The Journal of The Royal Astronomical Society of Canada

Journal

Le Journal de la Société royale d'astronomie du Canada

PROMOTING ASTRONOMY IN CANADA

June/juin 2018
Volume/volume 112
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Inside this issue:

Chilean sky

The Best of Monochrome.

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

Ron Brecher imaged the Jellyfish Nebula, with the large emission nebula, Sh2-249, and the blue reflection nebula, vdB 75 (near centre), acquired from his SkyShed in Guelph. Brecher used a Moravian G3-16200 EC camera with Optolong Hα, R, G, and B filters, a Takahashi FSQ-106 ED IV at f/3.6 on a Paramount MX. He also used a QHY5 guide camera on a 175-mm guide scope, processing the images in PixInsight. Shooting details: 25x10m R, 23x10m G, 22x10m B, and 44x10m Hα unbinned frames (total=19 hr).

Journal

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Royal Astronomical Society of Canada

Société Royale d'Astronomie du Canada

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Think you can name all 15 objects in this beautiful image? Stefano Cancelli turned his telescope about two degrees away from the central core of the Large Magellanic Cloud in the constellation Dorado. "At a resolution and scale of 1 arcsec/pixel, there are over 100,000 stars resolved in this image," he says. He used the Chilescope Robotic Observatory (near Ovalle, Chile), at ISO 500, with 500-mm aperture, 1800-mm FL, ƒ/3.6 corrected Newtonian Astrograph on an ASA DDM85 Equatorial Mount and a FLI Proline 16803 camera. It is a culmination of six hours of LRGB, unbinned, processed using ACP, MaximDL, FocusMax PixInsight, Photoshop, and Lightroom.

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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The Royal Astronomical Society of Canada
203 – 4920 Dundas St W
Toronto ON M9A 1B7, Canada

Email: nationaloffice@rasc.ca
Web site: www.rasc.ca
Telephone: 416-924-7973
Fax: 416-924-2911

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President's Corner

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

Are you ready? The biggest event of the summer is almost upon us. Our friends in Calgary want to see you at the Royal Astronomical Society of Canada's General Assembly from June 28 through July 1. We are celebrating our 150th Anniversary and we welcome all members of the Society to share some fine hospitality, excellent presentations, and the usual business of our Annual General Meeting. There will be plenty of opportunity to share your experience with friends new and old. Whether you are an active observer, professional scientist, or starting off learning about the night sky, there will be something special for you.

Enjoy presentations by special guests including former Canadian astronaut Dr. Robert Thirsk, internationally renowned science educator and writer Emily Lakdawalla, scientist Dr. Tanya Harrison of Arizona State University's NewSpace initiative, and Dr. Fereshteh Rajabi who will share insights into her journey from quantum physics to superradiance in astrophysics. Tours and special activities abound.

Make sure to register online right away: www.rasc.ca/ga2018

The 150th celebrations are a unique time to participate at the General Assembly and in local events at your Centre. Look back to our past with warmth and look forward to the future with optimism. We have much to be proud of. Make a point of thanking those volunteers and friends who helped feed your curiosity about our night skies. Remember those who served us in the past and are not here to celebrate with us. Thank you for allowing me to serve you during this amazing year.

As we close out the prior year, our Annual Report helps us reflect on all the good work done by so many people in our Society. The report is expected in May, and it highlights a few of the challenges and accomplishments of 2017 as we strive to fulfill our mission. We reached thousands of Canadians during the total solar eclipse and at events across our country. We also planted seeds and undertook new initiatives. The deficit we ended the year with is influenced by this work and increases in everyday expenses. Spending on the new Archive room and support for our fundraising expert are expected to bring benefits in the coming years. The efforts continue to be in line with achieving our objectives and engaging our members. We anticipate reaching new donors in 2018 and beyond to support our educational programs, outreach work, and efforts to protect our night skies. Thank you for your continued support. Please refer to the 2017 Annual Report for more commentary, financial details, and reports from our Centres.

We've made many strides forward in welcoming more people into our organization and building a healthy, welcoming culture. As promised, our Society's leadership has adopted new policies to help prevent harassment of any form. Our partners at the Centre level are setting the tone, and I encourage you to be part of the culture change at the local level. Harassment of any form has no place in our Society, and its up to all of us to do our part. We now have more appropriate means for affected parties to come forward without fear of retaliation, and we have clear guidance for our leaders.

We plan to open the doors on our Archives Room this spring with a newly renovated space where we can share a bit of our 150 years of astronomy history, as well as hold small meetings and presentations. We have started the prototyping of the RASC Remote Telescope with a modest investment in equipment, in anticipation of more significant funding that will allow us to operate a larger instrument in a sustainable way. Your support of these projects is appreciated, and I hope you will contribute financially to these projects, if able.

As we enjoy lighter evenings and hopefully warmer temperatures, it will be time to get outside and observe. Please take some time this summer to share the joy of the night sky with neighbours and friends. Let's celebrate 150 years of astronomy innovation in Canada, as I firmly believe in *looking up!* ✶

News Notes / En Manchette

Compiled by Jay Anderson

A Felted Supernova

Supernova hunters usually come in late, after the star has exploded and attracted attention by its sudden increase in luminosity. Once in a while, however, the searchers get lucky. That's what happened in February 2016, when an object nicknamed KSN 2015K lit up under the gaze of the *Kepler Space Telescope*. Even more fortunately, 2015K turned out to be a member of a class of objects known as Fast-Evolving Luminous Transients (FELT), a phenomenon that has baffled astronomers for several decades.

FELTs are stellar explosions that pop into view and then fade away quickly over the next few days; because of their brief lifetime, very few have been detected. In the absence of data, there have been a variety of theories to explain FELTs: the afterglow of a gamma-ray burst, a supernova boosted by a magnetar (neutron star with a powerful magnetic field), or a failed Type Ia supernova. Typical sky surveys only observe a star field for a brief time and then return several days later, so when *Kepler* detected 2015K's brightening, the explosion was exposed to observations at 30-minute intervals over many days—early and long enough to capture its rise time as well as its subsequent decay. The FELT event had a rise time of only 2.2 days and a time above half-maximum of only 6.8 days.

After modelling many alternatives, researchers concluded that KSN 2015K began as a star that collapsed to form a supernova—but this supernova was embedded in one or more very dense shells of dust and gas. The shell was thick enough to hide the initial supernova explosion, but when the ejecta ran into the shell, most of the debris' energy was converted to light. That burst of radiation lasts for only a few days—one-tenth the duration of a typical supernova explosion.

"We collected an awesome light curve," said Armin Rest of the Space Telescope Science Institute in Baltimore, Maryland. "We were able to constrain the mechanism and the properties of the blast. We could exclude alternate theories and arrive at the dense-shell model explanation. This is a new way for massive stars to die and distribute material back into space.

"With *Kepler*, we are now really able to connect the models with the data," he continued. "*Kepler* just makes all the difference here. When I first saw the *Kepler* data, and realized how short this transient is, my jaw dropped. I said, 'Oh, wow!'"

The *Kepler* observations indicate that the star ejected the shell less than a year before it went supernova. This gives insight into the poorly understood death throes of stars—the FELTs

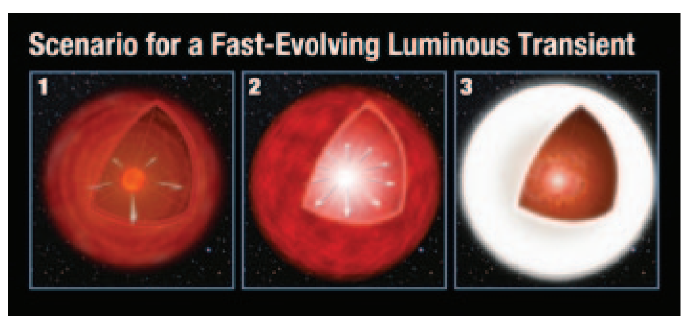

Figure 1 — This illustration shows a proposed model for a Fast-Evolving Luminous Transient. In the left panel, an aging red giant star loses mass via a stellar wind. This balloons into a huge gaseous shell around the star. In the centre panel, the massive star's core implodes to trigger a supernova explosion. In the right panel, the supernova shockwave plows into the outer shell, converting the kinetic energy from the explosion into a brilliant burst of light. Image credit: NASA / ESA / A. Field, STScI., NASA, ESA, and A. Field (STScI).

apparently come from stars that undergo "near-death experiences" just before dying, belching out shells of matter in mini-eruptions before exploding entirely.

"The fact that *Kepler* completely captured the rapid evolution really constrains the exotic ways in which stars die. The wealth of data allowed us to disentangle the physical properties of the phantom blast, such as how much material the star expelled at the end of its life and the hypersonic speed of the explosion. This is the first time that we can test FELT models to a high degree of accuracy and really connect theory to observations," said David Khatami of the University of California at Berkeley.

This discovery is an unexpected spinoff of *Kepler*'s unique capability to sample changes in starlight continuously for several months. This capability is needed for *Kepler* to discover extrasolar planets that briefly pass in front of their host stars, temporarily dimming starlight by a small percent.

Compiled in part with material provided by the Space Telescope Science Institute.

Not in my Back Yard

The galactic halo is the midden of the Milky Way. In the past 10 billion years or thereabouts, it has been subjected to disruption by passing dwarf galaxies, occasional supernovae, infalling cold gas, and the evolution of its constituent stars. Within its confines, astronomers have identified a population of chemically distinct stars mingled with the ghostly trails left by the intruding galaxies. Also embedded in the halo, close to the outer reaches of the galactic disk, lies a number of "over-dense" stellar populations, which were believed to have been left behind by the interaction of satellite galaxies and the Milky Way. These halo stars are grouped together in giant structures that orbit the centre of our galaxy, above and below its flat disk.

But, in a study published in the journal *Nature,* a team of astronomers led by the Max Planck Institute for Astronomy (MPIA) now have convincing evidence that some of these halo structures actually originate from the Milky Way's disk itself. The team of scientists investigated 14 stars located in 2 different halo structures lying on opposite sides of the Milky Way disk, about 14,000 light-years above and below the galactic plane.

The team obtained spectra of the halo stars using Keck Observatory's High-Resolution Echelle Spectrometer (HIRES). "The high throughput and high spectral resolution of HIRES were crucial to the success of the observations of the stars in the outer part of the Milky Way," said Judy Cohen, Kate Van Nuys Page Professor of Astronomy at Caltech.

Figure 2 — A 360-degree panorama view of the Milky Way (an assembled mosaic of photographs) by ESO. Credit: ESO/S. Brunier.

When comparing the chemical compositions of these halo stars with the ones found in other locations, the scientists were surprised to find that the chemical compositions are almost identical, both within and between these groups, and closely match the abundance patterns of the Milky Way outer-disk stars. This provides compelling evidence that the halo stars most likely originate from the galactic thin disk, the younger part of Milky Way, strongly concentrated toward the galactic plane.

"The analysis of chemical abundances is a very powerful test, which allows, in a way similar to DNA matching, to identify the parent population of the star. Different parent populations, such as the Milky Way disk or halo, dwarf satellite galaxies, or globular clusters, are known to have radically different chemical compositions. So once we know what the stars are made of, we can immediately link them to their parent populations," said lead author Maria Bergemann of MPIA.

"This phenomenon is called galactic eviction," said Cohen. "These structures are pushed off the plane of the Milky Way when a massive dwarf galaxy passes through the galactic disk. This passage causes oscillations, or waves, that eject stars from the disk, either above or below it, depending on the direction that the perturbing mass is moving."

"We showed that it may be fairly common for groups of stars in the disk to be relocated to more distant realms within the Milky Way—having been 'kicked out' by an invading satellite galaxy. Similar chemical patterns may also be found in other galaxies, indicating a potential galactic universality of this dynamic process," said co-author Allyson Sheffield of LaGuardia Community College/CUNY.

Compiled with material provided by Keck Observatory.

Push Me-Pull You Magellanic Clouds

On the outskirts of our galaxy, a cosmic tug-of-war is unfolding. The players are two dwarf galaxies, the Large Magellanic Cloud and the Small Magellanic Cloud, both of which orbit our Milky Way Galaxy. But as they go around the Milky Way, they are also orbiting each other. Each one tugs at the other, and one of them has pulled out a huge cloud of gas from its companion.

Called the Leading Arm, this vast debris field of H I clouds connects the Magellanic Clouds to the Milky Way. Roughly half the size of our galaxy, this structure is thought to be about 1 or 2 billion years old. Its name comes from the fact that it's leading the motion of the Magellanic Clouds.

The enormous concentration of gas is being devoured by the Milky Way and feeding new star birth in our galaxy. But which dwarf galaxy is doing the pulling, and whose gas is now being feasted upon? After years of debate, scientists now have the answer to this "whodunit" mystery.

"There's been a question: Did the gas come from the Large Magellanic Cloud or the Small Magellanic Cloud? At first glance, it looks like it tracks back to the Large Magellanic Cloud," explained lead researcher Andrew Fox of the Space Telescope Science Institute in Baltimore, Maryland. "But we've approached that question differently, by asking: What is the Leading Arm made of? Does it have the composition of the Large Magellanic Cloud or the composition of the Small Magellanic Cloud?"

Fox's earlier research focused on a trailing feature behind the Large and Small Magellanic Clouds called the Magellanic Stream. The gas in this ribbon-like structure was found to

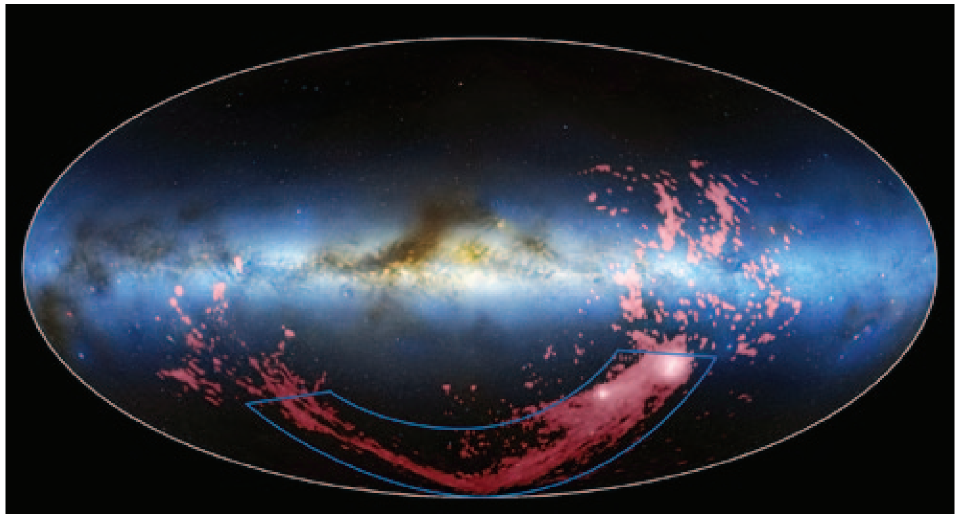

Figure 3 — A photo mosaic of an edge-on view of the Milky Way Galaxy, looking toward the central bulge. Superimposed on the galaxy are radio-telescope images, coloured pink, of the stretched, arc-shaped Magellanic Stream below the plane of the galaxy and the shredded, fragmented Leading Arm crossing the galaxy's plane and extending above it. These gas clouds are being gravitationally pulled apart like taffy from the Small and Large Magellanic Clouds (SMC, LMC), which appear as bright clumps within the gas. Image: ESA/Hubble and D. Nidever et al.; A. Mellinger; and A. Field.

come from both dwarf galaxies. Now Fox wondered about its counterpart, the Leading Arm. Unlike the trailing Magellanic Stream, this tattered and shredded "arm" has already reached the Milky Way and survived its journey to the galactic disk.

The Leading Arm is a real-time example of gas accretion, the process of gas falling onto galaxies. This is very difficult to see in galaxies outside the Milky Way, because they are too far away and too faint. "As these two galaxies are in our backyard, we essentially have a front-row seat to view the action," said collaborator Kat Barger at Texas Christian University.

In a new kind of forensics, the research team used the *Hubble Space Telescope*'s ultraviolet sensors to chemically analyze the gas in the Leading Arm. They observed the light from seven quasars, the bright cores of active galaxies that reside billions of light-years beyond the gas cloud. Using *Hubble*'s Cosmic Origins Spectrograph, the scientists looked for the absorption of ultraviolet light by oxygen and sulphur in the cloud. These are good gauges of how many heavier elements reside in the gas. The team then compared *Hubble*'s measurements to hydrogen measurements made by the National Science Foundation's Robert C. Byrd Green Bank Telescope at the

Green Bank Observatory in West Virginia, as well as several other radio telescopes.

"With the combination of *Hubble* and Green Bank Telescope observations, we can measure the composition and velocity of the gas to determine which dwarf galaxy is the culprit," explained Barger.

After much analysis, the team finally had conclusive chemical "fingerprints" to match the origin of the Leading Arm's gas. "We've found that the gas matches the Small Magellanic Cloud," said Fox. "That indicates the Large Magellanic Cloud is winning the tug-of-war, because it has pulled so much gas out of its smaller neighbour." In particular, low oxygen abundances (ranging from 4 to 13 percent of the Sun) excluded the Large Magellanic Cloud as a source. Gas from the Leading Arm is now crossing the disk of our galaxy, interacting with the Milky Way's own gas, and becoming shredded and fragmented.

This is an important case study of how gas gets into galaxies and fuels star birth. Astronomers use simulations to try to understand the inflow of gas in other galaxies. But here, the gas is being caught red-handed as it moves across the Milky Way's disk. Sometime in the future, planets and planetary systems in our galaxy may be born out of material that used to be part of the Small Magellanic Cloud.

Figure 4 — Jupiter's cloud bands—seen here in this image created by citizen scientists Gerald Eichstädt and Seán Doran, using data from NASA's Juno *spacecraft—extend more than 1,000 to 1,600 kilometres into the planet's interior. Image: NASA/JPL-Caltech/SwRI/MSSS/Gerald Eichstädt/Seán Doran.*

Deep Currents

NASA's *Juno* spacecraft is producing a steady supply of marvellous, detailed images of Jupiter, many of them processed by citizen scientists. Even the smallest telescope will show cloud belts stretching across the planet, but the new *Juno* images reveal the fascinating details of an array of whorls, loops, bright ovals, and contrasting dark and light bands. There's more than pretty pictures, however, as the spacecraft is also uncovering some of the hidden structure of the cloud bands.

