic option installed, then, well…

OK. Yeah. Yeah, but no. The day that your local optician upgrades you from the Mark I eyeball is probably still a way off. In the meantime, you can use "sensing" planetaria on a portable device.

There is an ascension of astronomy apps for smartphones and tablets (a number of which, in the future, I hope to cover here). Probably the best-of-breed for planetarium applications is *SkySafari*. It was *PC Magazine*'s Editors' Choice on more than one occasion. It has 4.6 stars out of 5 (no pun intended) in the Google play store. I will discuss the "Plus" version of the phablet app. The screen snapshots here are from an Android tablet with a 7-inch screen.

SkySafari (SS) is a remarkably powerful tool. As I use the application more and continue to learn its features, I grow increasingly impressed. How did they pack so many capabilities and options and text and photographs and graphics into a software program that runs on my modest Android tablet?! I did not think this possible on a small device (that nearly fits in my pocket). I think this is incredible.

Perhaps I am viewing *SkySafari* from an unfair perspective. My expectations might be out of reach. What I mean to say is that I have used a lot of planetarium applications on *full* computers. The bar is high: *Stellarium*'s eye-candy on a big Macintosh; *SkyTools* on a dual-monitor Windows quad-core workstation; *TheSky* precisely driving a Paramount ME; attractive *XEphem* on my Linux box; the to-the-point, fast *Cartes du Ciel* with rich charts.

I can't help but compare a new planetarium app to those I've used, and continue to use when at my desk. Is it accurate? Does it show double stars? Does it show data about objects (*e.g.* distance, orbital period, stellar class)? Can it simulate a telescopic field of view? Can it go into red mode? Can it simulate eclipses? Can it measure angular separation between

Figure 1 — SkySafari chart with Milky Way, constellations, constellation abbreviations, Saturn selected.

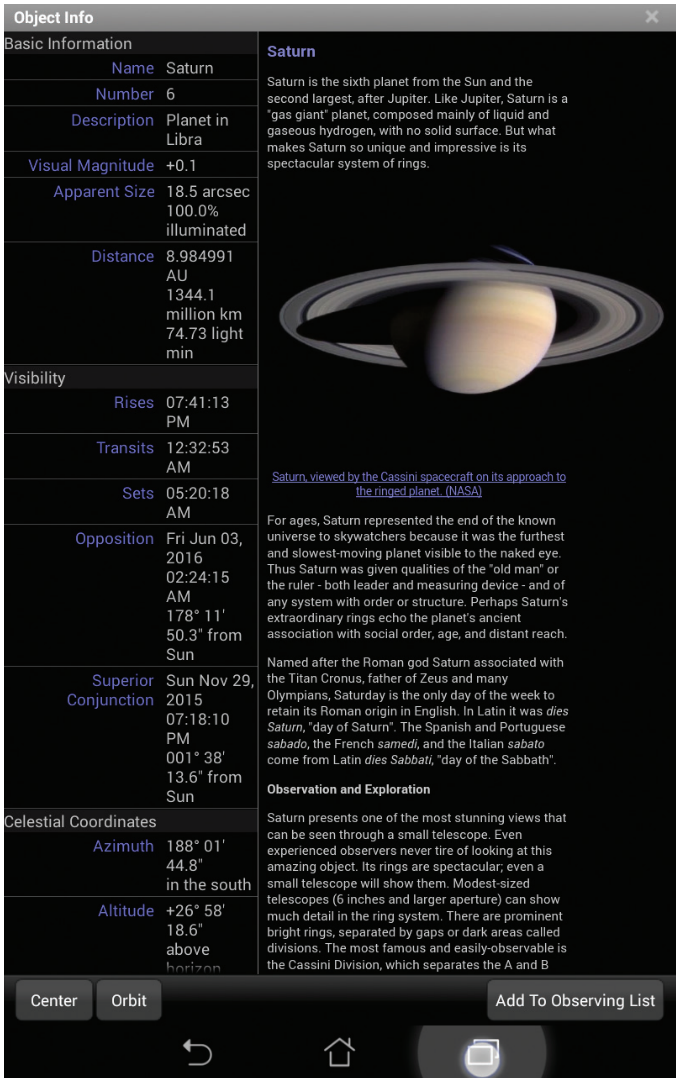

Figure 2 — Object Info screen with object details, verbose text, and photograph.

objects? Are the catalogues or databases deep? Is it easy and fun? It is fascinating to me that *SkySafari* passes these tests and then goes beyond with a number of unique features.

SS+ presents a realistic view of the night sky with shimmering Milky Way and skyglow over selectable panoramic landscapes. Out of the box, I find the presentation of stars very good, not too bright, not overly saturated, just a slight glow. Zoom in or out rapidly with the + or – buttons or, of course, pinching on the touchscreen. More stars and fainter stars appear naturally when zooming in. Clusters, galaxies, and nebulae wink into view. As one zooms into planets, they reveal their phase, surface details, atmosphere, and nearby moons. Comets show their tails. When you zoom into deep-sky objects, photographic images will appear, smoothly fading in and blending.

You can easily change the date and time in the app. With the *Time* toolbar at the bottom of the screen, you can go forward or backward incrementally by minute, hour, day, month, or year, in the number of units you specify. Via the *Settings* button, you will find convenient buttons for sunrise, sunset, dusk, *etc.* Touch *Now* for a real-time display.

Tapping on an object shows a cross-hair and its name. If you miss, try again; tapping a second time in the area makes the app choose a nearby object. Briefly, the name, an alternate name, the current magnitude, and the type of object shows in the title bar, along with the host constellation.

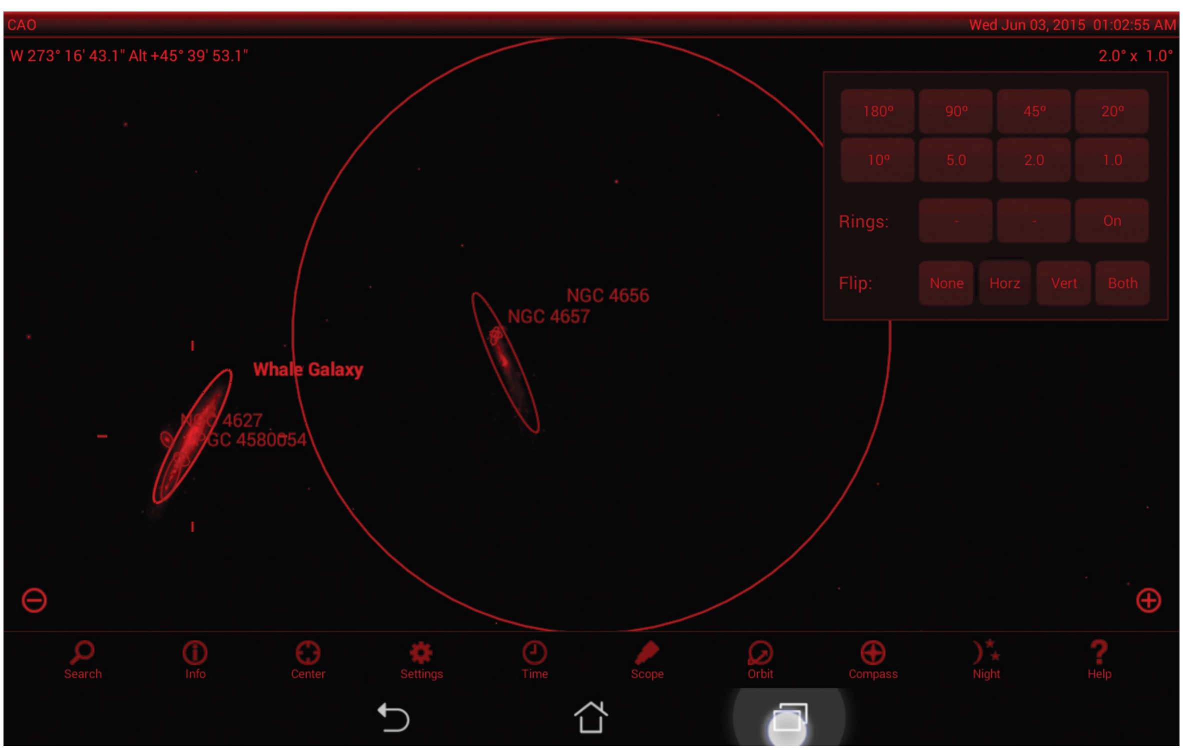

Figure 3 — Chart in red light mode, 1° field-of-view eyepiece circle, zoom/field panel.

Tapping the *Info* button or double tapping the item brings up the *Object Info* panel with an extraordinary amount of information with lengthy text descriptions along with some hyperlinks. Stars show with designations from other catalogues, such as the Draper, Harvard Revised, Flamsteed, Tycho, Struve, and Washington Double Stars. That alone is fascinating to me. It's very good cross-referencing and speaks to the ease of searching. Variable-star brightness ranges and periods as well as double-star separation and position angle are noted. Catalogues for galaxies include the UGC, PGC, and MCG. Distance in kilometres, astronomical units, light time, and/or parsecs is shown. I like how it uses light-minutes for nearby Solar System objects. Physical and orbital characteristics like the absolute magnitude, size, density, mass, eccentricity, and so on are noted. Planets, moons, and deep-space objects also include photos.

The *Search* feature is very robust. It supports browsing by object type or searching by word or text fragment. Choosing an object for the list drops you into the *Object Info* screen. If you tap *Center*, it will switch to the chart and highlight the object in the sky. Listed objects can be added to a list of objects you plan to observe that evening.

As much as I like the wide field, naturalistic views of the night sky, I also enjoy emulating the view in the eyepiece, and as I fumble and stumble into astro-imaging, I like being able to see a rectangle that mimics the camera chip. Happily SS+ does all this along with the Telrad circles. That said, it doesn't do the math. You need to know, or calculate, your ocular true field of view or camera field dimensions in degrees and enter those values.

It took me a while to find—extensive *Help* screens to the rescue—the ability to flip the field horizontally or vertically. Tap near the top-right corner of the screen to display the panel with zoom, field of view "ring," and view orientation buttons.

SS+ lets you choose locations from an extensive geographic database. You may also create custom locations for your favourite observing sites. Of course, it can detect your current location from the tablet.