The cloud bands of Jupiter were first observed by Galileo. Their latitudinal alignment is a consequence of the Coriolis force, which is unusually strong in the fast-spinning planet. Fast jet-stream winds, up to 360 km/h, divide the bands, and are easily mapped from orbit, but scientists have been uncertain about how deep the cloud structures extend.

During its 53-day elliptical orbit of Jupiter, the planet's gravitational field pulls on *Juno*, causing small shifts in the spacecraft's radio signal that reflect changes in distribution of mass on the planet. "*Juno*'s measurement of Jupiter's gravity field indicates a north-south asymmetry, similar to the asymmetry observed in its zones and belts," said Luciano Iess, *Juno* co-investigator from Sapienza University of Rome, and lead author on a *Nature* paper on Jupiter's gravity field.

On a gas planet, such an asymmetry can only come from flows deep within the planet; and on Jupiter, the visible eastward and westward jet streams are likewise asymmetric north and south. The deeper the jets, the more mass they contain, leading to a stronger signal expressed in the gravity field. Thus, the magnitude of the asymmetry in gravity determines how deep the jet streams extend.

The result was a surprise for the *Juno* science team because it indicated that the weather layer of Jupiter was more massive and extended much deeper than previously expected. The Jovian weather layer, from its very top to a depth of 3,000 kilometres, contains about one percent of Jupiter's mass. "These flows on Jupiter contain about one percent of the mass of Jupiter, which is equal to about three Earth masses," said Yohai Kaspi, a planetary scientist at the Weizmann Institute of Science, in Rehovot, Israel, and lead author of one study.

Another study found that the planet's interior moves as a single body beneath the clouds, behaving as a rigid solid despite its fluid nature. Earlier research explained that this is because the hydrogen that makes up much of the planet separates into protons and electrons that generate strong magnetic drag forces. These forces then fuse the circulations flowing in the interior.

Future research will investigate how deep Jupiter's Great Red Spot extends. "We know it's a storm that's lasted for hundreds of years sitting in the same place, but we've only seen it from the outside before," said "Now, with *Juno*, we can capture a 3-D picture of it, which could help shed light on why it's been there so long."

Compiled with material provided by NASA. ✶

Editor's Message

by Nicole Mortillaro

The other day, as I fought a relentless bout of insomnia, I lay on my sofa listening to Janna Levin in a NOVA PBS special with the somewhat melodramatic title "Black Hole Apocalypse."

As she chronicled the history on the theory and subsequent confirmation of black holes, I began to think about how much has been discovered in my rather cosmologically insignificant lifetime.

Black holes? Check. Exoplanets? Check. A picture of the early Universe? Check. A dummy launched on a car? Check.

My earliest memories of space and astronomy—though I had a deep love of it from the age of eight—are strongest from the late 1980s around the early 1990s. I remember reading Terence Dickinson's weekend columns in the *Toronto Star* with fervor; going to the Richmond Hill Public Library and taking out Helen Hogg's book, *The Stars Belong to Everyone*. But I remember the discoveries. The photograph from the *Cosmic Microwave Background Explorer* of our earliest Universe; of the first exoplanets discovered (one was incorrect, but still...)... I couldn't believe I was living in such an amazing time.

Since then we've:

- detected gravitational waves
- come to understand most stars are home to not just one, but multiple planets
- finally revealed what Pluto looks like
- been visited by an asteroid from another star system
- discovered numerous icy bodies in the Kuiper Belt
- landed on Titan (Figure 1)
- seen and flown through water vapour spewing into space from Enceladus
- suspect that Europa and Enceladus could be home to a subglacial ocean and thermal vents that could provide the necessary ingredients for life
- discovered that Mars was once a wet world and still has some of that water
- produced the most marvellous of instruments, the *Hubble Space Telescope*, and looked back 13.4 billion years in time

Shall I go on?

This is just in a span of 20 years.

Imagine if we could travel back in time and bring one of our members—say, Andrew Elvins or Clarence Chant—to here and now, 150 years after the first whispers of our Society began, and showed them quasars, pulsars, or the breathtaking images from *Hubble,* and say, hey, more and better is yet to come.

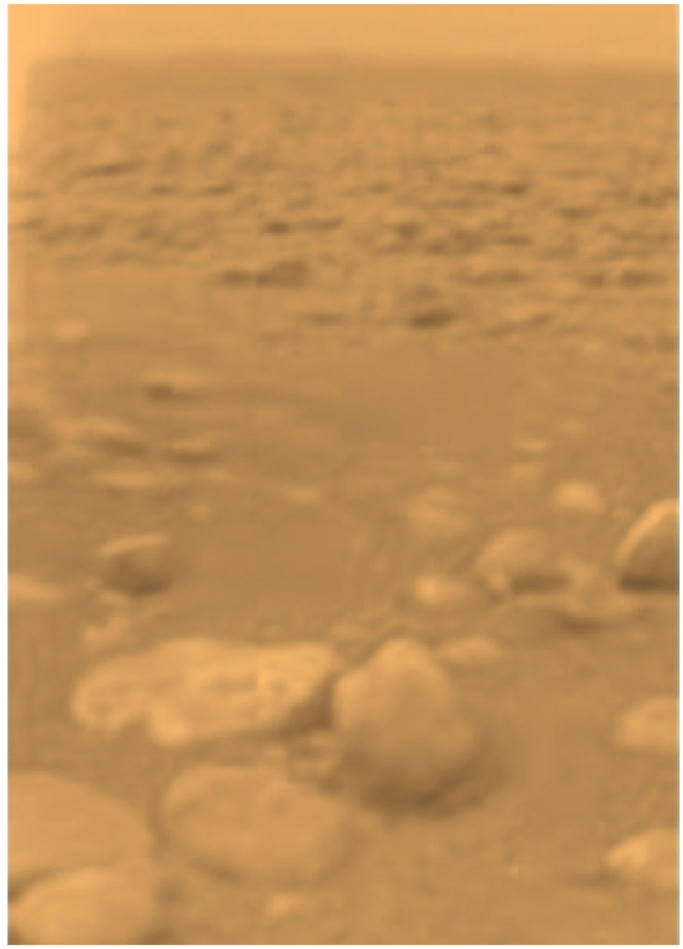

Figure 1 — Titan's surface as recorded by the Huygen's lander from ESA's Cassini *spacecraft on 2005 January 14.*

We owe them thanks for bringing us together; for founding a place where like-minded people can get together and share the love of the cosmos. We can only imagine what they'd think if they saw how far we'd come.

Yet...

We need to do more to continue their work. Yes, we are a society of knowledgeable and passionate people. But we are living in a wildly different time than our founders from 150 years ago.

Our Society needs a breath of fresh air, new means to share our passion with the public. We need to shed the façade of a stuffy club dedicated only to the experts. We need to be relevant. We need to embrace all the means we have—far more than our founders could have ever imagined—that allow us to share these new discoveries, and welcome those who share the passion of all the members who have come before us. It's done through outreach, through passion, and through acceptance.

In 150 years, will your name be remembered among those who shared the love of our Society?

We all have a role to play. What will yours be? ✶

The RASC's National Sesquicentennial Celebrations

by R.A. Rosenfeld, RASC Archivist (randall.rosenfeld@utoronto.ca)

Abstract

This paper offers a brief description of the Society's national programming for RASC 150.

Sesquicentennials, ours and others

As a cooperative astronomical endeavour, we have been around for a goodly time "advancing astronomy and allied sciences." Our origins make us nearly as old as the country, and our sesquicentennial follows on Canada 150 (in truth the Society can claim several "beginnings;" Rosenfeld 2017; Rosenfeld & Laird 2018). The RASC has chosen to celebrate 2018 as the sesquicentennial of the ultimately successful effort to forge a lasting association of astronomers in Canada. The original meeting on 1868 December 1 in Toronto, despite several vicissitudes, has led to a thriving national organization. In recognition of that fact we are unapologetically holding a year-long party.

There aren't many Canadian scientific and cultural intuitions that have accumulated years sufficient to celebrate their sesquicentennials, and the RASC is the first Canadian astronomical organization to do so. The most recent year-long countrywide celebration indulged in by the Society was the UNESCO International Year of Astronomy in 2009 (in cooperation with our sister organizations, CASCA and the FAAQ), and before that, we had a modest celebration of sorts in 1967–1968 to take stock of the progress of Canadian astronomy over the century since confederation (Hesser et al 2010; [Ed.] P. Russo & L.L. Christensen 2010; Northcott, Astronomy in Canada).

We're hardly the first voluntary astronomical organization to celebrate a sesquicentennial, although there have been relatively few in the English-speaking world. The one that comes readily to mind is the 150th anniversary of the Royal Astronomical Society in 1970 (Hujer 1971). The sesquicentenary of famous members of the profession are occasionally noted in the literature, as was done for J.L.E. Dreyer of NGC and IC fame—for reasons beyond their control, such honourees are constitutionally unable to assume a lively part in their celebrations (McFarland 2002). Astronomically speaking, the 150th anniversaries of astronomical research institutions are likely to occur in greater number than those of astronomical associations, because there are more of them, but their number will never be great. RASC Honorary Member Jay Pasachoff oversaw the sesquicentennial of the Hopkins Observatory at Williams College, the oldest surviving university observatory on the United States, in 1987 (Pasachoff et al. 1987).

Centennials appear to be celebrated more often than sesquicentennials, perhaps because a century is perceived as a more significant milestone than a century and a half, and we are culturally conditioned to the artificial dividing of spans of human history into hundred-year chunks, as if 100 years possessed some intrinsic significance (e.g. 17th century, 18th century, "the century of Newton," or "the century of relativity," and so on), or all of that combined with a feeling that a century is the largest portion of time extending beyond most of our lifetimes, which we yet feel we can almost "touch" or experience because we *could* live that long, and have met or know of people who are centenarians.

It is timely to note that the term "sesquicentennial" would probably have been unfamiliar to our ancestors who founded the Toronto

Figure 1 — Google Ngram of the occurrence of the lemma "sesquicentennial" (an ngram is a contiguous sequence of n items from a given sample of text). The apparent data points from before 1890 are almost certainly false positives.

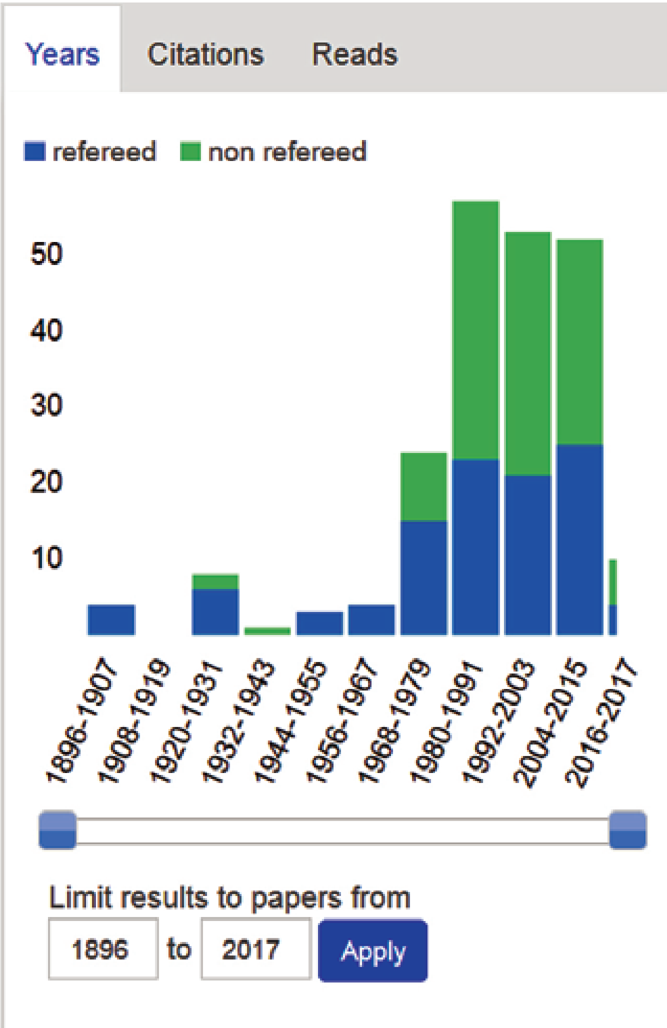

Figure 2 — Graph of occurrences of "sesquicentennial" in the SAO/NASA Astrophysics Data System (ADS) corpus.

Figure 3 — Screen capture of Paul Delaney, capably hosting the official opening event of RASC 2018, the National Star Party, on January 27.

Figure 4 — Screen capture of astronaut Dr. David Saint-Jacques of the CSA, conveying his congratulatory message to the Society.

Astronomical Club/Toronto Astronomical Society in 1868. The *Oxford English Dictionary* offers 1880 as the earliest printed citation for the term, which incidentally coincides with the period of the RASCs revivification (OED Sesquicentennial). A Google Ngram of the word (Figure 1) suggests its currency begins in the 1890s, and the term even manages a sporadic appearance in the astronomical literature around the same time, as indicated by the graph of frequency based on data from the NASA/SAO Astrophysical Data System (Figure 2). It is in origin an American coining.

At first sight, it might seem that most institutions usually have only one shot at celebrating the 150th anniversary of their founding. Upon further consideration, many institutions may find that they can claim more than one possible founding date, which to the historical literalist may seem an embarrassment of riches. Many institutions may choose the date most hallowed by tradition, or the earliest possible date, or the most romantic date as *the* occasion to be commemorated. The RASC of the present has chosen 1868 for the temporal origin of its sesquicentennial. There are good reasons for that choice, but none of the possible choices (1868, 1884, 1890) taken in isolation are unproblematic (Rosenfeld & Laird 2018, 77–78; Broughton 1994, 4–6, 19–20, 23). As our immediate past Honorary President John Percy has wisely said:

> "These things are seldom cut-and-dried. The University of Toronto dates from its charter in 1827, but nothing was built until the 1850's. In my column in the February 2018 Journal, I simply stress that we should give due credit to our founders 1868–1890 and beyond. Organizations like the RASC don't suddenly appear, fully-formed" (Percy 2018).

In the spirit of "live long and prosper," if the RASC survives to 2034, 2040, or 2053 (as one hopes), members then active may very well celebrate other Society sesquicentennials. May they make the most of them. A sesquicentennial, like any "big" anniversary, is after all, an opportunity to draw attention to the organization.

Returning to the sesquicentenary of the here and now, the Society through its RASC 2018 Working Group (WG)

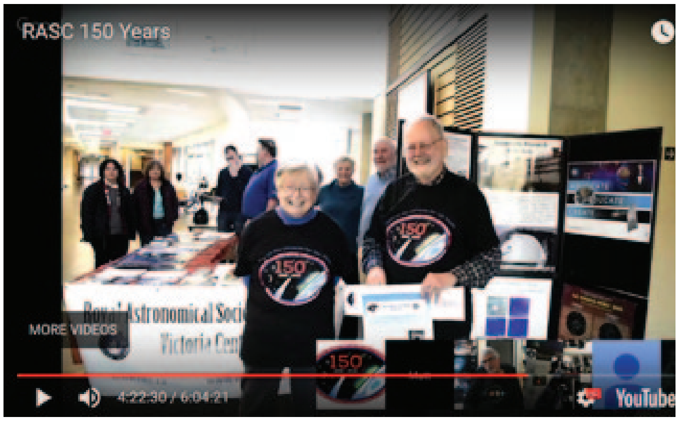

Figure 5 — Screen capture of RASC 2018 Working Group members Lauri Roche and Dr. James Hesser, FRASC, taking part in the Victoria Centre's contribution to the opening National Star Party.

has developed several programs to run during the year. In designing its programming, the RASC 2018 WG has endeavoured to strike a balance between exploring our past, celebrating our present, and looking to our future. Some activities have already launched, and several will be launching in the ensuing months. They are briefly outlined/introduced below.

The National Star Party, 2018 January 27

The opening event most fittingly was a national star party in late January (www.rasc.ca/national-star-party-2018). This was an online, rolling event, involving over a third of the Society's Centres, with each joining at 3 p.m. local time, and with the conclusion at 8 p.m. Eastern Time. The host of the event was the very capable and broadcast-hardened Paul Delaney (Toronto Centre; Figure 3), a member of the RASC 2018 WG, aided on the technical side by Allard Schipper (Toronto Centre). The platform used was Hangouts On Air with YouTube Live. A highlight of the event was astronaut David Saint-Jacques' greeting to the RASC from the CSA (Figure 4). Also appreciated were greetings from Nadine Manset and colleagues of the Canada-France-Hawaii Telescope on Maunakea (CFHT), Jan Cami and colleagues of the Hume Cronyn Memorial Observatory (Western University), and Rob Thacker and Dave Lane of the Burke-Gaffney Observatory (Saint Mary's University). Many participants found it invaluable to see what other RASC Centres and members were up to (Figure 5). The event unfolding across the country fostered an appreciation of how the RASC is sited on the Canadian landscape (and beyond), and a sense of connection in our shared commitment to explore and share the Universe. Those who want to revisit the event in whole or part can do so at either www.rasc.ca/national-star-party-2018, or www.youtube.com/watch?v=uN7IKkRwBK0.

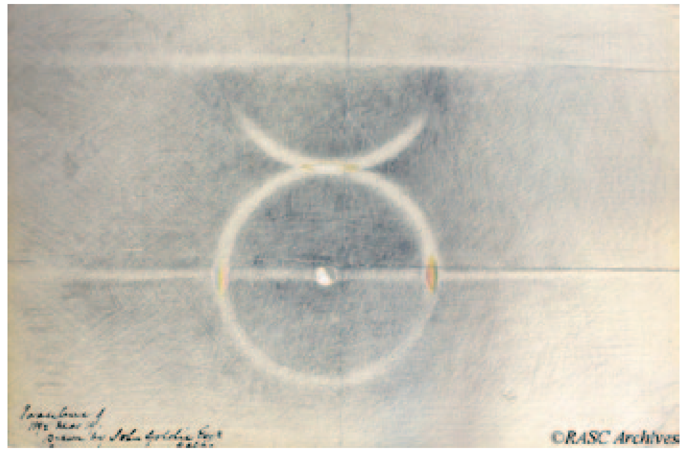

Figure 6 — RASC member John Goldie's evocative drawing of a paraselene from 1892 March 19. Reproduced courtesy of the RASC Archives.

Cultural Connections

The Cultural Connections component of RASC 2018 is intended to make available ideas and resources for RASC Centres to develop programming with other local cultural institutions, either partners from past efforts, or new collaborators, to explore the connections of astronomy with other areas of human activity, both traditional and untraditional (www.rasc.ca/cultural-connections-resources). Those who have done this in the past have discovered that such programming can reach sectors of the population not normally reached by RASC programming, or any astronomy programming at all, which is a plus. The latitude in possible programming is only limited by imagination.

By way of example, the Kitchener-Waterloo (K-W) Centre contacted a respected local gallery, the Homer Watson House & Gallery, dedicated to the heritage of the noted painter Homer Watson (1855–1936), to see if the gallery would be interested in a show illustrating the evolution of amateur

Figure 7 — Jeff Dawkins' image of the aurora. ©Jeff Dawkins.

representations of astronomical phenomena from 1868 to the present, to celebrate both the achievements of the K-W Centre, and more broadly RASC 2018 (National Gallery of Canada, Homer Watson; Homer Watson House & Gallery). The Gallery enthusiastically agreed to the K-W Centre's proposal (the project lead is Clark Muir), and the exhibit *Science and Art: 150 Years of Astronomical Imagery* was born. This is a marriage of the professional museological expertise and support of the Homer Watson House & Gallery staff with the astronomical expertise of the K-W Centre. The exhibition is built around images by local astronomers from the region spanning 1868–2018, with some early material drawn from the RASC's National Archives (Figure 6), the University of Toronto Archives and Records Management Service (UTARMS), and the Specula astronomica minima (the last is a private collection of astronomical artifacts). On loan from UTARMS will be a notable visual artifact of Canada's astronomical history & heritage, Gustav Hahn's painting of the Great Meteor Procession of 1913 February 9. This will be publicly displayed for the first time next to the version published in JRASC that year (for both images, see Rosenfeld & Muir 2011, 168, 171). Originals of the sort of tools used by early RASC astrosketchers will also be on display. A particular feature of the modern part of the show will be the nightscapes of K-W Centre member Jeff Dawkins (Figure 7). The exhibit is scheduled to run from September 9 to October 21, and any RASC member from across the country who happens to be in the Kitchener-Waterloo area during the exhibition is invited to attend.

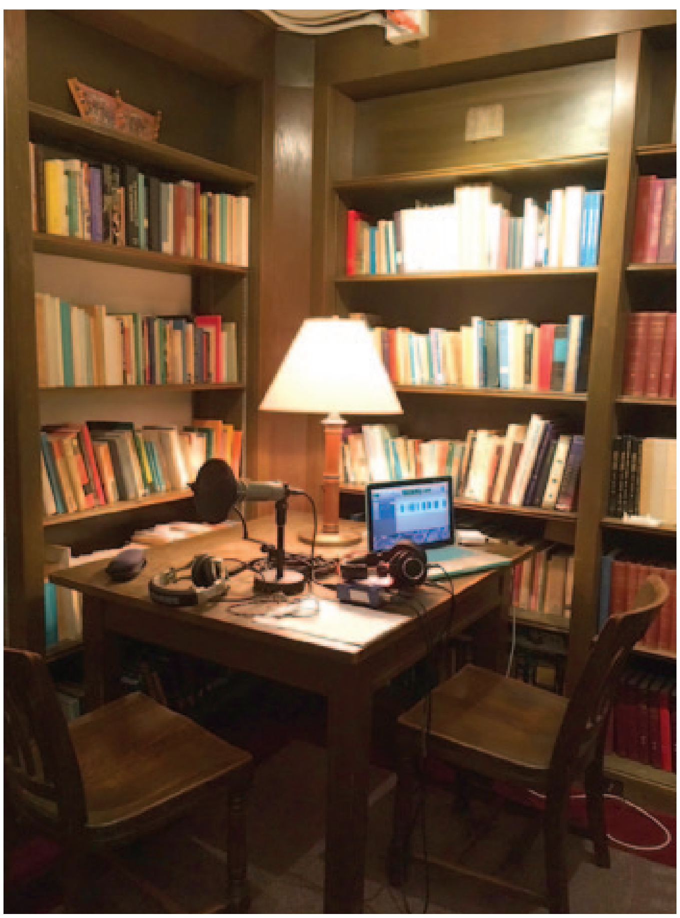

Figure 8 — Guerilla recording studio for the RASC podcasts. ©Chelsea Body.

The 2018 Podcast

Podcasting has grown in popularity and sophistication since the debut of the medium during the first half of the first decade of the 21st century. One reason to opt for a podcast over a videocast is the comparative ease of recording sound compared to recording high-quality video, even in this age of the relative democratization of visual recording and editing technologies. This sesquicentennial program was originally conceived as a videocast on the history of the RASC, but the switch to a podcasting format seemed a better match to our *matériel*, expertise, and personnel.

The podcasts present episodes of the Society's history judged to be of interest to members, and non-members alike. Their content is based on primary and secondary sources, both textual and artifactual, and leans heavily on our archival holdings. The producers set out to offer a view of the RASC's people, events, and remaining artifacts, which is not simply an anodyne or hagiographic repetition of what the Society thinks it knows of itself, but rather a contextualized and nuanced revaluation of the evidence as it exists. As of the time of writing of this article, work on the first three episodes has uncovered new evidence about our founding, and new ways of looking at our founders, and some of our earliest practices, with a connection to what we do at present (Rosenfeld & Laird 2018; Rosenfeld, 2018 Podcast: Episode 1 Supplement; 2018 Podcast: Episode 2 Supplement). Topics include the contested beginnings of the RASC, the RASC's varying commitment to citizen science, how science was and is communicated, the RASC's tradition of amateur telescope making, and the RASC and invisible astronomers.

The podcast will run all year, with a new podcast being recorded and released each month. The full slate of episodes is listed at www.rasc.ca/rasc-2018-podcasts. The podcasts are supplemented with dedicated webpages featuring images of documents and artifacts referred to in the episodes, along with further information and links.

The hosts of the podcast are Heather Laird (Calgary Centre) and the Society's Archivist (who is also the researcher and writer), the sound engineer and producer is Chelsea Body, the webmaster is Walter MacDonald (Kingston Centre), and the theme music by Eric Svilpis was commissioned especially for the series. We are particularly grateful for Chelsea's skill and expertise, and Walter's dedication.

RASC Mosaic

This project grew out of a suggestion of Brendon Roy (Thunder Bay Centre). When viewed from a distance, the mosaic presents a single visual image of a recognizable astronomical phenomenon, or a representational emblem of RASC identity, which, when viewed close up, resolves into its individual building blocks comprising pictures of Centres and RASC members engaged in astronomy, or of astronomical images produced by members. Its symbolism of embodying the RASC as a single whole, made up of the individual efforts of our constituent Centres and members, is an immediately attractive one.

Many Centres have contributed images, and they are being combined with historical images from our Archives of Centre activities, members, and the astronomical imagery they created. Combining images of the RASC of the present with images of the RASC of the past adds another easily comprehended strand of symbolism, the temporal strand portraying the continuity of our cooperative commitment to astronomy. These will become the material of the mosaic, which will be officially unveiled as a banner at the 2018 GA in Calgary and will also be available in electronic form for Centre and member use on www.rasc.ca/rasc-2018-mosaic. The lead on this project is June MacDonald (New Brunswick Centre), assisted by Heather Laird (Calgary Centre), with professional design help from Janice McLean.

Imagining the Skies

A broadly conceived participatory celebration of astronomy without an active imaging component is inconceivable, so the RASC 2018 WG designed one, for members and non-members alike. *Imagining the Skies* is an "astrophotography, sketching, and creative arts contest," with two concurrent contest streams:

1) one for entries of astrophotographs, and sketches done at the eyepiece; and

2) the other for entries in all other media, including painting, drawing, textile arts, stained glass or any mixed media.

And there are three categories of entrant (self-selected);

1) novice, for those new to astronomy observing, astrophotography, sketching at the eyepiece or working in a new medium in 2018;

2) intermediate, for those who have under five years of experience in astrophotography, sketching, or another medium; and

3) experienced, for those who have been working with astrophotography, sketching, or another medium for more than five years.

The project leads, Lauri Roche (Victoria Centre) and Jim Hesser (Victoria Centre), particularly want to encourage those who've not tried astrophotography, astrosketching, or astronomical art, to give it a try, and submit their work to the contest.

Voting is participatory as well. Everyone is invited to vote for their favourite entries within each category all year long, from the home page of the contest. Votes in each section will be totalled for quarterly recognition. At the end of the year, the public will vote on the highly ranked quarterly submissions and an expert panel of RASC members will also choose their favourites to come up with the final winners in each category.

The prizes are modest; the twelve winners will each receive a plaque with their winning image; their images will be published electronically on the contest website(s) and in a RASC periodical; and the recognition for and satisfaction from having won.

The project leads are very grateful to Doug Renehan for help in designing, building, and curating the project website, and Walter MacDonald for assistance.

Contest details can be found at: imaginingtheskies.ca.

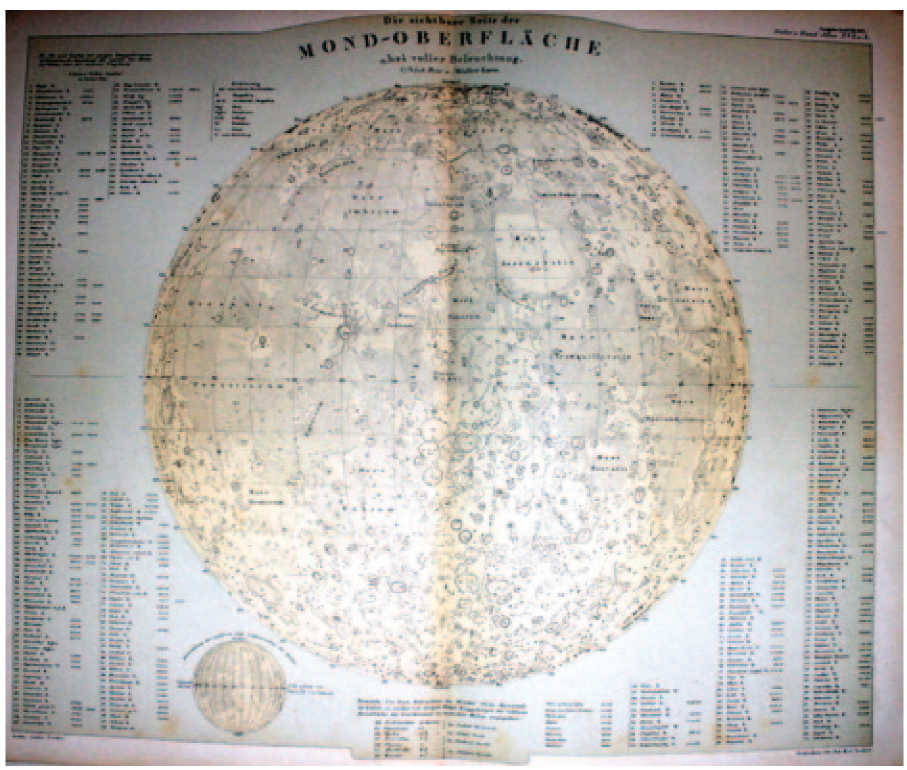

Figure 9 — Beer and Mädler's map of the Moon, in the 1872 version from Stieler's Handatlas. Reproduced courtesy of the Specula astronomica minima.

A Shared Sky: the RASC 1868–2018

A celebration of a considerable swath of the life of a Society ought fittingly to have a major historical undertaking among its activities. A sesquicentennial is by its very nature a historical event. *A Shared Sky: the RASC 1868–2018* (aka RASC 2018—*the* history book) is a major multi-author collaborative project to examine aspects of the RASC's history hitherto neglected, and to re-examine our present historical understanding of the Society. It's not generally recognized how few people are seriously engaged in research into Canada's astronomical history and heritage. A good proportion of that select cohort are members of the Society's History Committee, such as Peter Broughton, FRASC (Toronto Centre), Roy Bishop, FRASC (Halifax Centre), Chris Gainor (Victoria Centre), and Clark Muir (K-W Centre), to name a few.

Looking into our history is not just a historical exercise. Viewing our past enables us to see the foundations upon which the modern RASC is constructed, and to build for the future. The better we know the nature, variety, and range of the astronomy experienced within the RASC across time, the better we can know ourselves, and the possibilities for renovation, renewal, and innovation. Significant anniversaries can provide significant opportunities for reflection, and reassessment. They can also spur new efforts to bring to light stories previously unknown, to complete stories only partially known, and to discern what we've missed in stories we thought we thoroughly knew.

A Shared Sky: the RASC 1868-2018 has two components. The first is a symposium on the history of the RASC, which will feature invited speakers talking on various aspects of our practice of astronomy over 150 years. Due to the generosity of the local arrangements committee of the 2018 GA in Calgary, the symposium will be an integral part of that event. The abstracts and speakers' biographies can be viewed at: rascga2018.ca/a-shared-sky-the-rasc-at-150.

The second part of *A Shared Sky: the RASC 1868–2018* is the production of a peer-reviewed edited book based on the talks given at the GA, with additional solicited contributions to round out the contents. The book will be the first extended historical work on the RASC since the appearance of Peter Broughton's *Looking Up*, which was published nearly a quarter century ago, and much of our history has been uncovered since that time, by Peter and others.

The leads on *A Shared Sky* are the Society's Archivist and Heather Laird.

In addition to being the venue for the first stage of *A Shared Sky*, the 2018 Calgary GA itself will be a memorable locus for our sesquicentennial. Two Crown Agencies will be on hand to make exciting announcements of direct relevance to our 150th anniversary.

Viewing the Moon Across Time

The most recently launched of our sesquicentennial projects is an observational one, with an interesting historical twist. Have you ever wondered what the observing experience was like for the first members of the Society? Was it very different from what we are used to in the 21st century? How have things changed? Now is your chance to find out!

Viewing the Moon Across Time provides an opportunity to creatively enjoy the flavour of past amateur astronomy, through active engagement with its materials (Figure 9). The resources provided by this project enable experimentation in exploring past styles of observing, in using earlier equipment and techniques (or their nearest modern equivalents), and in recapturing the intellectual formation of observers at the very beginning of the Society. You are invited to be as "authentic" as you like in recreating the experience of observing the Moon in 1868. The protocol outlined here can be applied to active experimentation with materials from any time before the present.

Of course, it is literally impossible to step into the past, and forget the current state of scientific and technological knowledge, to erase from our memories up-to-date visual imagery of the Universe, and to process observational experience exclusively through the former worldview and emotionally mediated responses of a past stage of human culture. We are not interchangeable with our ancestors of even half a century ago. Nonetheless, there is much to be gained from seeing how our predecessors observed, through actually trying to master their processes. No paper account of past observing protocols can fully reproduce the gain in visceral knowledge from actually *doing* in real time what those sources describe.

In common with the other RASC 2018 projects described earlier, *Viewing the Moon Across Time* is not just a historical exercise of "cosplay" at the telescope. It has direct applicability to how we do astronomy now. In exploring "How did our predecessors observe?" and other questions, such as:

- "Are there skills we have forgotten, which could benefit modern observing?"
- "What did astronomers of the past see at the eyepiece?"
- "To what extent are our visual vocabularies of astronomy different from theirs, and why?" and
- "What can we learn from the familiar and unfamiliar in our predecessors' approach to the night sky?"

we can improve our own craft of observing, and enrich our resources for education and public outreach. A healthy science is an evolving science. If we are honest with ourselves, the final question we should ask ourselves is "Are we ready to admit that as we view the astronomy of 1868, so our astronomy of 2018 will be viewed in 2168?" The project lead is the Society's Archivist.

Resources for *Viewing the Moon Across Time* can be found at: www.rasc.ca/rasc-2018-viewing-the-moon-across-time.

Remote Telescope Project, and Refurbishing the Archives

There are several projects of national reach that don't fall under the aegis of the RASC 2018 WG, but which certainly merit inclusion here.

A remote telescope has long been a project the Executive Director, Randy Attwood (Mississauga Centre), has wanted to realize for the Society. Due to his efforts, in March of this year the Fundraising Committee and Board of Directors finally approved the funding for a 40- to 60-cm telescope, fully equipped and flexible for imaging, in a suitably remote location such as the Sierra Remote Observatories site in California.

An initial description of the remote telescope project was published in the 2018 March Bulletin, and by the time this issue of the *Journal* appears, the project should be much further advanced.

A second project is the expansion, and refurbishment, of the Society's National Archives, to better fulfil its mission of preservation of our material heritage, and further accessibility to the remains of our past. The space will also provide a culturally rich space for meetings, an appropriate place for delivering programs *in situ*, and remotely, and a setting for media appearances of the staff, and others. This project will be complete by the time this paper is published.

The Society has much to celebrate, and much to look forward to, as it continues to "promote astronomy and allied sciences" into this century, and the next. ✶

Acknowledgements

This research has made use of NASA's Astrophysics Data System. The author wishes to thank the members of the RASC 2018 WG—Paul Delaney, Jim Hesser, Heather Laird, June MacDonald, and Lauri Roche—for their collegiality and hard work, Chelsea Body and Walter MacDonald for dedicated technical expertise, Julia Neeser, Renata Koziol, and Randy Attwood for much help in furthering our sesquicentenary, and Robyn Foret and colleagues of the local arrangements committee for the 2018 GA.

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Carl Beals and P-Cygni Profiles

by Donald C. Morton
Herzberg Astronomy and Astrophysics Research Centre
National Research Council

Abstract

At the Dominion Astrophysical Observatory from 1927 to 1946, Carlyle Beals became an international authority on Wolf-Rayet stars and the related small class of P-Cygni stars. The latter stars and some Wolf-Rayet stars have narrow absorption lines on the short-wavelength edge of some emission lines, often with Doppler velocities exceeding the escape velocity, thus indicating mass ejection from the stellar atmosphere. A far-ultraviolet spectrum obtained in 1965 with a rocket-borne spectrograph discovered the same phenomenon in the normal hot supergiants in the Belt of Orion demonstrating that the mass loss identified by Beals is a general property of all hot luminous stars.

Introduction

Carlyle Smith Beals (1899-1979) (Fig. 1) was born in Canso, Nova Scotia. He received a BA in physics and mathematics in 1919 from Acadia University followed by an MA on Triboluminescence Spectra (Beals 1923) at the University of Toronto under J. C. McLennan. He continued his studies at Imperial College in London, England with Alfred Fowler, receiving a Ph.D. on the spectrum of palladium in 1926 (Beals 1925). He returned to Acadia for a year as an Assistant Professor of Physics.