Again, SS+ does some things I have only seen rarely in other apps. It can show the sky chart, for example, in white-on-black, an inverse scheme, which in some cases, aids the human eye in spotting faint fuzzies. When viewing the details of a star, I like how SS+ shows star temperature in Celsius and Fahrenheit, in addition to Kelvin.

Another unusual aspect of SkySafari is the voluminous data on constellations. Yes, it can show the stick-line figures but you can choose the modern or classic style. You can show full names or abbreviations. Constellation boundaries can be displayed as outlines, but I like that when you tap in empty space, the constellation area is highlighted. The text information on constellations is impressive, delving into history and mythology, notable stars, and enclosed deep-sky objects.

SkySafari Plus has a very nice feature called *Tonight's Best*. This is accessed via the *Search* command and automatically lists noteworthy objects to view in the evening. As in a standard search, bolded items are objects well above the horizon; dimmed items will appear later in the night. When you tap the *Highlight Objects* checkbox, the featured objects are circled in the star chart, making them very easy to target and hopefully spot. This option is especially handy for star parties or when guiding the neighbours through the celestial wonders.

SkySafari is clearly very capable, with good charts and detailed object information close at hand. Still, that's not the reason I sprang for the app.

My favourite aspect of these types of portable software tools is that they can use the phablet's built-in sensors, like the compass, radios, and accelerometers, so it knows where ***it*** is and where ***you*** are aiming it. Make sure the time is set to *Now*, then shake your phone or tablet to trigger the live view. With this dimensional data, the display then shows you a labelled, demarcated version of the sky overhead, where you're looking, quickly answering perhaps the most common question of the night sky: what is that?

Equally compelling is the ability to find an object. When the *Compass* mode is active, perform a *Search*. An arrow will appear on the sky chart nudging you in the right direction. Twist and turn, reduce the size of the arrow, closer, closer, there! Look up! Easy-peasy.

To really impress your friends and family, on spotting a bright, non-blinking point of light smoothly sliding across the sky, aim *SkySafari* at the UFO, and a label for the man-made satellite will appear near the slowly moving green point. That is very slick.

I know the sky pretty well, but I have used the app on a number of occasions to confirm what I was seeing or to correct an assumption or to help me when I'm "turned around." I'm learning new tricks! For example, last night, as I walked home from the subway, I took in the dark blue sky from the tree-lined street. A few stars were visible from the city, less than normal with the darned full Moon in my face. I looked up and noted a very bright yellow-orange object. Way too high, too far from the ecliptic, for a planet. Hints of the Big Dipper's handle nearby. I held the tablet overhead. I thought so: it was Arcturus, but it was so bright! *SkySafari* told me it was magnitude 0.2. Ah, OK, made sense. Clearly it was a mag 3 sky and Arcturus was popping. Questions, brief confusion, instantly resolved.

In lieu of augmented fields in my bionic eyes, I find *SkySafari* an outstanding tool when outside and taking in the sky.

The powerful app is available for the iOS platform, *i.e.* for your iPhone, iPad, and iPod Touch as well as Android-based devices. There are three versions of this mobile app. The "basic" version is very inexpensive and is a great tool for the new amateur astronomer getting started or the kids getting into science or the binocular astronomer. It has 46,000 stars down to magnitude 8 and over 200 deep-sky objects. It costs less than $3.

Figure 4 — Chart showing Tonight's Best objects circled, also constellation area highlighted.

The highly accurate Plus edition includes 2.5 million stars down to mag 12, over 30,000 deep-sky objects including all the NGC and IC objects. It also lets you orbit around Solar System bodies and watch double stars move about their shared barycentre. Observing session planning and logging is possible at this level. In addition, Plus offers telescope control (which I have not yet tried). $15.

The Pro level takes it to an incredible "extreme." 15 million stars to mag 15. Beyond the limits of an 8-inch instrument! Three-quarters of a million deep-sky targets for your viewing pleasure. Over a half a million objects in our home Solar System. Wow. Pro also includes high-resolution maps of our Moon and Mars. All in your purse or (large?) pocket. Amazing, but it comes at a price as one of the more expensive mobile apps, $40—and there's the hidden cost of a bigger memory card...

If you use Apple devices at home and on the road, there are also MacOS X versions optimised for the big screen and a mouse.

A special note is due if you're going to take the plunge: carefully consider the version that best suits your needs; upgrades to higher versions are, generally, not an option.

http://skysafariastronomy.com/index.html

Surf into the Simulation Curriculum for more information, prices, *etc.* Does that company name sound familiar? A couple of years ago, *SkySafari* was bought by the company that makes *Starry Night*, yet another powerful planetarium simulator.

SS+ is a fantastic tool for all levels of astronomers and appropriate for every member of the family. People new to the hobby can find things and learn the sky. It is a very accessible tool at star parties. Some are using the app as their mount controller, slewing to objects of interest, easier and faster than using the stock hand controller. All in a convenient, compact package. For those with a good, modern smartphone looking for a decent, accurate planetarium app, you can't lose with this.

I recently purchased the Plus edition of *SkySafari* for my new ASUS tablet. Lots to learn (and read!) but I'm really enjoying it when I'm out and about. Already it has proven itself to be well worth the fee. My favourite part? It helps immediately, after a few taps, answer questions like, What is that? Where is it? How far away is that? ✶

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

Maker's Minute

Using an LCD Display for a Simple Power Monitor

by Rick Saunders, London Centre
(ozzzy1@gmail.com)

Since I started writing these Arduino articles, I've received emails asking about the use of displays with an Arduino, and a few have asked about splitting the power monitor out of the anti-dew unit and adding a display. In this article, I'll cover both. This inexpensive and (potentially) powerful power monitor can be put together for a few dollars and an hour or so using "Cheap Stuff from China."

This project will test and display the current draw of a homemade, anti-dew strip and the voltage coming from an AC adapter that delivers 12.2V with no load. The strip is comprised of a handful of resistors wired in series to give a total of 9.5 ohms. Ohm's Law says that this should, using 12.2V as a power supply, draw 1.28 amperes. The values read by the project will be shown on an LCD character display.

The display I chose for this project is a 16-character by 2-line part implemented as a "shield." This is a small board that plugs directly onto the top of an Arduino. Using a shield is no different than using a "bare" display electronically; the mounted shield is shown in Figure 1. You can't see the Arduino itself under the display board. I've soldered some pin-headers onto this one to allow wires from the sensors to be plugged in.

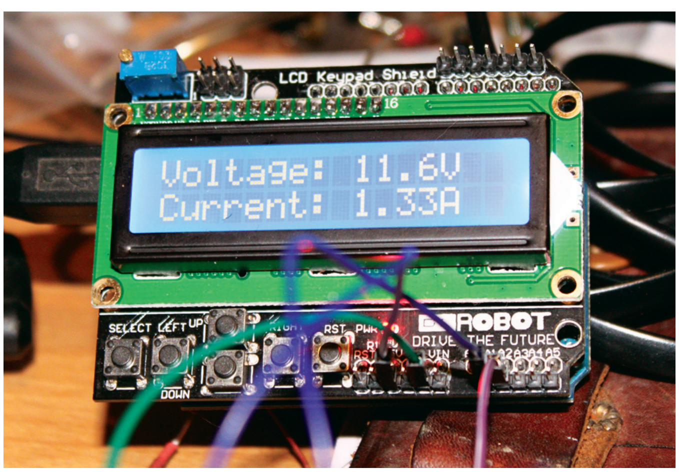

Figure 1

The leads coming up from the sensors (out of the picture at the bottom) provide the sensor circuit with 5V and ground. The two leads bringing in data from the sensors connect using the jumper wires just below the "ROBOT" artwork on the display. The USB cable powering the Arduino exits to the left.

This display has six buttons available (to the lower left, below the display window: select, left, up, down…) that can be used for just about anything but are difficult to get to if one puts the device into an enclosure. Along the top-right edge of the display are seven pin headers that can be used to control things such as LEDs or switches to turn things on or off. One use might be to shut off the load should the power not be within spec (short circuit, *etc*.).

Notice that even though 12.2V is provided to the circuit, the monitor is showing 11.6. This is due to the voltage drop along the wires I'm using (they're very small gauge) and the load of the anti-dew heater. That's normal.

As I noted, one doesn't have to use a shield with a display on it. Any "Arduino Compatible" display on eBay will work. The "standard" character displays sold on eBay are almost all driven using a Hitachi HD44780 controller, and the shield I used (Figure 2) is no exception.

A "bare" display looks like the one in Figure 2 with just a row of through-holes along the upper left edge where wires that will run to Arduino pins are connected. Some displays come equipped with a small board attached to the through holes that connects to the Arduino using a serial schema called I2C (inter-integrated circuit... pronounced I-square-C). This type frees up some Arduino pins for other duties. A standard 4-bit display is shown in Figure 3, running on the breadboard controlled by a little Arduino Nano.

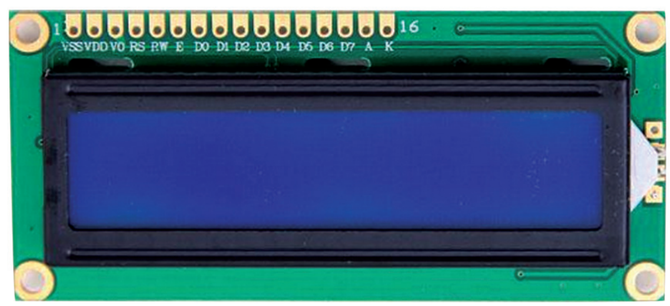

Figure 2

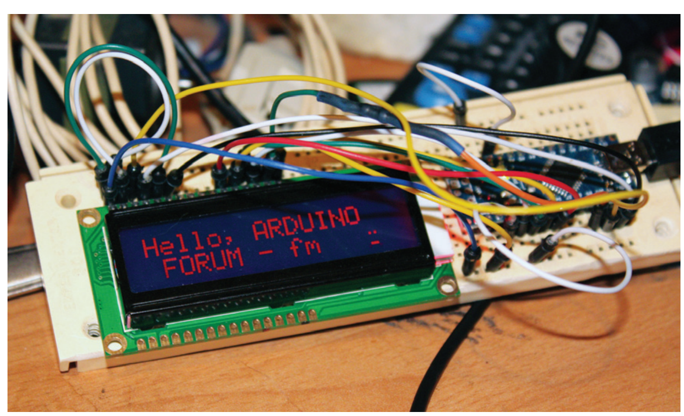

Figure 3

The program below dictates which Arduino pins control the display, and in the code I've provided, that line is:

```
LiquidCrystal lcd(8, 9, 4, 5, 6, 7);
```

This initializes the display with the following parameters:

```
lcd(rs, enable, d4, d5, d6, d7)
```

The arguments—rs, enable, d4, d5, d6, d7—are the names of the pins along the top of the display in Figure 2. Only four of the data lines are needed so d0 to d3 can be omitted. The "rw" pin can be tied to ground and therefore omitted. The shield (as used) is initialized using "rs" connected to Arduino pin 8, "e" connected to Arduino pin 9, and d4 to d7 connected to pins 4 to 7. The other pins used are Vss (ground), Vdd (+5V), V0 (contrast voltage), A (back-light anode) and K (back-light cathode). The back-light is simply an LED. I connect A to a PWM pin through a resistor to control the brightness and V0 to another PWM pin to control contrast.