The Dominion Astrophysical Observatory

Beals began his astronomical career at the Dominion Astrophysical Observatory (DAO) in Victoria in 1927 as Assistant Astronomer, becoming First Assistant Astronomer in 1940. Following a suggestion by the Director, J.S. Plaskett, Beals began investigating Wolf-Rayet (WR) stars, an uncommon type of star with broad emission lines of hydrogen, ionized helium, and doubly ionized carbon, indicating a high surface temperature. He quickly became an authority on these stars with a presentation in August 1929 at the 42nd meeting of the American Astronomical Society in Ottawa (Beals 1929a), a *Journal* paper (Beals 1929b), a DAO publication (Beals 1930a) and a popular account (Beals 1930b). He validated the hypothesis that the broad lines resulted from an expanding atmosphere by showing that the width of the emission lines increased roughly linearly with wavelength. Also in Beals (1931) he showed that the flat-topped emission lines found in many WR

Fig. 1. Carlyle Smith Beals

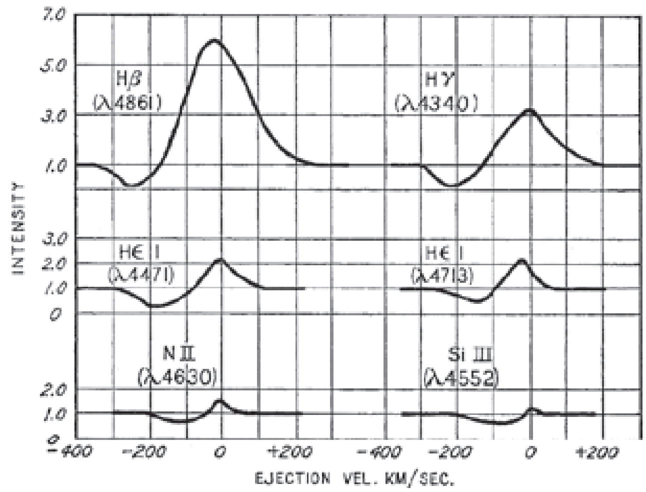

Fig. 2. P-Cygni profiles in the spectrum of P Cygni observed at the DAO from Beals (1953).

stars were consistent with a simple model of an expanding atmosphere. Furthermore, a subset of WR stars had narrow absorption lines on the short-wavelength edge of some of the emission lines, indicating high-velocity ejection along the observer's sight line. In the most extreme cases the Doppler shifts implied velocities were a few thousand kilometres per second. Altogether Beals published 9 papers and 5 conference abstracts specifically about these stars.

As further evidence of mass ejection from Wolf-Rayet stars, Beals noted similarities with the spectra of some novae and with a curious class known as P-Cygni stars. By definition these stars have absorption on the short wavelength edge of at least one emission line, but the emission typically is much narrower and the ionization less energetic than the WR stars. The prototype P Cyg* = 34 Cyg was unknown before the year 1600 when it appeared as a 3rd magnitude star until 1606. Then it gradually faded becoming invisible before brightening again to magnitude 3.5 from 1655 to 1659. Smaller fluctuations followed until 1715 when it settled close to its present V = 4.81, B-V = +0.42. The modern spectral type B2pe labels it as peculiar with emission lines.

**The P label is not an indicator of a variable star, but a holdover from Bayer's catalogue after he used all the Greek letters. (http://stars.astro.illinois.edu/sow/pcyg.html).*

These stars became a major research topic for Beals, eventually resulting in 11 published papers and 6 abstracts. His last paper on this topic (Beals 1953) was a comprehensive 137-page contribution to the *Publications of the Dominion Astrophysical Observatory*. It provided a thorough review of each of the 69 known P-Cygni stars, combining his extensive knowledge of the literature with the analysis of his own DAO spectra (Fig. 2) and plates lent by American colleagues. The underlying spectral types ranged from O5 to A4 and the absolute magnitudes M_V from -8.4 to +6.0, though rather uncertain in many cases. As with the Wolf-Rayet stars, Beals assumed the driving force was radiation pressure and developed simple geometrical models for the expanding atmospheres to account for a variety of profiles.

Along with his stellar observations at the DAO, Beals contributed to early studies of interstellar absorption lines, demonstrating cases of multiple absorbing clouds (Beals 1938) and noting the diffuse nature of the band at 4430 Å (Beals and Blanchett 1938). This was the first of the many diffuse interstellar bands, all of which still remain unexplained. Beals also was active in enhancing instrumentation at the observatory including a microphotometer for scanning spectrograms (Beals 1932) and improved capabilities for the spectrograph on the telescope (Beals, Petrie and McKellar 1946).

P-Cygni Profiles

My own connection with Beals and his DAO research arose while I was based at Princeton University. Lyman Spitzer had hired me to run a NASA-sponsored program to put simple instruments on sounding rockets in preparation for an orbiting telescope to observe the ultraviolet spectra of stars. I was using an objective spectrograph in which a Schmidt camera with a 5-cm aperture and a 5-degree field of view photographed starlight reflected off a plane grating, all inside a 15-inch-diameter Aerobee rocket. To resolve stellar absorption lines, we reduced the jitter of the rocket pointing system in the dispersion direction with a novel passive gyroscopic stabilization using a massive rotor from a bomb sight purchased at a war-surplus outlet in New York City.

My target on 1965 Oct. 13 at the White Sands Missile Range in New Mexico was the three bright stars forming the belt of Orion — δ (O9.5 II), ε (B0 Ia) and ζ (O9.5 Ib) — chosen because of the possibility of recording all three spectra on the same exposure. On recovering the payload in the desert the next morning and processing the film, I saw that the spectra had the anticipated strong absorption lines of the Si IV doublet at 1394 and1403 Å and the unresolved C IV doublet at 1549 Å plus unexpectedly strong emission on the long-wavelength side of each doublet (Fig. 3 and Morton 1967a). Back in Princeton, I used the zero-order images of other stars in the field to determine an absolute wavelength scale. I was astonished to discover that the emission lines were at the expected laboratory wavelengths and the absorption lines were displaced shortward by about 9 Å corresponding to a Doppler velocity toward the observer of approximately 2000 km s^{-1}!

Needing some advice from an experienced stellar spectroscopist, I telephoned Jack Heard, Director of the David Dunlap Observatory. He had hired me as an assistant there during my undergraduate years (1952-1956) at the University of Toronto. When I explained what I had observed, he advised me to look into Beals' papers in the DAO Publications. Soon I was reading about P-Cygni profiles and quickly realized they were present in my UV spectra with the Doppler shift of the absorption lines implying the stars were ejecting their atmospheres at 2000 km s^{-1}. However, these Orion stars were not known as P-Cygni stars. They were classified as normal supergiants (or a bright giant in the case of δ Ori) by their visible spectra. In fact, all three of them were the standards for their class as defined by Johnson and Morgan (1953).

My rocket spectra demonstrated that the P-Cygni phenomenon, which Beals had documented so thoroughly, is not limited to a few peculiar stars. It is the norm for all hot luminous stars when observed at ultraviolet wavelengths that include the C IV or Si IV resonance transitions or similar ones such as the N V doublet at 1241 Å. In the hot atmospheres of the O and B stars, mass ejection reveals itself best in the strong far-ultraviolet absorptions from the ground state of multiply ionized atoms rather than in the weaker absorption lines from excited levels at visible wavelengths. I applied some simple theory to the observations (Morton 1966b) and estimated a mass-loss rate of 10^{-6} $M_{sun}yr^{-1}$ for the Orion stars.

In later observations with the *Copernicus* satellite, Snow and Morton (1976) found shifted absorption lines across all normal O and B spectral and luminosity classes except for subgiants (class IV) and main-sequence stars (class V) of spectral type B1 and cooler. Lamers and Morton (1977) derived an ejection rate of $(7±3)x10^{-6}$ $M_{sun}yr^{-1}$ for the O4 If star ζ Puppis. Figure 4 reproduces, from the *Copernicus* satellite, spectra of the N V doublet for ζ Oph (O9.5 V) and ζ Pup (O4 If).

Since these early days, the study of P-Cygni profiles and stellar winds has progressed wonderfully through observations by the International Ultraviolet Explorer and Far Ultraviolet Spectroscopic Explorer and the detection of radio, infrared and X-ray emission. Also, as discussed by Lamers (2008), the associated theoretical work has given us a good understanding of the dynamical and radiative processes, though unresolved problems remain such as the wide range of ionizations often present and the possibilities of clumping and asymmetric flows.

The discovery of the broad-absorption-line quasistellar objects (BAL QSOs) extended P-Cygni profiles to the extragalactic universe. As might be expected for such luminous sources, the effects can be much stronger. In Fig. 5, for example, the spectrum of 0105-2634 by Hazard, McMahon and Morton (1987) shows terminal speeds of 0.08 and 0.06 of the velocity of light respectively for the C IV and N V absorptions relative to the emission lines. Often the profiles are significantly different from the stellar examples as in this case where the

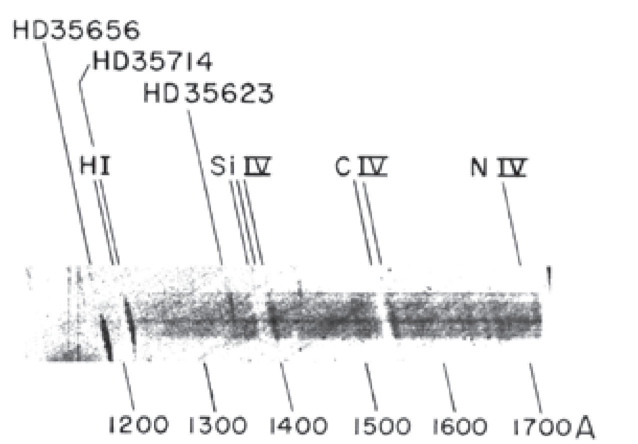

Fig. 3. Rocket far-ultraviolet spectrum of the normal supergiant ζ Ori (O9.5 Ib) from Morton (1966) showing the P-Cygni lines of Si IV and C IV. The black emission lines are at the star's radial velocity while the displaced absorption lines indicate mass ejection up to 2000 km s^{-1}. The wavelength scale at the bottom is in Angstrom units.

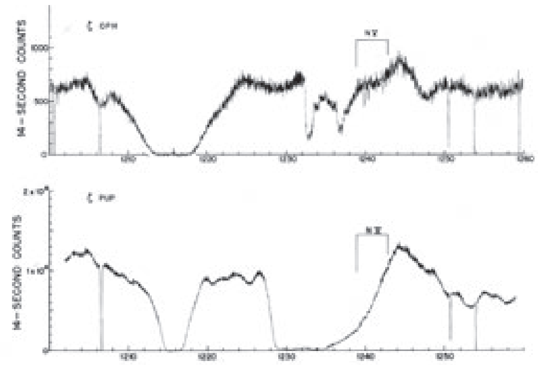

Fig. 4. Copernicus *far-ultraviolet spectra of the P-Cygni profiles of the N V doublet in the O9.5 V star z Oph and the O4 If star ζ Pup from Morton (1976). The respective terminal velocities are 1580 and 2880 km s-1. Both scans include the broad interstellar absorption line of H I Lyman a at 1216 Å and the narrow ones of N I on the left and S II on the right. The horizontal scales indicate wavelengths in Angstroms.*

long-wavelength edge of the absorption is separated from the emission.

Dominion Astronomer

In 1947 Beals moved to Ottawa to become Dominion Astronomer at the Dominion Observatory (DO) in the Department of Mines and Technical Surveys (DMTS) until his retirement in 1964. There his responsibilities included geophysics as well as astronomy at both the DO and the DAO. Nowadays in Canada this position, without the geophysics, is essentially equivalent to that of the Director General of the Herzberg Astronomy and Astrophysics Research Centre at the National Research Council (NRC). In 1970, following the recommendations of the 1960-1963 Glassco Commission, Parliament left the geophysics part of the Dominion Observatory with the Department of Mines and Technical Surveys (DMTS), now Natural Resources Canada, and merged the astronomy with the radio astronomy program that NRC already supported at the Algonquin Radio Observatory, thus giving the Council the responsibility for all national astronomy facilities.

During his tenure as Dominion Astronomer, Beals approved the addition of photographic zenith tubes in Ottawa and Alberta to better track the wandering of the North Pole, two meteor cameras in Alberta to record their frequency and aid in locating remnant meteorites on the ground and a 1.2-m telescope with a coudé spectrograph at the DAO to record high-resolution spectra. Beals also introduced solar physics at the DO through the purchase of a birefringent Lyot filter to study solar flares with monochromatic images in the hydrogen Balmer alpha line. The successful operation, maintenance and contributions to the World Data Center by Vic Gaizauskas eventually led to the establishment of the Ottawa River Solar Observatory.

Particularly important for Canadian astronomy was the establishment of the Dominion Radio Astrophysical Observatory with a 26-m telescope near Penticton, BC. Hodgson (1994) described how Jack Locke had arranged a series of colloquia on radio astronomy at the DO during the winter of 1955-56 to review the literature in this increasingly important field. Then, in March 1956, Beals attended a meeting of the American Astronomical Society in Columbus Ohio. According to Victor Gaizauskas (private communication), who travelled to the meeting with Beals, there was much discussion about constructing major radio facilities in the United States so Beals returned to Ottawa convinced that Canada should do the same. The following month he wrote a letter to the Deputy Minister of Mines and Technical Surveys, which resulted in a Treasury Board submission on September 9. There was a competing one from the NRC, but Beals convinced the NRC President, E. W. R. Steacie, to let the DMTS proposal go first. It had the advantage of building on the research experience in galactic structure at the DAO. The Treasury Board approval came on Nov 30, less than eight months after the original letter. See also Locke (1998).

Along with his administrative duties in Ottawa, Beals continued his scientific research. He completed his extensive analysis of the P-Cygni stars and submitted the manuscript in May 1950 (Beals 1953). He also supervised the PhD. thesis of a colleague at the Dominion Observatory, John Rottenberg (1949) (Tenn 2016). Rottenberg (1952) continued the theoretical analysis of P-Cygni profiles in a paper in *Monthly Notices* and later Beals and Rottenberg (1956) discussed all types of emission-line stars in the *JRASC*. With Bev Oke, Beals reported an analysis correlating the estimated distances of O, B and A stars with the strengths of the interstellar calcium and sodium absorption lines (Beals and Oke 1953).

The discovery of the 3-km-diameter New Quebec Crater in 1951 stimulated interest in finding impact craters elsewhere

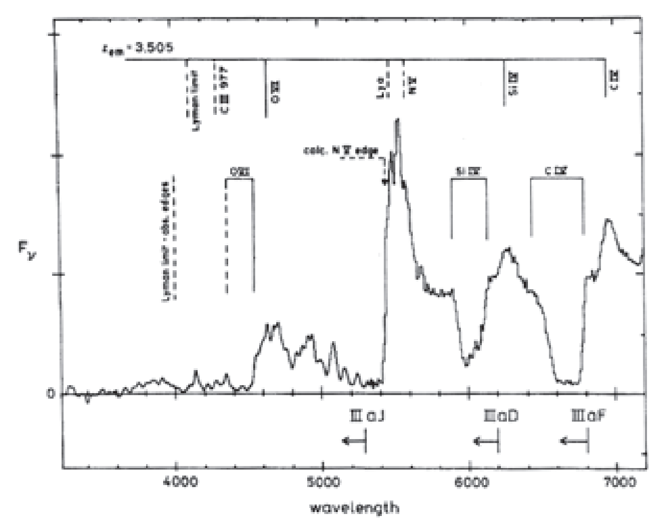

Fig. 5. Spectrum of the broad-absorption-line quasar 0105-2634 observed by Hazard et al. (1987). The solid vertical lines near the top of the figure label the emission lines while the next row indicates the edges of the absorption troughs of the O VI, Si IV and C IV doublets. The N V absorption is blended with Lyman a of neutral hydrogen. The wavelength scale is in Angstroms. Above it are the limits of the photographic emulsions used in the discovery of this quasar with the United Kingdom Schmidt Telescope.

in Canada, particularly in the Precambrian Canadian Shield where features are less likely to be hidden by sedimentary overlay. Beals and geophysics colleagues at the Dominion Observatory initiated a search of aerial photos of Ontario and Quebec and found four candidates with circular features. (Beals, Ferguson and Landau 1956). These surveys and follow-up ground investigations became Beals' primary research interest. This evolved to include analyses of lunar craters that continued during his retirement (Beals and Tanner 1975).

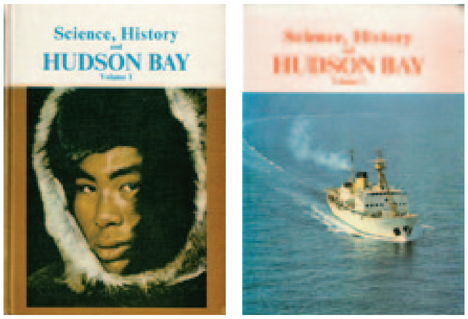

Fig. 6. Covers of the two volumes of the encyclopedia on Hudson Bay edited by Beals.

Another retirement project was editing the two-volume 1058-page encyclopedia *Science, History and Hudson Bay* shown in Fig. 6 (Beals and Shenstone 1968). This included chapters by Beals, Ian Haliday and Tuzo Wilson discussing the possibility that the great arc with a 227 km radius forming the southeastern shore of Hudson Bay resulted from an asteroid impact.

Beals' accomplishments as a scientist and an administrator were recognized in many ways including election to the Royal Society of Canada in 1933, the Royal Society in 1951, President of the Royal Astronomical Society of Canada 1951-52, President of the American Astronomical Society 1962-64 and the Leonard Medal of the Meteoritical Society in 1966. In 1958 the Professional Institute of the Public Service of Canada awarded Beals its Gold Medal "for his contribution in raising the Dominion Observatory to the standing of one of the world's leading institutions in the fields of astronomy and geophysics. Then in 1969 he became an Officer of the Order of Canada. In 1980 the Canadian Astronomical Society honoured his memory with the establishment of the biannual Beals Award to a Society member "in recognition of ground-breaking research".

Further to the history of the DAO, Beals (1968) elaborated on the early days of the Observatory in a lecture at the August 1968 meeting of the American Astronomical Society in Victoria. There he revealed that a hermit once lived on the property, sheltered under an overhanging rock. The site is on the north side of the hill beyond the dome of the 1.2 m telescope and the dormitory. ✶

Acknowledgement

I wish to thank Dr. Alan Batten and Dr. Victor Gaizauskas for important additions to this account.

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Introduction to Photometry

by Noshin Atiah, Huyen Dang, Gabriel Sewell, Ryan Funk, Karim Vaiji, Tanjim Shahid

Note: This submission comes to us from the students of Jasper Place High School via Ian Doktor.

Introduction to KIC 8462852

KIC 8462852, also known as Tabby's Star, is an 11.7-magnitude variable star located in the constellation Cygnus. The star has so far exhibited an unusual history of variable brightness, with frequent but unpredictable small dips in brightness. However, it has exhibited two large dimming events of approximately 15% on 2011 March 5 and 22% on 2013 February 28. We now know as of 2013 February 28 that there exist brightening periods as well as dimming periods, once in 2007 and once in 2014 (Star, 2017).

Discovered with the *Kepler Space Telescope* (Landau, 2017), variability in stars like Tabby's Star was expected to be due to transiting planets. As the transit of a giant Jupiter-sized planet in front of our Sun could only exhibit a decrease in luminosity of about 1%, several alternative theories have been introduced. The currently most likely theory is the presence of an uneven ring of dust orbiting the star, with the main support for the hypothesis being that the star's infrared light does not decrease as much as the star's ultraviolet emissions. This theory was proposed by NASA on 2017 October 4[b].

Due to the star's visibility in medium-sized amateur telescopes, KIC 8462852 can be observed and logged by amateur astronomers and citizen scientists across the world. The aim of this photometric investigation was to observe the star's brightness by comparing it to surrounding stars over the course of 13 days, contributing to the data available on the star and helping to confirm or reject any hypotheses on the star's nature.

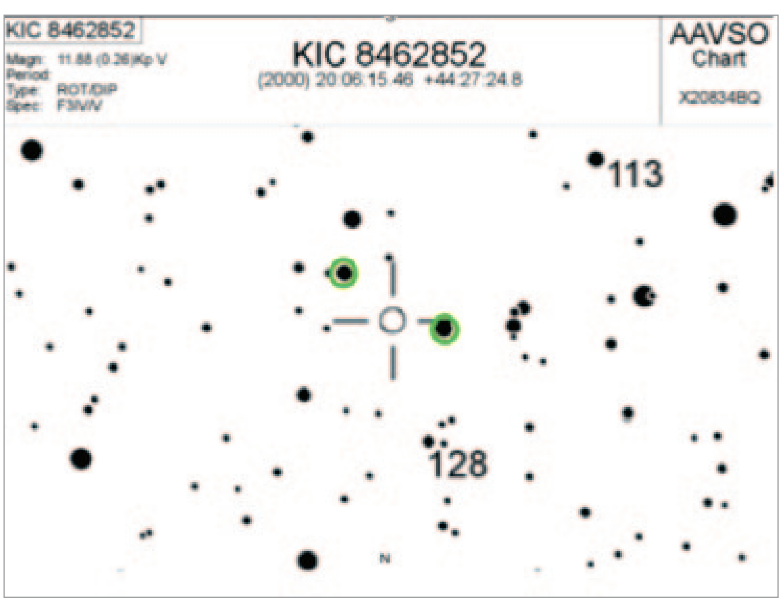


Figure 1

Notable Hypotheses on Variability

KIC 8462852 is home to some of the most bizarre of astronomical hypotheses. To be able to account for a 22% dimming, day-long dips, and overall stochastic nature, complex and sometimes far-fetched theories have been proposed.

This star's most infamous theoretical explanation is that a highly advanced civilization that orbits this star is assembling a megastructure. After obtaining resources from other planets, they are in the process of construction of a Dyson Sphere—a giant solar-energy harnessing machine that encompasses their sun. While this remains a falsifiable hypothesis, most scientists do not take it seriously as no proof has been conclusively found. Meanwhile, the Search for Extraterrestrial Intelligence Institute (SETI) has been searching for signs of civilization from this star. So far, it has not been able to detect radio emissions, ultra-fast optical transients, or laser light signals.

Another more likely and testable theory invokes a giant, ringed, Saturn-like planet trailed by Trojan asteroids in front and behind, much like Jupiter (Ballesteros, 2017). The asteroids would accompany the planet in its L4 and L5 Lagrange points. The orbital period of this planet would be around 12 years with a semi-major axis of approximately 6 AU (the semi-major axis is half the length of the longer axis in an ellipse). This is a particularly interesting theory as we have the ability to test it observationally. Should it be the correct concept, we will be able to see a series of dips in early 2021 from the first swarm of asteroids and in 2023 another grand dip when the planet transits. If our data from October 2017 were to show a dip, we could disprove the theory. If they do not, we have reason to continue to expect the 2021 and 2023 dips in brightness.

Another theory was developed in 2016 when NASA researchers (Landau, 2017) recognized that KIC 8462852's dimming in infrared did not match the dimming in ultraviolet light. Infrared was noticeably less, meaning that any particle greater in size than an interstellar dust particle could not be the explanation to the variability, as larger particles would equally obstruct all wavelengths of electromagnetic radiation. Thus, the alien megastructure theory is most probably negated. It can then be assumed that a cloud of dust particles orbits the star about every 700 days. These particles would have to be larger than interstellar dust so that they are massive enough to remain in orbit. (Particles that are too small would be pushed away by the pressure of the star's radiation.) Albeit, they must be small enough to non-uniformly block different wavelengths of light. Though recent and still speculative, this provides an eminently realistic and possible solution to the confusion of KIC 8462852.

Since the realization that Tabby's Star is experiencing increases in brightness along with its decreases is recent, theories explaining the brightening are not yet available.

What is Photometry?

Astronomical photometry is the measuring of a star's light intensity. The radiative flux of a star can give evidence for the intrinsic properties of the star. The other potential use for these data is to gather evidence for the presence of orbiting bodies around the star, for example a planet. Empirical evidence for bodies in orbit will manifest as dips in the flux recorded from the star over a period of time. To make these observations of a star, one must capture photometric data. One way to do this is to use a CCD camera in the focal plane of a telescope to capture an image of a star. The image collected is called a light frame. Light frames contain an array of data including imperfections. To rid the image of imperfections, one must also collect bias frames, dark frames, and flat frames. Bias frames are images collected with the lens cap on the telescope and at the same ISO as used for the light frame. This is done to isolate and remove inherent flaws in the camera's sensor. Dark frames are also collected with the cap on the telescope, except all the exposure settings must be identical to that of the light frames. In contrast with the other two calibration frames, flat frames are used to correct unwanted vignetting and sensitivity gradients. Now these three calibration frames must be subtracted from the raw files. Once we have created these corrected light frames, we can begin analyzing their contents.

With the corrected frames, we were able to use photometry programs such as IRIS (Buil, C. 2014) to collect meaningful data for intensity. These programs are designed to analyze the pixels in the light frames and complete the necessary calculations to solve for intensity. To observe changes in intensity, one must analyze multiple corrected light frames taken over a period of time. This process can become lengthy; many programs have automated photometry capabilities in which they are able to take measurements from the same position on all images that have been uploaded. To utilize this feature, the images must be aligned so the stars are at the same positions in all of the images. The program we used to complete this was *Nebulosity*. After aligning, IRIS was set to find the intensity of our star of interest and its neighbouring stars for comparison. The measured intensity values were then compared in *Excel*, and the variable magnitude of KIC 8462852 was then found through comparison to its neighbours. With the data collected, we then plotted a light curve to better show the trends in flux variation.

Equipment

Realistically, photometry data can be collected with equipment as simple as a starter DSLR and a camera lens. The images used for this investigation were collected with a CCD camera, through an 11″ Schmidt-Cassegrain telescope, with a focal reducer to reduce the focal length to 2300 mm. A tracking mount is used, because it allows for longer exposures without trailing.

Processing Data

After each night of taking 45 frames at 30-seconds per exposure of the star and multiple calibration frames, we processed the data. The images were aligned as described above.

To compare our star of interest to its neighbours in IRIS, under "Tools" click "Select Objects." With the pointer, select the star of interest and two other nearby stars. We have KIC 8462852 as our main star (in the centre of the target) and the two circled in green as comparison stars in the AAVSO star chart shown in Figure 1.

We use "Automatic Photometry" under "Tools" to obtain the intensity of the star of interest, as well as our comparison stars. The "Automatic Photometry" tool calculates the intensity of the selected stars in all 45 frames and outputs the data in a text box, exportable to *Excel*. In the text box, the first column is the Julian date, and the following columns are the intensity of the selected stars. In *Excel*, we found the relative flux between each of the stars. This was done using the function where star1 and star2 are the intensities gathered by IRIS. We then plotted the three relative functions against their Julian date to create light curves.

Interpretation of the Light Curves

The light-curve graphs of KIC 8462852 will conclude this article. These diagrams should demonstrate any dips or dimming in magnitude or the lack thereof. In Figure 2 we show the relative fluxes of the three stars taken in pairs. On the *x*-axis is the Julian Date (a count of days and fractions of a day where each whole number represents one day after 4713 January 1 BCE at 12:00 noon; e.g. 2018 January 1 at 00:00 is 2458119.5). On the y-axis is the change in magnitude, or in other words, the differential brightness, between each of the three stars. Each point is the logarithmic ratio between one star and another representing one photo. To read from this graph, know that if the non-variable stars have identical light curves with the same fluctuation, it is expected that the third star should follow such a curve as well, if it has a constant brightness. If not, it suggests that this star has just experienced a dip or peak in brightness.

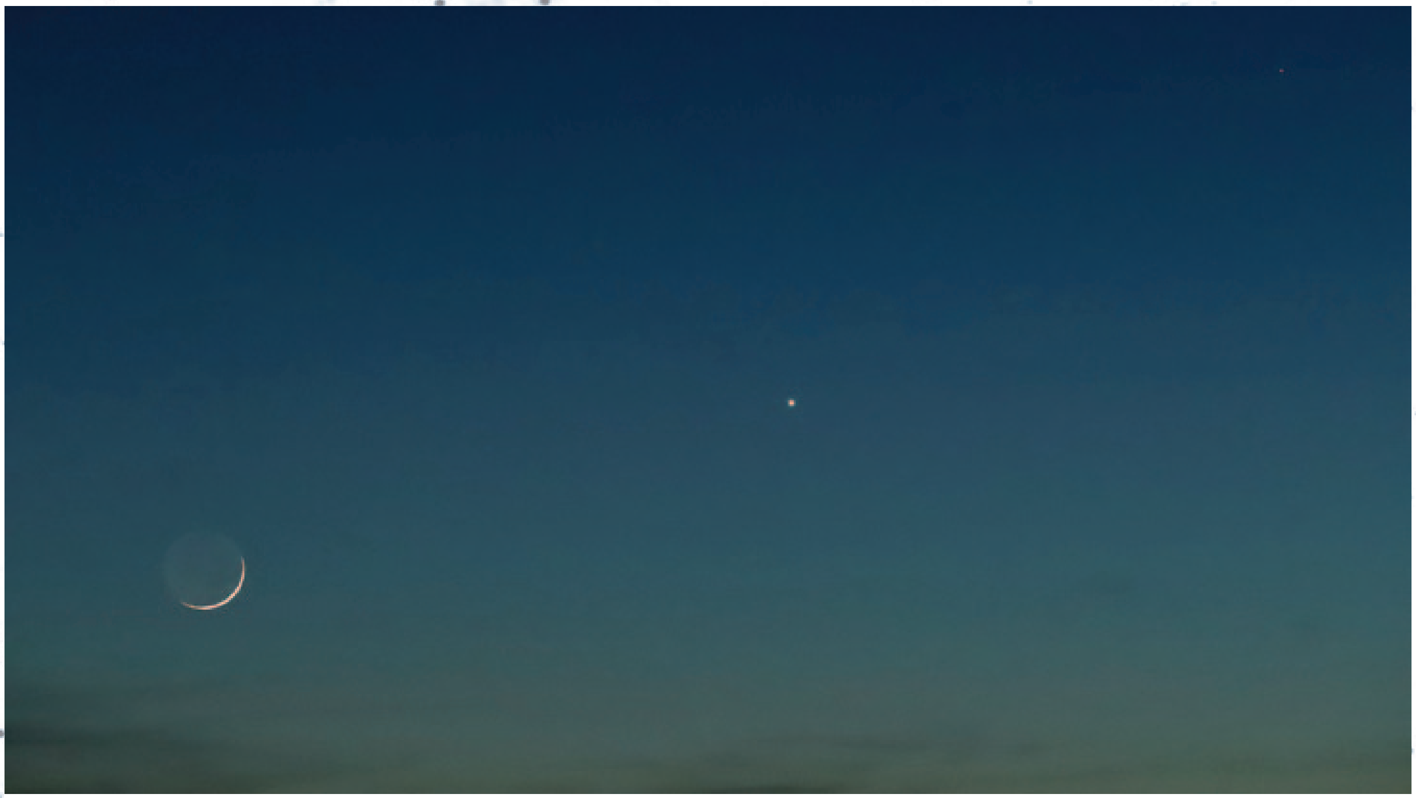
The second graph (Figure 3) begins on Sunday, 2018 October 8, and ends on Saturday, October 21, with each data point representing one day of data collection. On the y-axis, this time is actual magnitude starting from 12.35th magnitude to 12th magnitude. Recognize that, as the magnitude increases, brightness decreases (e.g. a 12th-magnitude star is brighter than a 13th-magnitude star). Each point is the average

Continues on page 120

Pen & Pixel

Dan Meek took this LRGB image of NGC 1333, found in Perseus, over 5.5 hours with a 5″ refractor and a QSI CCD camera. This impressive reflection nebula is home to hundreds of stars less than a million years old, most of which are hidden in the optical by the dust. (top)

A rose is a rose... Klaus Brasch imaged the Rosette Nebula in stunning detail. This multi-combo mosaic was generated by combining some two dozen images taken with an Astro-Physics 155 Starfire and a 12.5-inch PlaneWave CDK, with a modified Canon 6D and IDAS LPS-V4 filter. Total exposure time was 1 hour at ISO 3200-6400, processed with Registar and Photoshop CS6.(right)



Chris Baldock imaged the 1.4-day-old Moon (just 2.3% illuminated) together with Venus (centre) and Mercury (upper right) in the evening sky on 2018 March 18.

Journal *Production Manager James Edgar captured the aurora on the night of 2016 September 27 just north of his home in Melville, Saskatchewan. The Northern Lights were very active that night, and this is just one of nearly 350 images taken with a Canon 60Da, mounted on an iOptron SkyTracker, and shot through a Canon 8–15 Fisheye lens at 9-mm, ƒ/4, and ISO 4000 for 48 seconds; processed using Adobe Lightroom.*

Continued from page 117

magnitude for our star, KIC 8462852, over the course of 45 minutes in one night. Gaps in data are due to poor skies disabling our picture taking.

The following graph, Figure 2, is the collection of data from the night of October 21, with each point being taken from one photo.

The next graph, Figure 3, includes all the collected data over the 13 days of observation.

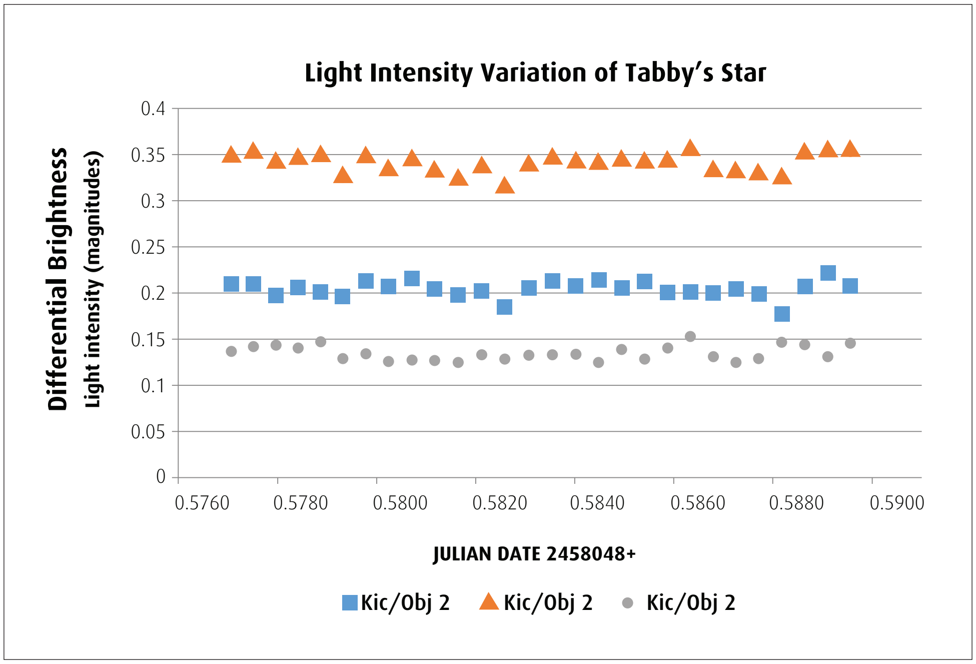


Figure 2

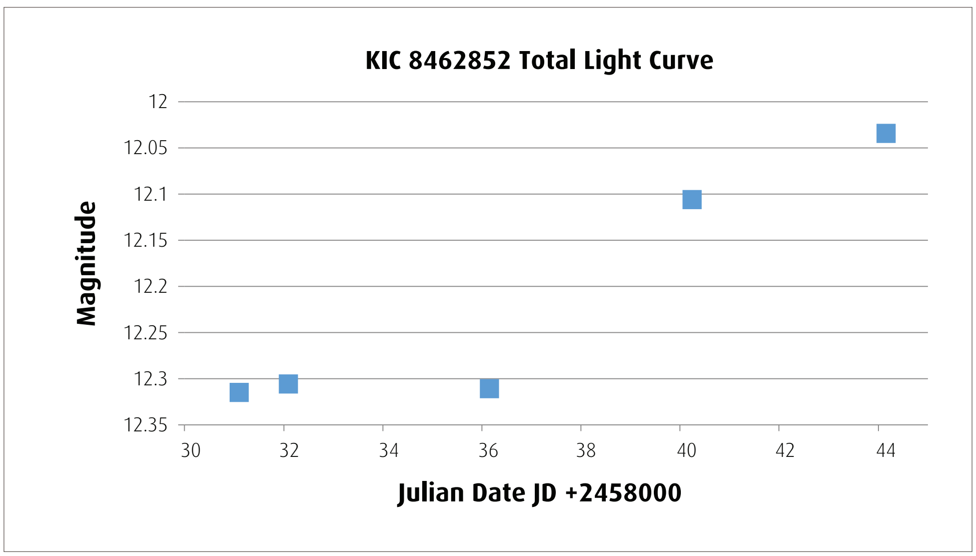


Figure 3

Conclusion

Currently, organizations around the world continue to observe Tabby's Star. For example, SETI is researching potential laser emissions from the star that could give us insight on the Alien Megastructure conjecture, while other amateur astronomers like us take measurements from the star for projects just like this.