The sensor circuits

The voltage sensor is the same as in the anti-dew project: a voltage divider comprised of a 2000-ohm and a 1000-ohm resistor. The layout is 12V—>2000—><—1000<—ground with the junction connected to an Arduino analogue pin.

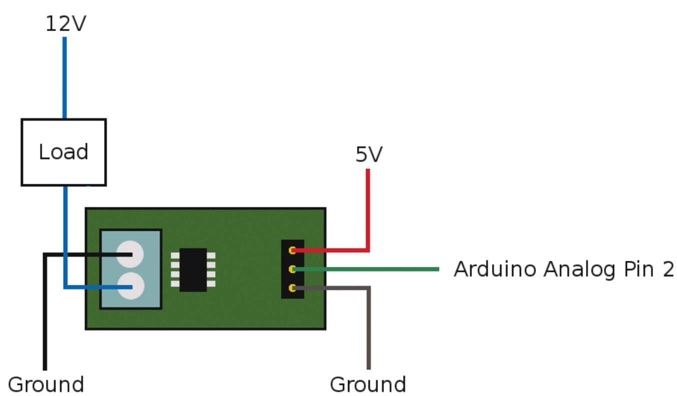

Figure 4

The current monitor for this project is an ACS712 Hall-effect chip on a "breakout board." These chips come in a few flavours: 5A, 20A, and 30A. For very small currents, the 5A part works best, as it has better resolution. The 30A part for is fine for monitoring the currents over 1 ampere that amateur astronomers generally work with. If you're ordering on eBay, make sure that you get the one you need.

The ACS712 board has five connections (Figure 4). Three are standard pin-headers and are used to power the chip and send data to the Arduino; two are for the sensed-current. The three pins on the right of Figure 4 connect to Vcc (5V), ground, and an Arduino analogue pin (in this case A2). The load is connected to ground through the sensed-current screw connectors.

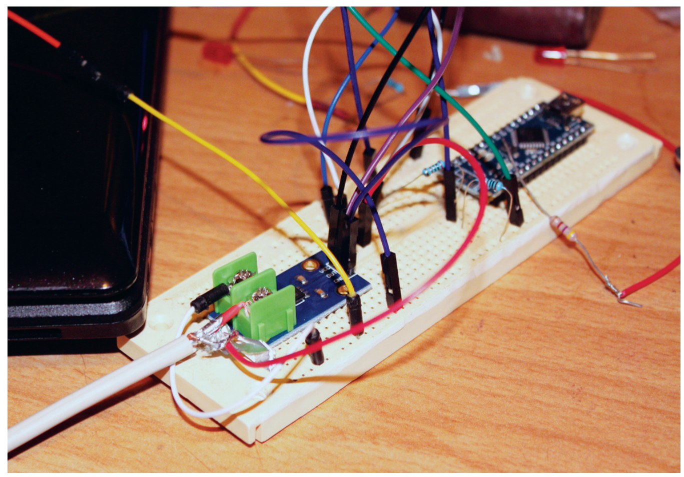

Figure 5

The chips send a voltage to the analogue pin on the Arduino with a resolution of 66mV per ampere. As with the voltage divider, the return is a count number from 0 to 1023. To return the actual current sensed, some more math is needed:

Current sensed = (512 – number of counts) * (5/.066) / 1023

The first part is due to the fact that the chip is bi-directional and 0 amps would be the ½ way point, which is at 512 counts.

The breadboard in Figure 5 may look a bit confusing but it's fairly simple. The ACS712 board is the blue board at the bottom left (a spare Arduino Nano is on the other end of the breadboard). The load (my anti-dew strip) is attached to the thick wire leading to the bottom left in the graphic. 12V power comes in from the upper left. You can just make out the two resistors of the voltage divider behind the cluster of jumper wires to the right of the blue ACS712 board. The display is out of the picture to the top.

The device has two sensors connected—one monitors the voltage and the other monitors the current draw. The first is a simple voltage divider made from two resistors and was described in my anti-dew article.

Now, the code to get it all working. Fortunately, it's simple and is provided. It's fairly easy to follow and, after looking at the instructions above, you should be able to figure it out nicely. ✶

Rick Saunders became interested in astronomy after his father brought home a 50-mm refractor and showed him Saturn's rings. Previously a member of both Toronto and Edmonton Centres, he now belongs to the London Centre and is mostly interested in DSLR astrophotography.

```
#include <LiquidCrystal.h>          // the LCD driver library
#include <floatToString.h>          // the convert-a-float library

LiquidCrystal lcd(8, 9, 4, 5, 6, 7); // initialize the LCD

float total = 0.0;              // Running current total
float curNow = 0.0;             // The reported value
char outStr[17];                // Formatted output string

void setup() {
      lcd.begin( 16, 2 );       // start the library
      lcd.clear();              // clear the display
}

void loop() {
      // read the two sensors then wait half a second
      for ( int a = 1; a < 3; a++ ) { readValue( a ); }
      delay(500);
}

// read the values
void readValue( int sensor ) {
      float readVal;                  // the actual voltage or current
      char valStr[7];                 // above turned into a string
      int readValue = analogRead( sensor );
      switch( sensor ) {
            // read the voltage
            case 1:
                  readVal = readValue / 1023.0 * 15.0;
                  floatToString( valStr, readVal, 2 );
                  sprintf( outStr, “Voltage: %sV”, readVal );
                  break;
            // read the current
            case 2:
                  readVal = ( 512 - readValue ) * ( 5 / .066 ) / 1023.0;
                  floatToString( valStr, readVal, 2 );
                  sprintf( outStr, “Current: %sA”, readVal );
                  break;
}
// clear the line of the previous data
lcd.setCursor( 0, mode - 1 );
      lcd.print( “       ” );
      // display the new data
      lcd.setCursor( 0, mode - 1 );
      lcd.print( outStr );
}
```

Dish on the Cosmos:

Whence Came the Globulars?

by Erik Rosolowsky, Department of Physics, University of Alberta

Globular clusters are classic deep-sky objects for astronomers. There are 29 globulars in the Messier catalogue with most visible during the northern summer. In addition to being a popular target for optical telescopes of all sizes, they present several mysteries worth unravelling. These clusters are often described as being "red and dead"—"red" because they are dominated by red low-mass stars and red giants, and "dead" because they have no signs of ongoing star formation. Measurements of their age indicate that these clusters were formed early in the Universe, with most being formed roughly at the same time as galaxies: about 12 billion years ago. They stand out because they are found above and below the plane of the Milky Way and so are unobscured by the dust in the galactic midplane. This clear view makes them popular deep-sky targets.

Like other stars and clusters in our galaxy, the clusters are orbiting around the collective mass of the Milky Way. Most stars orbit in the same direction, forming a well-organized galactic disk, but globulars have orbits running in all directions. Why do they have such jumbled orbits? In addition, globular clusters are huge as far as clusters go. They can have millions of stars, while a typical cluster formed in the disk of the Milky Way today would include only thousands. Since we see star clusters forming in the Milky Way and nearby galaxies, are there star clusters forming today that will eventually age into being globular clusters?

Their unique features suggest that globular clusters formed under special circumstances that are rare in the current Universe. Globulars are thus fossils of a bygone cosmic age. In my last column, I discussed how gravitational lenses gave us a view on this same early period in the Universe. During that time, clouds of gas were assembling to form galaxies and the properties of this gas led to a boom in the globular-cluster formation. Even with the best telescopes of today and tomorrow, we will not be able to see how those clusters formed in detail because of their great distances. However, astronomers have been hunting for globular-cluster analogues that are forming now in nearby galaxies. Finding such clusters would give us a "local" laboratory in which to examine how star formation proceeded in the distant past. Unfortunately, these young clusters must be rare, or else we would have found several of them already. Identifying such clusters should be easy: we need to find millions of stars, including young stars, in a relatively small volume 30 light-years across. To give an idea of how dense and bright such a cluster should be, if Earth were in such cluster, there would be 1000 times as many stars in the sky (Figure 1)!

The *Hubble Space Telescope* has found a few candidates in the local Universe that astronomers have taken to calling "young massive clusters," having long since run out of clever names. These systems aren't quite massive enough or dense enough to become globular clusters. If these modern analogues could become globulars, we should see globulars with a range of different ages instead of a rather narrow age range around 12 billion years. We suspect that many young, massive clusters may form over the lifetime of a galaxy, but most of these clusters are stripped away to nothing by the collective tides of the surrounding stars. If a cluster were massive enough and dense enough, it could last for billions of years and be seen as a globular in the far future.

These young, massive clusters also point to where we can hunt for the proto-globulars. The new clusters are found in galaxies with large quantities of gas crammed into a small volume. The gas-rich centre of our own Milky Way hosts a few young, massive clusters, but none are found in the sedate backwater of the disk where the Sun currently orbits. The Milky Way's young, massive clusters are still relatively low-mass. Searching farther afield, we can look for galaxies that are exceptionally gas-rich as hosts for these proto-globulars.