Due to the minimal amount of data, making any definitive conclusions would prove difficult. We would need more data consistently and over a longer period. As a result, our light curves are unable to prove or disprove any hypotheses for the explanation of KIC 8462852's erratic nature. Albeit, while we may be unable to draw any reasonable conclusions from our data points we have learned, through the process of photometry, how much information we can gather through relatively simple science. We, the students of Jasper Place High School, encourage other amateur astronomers to attempt a photometry project of their own to see for themselves how practical science can be applied. ✶

Acknowledgement

This article is inspired and founded on the work of Ian Doktor, a teacher at Jasper Place High School, without whom we could not have done this project. Mr. Doktor has provided us with the opportunity to participate in such a project and has demonstrated to us science in action. We would like to express our appreciation to him.

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Mars in 2018

by J. Randy Attwood, RASC Executive Director

During a trip to visit family in New Brunswick in 1971, I noticed a brilliant red-coloured star low in the southwest. I soon determined that this was the planet Mars. Mars isn't always brilliant and impressive; I was just lucky to be seeing it at one of its closest approaches to Earth in my lifetime.

Earth makes one trip around the Sun in about 365 days, an Earth year. Mars takes longer—some 687 Earth days, or 1.88 Earth years. When Earth in its faster orbit catches up to Mars such that the two planets are in a straight line with the Sun, both being on the same side as the Sun, we say that Mars is in opposition. The two planets are as close as they get. At opposition, Mars is visible all night, rising at sunset and setting at sunrise.

By the time Earth has made another one-year trip around the Sun, Mars has moved along in its orbit. It takes Earth another 413 days—over a year—to catch up. The time between Mars oppositions is 778 days, approximately 2 years and 2 months.

As the two planets orbit the Sun, the distance between Earth and Mars varies from approximately 56 million kilometres to 378 million kilometres, which explains why Mars can appear as a brilliant red star sometimes and only as bright as the stars in the Big Dipper at other times.

Mars is best seen in a telescope near opposition. Not all oppositions are the same, though. Mars's orbit is elliptical, so some oppositions are great, while others are not so good. If the opposition takes place when Mars is near perihelion (its closest point to the Sun), the Earth–Mars distance is approximately 56 million kilometres. If it takes place near aphelion (its farthest point from the Sun), the Earth–Mars distance is approximately 99 million kilometres. This can make a big difference when viewing Mars through a telescope. Close Mars oppositions took place in 1971, 1988, 2003, and will in 2018.

This year, at opposition, Mars will be nearly as close as it was in 2003 and won't be as close again until 2035. So it is a great opportunity to observe the planet.

Mars' path through the night sky seems peculiar. The ancients noticed that Mars moves east, slows down and stops, then spends several weeks seeming to move west. It then slows down and stops and continues its eastward motion. Trying to explain this in an Earth-centred Solar System was a challenge to say the least. This odd motion of Mars can be explained by looking at the motion of Earth with respect to Mars. As Earth catches up to and passes Mars, Mars' position as seen from Earth seems to slowly change against the background stars, independent of its motion around the Sun. We call this retrograde motion.

OPPOSITIONS OF MARS, 2010–2022

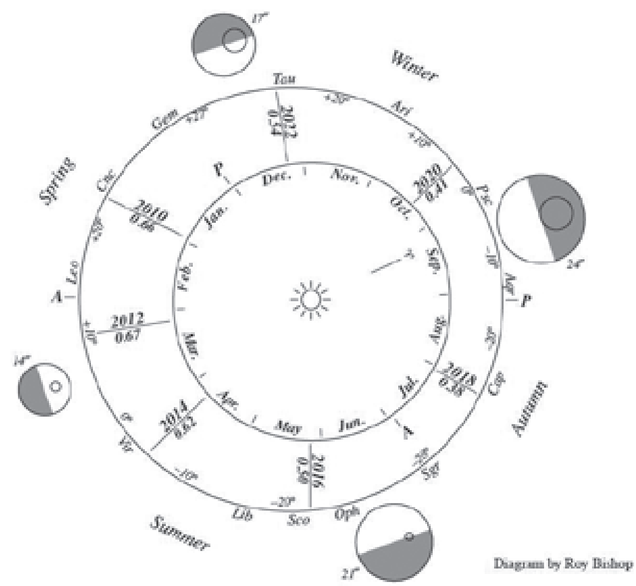


Figure 1 — Past and future oppositions of Mars showing how the distance from the Earth to Mars varies from opposition to opposition (see page 220 in the current Observer's Handbook *for a complete description). Diagram by Roy Bishop.*

An interesting astro-imaging project is to follow Mars's path through Sagittarius and Capricornus from May through November. In May and June, Mars will move east through Sagittarius and Capricornus. Then it will stop and move west in July and August before it resumes its eastward motion again in September.

Most of the time Mars presents as a very small orangish disk with few, if any, features. Around opposition you may be able to detect some surface markings or a white polar ice cap. There were two times when I was impressed observing Mars through a telescope. The first was in April 1976 when Mars occulted, or covered up, a bright star in Gemini, Epsilon Geminorum. Luckily, my Celestron 8 has very good optics. The resolution when looking at planets is outstanding when the seeing is good, and that night the seeing was quite good. I remember seeing Mars slowly approach the star and just before occultation the two resembled a red giant star next to a white dwarf star. At occultation, the star did not blink out in an instant but slowly dimmed as its light passed through the tenuous Martian atmosphere.

The other time I was impressed was in August 2003. Mars was making its closest approach to Earth in thousands of years, not to be outdone until 2287. Favourable Mars oppositions are always in August since Mars' perihelion is in Capricornus, a summer constellation.

The newly formed Mississauga Astronomical Society (now the Mississauga Centre) was holding its first major public outreach event. We held the event near the City Hall and Central Library complex, which is surrounded by condominiums. Mars was low in the southwest and had to be viewed between the

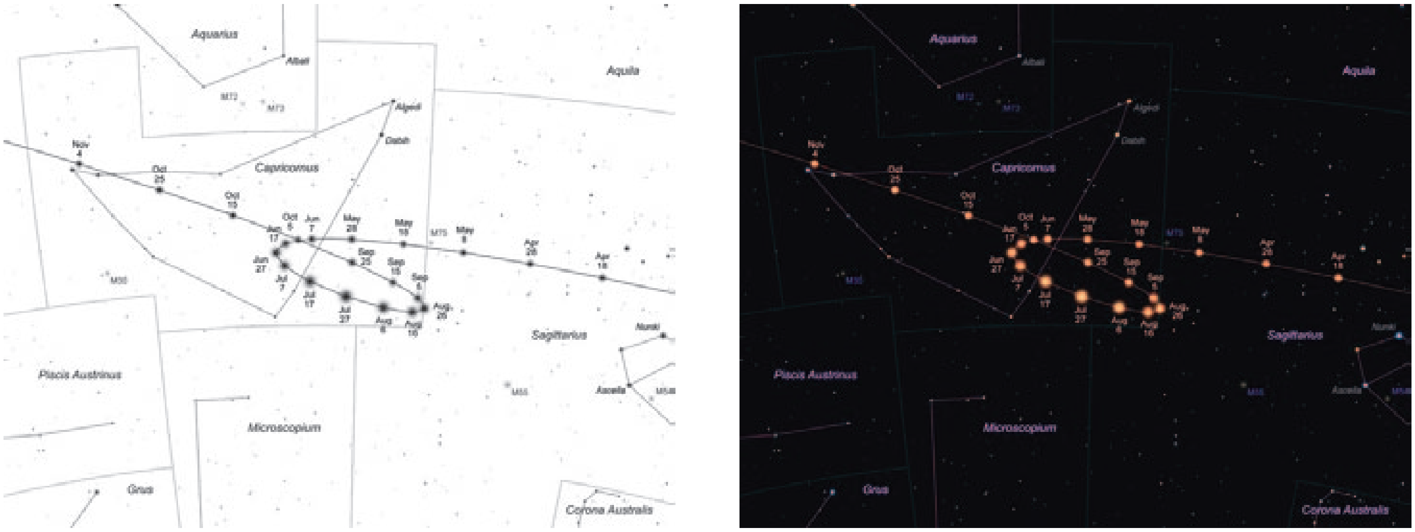


Figure 2 — (one Colour and one B&W) Path of Mars through the night sky from April to November 2018, showing its retrograde motion. Diagram by Glenn LeDrew.

condos. The turnout was very good, and each telescope had lineups of 20 to 30 people. As the evening progressed and Mars moved across the sky, we had to move the telescopes to follow Mars between the condos. It was comical to see the long lineups shuffle as we moved the telescopes.

The media coverage was good, and we continued long after our 11 p.m. advertised stopping time. People were still arriving at 1 a.m. Before we closed up shop for the night, I took a last look at Mars. The seeing had improved, and the image was the best I had ever seen. I remember seeing a lot of detail on the planet and actual detail in the polar cap.

How will the 2018 opposition compare to the 2003 opposition?

The angular diameter of Mars in 2003 was 25.11 arc seconds. This year it will be 24.31 arc seconds, a difference of only 3%. So the view of Mars this year should be just as good as the view in 2003. (It was 24.91 arc seconds in 1971.)

During a close Mars opposition, I am impressed how the planet appears to the naked eye, as a brilliant red "star" brighter than Jupiter. This summer when you are observing the red star, you might think about the future of space exploration and the fact that in the next few decades people may finally make the trip to Mars.

One thing to consider when we send people to Mars is the communication time: During the Moon landings, the distance between Earth and the Moon meant that radio signals made the trip in just over one second. When people finally go to Mars, talking to them will be more challenging. Since the Earth–Mars distance varies so much, so, too, will the radio travel time. At its farthest point (378 million kilometres), it will take 21 minutes for a one-way conversation. You say hello and have to wait 42 minutes to get a reply. Mission control won't be able to help with problems right away.

At a close opposition like the one this year, when Mars is only 58 million kilometres away from us, the one-way radio travel time is just 3.2 minutes.

In 2003, during the close opposition, an Internet hoax started, stating that Mars will appear in the sky as big as the full Moon. Unfortunately, the hoax appears every August, like clockwork. No doubt it will appear again when Mars is in the news later this year.

I look forward to setting up my telescope later this year at public star parties, pointing it at Mars, and talking to visitors about this interesting planet. ✶

Observing Tips

Observing and Drawing Mars

by Denis Fell, Edmonton Centre
(Denis_Fell@yahoo.com)

[Note from Dave Chapman, RASC Observing Committee Chair: This is the fifth in a series of observing articles contributed by RASC members. With Mars at a close opposition in July 2018, now is the perfect opportunity to provide the visual observer with a guide to equipment and methods. For future columns I am looking for practical content contributed by active observers—please email me at observing@rasc.ca with your ideas.]

Introduction

The first question I usually get when I talk about observing Mars is: why bother, when all those spacecraft and rovers are there, returning images with detail you could never see with your telescope? The answer is simple: every two years, when Mars is close enough to Earth that amateur telescopes can resolve surface detail and weather on Mars, visual observers are smitten by the possibility of seeing something new. The dark markings (albedo) on the surface can change as they are covered and uncovered by blowing dust, and clouds grow and move around the planet; dust storms move across the face of the planet, sometimes obscuring large portions or even the entire surface; polar caps shrink or grow with the season. Indeed, many times scientists are notified of events happening on Mars by amateur astronomers.

Below, I will not cover the particulars of the 2018 apparition of Mars: for those, see the excellent article by Murray Paulson in the Planets and Satellites section of the current *RASC Observer's Handbook*, and the foregoing article. Rather, I will share the approach and methods that have proven fruitful for me over 40 years of observing and recording each appearance of Mars in our skies.

Observing Mars—Equipment

As the articles mentioned above point out, the planet remains at some distance from Earth until late northern hemisphere spring, presenting a small disk diameter for the observer to work with. Your telescope therefore has to be capable of high magnification without exceeding the limits of the instrument. Since atmospheric conditions vary greatly, they further limit what the telescope itself can deliver. Average resolution of fine detail is limited to 1 arcsecond or greater, often as much as 3 arcseconds due to air movement, both at high altitude (from jet streams and frontal systems), and from ground effect (turbulence from structures radiating heat after daytime solar heating). Degradation of transparency due to clouds of various types and altitude also greatly influences the ability to resolve fine detail on the planetary surface.

Most instruments available to amateurs today have short focal ratios, the industry having responded to the increased demand for small telescopes that are very portable, and to deep-sky imagers who want fast objectives with a wide field of view. Now there is a plethora of telescopes having focal ratios $f/5 - f/7$, both refractors and Newtonian reflectors. The exceptions are Schmidt-Cassegrains at $f/10$ and Maksutov-Cassegrains at $f/12 - f/15$. To provide the long effective focal lengths required for planetary viewing with currently available eyepieces, we must use magnification amplifiers such as Barlow lenses and Tele Vue PowerMates™ (see Figure 1). These devices optically double or triple (or more, up to 5x) the effective focal length of the telescope. With a 2x Barlow, the observer with a 100-mm refractor with a focal length of 500 mm has now a telescope with an effective focal length of 1000 mm, so a 10-mm eyepiece will give 100x instead of 50x. Besides getting higher magnification, the observer enjoys the advantage of greater eye relief, which reduces eye fatigue. Not only will you enjoy the view better, you will observe more detail.

Figure 1 — Magnification amplifiers: a Barlow lens and two PowerMates™ (all illustrations by the author).

Be careful not to exceed the magnification limit for the size of the objective (2x the aperture in millimetres or 50x the aperture in inches) or the image will be degraded. Choose magnifications according to viewing conditions—some nights will allow very high magnification and others will not. Generally 200x is tops for small to medium instruments and 300x for large telescopes. As a guide, you should strive for an apparent disk diameter close to 0.5°, that is, the diameter of the full Moon seen without optical aid. For example, in a high-quality 150-mm telescope, the maximum magnification of 300x would magnify the 10″ disk of Mars (late April and late November) to 1.7 full Moons; at 12″ (mid-May and late October) the same magnification gives 2 full Moons; and at 24″ (near opposition in late July/early August), 4 full Moons. Using a magnification of 200x will yield smaller disk views, but still enough to see a sufficient amount of detail, atmospheric seeing and transparency willing. Obviously, telescopes of all apertures will give the best views in July and August.

A word about resolution of fine planetary detail: many believe that Dawes' limit (116 divided by the objective diameter in millimetres) gives the maximum resolution in arcseconds for their instrument. That is true for point objects like double-star separations but does not hold true when it comes to high-contrast, linear details. For example, the Cassini division in Saturn's rings (about 0.35 arcseconds) is clearly seen in high-quality 80-mm and 100-mm telescopes. When conditions are right and Mars is close, you can see amazing detail, once you learn how to see and what to look for.

Figure 2 — An assortment of Kodak Wratten dyed-glass colour planetary filters.

Turning to visual planetary filters for eyepieces, for decades Mars observers have used dyed-glass colour filters, mainly Orange #21, Red #25, and Light Blue #80 (Kodak Wratten series); red and orange to accentuate surface albedo markings and dust clouds, light blue to enhance atmospheric clouds. Yellow #15 is used to cut through some of the haze and dust present in our own atmosphere. Dyed-glass filters act by blocking all but the actual color of the filter itself. Modern filters are multicoated, allowing sharper, cleaner definition of planetary detail. Be aware that filters block some light from the image, so choose the filter that works best for your telescope and eyepiece combination.

Over the years, I have found the Tele Vue Mars Bandmate™ filters to be very effective (unfortunately, they have been discontinued, but may be available used). The Mars Type-A is a dual-band filter with different dielectric coatings on each side of the substrate. The dual-band nature of the filter permits green and red through, while rejecting all other visible colors. The effect is to enhance detail on the Martian surface, while preserving the natural colour of the polar caps and the rest of the surface. Since this filter provides a most natural view, it is highly recommended for public viewing. The Mars Type-B filter has a high-efficiency, single-band dielectric coating that achieves penetrating views of the Martian surface. Initially I use the "B" filter for maximum resolution of the dark albedo regions, switching to the "A" filter for an integrated view.

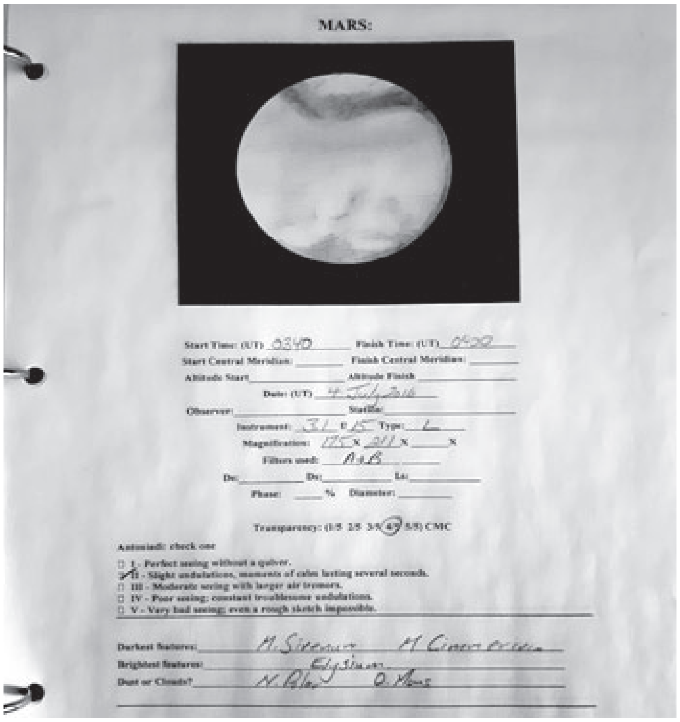
Drawing Mars

The reasons for recording your observation as a drawing are twofold: first it trains your eye and brain to truly **observe**—as you look at different features and portions of the disk, you learn to pick out subtle variations in the darker features, thin indistinct markings in the desert areas, yellow dust clouds, and white atmospheric clouds, hazes, and fog. Second, as you progress, you learn proper placement of features in relation to one other. Start with the most prominent polar cap and gauge feature placement using a centre line on the disk as a second reference. Work carefully, outline the major features, and shade them according to what you see, blending with your finger and using the eraser to lighten areas, I usually outline clouds with a dashed line and dust with a dotted line—these can be refined later when you finish the sketch indoors.