Galaxy collisions and mergers produce the most extreme collections of star-forming gas. The closest major galaxy

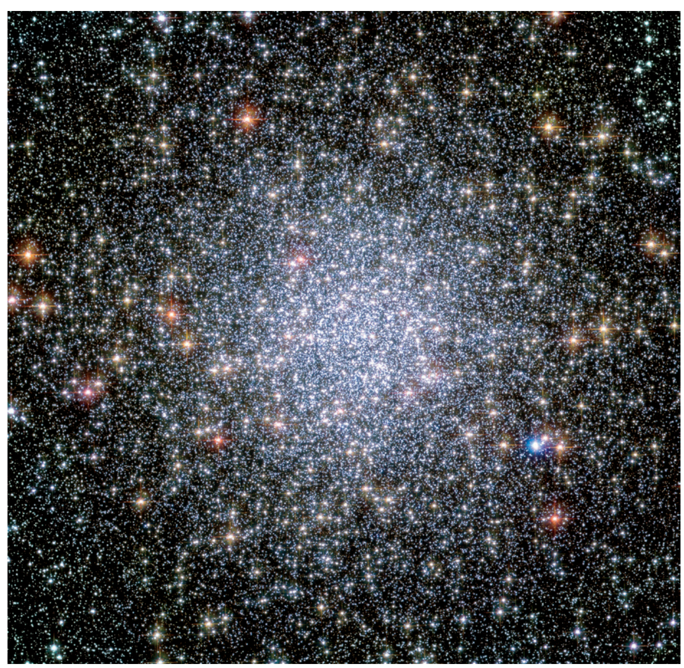

Figure 1 — A Hubble Space Telescope *view of the centre of the nearby globular cluster 47 Tucanae. This image shows the huge density of stars in globulars and shows what a night sky would look like if Earth were found in such a cluster. Image credit: NASA and ESA*

collision that is going on near the Milky Way is called the Antennae (Figure 2, top panel). This colliding pair hosts several young, massive clusters. Notably, the system is also gas rich and appears to host many of the clouds that will then go on to form new clusters. Playing a hunch that the gas could tell us more about globulars, astronomers in Charlottesville, Virginia requested some time using the Atacama Large Millimetre Array (ALMA) to study the properties of this gas. Using ALMA's excellent resolution, they found many star-forming clouds with properties a little more extreme than those found in our own galaxy (Figure 2, middle panel). However, buried in the mire of these clouds, they found something new: an incredibly compact blob of dense gas (Figure 2, bottom panel). Even with these ALMA observations, we cannot definitively measure the blob's size, only limiting it to be smaller than 70 light-years. This still means it could be compact enough to become a globular. Its mass is over 5 million solar masses, also pointing to having enough material to form a dense cluster. What makes this find particularly lucky is that such a blob of gas should collapse within a million years. While this seems absurdly long from a human perspective, it is short on a cosmic timescale. The short times are also a clue to why we haven't found such systems before. The blob of gas is also devoid of all signs of star formation, another hallmark of the system's youth.

The Antennae also provide some clue as to why we don't see such blobs in our galaxy. The environment where this blob of gas is found has an extremely high pressure, though this is only a relative statement. The "high pressure" region is comparable to the best vacuum systems we can build here on Earth. When this pressure acts on a cloud, it is enough to confine the gas into a proto-cluster. Such high pressures aren't found in most galaxies but are relatively common in merging systems. Since mergers were far more common in the early Universe, this helps explain why so many globulars were formed then and why new globulars are not easy to find.

This is another discovery that was impossible before ALMA. The location of the Antennae in the southern sky combined with the distance to the system prevented previous millimetre-wave telescopes from seeing the formation sites of young, massive clusters in mergers. Even though there is a huge amount of gas in a cosmically tiny region, it remains cold—only ten degrees above absolute zero—so it cannot be seen in any other kind of light. I also have a personal connection to this story. One of the lead scientists on the team, Adam Leroy, was my officemate in graduate school. We have been talking about the quest for proto-globulars for over a decade. As we meet up over the years, we always discuss the steps up the ladder of discovery that have culminated in this work. I am happy to see how hard work and the long pursuit of this question has turned into new insights and understanding about 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.

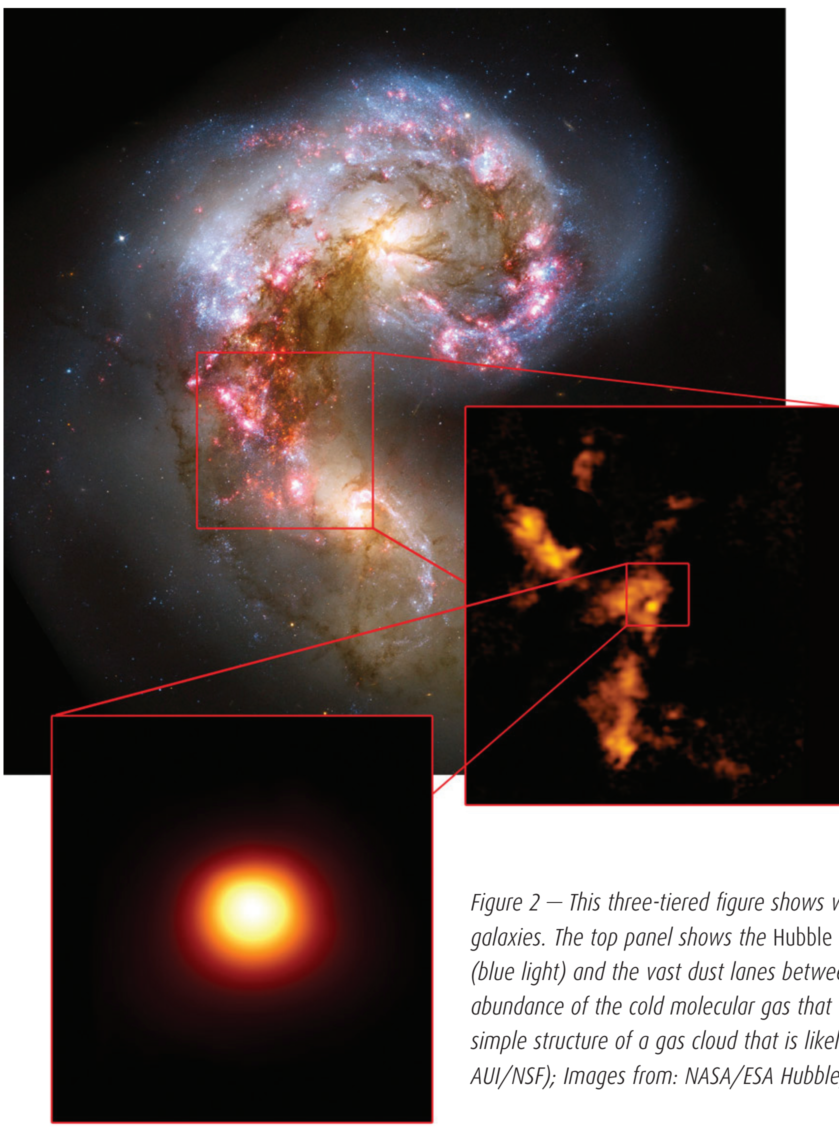

Figure 2 — This three-tiered figure shows where an extreme gas cloud is found inside the merging Antennae galaxies. The top panel shows the Hubble Space Telescope *view of the merger, which highlights young stars (blue light) and the vast dust lanes between the galaxies. Zooming in on one of these lanes reveals an abundance of the cold molecular gas that forms stars (middle panel). Zooming in on the gas reveals the simple structure of a gas cloud that is likely to be a proto-globular cluster. Image Credit: B. Saxton (NRAO/AUI/NSF); Images from: NASA/ESA Hubble, B. Whitmore (STScI); K. Johnson, U.Va.; ALMA (NRAO/ESO/NAOJ)*

John Percy's Universe

Astronomical Misconceptions

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

Students and the general public know a lot of things about astronomy. Many of them are wrong. This is something that becomes quite apparent to someone like me, after half a century in astronomy teaching and outreach. But it's something that every beginning astronomy teacher, outreacher, or communicator must know. People build on their existing knowledge; this is called constructivism. That knowledge may be wrong. This is beautifully illustrated in the video *A Private Universe* (Sadler and Schneps 1987)[1].

There are misconceptions about astronomy itself. I occasionally get mail addressed to the Department of Astrology. There's a tendency to equate astronomy with space science and technology, or to assume that all astronomy is done by NASA with the *Hubble Space Telescope*. Many people have misconceptions about astronomers—that they are gray-bearded men, looking through refracting telescopes. I am pleased to report that my colleagues—especially the younger ones—are a very diverse group!

University of Maine astronomer Neil Comins has a list of over 1500 astronomy misconceptions on his website[2] and has discussed these in his book *Heavenly Errors* (Comins 2001). Here are some common and/or interesting misconceptions, based on my own experience, on the work of Comins, Sadler, and others, and on a useful "misconceptions about astronomy" website at Sacramento City College[3].

Some Common Misconceptions

The seasonal changes in temperature are caused by the changing distance of the Earth from the Sun. This is the granddaddy of astronomical misconceptions. The changes are actually due to the changing height of the Sun above the horizon (high in the summer, low in the winter) and by the changing length of the day (long in the summer, short in the winter). It's difficult to overcome the simple belief that "closer is warmer."

There's a second misconception on this topic. People "know" that the seasonal changes have something to do with the tilt of the Earth's axis, so they think the changes are because the northern hemisphere is closer to the Sun in the northern summer—an easy mistake to make when textbook diagrams of the Earth and the Sun are not to scale.

The phases of the moon are caused by the Moon passing through the Earth's shadow. This is a misconception that can be addressed by a simple, 3D, hands-on activity using a light bulb, and a Styrofoam™ ball, moved around the observer's head to model the changing relative positions of the Moon, Earth, and Sun.

There is a "dark side of the moon." Yes there is, but it isn't always the same side, or the back side; it's the side that is not illuminated by the Sun. Maybe it's that "dark side" sounds mysterious, or it's the Pink Floyd song.

The Moon is visible only at night. It's visible in the afternoon before full Moon (and especially around first quarter) and in the morning after full Moon (and especially around last quarter). Perhaps people just don't look for the Moon in daytime.

The Moon is white i.e. *highly reflective.* In fact, the Moon is as dark as coal; it reflects only about 5 percent of the light that falls on it. But it certainly looks white, against a dark sky.

The Moon is larger when seen close to the horizon. It certainly looks larger; this is a well-documented optical illusion. But hold an Aspirin™ against the Moon's disc when it is close to the horizon, and then again when it is high in the sky. The Aspirin™ approximately covers the disc, at both times. The Moon's apparent size does not change.

The media have recently become enamoured by the concept of the "supermoon," when the Moon is a few percent closer to Earth, and therefore slightly bigger and brighter. Most people can't tell the difference.

Astronauts feel weightless because there is no gravity in space. Gravity in near-Earth orbit is almost as great as on the Earth's surface. The astronaut feels weightless because she and the spacecraft are both falling freely downward, while being carried sideways by the spacecraft's orbital velocity.

The Apollo moon landings never happened; they were faked. This is more than a misconception, it's a conspiracy theory, believed—for some reason—by about one-sixth of Americans.

The planets in the Solar System are closely and equally spaced, and in a straight line. That's how many textbook diagrams show them, for convenience. But they are well and increasingly spaced out, and in various directions. It's instructive to make a scale diagram—with a roll of toilet paper, for instance.

The asteroid belt is densely-packed. So it seems on many diagrams, and in cartoons. It's actually well-spaced out, as is the rest of the Solar System.

There's a "planet X." Sounds mysterious. Sometimes this name referred to an undiscovered tenth planet, before Pluto was demoted. Or to an undiscovered rogue planet that periodically approached the Sun and Earth, and wreaked gravitational havoc.

Comets streak through the sky with their tails trailing behind them. They may look that way in images, but they actually move majestically through the sky over many weeks, with their tails always pointing away from the Sun.

"Shooting stars" or "falling stars" are stars. They are meteors, momentary flashes of light as a tiny space rock encounters the atmosphere, and transforms its energy of motion into light.

The purpose of a telescope is to magnify. People have probably seen too many advertisements for 299× "trash telescopes." The primary purpose of a telescope is to gather light (light-gathering power) and to see fine detail (resolving power). The merits of the telescope depend on how well it can do these.

Polaris is the brightest star in the night sky. In fact, Sirius is the brightest; Polaris ranks about number 47. But Polaris is certainly the best known star in the (northern) night sky.

All stars are white. To the casual observer, they may appear that way. But look at Betelgeuse (reddish) and Rigel (bluish) in Orion in the sky, or on a colour image, and the slight difference in colour is apparent.

The Sun is an average star. It is actually bigger, hotter, and more luminous than 90 percent of the stars in our Milky Way galaxy. Compared with the brightest stars, however—which is a highly biased sample—the Sun is actually one of the least luminous.

During a total solar eclipse, the Sun emits strange, deadly rays. People, such as some school principals, are aware that it is not safe to look at the Sun directly, but that's because of the burning power of its normal light and heat. Only during an eclipse is one tempted to look at the Sun directly. Of course, there are safe ways to observe the Sun.

At the end of its life, the Sun will explode, and turn into a black hole. That's what the first edition of Trivial Pursuit™ said. At the end of its life, the Sun will simply cast off its outer layers as a planetary nebula, exposing its white dwarf core. Only rare, massive stars turn into black holes.

Black holes are cosmic vacuum cleaners, gradually sucking up everything in our galaxy. Stellar-mass black holes may absorb gas from a companion star (as in Cygnus X-1), but the distances between stars are so vast that the black holes do not affect other stars. Supermassive black holes at the centres of galaxies occasionally swallow stars—whole—but only if they happen to stray there.

"Light-year" is a unit of time. It certainly sounds that way, but it is actually a unit of distance—the distance that light travels in one year.

The Big Bang was an explosion of matter into pre-existing space. This is one of many misconceptions about the Big Bang, and other aspects of cosmology. According to Einstein's general theory of relativity, space and matter are linked together, and expand together. In 2015, we celebrate the 100th anniversary of Einstein's famous theory.

Deeper, More Complex Misconceptions

There are misconceptions that go deeper than simply "conception." Over a third of Americans believe that their lives are influenced by the positions of the Sun, Moon, and planets, relative to the horizon and the background stars. About half of university arts and science students pay some attention to their horoscopes (De Robertis and Delaney, 2000). Astrology is deeply rooted in history and culture, but numerous studies—including ones in which astrologers helped with the design (Carlson, 1985)—show that there is no astronomical basis to astrology. People may benefit from the advice of the astrologer, or from the placebo effect, but "it's not in the stars."

The roots of astrology go back for millennia, but the belief that Earth is being visited by space aliens in "flying saucers" is a product of the Space Age and the Cold War. Erich von Daniken, a convicted embezzler and fraud, and an accused plagiarizer, wrote breathless pseudoscientific books such as *Chariots of the Gods*, claiming that ancient structures such as the pyramids of Egypt, and Stonehenge were built by "ancient astronauts" from space—despite the complete absence of evidence. These books have sold millions of copies, and been made into long-running documentaries. Why the popularity? Because they sound convincing, and sound exciting, even though they have no basis in fact.

And then there is the belief, by over a third of Americans, that the Universe, Earth, and life were created essentially in their present form, a few thousand years ago, despite the overwhelming evidence that we live in an ancient, evolving Universe. This belief is based on one interpretation of one scripture of one religion, but this "way of knowing" is so powerful, in some people's minds and cultures, that it overwhelms any formal or informal education—especially as, according to a recent study at Penn State University, many science teachers in the US are unwilling or unable to teach about evolution.

It's one thing to develop effective ways to teach about the cause of the seasons. It's another thing to stem the tide of irrationality about astrology, space aliens, and young-Earth creationism. One could argue that astronomical irrationality doesn't matter, but irrationality matters when it applies to our health, our economy, and our environment. Critical thinking is an essential tool in modern life, and should be at the core of science education. Astronomy has the advantage that it has the power to interest and excite young people about science, and perhaps make them more receptive to the merits of the scientific method. ✶

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De Robertis, M.M. and Delaney, P.A. (2000). A second survey of the attitudes of university students to astrology and astronomy. *JRASC, 94*, 112.

John Percy FRASC is Professor Emeritus, Astronomy & Astrophysics and Science Education, University of Toronto, and Honorary President of the RASC.

Endnotes

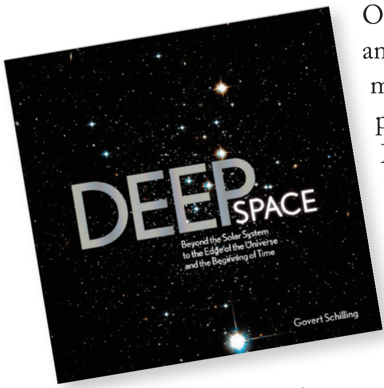
1 www.learner.org/resources/series28.html

2 www.physics.umaine.edu/ncomins

3 www.scc.losrios.edu/pag/observatory/44-common-misconceptions-astronomy

Reviews / Critiques

***Deep Space: Beyond the Solar System to the Edge of the Universe and the Beginning of Time* by Govert Schilling, 224 pages, Black Dog & Leventhal Publishers, 2014. Price: $29.95 USD Hardcover ISBN-13:978-1-57912-978-1**



Our understanding of the Universe and how it works has undergone mind-boggling changes over the past century. The belief that our Milky Way galaxy was the entire Universe has progressed to the view that it is merely an average galaxy amid uncounted others, possibly within a multitude of multiverses. And that is only the start. The past century has also populated our cosmos with new and strange objects: black holes, quasars, pulsars, and many other puzzling entities.

Many of us grew up with the knowledge that our Universe is expanding, but to our surprise, we have learned recently that it is expanding at a growing rate. This puzzling finding compels us to admit that the matter we can see or otherwise detect does not account for everything in the Universe. Astrophysicists have now attached the name “dark matter” to this new “stuff,” but its exact nature is still a matter of conjecture. And then there is dark energy.

It’s a challenge to keep up with what we are learning about our Universe. There is an explosion of knowledge, thanks to spaceborne instruments like the Hubble Space Telescope, more advanced telescopes of varying types on Earth, expanding theoretical modelling, and growing numbers of astronomers to interpret all that data.

A number of books have appeared to help people keep up with this flood of information, one of them being Dutch astronomy writer Govert Schilling’s latest book, *Deep Space: Beyond the Solar System to the Edge of the Universe and the Beginning of Time*. This well-designed, coffee-table-sized book uses a combination of images from today’s telescopes, graphics, and text to take readers on a tour of the stranger sights in the Universe. Schilling is well equipped to lead this tour, as he is a well-regarded science writer whose columns are found regularly in *Sky and Telescope* and *Science*.

This book is highly useful as a reference on specific objects or types of objects for armchair astronomers. For those of us who like to make good use of our telescopes, the articles on each of the featured bodies also include the constellation in which it is located, right ascension and declination, and a reference to a set of star charts in the back.

Deep Space begins with a look at our own Solar System, although it is only a short look, because this book is a companion volume to Marcus Chown’s 2011 publication, *Solar System*. After the local neighbourhood, Schilling moves on to a long section about the birth of stars, another on the variety of stars in the prime of life, and a third on dying stars and the spectacular results of their death throes. After a following section on our Milky Way galaxy, *Deep Space* moves on to the many types of galaxies and galactic clusters in our Universe and then wraps up with views of our Universe as a whole.

Along the way, Schilling pauses to discuss the history of astronomy and how the instruments of yesterday and today have enlarged our knowledge of our Universe. The future isn’t forgotten either, as the author provides us with a peek at what is to come, including the *James Webb Space Telescope*.

Schilling, of course, deals with planets orbiting other stars, but sticks to what has been discovered so far. He explains that the exoplanets discovered in the last 20 years have defied expectations. The growing variety of these surprising planets is covered well in *Deep Space*’s section on exoplanets.

The author is very well versed in the topics covered here, and I learned a few things reading *Deep Space*. But what is most impressive is the variety of images incorporated in the book, all with explanations and context presented in an attractive form. Though readers will find that some images are familiar, *Deep Space* includes many that will be new.

This is a good book for sitting down and reading from cover to cover, for quick reference or even for a casual browse. The writing is accessible and lively, and the impact is enhanced by the illustrations. ✶

Chris Gainor

Dr. Chris Gainor is the Society’s 1st Vice-President, author of several books, and a premier astronomy historian.