As Mars rotates 14.6° per hour, you should strive to complete your sketch in 15–20 minutes to avoid distortion of the overall drawing. Take note of the start and stop times in order to calculate the central meridian of your drawing. Write down the date, location, observer, instrument, magnification, filters, seeing, transparency, and any noteworthy features or circumstances.

I have designed an observing form that I print as needed (see Figure 3). If anyone wishes a copy (PDF file), email me and I will send one. I use a clipboard with a red light, sketch the surface markings using a soft pencil (type B), then use my eraser and fingertips to smudge and blend. For colour, good-quality pencil crayons work well—blend the colours as you did with the pencil. Dark areas often appear greenish to the eye but that is mainly a contrast effect against the pink/orange background that fooled early observers into thinking there was vegetation on Mars. Dust clouds are yellowish and atmospheric clouds white.

Figure 3 — Tele Vue Bandmate™ Mars filters (discontinued).


MARS:

Start Time: (UT) 0340 Finish Time: (UT) 0420
Start Central Meridian: ______ Finish Central Meridian: ______
Altitude Start ______ Altitude Finish ______
Date: (UT) 4 July 2016
Observer: ______ Station: ______
Instrument: 3.1 f/15 Type: L
Magnification: 175 x 211 x ______ x
Filters used: A, B
De: ______ Ds: ______ Ls: ______
Phase: ______ % Diameter: ______

Transparency: (1/5 2/5 3/5 4/5 5/5) CMC

Antoniadi: check one
- [ ] I - Perfect seeing without a quiver.
- [x] II - Slight undulations, moments of calm lasting several seconds.
- [ ] III - Moderate seeing with larger air tremors.
- [ ] IV - Poor seeing; constant troublesome undulations.
- [ ] V - Very bad seeing; even a rough sketch impossible.

Darkest features: M. Sirenum M. Cimmerium
Brightest features: Elysium
Dust or Clouds? N. Polar O. Mons

Figure 4 — The author's custom Mars observing form (email denisfell872@gmail.com to request a copy).

Drawing is easier when you are seated, allowing your eye to stay centred on the disk, thus reducing fatigue. Consider either a lawn chair or a dedicated, adjustable observing chair, I seldom use a diagonal on my refractors, as it reverses the image and just adds another piece of glass to absorb light, especially when using Barlows and PowerMates™.

If you have not done planetary drawing before, to prepare yourself, place an image of Mars across the room so it will be about the size you expect see in your telescope, and practice making drawings. Soon you will become more adept at rendering what you see on paper. Continued practice will allow you to hone your skills, and you will produce a drawing that you are happy with. Figure 5 shows a series of steps that illustrate the development of a drawing.

In previous times, I used a set of maps at the telescope to orient myself to the area I was observing, but I have found there are very good apps for mobile devices for use at the telescope. For the iPhone and iPad, look for Mars Globe on the iOS App Store (there is a MacOS version as well, called Mars Atlas). For Android devices, look for Physical Mars on Google Play. These will provide up-to-the minute data and information about Mars, along with globe views.

Final Image Treatment and Sharing

Once indoors, when you have all the data recorded and the drawing cleaned up, you can scan it into a graphic editing program and use the computer to adjust levels and contrast, and to apply selective blurring tools to achieve a look similar to

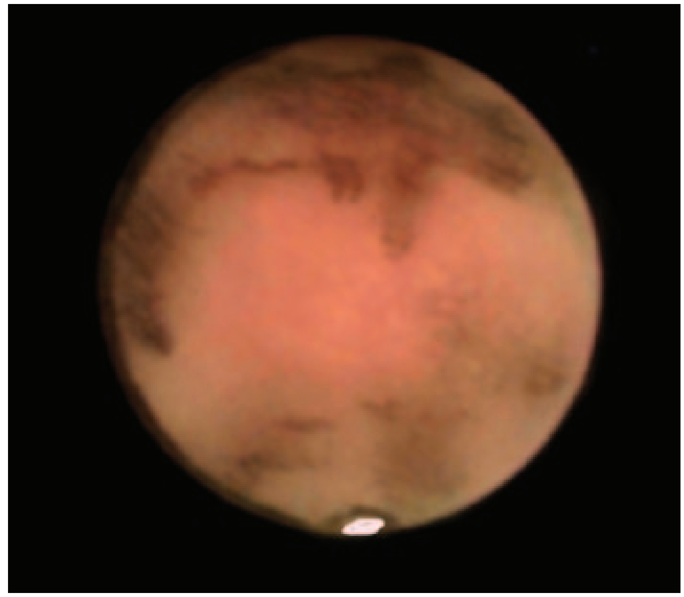


Figure 5 — An example of a final drawing, with colour.

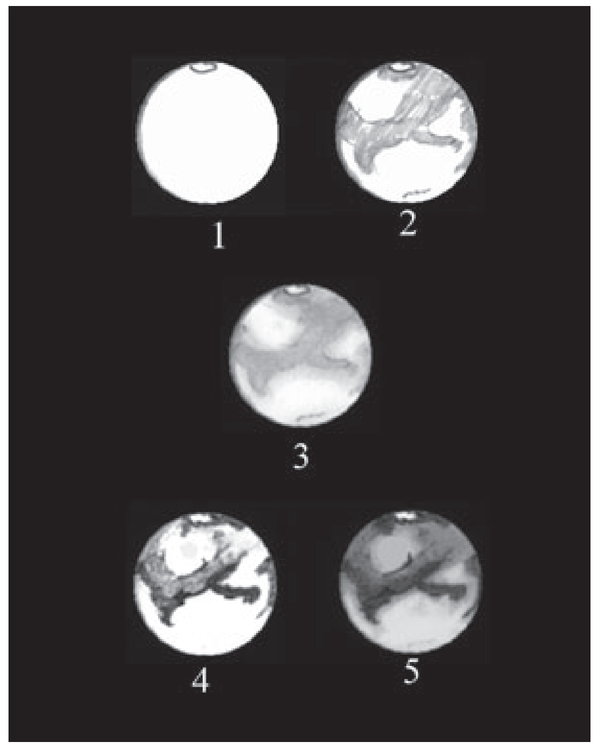


Figure 6 — The stages of drawing Mars at the eyepiece.

that in the eyepiece. Clouds and polar caps can also be brightened. I usually do two versions, one for a permanent record in my logbook and one for posting to online observers' groups and social media.

Links to sites where you may upload your image and view the work of others:

Yahoo Mars Observers Group
groups.yahoo.com/neo/groups/marsobservers/info

ALPO 2018 Mars apparition
www.alpo-astronomy.org/jbeish/2018_MARS.htm

ALPO Japan Mars
http://alpo-j.asahikawa-med.ac.jp/Latest/index.html

International Mars Observers
www.mars.dti.ne.jp/~cmo/ISMO.ht

As always, I welcome questions or comments on this topic, email at denisfell872@gmail.com. Enjoy Mars 2018 and share your drawings and experiences. ✶

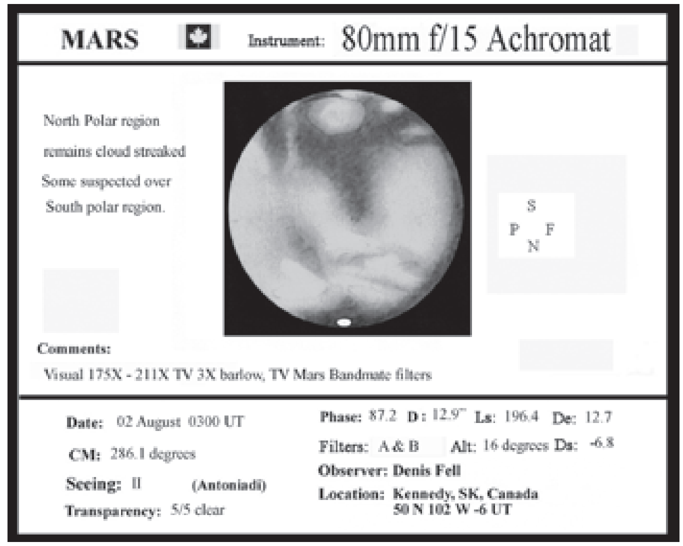


Figure 7 — Final monochrome drawing with observing details, for logbook and sharing.

Note: The Tele Vue Mars Bandmate filter series has been discontinued, but Orion Telescopes has a Mars filter with the same capabilities as the old T-V Mars 'A' filter. (https://www.telescope.com/125-Orion-Mars-Observation-Eyepiece-Filter/p/5599.uts)

Denis Fell has been observing and drawing at the eyepiece since 1971, and joined the RASC in 1974. He is well known for his Mars drawings over the years, some of which have been published in the ALPO Journal *and the RASC* Observer's Handbook. *Denis is retired, and observes and draws through 80-mm refractor and 203-mm reflector from Wetaskiwin, Alberta.*

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CFHT Chronicles

Galactic Cannibalism

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

Our year at CFHT continues to be full of science and SPIRou, despite a difficult winter season. Let's dive into our first news release of the year, SPIRou updates, and information on our Maunakea Scholars program.

In early February, one of our former French resident astronomers, Jean-Charles Cuillandre, was part of a team announcing a new discovery around a familiar region of the sky, Stephan's Quintet. Many readers will be familiar with Jean-Charles's work if not his name: he is the mastermind behind the CFHT calendar—a project he still works on from Paris.

The image reveals structures undetected thus far, in particular a very extended red halo composed of old stars, and centred on an elliptical galaxy, NGC 7317. These results were published in the *Monthly Notices* of the Royal Astronomical Society in February by the team from the Observatoire Astronomique de Strasbourg (France), CEA Saclay (France) and the Lund Observatory (Sweden).

The wide-field image captured with Megacam, our 380-megapixel camera, is actually focused on the nearby galaxy NGC 7331, a galaxy closer than the more distant Stephan's Quintet. The image shows several features common to galaxy clusters, including some very dim and extended filaments of interstellar gas or galactic cirrus. Stephan's Quintet was named after French astronomer Édouard Stephan who first observed the compact group of five spiral and elliptical galaxies in 1878. The *Hubble Space Telescope* immortalized this region after observations of the group became one of the telescope's most iconic images.

Stephan's Quintet is a perfect target for studies on the collective evolution of galaxies. Such collections of galaxies are subjected to a range of gravitational interactions ranging from slow collisions creating gravitational stellar streams, high-speed galactic collision, gas ramming, starbursts, and creation of intergalactic stellar systems.

Along with the expected observations described in the paragraph above, the image also reveals unexpected structures, including some undetected thus far. In particular, astronomers discovered a very extended red halo composed of old stars, and centred on an elliptical galaxy, NGC 7317, which had been ignored in previous studies on the dynamics of the global collision. The detection of red stars implies that this galaxy has been interacting for a very long time with the other members of the group of galaxies. Interactions such as the one seen in these observations are called galactic cannibalism, which occurs when the gravitational forces from a larger galaxy or group of galaxies slowly tear apart a smaller galaxy. Characteristic features of galactic cannibalism are streams or halos of stars orbiting the larger galaxy, like the halo of red stars seen around NGC 7317.

Figure 1 — Full-field of view of the CFHT-MegaCam image in optical wavelengths (strong colour saturation and contrast reveal the nature of the various components). Credit: CFHT, Pierre-Alain Duc (Observatoire Astronomique de Strasbourg) & Jean-Charles Cuillandre (CEA Saclay/Obs. de Paris).

A first implication is that Stephan's Quintet is far older than currently admitted. The models of formation and evolution of this emblematic system will have to be revised. Ultimately, astronomers hypothesize that the galactic cannibalism around NGC 7317 will lead to the formation of a giant elliptical galaxy.

This new result illustrates the current renewed interest in the scientific field for deep imaging on nearby galaxies. Many observing programs, including several developed at CFHT, which is particularly well suited for such studies, aim at decoding the past history of galaxies through the detection in their direct environment of faint extended features, a technique known as galactic archeology.

"With MegaCam, CFHT is at the forefront of an observing technique called low-surface-brightness imaging." says CFHT director of science Daniel Devost. "This allows astronomers using CFHT to make discoveries like the galactic cannibalism discovery within Stephan's Quintet."

Our own Milky Way Galaxy may be cannibalizing smaller satellite galaxies orbiting us. Astronomers observe streams of hydrogen gas and stars arcing from the Large and Small Magellanic Clouds. These dwarf galaxies are located 160,000 to 200,000 light-years away from the Milky Way, but are significantly smaller than the Milky Way. The immense gravity of the Milky Way slowly pulls the smaller galaxies apart, causing the transfer of materials between our galaxy and the clouds. That is a different story for a different day and an active area of research using CFHT…

Figure 2 — Zoom on Stephan's Quintet in true colours as featured in the CFHT/Coelum 2018 calendar. NGC 7317 is the lower right member of the group. Image: CFHT/Coelum, Jean-Charles Cuillandre (CFHT/CEA Saclay/Obs. de Paris) & Giovanni Anselmi (Coelum)

Each year since 2000, CFHT produces in collaboration with the Italian editor Coelum, the *Hawaiian Starlight* calendar, based on beautiful images of the sky captured by MegaCam. These images result from special observations obtained through CFHT director's discretionary time when atmospheric conditions, in particular the stability of the atmosphere, are not suitable for regular observations. Some of these images sometimes turn out to be of great scientific interest: such is the case here for Stephan's Quintet.

SPIRou Update!

As frequent readers of this column may recall, SPIRou is CFHT's newest instrument. SPIRou (SpectroPolarimètre Infra-Rouge) belongs to the next generation of astronomy instruments with the goal to find Earth-like planets in the habitable zones of nearby red-dwarf stars. It is capable of detecting the tiny wiggle in a star, which indicates the presence of planets. In our last column, we announced SPIRou's arrival. This time around, we can happily announce that progress has been made!

Quick recap from last column: The instrument arrived in 13 boxes from France in the middle of a pretty intense winter. In short order, the boxes were unpacked and the instrument assembled with the optics aligned. Like all infrared instruments, SPIRou must be cooled to a very low temperature, on the order of 80 kelvin. More importantly, to achieve the high radial-velocity precision required for the instrument's science goals, the temperature must be stabilized at a few millikelvin. To achieve this frigid temperature and subsequent stabilization, the instrument is housed in a cryostat. SPIRou's optical bench slides into a large metal cylinder—this cylinder is a cryostat. The cryostat is pumped to a near vacuum and cooled with liquid helium, creating the temperatures needed for SPIRou. Early March brought the first testing of the cryostat environment.

Also in early March, the science and engineering teams tested the instrument's guider on the sky. The guider operates at IR wavelengths to ensure the observer sees the target field of view the same way as the instrument will. This is a necessity because many of the SPIRou targets are bright in the IR while faint in the optical. If the guider operated at optical wavelengths, the remote observer would have a greater chance of a mistake. The first round of guider tests was successful.

More excitement occurred in late March when the Hawaii 4RG detector arrived. The Hawaii 4RG detectors are the cutting edge in infrared detector technology. For those detector enthusiasts out there, the 4RG has 4k x 4k 15-micron pixels, which will be read out continuously to avoid increasing the temperature of the cryostat (remember that millikelvin temperature stabilization mentioned above). For everyone else, insert a dropped jaw here because the Hawaii 4RG is an astonishing piece of technology.

SPIRou's 4RG is the only one on Maunakea and possibly the only one that will be doing astronomical research this year. For reference, the *James Webb Space Telescope* is using Hawaii 2RG detectors. Due to special regulations, we cannot publish a picture of the detector, but the manufacturer Teledyne has an approved image on their website (www.teledyne-si.com/products-and-services/imaging-sensors/hawaii-4rg).

The next SPIRou engineering run is scheduled for mid-April. Stay tuned for more updates.

MKS Program

In this column a year ago, I wrote about the Maunakea Scholars (MKS) program and I want to share a scientific result from one of the student groups. In 2016, CFHT and Gemini piloted the Maunakea Scholars program for Hawaii high school students. Students from two schools—Kapolei on Oahu and Waiakea on the Big Island—researched and wrote proposals for submission to CFHT to receive observing time for their own independent research. The students worked with mentors from the University of Hawaii's Institute for Astronomy and Gemini Observatory to refine their topics.

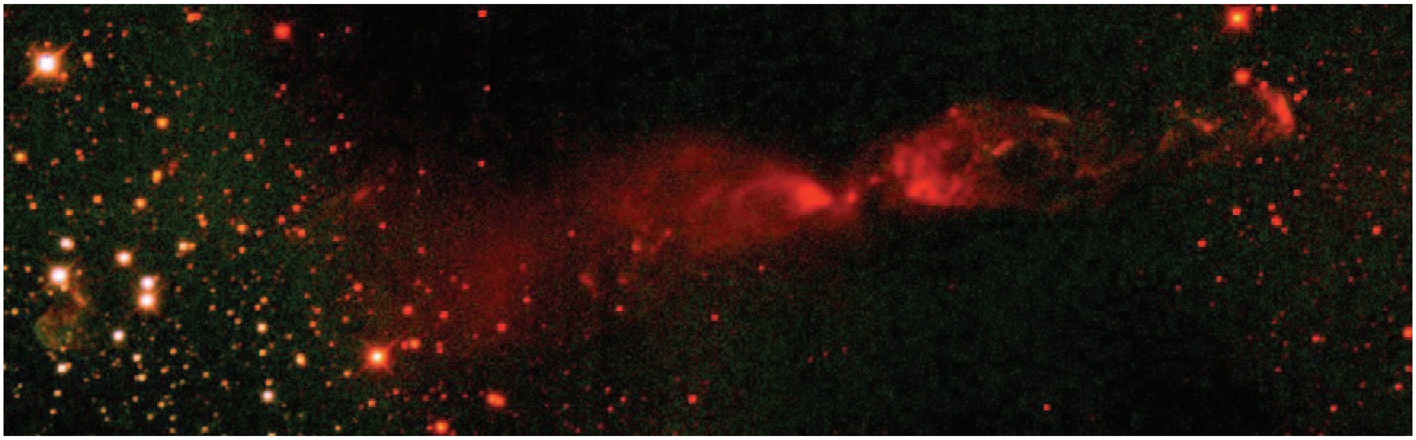


Figure 3 — MHO object in LDN 483 as seen in Ks band. Photo credit: Rousseau-Nepton/Steele/Sanchez/CFHT.

Post submission, CFHT staff reviewed the proposals and selected three.

We expected proposals requesting time to take pretty pictures but received quite the opposite. Students requested time on all four of CFHT's instruments—MegaCam, WIRCam, Espadons and Sitelle—and for deep topics ranging from comets to white holes and everything in between. This is still the case, this year's cohort will be observing planets in our Solar System, black holes, unusual star-burst galaxies, and much more.