CFHT Chronicles:

Queue It Up

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

Picture this: you are a professional astronomer with time on one of the Maunakea Observatories. You were assigned three nights on the telescope. You prepared for this observing run for months, every detail planned to the minute to maximize your productivity. You calculated every offset, every readout time, and every slew. The telescope's time allocation committee (TAC), the astronomers who decide which programs receive telescope time and their rankings, ranked your project #1, the highest priority. You are on top of the world, almost literally. And the all-too-thinkable happens—it snows. And snows. By the time the snow ploughs clear the road and the ice on the dome melts enough to safely rotate, your nights are over and another astronomer is on the schedule. You pack your bags and return home, cursing that your target is optimally observed in winter.

The above scenario occurred more than once this past winter on the summit. Astronomers eager to observe went home disappointed due to lots of snow and ice. But lost nights can occur any time of year. The skies above Maunakea are clear ~300 days of the year, a fantastic number unless you are observing on one of those other 65 days. And while the technical staffs of all the observatories work tirelessly to maintain the telescope, dome, and shutter, all still occasionally break, leaving astronomers out of luck and without observing time. Observing is a 365-day-a-year job; we do not take weekends and holidays off and observatories schedule every night. If weather or technical problems prevent observations from occurring, that is too bad. The next clear night may be already allocated to someone else.

Except at CFHT. Since 2001, we have operated at least partially in Queued Servicing Observing mode (QSO). Only eleven people have operated our workhorse instrument, Megacam (our 340-megapixel wide-field camera), since its commissioning in 2003. Same with Wircam, the wide-field infrared imager. Espadons (an echelle polarization spectrograph) was initially operated by the primary investigators (PIs) of the observing programs, but it was integrated into the QSO system in 2007, roughly two years after its commissioning.

What is QSO and why do we use it? In queue, another name for QSO, the PIs never set foot at CFHT. They do not go to the summit and operate the instruments themselves. In fact, they do not get assigned specific nights. Instead the TAC allocates them a ranking and a set number of hours. Each of CFHT's constituent countries has a separate TAC: Canada, France, Hawaii, Taiwan, China, and Brazil. For example, a "Canada A1" ranking with 36 hours means your program is the top-ranked program on CFHT from Canada and 36 hours of telescope time will be devoted to completing your observations.

Once a PI receives their ranking and time allocation, they use PH2, a detailed online form designed and managed by CFHT,

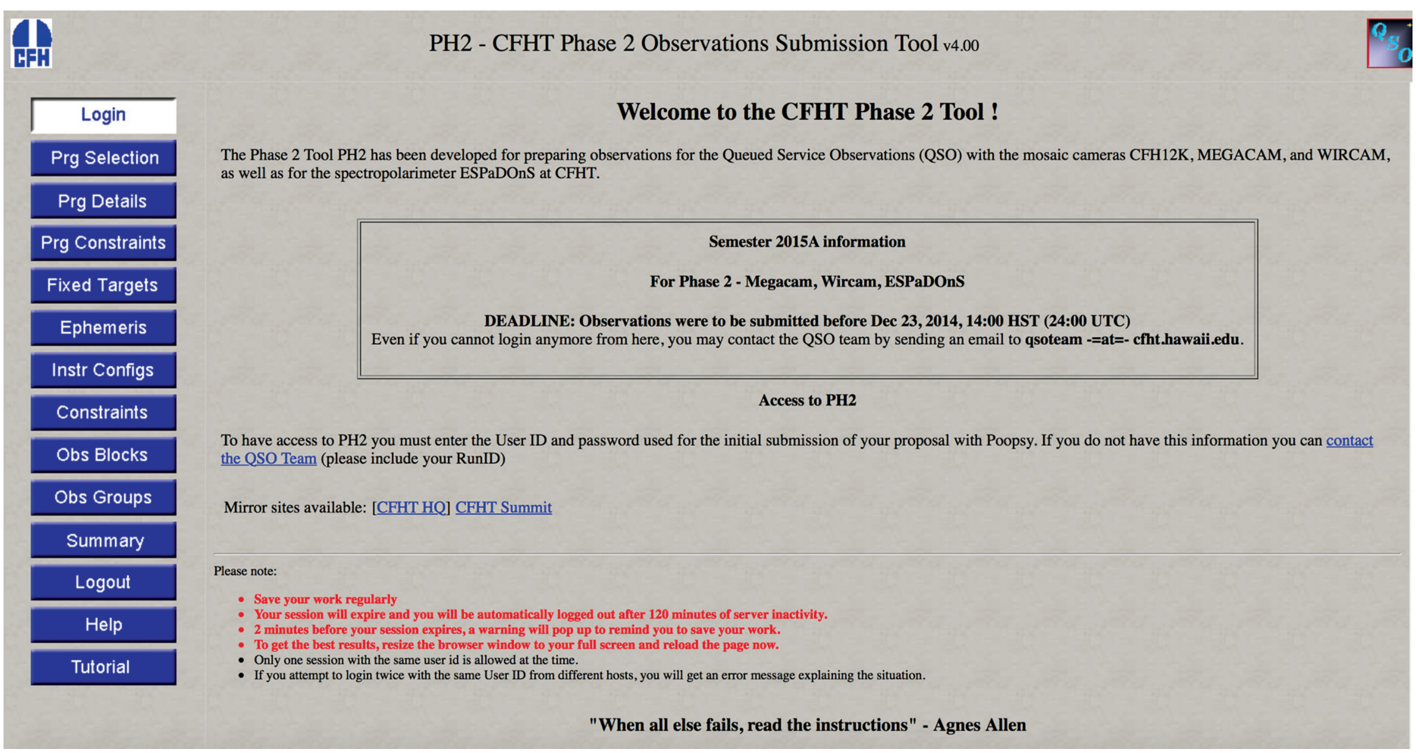


Figure 1 — CFHT's PH2 web tool used by astronomers to enter the details of their programs.

to detail their observations. Within PH2, the PI creates observing groups (OGs) and selects all the necessary information to complete their program effectively; the image-quality range (IQ), sky background, photometric vs non-photometric conditions, *etc*. They can also schedule time-sensitive observations and leave comments for the QSO team to consider when observing or scheduling. All information for all programs is stored within a custom database.

From this database, the QSO team creates queues or plans for every night. CFHT astronomers and queue specialists take turns creating the queues in the role of Queue Coordinator (QC). A typical QC shift lasts 5-10 nights. Each queue is made up of OGs created by the PIs. The length of an observing group varies from <5 min to a maximum of 2 hours. Queues tend to be based around image quality, but the biggest defining quality of an OG is its program ranking. This is the beauty of the queue system; we can discriminate based on weather and sky conditions. The highest-ranked programs get observed in the optimal conditions. No longer does that A1 program get snowed out.

The number of queues per night varies based on the instrument. Megacam tends to have the most queues; the number of programs combined with the vast difference in IQ requests leads to 5–6 queues per night. The QC always creates a queue for suboptimal conditions, those other 65 nights a year, containing programs that do not need subarcsecond seeing or can tolerate thin cirrus. These "snapshot" queues are the secret weapon behind CFHT's amazing calendar images and the whole Hawaiian Starlight project. These images are taken during poor seeing (>1.2″). Granted, many astronomers would consider killing for sky conditions that we deem "poor," but it is all relative. You do not come to Maunakea for >1.2″, you want <0.8″. The queue system allows us to fill time in poor conditions with stunning images for the public.

On the other extreme, Espadons tends to have 1–3 queues each night. In spectroscopy, IQ is less of an issue; the same with clouds. The defining characteristic of an Espadons OG is mode—spectroscopic or polarmetric. We can switch modes once per night, but new calibrations must be taken when that occurs. The QC needs to take that into account when creating the queues.

At night, the remote observer selects observations from the queues based on the sky condition. Each observation is populated into our logbook (another custom piece of software) and graded by the observer on a scale of 1–5. They perform quality control on the images, asking themselves if the image meets the criteria set by the PI and if the stars look round, *i.e.* the instrument's guider worked properly. Anything out of the ordinary, such as extinction due to clouds, receives a comment. As conditions change, observers switch queues to optimize the observations. A night that starts out on an A1 program requesting 0.6″ seeing can end on a snapshot program if the sky conditions worsen. A dream night for one of our observers is all Q1, all night.

The next morning, the QC is back at work. They review the logbook and validate those images meeting the PI's criteria.

Figure 2 — A Megacam queue. Each block is a different observation. The gray blocks have been validated already, a great visual indicator to the queue coordinator that they are completed observations.

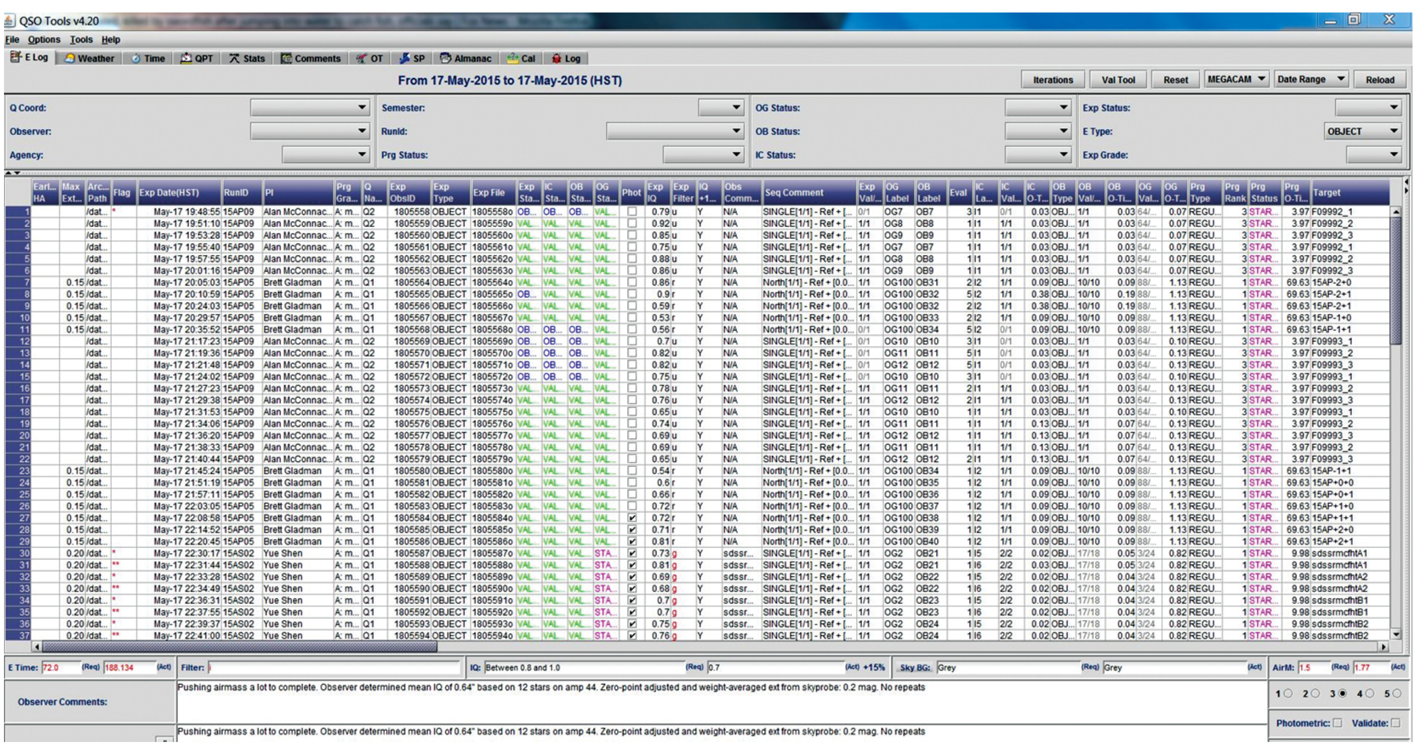


Figure 3 — CFHT's QSO log book. Each observation has one line where the remote observer enters a grade and comments for the image. The queue coordinator can copy the comments that are relevant to the PI whose data it is. Only the queue coordinator comments are visible to the PI.

Once validated, the OGs are flagged as observed in the database, preventing them from being re-observed. Observations that do not meet the criteria are not validated, making them eligible to be re-observed. The PI still receives these images and often times they can be used, especially when combined with other less-than-optimal images, but that is the decision of the PI, not the QC. In some cases, the QC, after evaluating borderline images, will contact the PI and simply ask if the image is acceptable. The QC then restarts the process of creating queues for the upcoming night. During a shift, the QC is on call at night. If the observer has a question or concern about an observation, they call the QC, who offers guidance.

There is more to QSO than ensuring the best programs get observed and taking the freedom to collect stunning PR images. Where QSO shines is in CFHT's ability to observe in support of large surveys and unexpected targets. The conventional way of observing does not give the flexibility needed for surveys. Megacam's first large survey was the CFHT Legacy Survey (CFHTLS), which was comprised of deep, wide, and very-wide components. The deep survey monitored one small area of the sky every few nights in multiple filters for five years, searching for supernovae. When one was found, the deep team used other telescopes to conduct spectroscopic follow-ups and to determine the light curve. The over-22,000 images taken for CFHTLS paved the way for other Megacam surveys including the PanAndromeda Survey (PANDAS), the Next Generation Virgo Survey (NGVS), and Outer Solar System Origins Survey (OSSOS), one of our current large programs. The discoveries do not stop when the survey does; archived data from these large programs yield results years later. In May, astronomers using NGVS data announced the discovery of hundreds of dwarf galaxies in the Virgo Cluster, far more than found within our own Local Group. The discovery begs the question, why are the environments of Virgo and the Local Group so different?

Surveys are also conducted using Wircam and Espadons and, once again, it is the flexibility of scheduling provided to CFHT by QSO that allows these surveys to be conducted. Under other circumstances, it would be difficult to get an hour a night, every third night that an instrument is on the telescope, for 5 years, outside of queue.

Unexpected targets are generally Near-Earth Objects (NEOs). They are not wholly unexpected; several PIs each semester expect to find the unexpected using other telescopes like Pan-STARRS on Maui. The PIs apply for CFHT time, assuming they will discover potential NEOs elsewhere and use Megacam for follow-up. The astronomers are granted time, but unlike most PIs, they do not fill out a PH2 at the start of the semester. Instead, they request time and create OGs by 4 p.m. for that evening's observations. These last-minute OGs are usually very short: 3–5minutes. The QC adds the OGs to the queues and boom—asteroid or comet observed. These PIs also get special fast access to their data and download raw data the next morning.

Other astronomers wait until the end of an observing run or even end of the semester to receive their data. The data is reduced by CFHT and the PI downloads it from a secure FTP site allocated for their program. They are then free to process the data, as they like. The proprietary period on CFHT data is one year, and then it is accessible to anyone via the Canadian Astronomy Data Centre (CADC). I encourage everyone reading this to go and take a look (www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/en/cfht/index.html).

When discussing CFHT's agencies earlier, I skipped one—ourselves. CFHT's director, Doug Simons, has discretionary time. PIs, including CFHT staff astronomers, can request observing time directly from Doug at any time during the semester. They submit a proposal to the QSO team. If accepted, they are set up with an account in PH2 and we begin taking their data. Discretionary time is often used for targets of opportunity, by PIs who need additional time, and by CFHT staff.

After reading the wonders of queue, you may be wondering why anyone would be crazy enough to do it any other way. Queue does not work for every observatory. CFHT's suite of instrumentation lends itself to surveys. With the large field of views of our cameras, Megacam and Wircam, PIs can image areas of the sky looking for targets such as supernovae, all of Virgo, or Kuiper Belt Objects. Using CFHT is akin to trying to find a dropped penny on a dark night under a streetlight. You will find your penny much faster under a streetlight than scanning the dark with a flashlight. We are the streetlight. Larger aperture telescopes like Gemini and Keck are the flashlights. Over several hours of integration, their large mirrors collect the light needed to examine closely faint, distant objects discovered by smaller telescopes like CFHT.

The astronomer's science goals also play into the decision to queue or not to queue. Queue mode works best when the astronomers have a general idea of the brightness of their targets or can spend hundreds of hours integrating to find the faintest targets over a large field of view, like in the Virgo Galaxy Cluster. Because astronomers are not at the telescope taking their own data, they have limited flexibility to adjust integration time or targets. At CFHT, they can ask for an adjustment for the next day or the next instrument run, but not the next exposure. In contrast, during classical observations, the astronomer can adjust those parameters on the fly to maximize their observations.

In queue mode, fewer astronomers and students visit the telescope. The invaluable experience of operating a telescope and taking your own observations is limited. For our Canadian resident astronomers, operating a telescope, most notably Observatorie du Mont-Mégantic, provided them with the experience they needed to work at CFHT.

Despite the potential drawbacks, operating in Queue mode works for CFHT. The research conducted by astronomers using CFHT opens a deeper understanding of our Universe for us all. ✶

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.*

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

In Memoriam:

Bruce Andrew McIntosh (1929 – 2015)

by Peter Brown, Western Meteor Physics Group, University of Western Ontario

Bruce McIntosh, a long-time meteor researcher, passed away February 14 in Toronto. Bruce was born in the town ofWiarton, Ontario, in 1929 and did post-graduate work at the University of Western Ontario (M.Sc. 1953) and McGill University (Ph.D. 1958) in physics. Bruce became a staff scientist in the Division of Radio and Electrical Engineering at the National Research Council soon after obtaining his M.Sc. He married Louise in 1954, and their first son was born in 1955. Bruce and family moved to Montréal soon afterwards, where he concentrated on completing his Ph.D. studies, and where Louise gave birth to their second child. He returned to NRC in Ottawa in 1959, where his third and fourth children were born.

Figure 1 — Dr. Bruce McIntosh shortly after his graduation from the Physics program at McGill University.

Bruce began his scientific career focused on radar studies of meteors, a topic of particularly great interest in Canada in the 1950s, driven initially by the practical considerations related to the development of the JANET forward-scatter radio communication system. Bruce worked in the meteor group at the NRC led by Peter Millman, first as part of the upper-atmosphere research branch of the NRC and later as a member of Herzberg Institute of Astrophysics. Together with Millman and D.W.R. McKinley, he performed much of the early statistical work on meteor radar measurements made at the Springhill Observatory, including compilation and analysis of some of the first long-term radar meteor echo records (Millman and McIntosh, 1964; 1966).
Bruce's professional collaborations expanded in 1966 when Dr. Milos Simek and Dr Jan Stohl spent an extended research visit to Ottawa (very unusual at the time), where they worked together on radar meteor interpretation. An extended reciprocal visit by Bruce and his family in 1973 to Ondrejov Observatory (in the former Czechoslovakia) cemented a lifelong friendship between Milos and McIntosh, and signaled the beginning of a long-term collaboration lasting through the remainders of both of their careers. Over the next two decades, they produced a series of long-term studies of radar meteor streams using data from both the Springhill observatory and the Ondrejov radar, establishing baselines of activity for several major showers that would be later be used to help model the streams. In 1989, McIntosh's contribution to science in Czechoslovakia was recognized by the Czechoslovak Academy of Sciences, when they awarded him with the *Gold Medal of Merit in the Physical Sciences*.

These long-term shower studies would later lead McIntosh to expand his research into modelling the dynamics of the major meteoroid streams, a topic just coming of age in the 1970s and 1980s with the advent of faster computers. In particular, with the return of 1P/Halley in 1986, the topic of the Halley meteoroid streams (the Orionids and Eta Aquariids) and their evolution became a major focus for the International Halley Watch (IHW). Together with Anton Hajduk of the Astronomical Institute of the Solvak Academy of Sciences, Bruce developed the ribbon-model for the Halleyid streams (McIntosh and Hajduk, 1983), which was widely used in the community for understanding and interpretation of IHW meteor-shower observations. His longtime interest in stream modelling, combining the best available information from comet observations and meteor measurements, culminated in a widely cited work on the enigmatic Quadrantid shower (McIntosh, 1990). The main results of this paper still form the basis for modern studies of this unusual meteor shower.

Bruce's inquisitive nature led him to explore several other areas of meteor science. These included studies of fireballs (McIntosh, 1970), and together with the late Douglas ReVelle, some of the earliest measurements dedicated to the detection of fireball infrasound (McIntosh *et al.*, 1976). His study of the Leonid shower returns of the 1960s (McIntosh and Millman, 1970) proved very helpful when he participated in the 1999 global Leonid observing program, making him one of the few active meteor scientists whose research spanned an entire period of the Leonids (34 years).

Bruce McIntosh's deep physical insight and quiet nature will be dearly missed by all who knew him. ✶

Millman P.M., and McIntosh B.A. (1964). Meteor Radar Statistics. I. *Canadian Journal of Physics 42*: 1730–1742.

Millman P.M., and McIntosh B.A. (1966). Meteor radar statistics. II. *Canadian Journal of Physics 44*: 1593–1602.

McIntosh B.A. (1970). On the end-point height of fireballs. *Journal of the Royal Astronomical Society of Canada 64*: 267–281.

McIntosh B.A., and Millman P.M. (1970). The Leonids by radar—1957 to 1968. *Meteoritics 5*: 1-18.

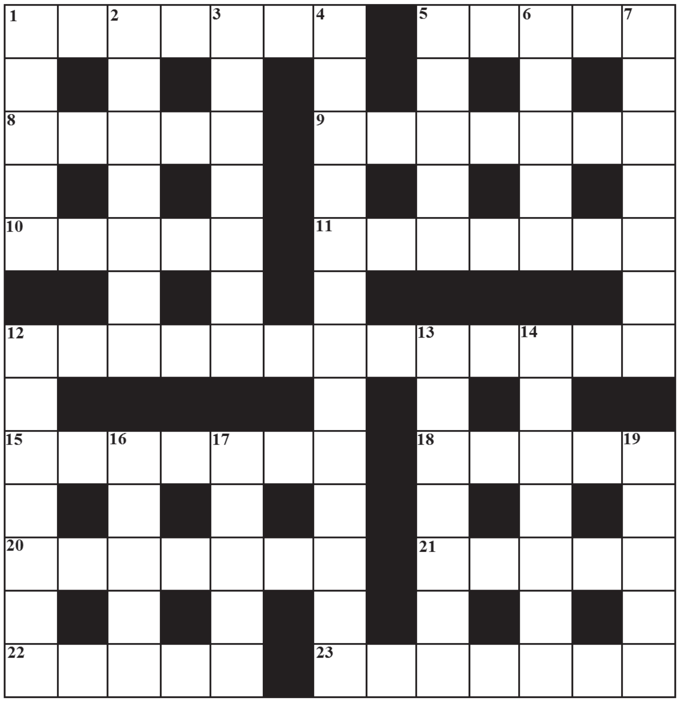
McIntosh B.A., Watson M., and ReVelle D.O. (1976). Infrasound from a radar-observed meteor. *Canadian Journal of Physics 54*: 655–662.

McIntosh B.A. and Hajduk A. (1983). Comet Halley meteor stream – A new model. *Monthly Notices of the Royal Astronomical Society 205*: 931–943.

McIntosh B.A. (1990). Comet P / Machholz and the Quadrantid Meteor Stream. *Icarus 86*: 299–304.

Astrocryptic

by Curt Nason



ACROSS

1. Low poles lead alien to when we start deep-sky observing (7)
5. It's back with copper inside of the shield (5)
8. Where telescopes are often pointing when out in quiet surroundings (5)
9. Stereo blasted before dawn from a magnetic-related crater (7)
10. Nitrogen detected in a bad oxygen line of the solar spectrum (1-4)
11. I choose McNaughton to test their mounts (7)
12. Somehow save Rob before Conservatives get the domes (13)
15. He will ruin Easter dinner writing a celestial handbook (7)
18. Subfamily returning from the Sun, for example (5)
20. Speedy particle heavyweight with internal pain (7)
21. Stoned woman in the asteroid belt (5)
22. Curious glare from a Magellanic Cloud (5)
23. Yokels get no return from a compact galaxy group (7)

DOWN

1. Fly in the sky across the Starmus Canary Island (5)
2. Lacus or other lunar feature seen through them (7)
3. He plays cards round, brightly leading the queen (7)
4. Devious romantic plot starts her lunar period in spring (8,5)
5. Take trips around HR instability area (5)
6. "As seen in Serpens Caput," Terence Dickinson might say (5)
7. Dione is rocked by 53 isotopes (7)
12. Minimal information in examination of element like eccentricity (7)
13. Type of interstellar molecule lost in cargo (7)
14. Genius confused about round, extrusive rocks on the Moon (7)
16. What a nova might do in precursor stage (5)
17. Not a Big Bang proponent, according to him? (5)
19. Pluto's investigator looks unhappy (5)

Answers to June's Astrocryptic

ACROSS

1 PHASE (anagram); **4** KORONIS (oro in sink (rev)); **8** SYNODIC (anag); **9** GEMMA (gem + ma); **10** HELIX (he(Li)x)); **11** ATLASES (Atl + anag); **12** NERNST (ne(RN) st); **14** POGSON (POGS + no (ret)); **18** RETICLE (2 def); **20** TESLA (anag); **22** BIHAM (B + (I(ha)m); **23** LINBLAD (oops - misspelling of Lindblad) (Al (rev) in anag); **24** SKYGLOW (2 def); **25** SORER (Sporer – p)

DOWN

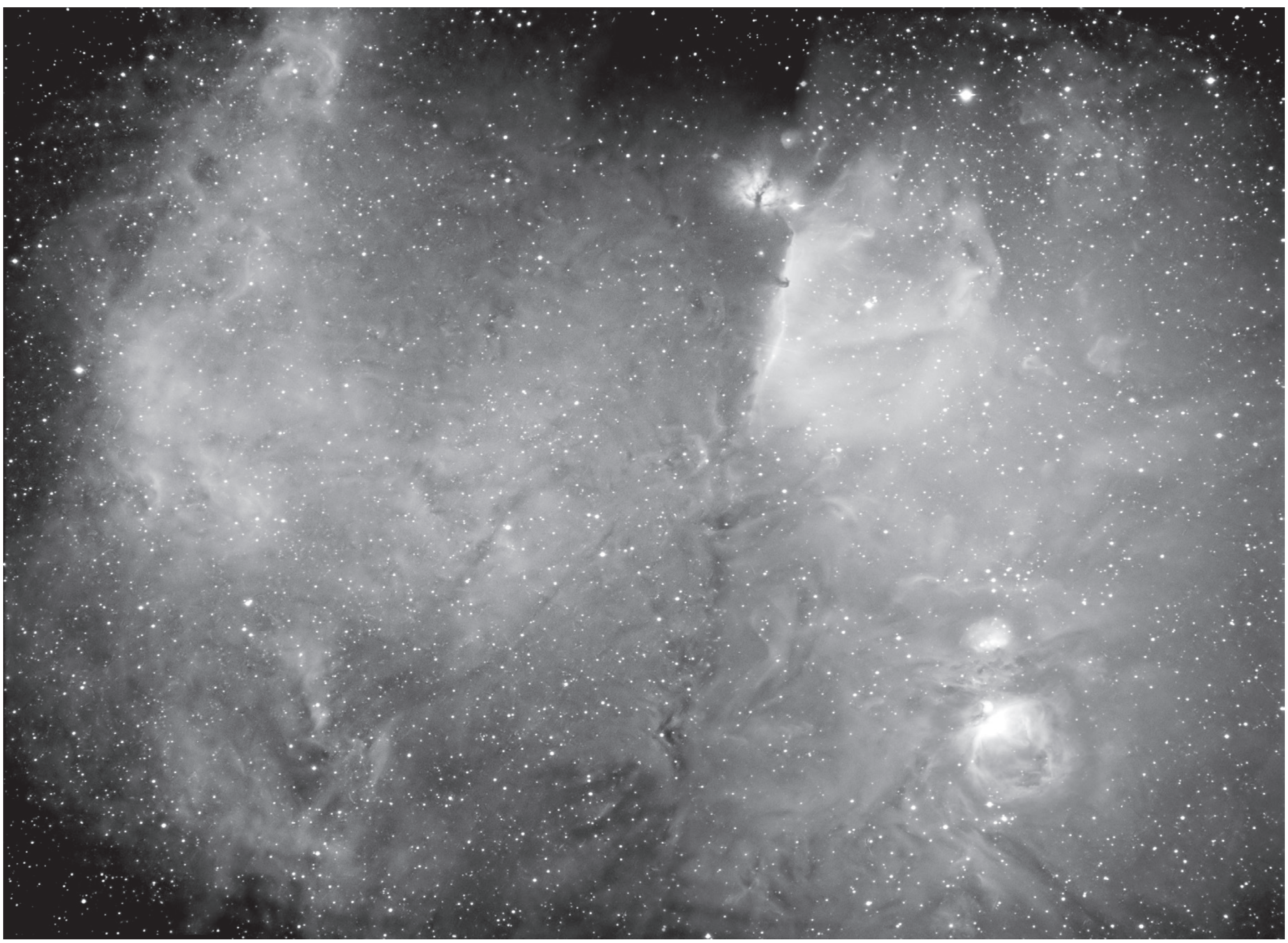
1 PASCHEN (homophone); **2** ANNUL (N in Luna (rev)); **3** EUDOXUS (homophone + us); **4** KOCHAB (cha in Bok (rev)); **5** RIGEL (rig + el); **6** NEMESIS (Ne + mes(I)s; **7** STATS (palindrome); **13** RITCHEY (hidden); **15** OCTANTS (Oct + ants); **16** NEANDER (hid); **17** YELLOW (yell ow);**18** REBUS (Cerberus - Cer (anag)); **19** CAMEL (2 def, Camelopardalis); **21** SOLAR (sol + Ar)

It's Not All Sirius

by Ted Dunphy

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

Great Images



Jim Chung took this three-image H-alpha mosaic of the Orion Nebula and its environs back in 2010, but it probably hasn't changed very much in the intervening years. Sure is a lot of stuff out there. The Orion Nebula is in the lower right and the Horsehead Nebula, along with the Flame Nebula, are obvious in the upper centre. Jim used a QSI352 camera with an Olympus Zuiko f/3.5, 136-mm lens and a 3-nm Astrodon filter. Exposure was 5×300 s for each image in the mosaic.

Journal

Great Images

Moonlight and aurora—an unlikely combination for those of us at low latitudes where the two are typically in opposite parts of the sky. However, at 70° north, in the fjords of Northern Norway. The Moon can be circumpolar and the auroral oval is at the zenith. Judy Anderson took this auroral treat while sailing through Norway's coastal islands in March. The view is across the wake of the boat, looking toward the Big Dipper and the North Star. Judy used an 8-mm fisheye lens on a Canon T1i for this 8-second exposure at ISO 3200.