Each year the program expands by leaps and bounds. In the 2017–2018 school year we worked with over 200 students from 10 public high schools across four islands. All of the Maunakea Observatories offer telescope time to these students, providing an unparalleled opportunity for the students to achieve their science goals.

Last year's cohort from Honokaa High School included two students whose CFHT data included an unexpected find. The students, Hoku Sanchez and Keilani Steele, found an ESO article from 2015 describing the potential collection of protostars buried in the nebula LDN 483, located 700 light-years away in the constellation of Serpens. They proposed to image LDN 483 in three filters with MegaCam (i, r, and u) and WIRCam (J, Ks, and Y). Their proposal was successful, and last June they conducted their observations. After data processing and assistance adding colour and combining the slices from CFHT astronomer Laurie Rousseau-Nepton, the students found a type of Herbig-Haro (HH) object deeply embedded in LDN 483, visible only in the Ks band.

HH objects form when a newly formed star releases jets of partially ionized gas, which interacts at high velocities with surrounding gas. When HH objects are observable only in the IR, they are called Molecular Hydrogen emission-line Objects (MHO). MHOs form in the same way as classic HH objects, however their interaction with the surrounding nebula causes emission from IR molecules (see Figure 3 above).

Figure 4 — Hoku Sanchez and Keilani Steele with their poster at the 2018 Hawaii State Science Fair.

The students did not anticipate finding an MHO in their data, so their analysis is incomplete. However, their discovery led them to the state science fair, the first for Honokaa High School in recent memory. Their project did not win, they lost the astronomy category to an on-going project entitled "A Runaway Star Candidate Selection and Analysis, Year 2" by Celeste Jongeneelen. Celeste is mentored by one of the Maunakea Scholars mentors, astronomer JD Armstrong from the University of Hawaii's Institute for Astronomy, so I am confident it was a great project.

Keilani plans to major in astronomy next year at either the University of Arizona or the University of Washington. Hoku plans to major in business, but is considering adding an astronomy minor or at least some classes at either the University of Oregon or Grand Canyon University. Congratulations to these two students and we look forward to sharing more discoveries from our Maunakea Scholars.

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.

Skyward

A Voyage Back in Time

by David Levy, Kingston & Montréal Centres

The Regal Princess is a beautiful, majestic cruise vessel designed to sail to exotic destinations. In February, Wendee and I boarded it for a single reason: we wanted to visit the El Caracol Observatory at Chichen Itza.

Did we take a seven-day cruise just to see an old pile of rocks? Indeed, we did. On the penultimate day, we climbed aboard a ferry boat, crossed an endless stretch of water separating the island of Cozumel from the mainland of the Yucatan peninsula, and then took a two-and-a-half-hour bus ride across Mexico's Yucatan peninsula, near the site of the cosmic impacts that led to the extinction of 90 percent of the species of life on Earth, including the dinosaurs. We saw this incredibly rich and beautiful forested land before arriving at the enchanting Chichen Itza. One of the great cities of the Mayan civilization, Chichen Itza's two pyramids, multiple stone columns, and other buildings still rise in triumph to face the sky.

Figure 1 — The Platform of Venus. I thought I had missed it, but I have this photograph of it! Both photos by David Levy.

Much as these features attracted our interest, our goal was to encounter El Caracol, the observatory. Although a large stone dome sits atop the structure, it never housed a telescope. What it did offer was three viewing ports through which observers could view a single object: the planet Venus. The Mayan culture considered Venus extremely important: they referred to it as *Chak Ek*, or The Great Star. (Although we were told that the Mayan observers viewed the sky only by reflection through water, I can find no evidence to support that.)

Why would Venus, Earth's sister world, inspire such interest among a people that flourished 1300 years ago? The Mayans, it turns out, were one of the great pre-Columbian civilizations, and it has been a UNESCO World Heritage site since 1988. The Mayans were scholars, athletes, scientists, at a time when modern Europeans were barely able to write. They had an alphabet, wrote in hieroglyphics, and built structures to teach them about the movements of objects in the heavens.

Figure 2 — The El Caracol Observatory Building. Its dome was never designed to rotate, but rather to house viewing ports for ease in observing Venus.

They had a special interest in Venus and they built a great observatory to study its motion. They designed the stairs at the front of El Caracol to face 27.5 degrees north of east, out of line with the other buildings but a perfect match for the position of Venus at its most northerly extreme. Further, a diagonal formed by the northeast and southwest corners coincides with the position of sunrise at the summer solstice and that of sunset at the winter solstice.

At the top of the dome is the base of a tower. In its heyday the full tower was cylindrical. It was reached via a narrow winding staircase loosely translated to *caracol*, or snail. Three openings serve as viewing shafts to allow observers to watch Venus rising at its northern and southern extremes, and sunrise and sunset at the equinoxes.

Based on the careful observations they made, the Mayan astronomers concluded that the rise and fall of Venus as a morning star takes 263 days, followed by an absence of 50 days, during which Venus is not visible. The rise and fall of Venus as an evening star also takes 263 days, followed by an absence of only 8 days. The total cycle lasts 584 days. They also discovered that five such "synodic periods," divided by eight, equals almost exactly eight years.

Despite their many accomplishments, the Mayans could not actually observe Venus. That had to wait for the present, when crowds of tourists visit the site, and at least one of those visitors brought along a telescope. The Mayans could not see Venus through a telescope because they had no telescope. But I did, and through it I can see that Venus is a world with phases like the Moon.

We voyaged a great distance, but the most exciting aspect of it was our journey through time. For a brief period, we were immersed in another era during which some very smart people looked to the stars, understood the motions of the planets almost as well as we do today, and asked questions about the sky.

Ever Edith

The stars, it somehow appears, were aligned in good fortune when my Mother, Edith Pailet Levy, was born in New Orleans on 1918 June 1. Just one week later, a total eclipse of the Sun tracked all the way across the United States from Oregon to Florida. A few weeks ago, when I told her about this eclipse, Mom appeared to appreciate what I was talking about. But she had no idea about the rest of that story: when darkness fell across North America that very night, a bright nova appeared in the constellation of Aquila near Altair. Not everyone could enjoy the eclipse that June 8, but practically everyone could spot the brilliant exploding star that for a few nights was the brightest one in the sky. It is well described in Leslie Peltier's autobiography *Starlight Nights.*

When Mom married my father in 1939, she was a medical student, who, by the early 1950s, became fascinated with the turn genetics was taking in the wake of Watson and Crick's discovery of the structure of the DNA molecule. She also became acquainted with the little stargazing expertise that Dad had. Interested in navigation as part of his sailing pastime, Dad was also an avid reader of books that included *Cole of Spyglass Mountain*, the riveting story of a young amateur astronomer who discovered evidence of life on Mars.

Mom got her own taste of the story when, in 1994, she joined Carolyn and Gene Shoemaker and myself in Washington, D.C., to observe the first-known impact of a comet against a planet. Comet Shoemaker-Levy 9, which Gene and Carolyn Shoemaker and I discovered in March 1993, had split into more than 20 fragments, each of which collided into Jupiter's southern hemisphere during an unforgettable July week. Carl Sagan, then one of the most prominent astronomers of our time, when he met my mother, was far more more interested in my mother's career in genetics than he was in mine as an astronomer.

Mom enjoyed signing letters and notes to family and friends "Ever Edith," and so that became the title of a collection of memoirs my sister Joyce assembled a number of years ago. Eleven years ago, Mom enjoyed a brief look at bright Comet McNaught through binoculars as it appeared in the twilight sky of early 2007. In late January this year, we had our conversation about the great eclipse of 1918. That was the last time I enjoyed a reasonably intelligent conversation with her. Mom died during the afternoon of 2018 March 24, just nine weeks short of what would have been her 100th birthday. My bother

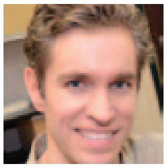
Figure 3 — The picture was taken at our twin nephews' Bar Mitzvah in 1996. From left to right are Wendee, me, and Mom.

Gerry and his son, my nephew Michael, were there soon after. On or close to my Mom's bed were three items: a phone book, a medical alert device, and a bound, inscribed copy of my doctoral dissertation about the night sky in english literature with a place marker inside. Considering that she could not read in her last year, knowing that the book was nearby might have been a source of comfort to her, and the image of it surely is now to me. ✶

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

Dish on the Cosmos

Shedding Light on the Cosmic Dawn



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

This is a risky column to write. It is barely past the spring equinox and the astronomy community is buzzing with discussion about Cosmic Dawn. By the time you read this, new results could be released that invalidate the big discoveries described below: void where superseded by new data.

The news is that astronomers using a radio telescope seem to have detected the signatures of cosmic dawn, which refers to the time when the first stars turn on and start the process of heating and ionizing the entire Universe. The Big Bang theory holds that the Universe began in a hot, dense state (as the song from the sitcom of the same name runs), which then expanded and cooled. Less well discussed is that the Universe was also smooth, with all of the matter and radiation spread out nearly uniformly. With the cooling, all of the hot hydrogen plasma (free protons and neutrons) combined together to form neutral hydrogen gas. Then, for hundreds of millions of years, the Universe just expanded and cooled off with nothing to create new light. Astronomers refer to this era of the Universe as the dark ages, though the light from the hot early Universe is found throughout. Now, we see that light as the Cosmic Microwave Background, which is what happens when cosmic expansion stretches out the light from the Big Bang into longer wavelengths. This stretching is called the cosmic redshift because the light shifts toward the low-energy red part of the spectrum.

Cosmic Dawn is the story of gravity. While the Universe began as mostly smooth, it had small fluctuations in the density driven by the collection of dark matter. Dark matter is thought to be an unknown "shadow" particle that primarily interacts with normal matter through gravity. Those high-density regions of dark matter have more gravitational attraction than the surrounding lower density material and begin to collapse faster. As the dark matter contracts down to form the first halos of galaxies, the gas falls down with the dark matter. There is more dark matter in the Universe than gas, so the gas just follows wherever the dark matter starts to collect. Indeed, dark matter is thought to be essential for the formation of galaxies because the gas in the Universe cannot, by itself, form galaxies fast enough to reach the galactic sizes we see around us today. As the gas collects in the bottom of these dark matter halos, it cools off and the gravitational contraction runs away: denser means more gravitational force that makes the gas denser, etc. These dense objects eventually get material pulled close enough to ignite nuclear fusion and create the first generation of stars, marking the start of cosmic dawn. Figure 1 illustrates a schematic view of this process where the first stars begin to appear in a filamentary web of gas and dark matter. Many questions about those first stars persist: what was the first generation of stars like? How quickly did those stars form? Could any of the stars from that first generation still be alive today?

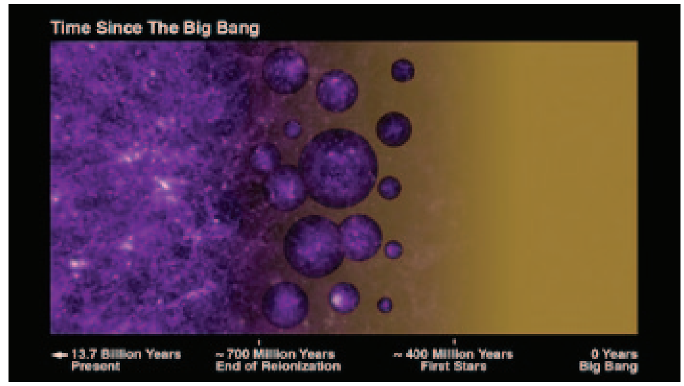


Figure 1 — A schematic diagram of cosmic dawn and reionization. The figure depicts the state of the Universe through its age and the effects of stars heating and ionizing the gas between galaxies after the dark ages. The filamentary structures on the left depict the cosmic web of galaxies. Image Credit: NASA.

Those first stars that emerged when the Universe was only 3 percent of its current age kicked off a new era, pouring out huge amounts of ultraviolet radiation. Eventually, enough new photons were created to ionize nearly every atom in the entire Universe, splitting the electrons and protons apart again. However, since the Universe had expanded so much, the density of most of the gas between the proto-galaxies is so low that it cannot then combine again and become neutral. This one-way step is called cosmic reionization, which is illustrated by the bubble-like features shown in Figure 1, lighting up the Universe.

The signature of cosmic dawn marks the first few steps in this heating and ionization process. The radio signal that is detected is from a spectral line of atomic hydrogen from the dark ages. Normally this line has a high frequency of about 1.4 GHz (comparable to the radio waves generated by your cell phone). However, because of the expansion of the Universe, the light from these radio waves gets stretched out to lower frequency radiation and ends up near 80 MHz. For comparison, the FM radio band runs from 87 to 108 MHz so these radio signals are right near the waves you can pick up from local stations on your car radio. This spectral signature of hydrogen shows up as a cool gas absorbing the light from the cosmic microwave background. We can only see this hydrogen absorption when the stars turn on. Paradoxically, the light from the new stars ends up cooling the hydrogen that is responsible for the spectral line because the radiation ends up coupling together the gas temperature near the stars (relatively cool) to the large-scale gas through the Universe. The net effect of

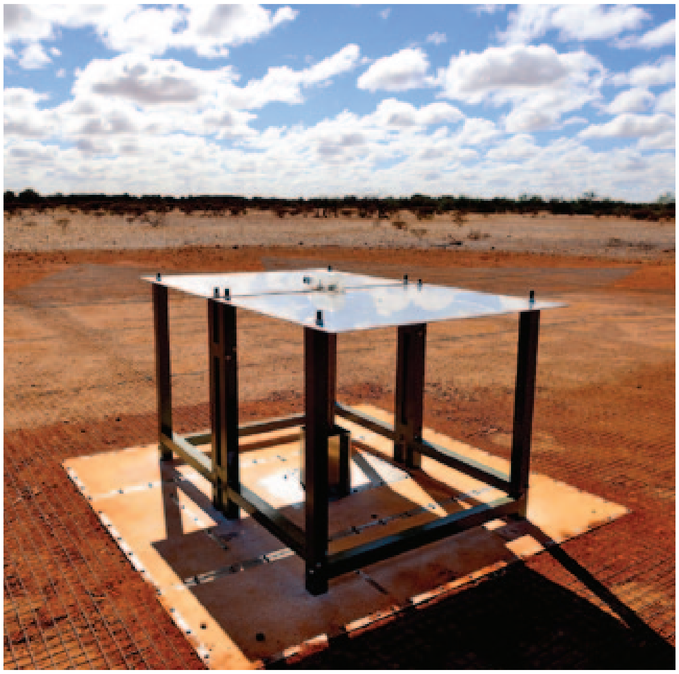


Figure 2 — The EDGES telescope, a simple experiment in western Australia. The mesh on the ground protects the telescope from stray radiation and the telescope consists of the two metal squares connected to wires and amplifiers to detect the radio waves that land on the metal. Image Credit: CSIRO.

the first stars turning on is to produce a small dip in the radio spectrum near 78 MHz. It is this small dip that astronomers report detecting using the EDGES telescope shown in Figure 2.

The telescope itself is a rather unassuming flat metal table in a barren landscape. It is hard to imagine such simple technology making the major discovery of the signatures of the first stars. It looks like nothing more than a metal table situated in the Australian outback. The location is special: this is one of the quietest places on Earth in the radio spectrum, far from the contaminating radio emission of civilization. We are fortunate that the signal is at 78 MHz and not 10 MHz higher where the FM band would completely destroy our hopes of detecting it.

The simplicity of the telescope is striking, but this is because the signal is found in all directions. Indeed, the telescope wants to focus beyond the foreground emission from our planet, Solar System, and galaxy, and see the first stars turning on in all directions. It is a truism of astronomy that we are looking back into the past when we look out at the sky. The first stars turned on everywhere at once in the Universe, so we can look in any and all directions to see the signal. The direction isn't special, but the timing of the event is unique. Thanks to cosmic expansion, the temporal signature is frozen in at a particular frequency of the spectrum. Since the signal is seen in all directions, there is no need for a focusing dish or antenna to make the telescope sensitive in just one way. I remember discussing the signal with Don Backer, one of my professors in graduate school. He would exclaim, "This signal is everywhere; you can detect it on a paperclip!" The sentiment is entirely correct and one of the competitors with the EDGES telescope, started by Don and his collaborators, is called PAPER.

There are two key steps to making this measurement. The first is to remove the foreground emission from the galaxy and others. The galaxy is filled with high-energy particles called cosmic rays that are boosted up to particle-accelerator speeds by supernova explosions. These cosmic rays whiz around the galaxy, trapped by the magnetic field, and they give off radiation. This radio light is thousands of times brighter than the signal at 78 MHz, which requires careful subtraction to remove the foreground signal. The second major difficulty is that radio telescopes are not uniformly sensitive at all different frequencies. If the telescope is 0.01 percent less sensitive at 78 MHz compared to 70 MHz, that could also explain the signal. Knowing the telescope's sensitivity to this precision is incredibly difficult. It would be quite easy for one or both of these effects to lead to a signal that looks like the putative signature of cosmic dawn that is claimed to have been seen on the EDGES telescope.

In all fairness, the research team that published the signal found this result and did the scientific thing: they explained how they made their measurement and what they saw. They outlined all the checks they did on their system to come to their conclusions. There was a brief speculation on the importance of the signal and the team comments that the signal is twice as strong as expected. However, the news was everywhere as theorists tried to explain the strength of the signal and other radio astronomers pointed out potential issues with the observations. We have here a wonderful opportunity for the scientific method: there has been a strong claim made by one team and there are four other experiments operating now that aim to see the same result with entirely independent telescopes. It is only a matter of time before each of these teams combs through their data and can say whether they see the same signature or not. By the time you read this column, those results may be out, changing whether this result is confirmed or questionable. More experiments will be the best test of whether we really have caught the first stars lighting up the Universe.

Read more about EDGES here:
www.haystack.mit.edu/ast/arrays/Edges ✶

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

The August *Journal* deadline for submissions is 2018 June 1.

See the published schedule at
www.rasc.ca/sites/default/files/jrascschedule2018.pdf

Second Light

Black Holes in Abundance in the Galactic Centre Region

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

Over the past couple of decades, it has become apparent that supermassive black holes—those with masses greater than about a million solar masses—exist at the centres of all large galaxies, like the Milky Way. The jury is still out about their presence in dwarf galaxies. But a clear prediction of models of the dynamical evolution of large galaxies is that stellar-mass black holes—those with masses from about five solar masses to several hundred solar masses—should migrate to the vicinity of the supermassive black hole. The easiest to observe black holes are those in low-mass X-ray binary systems, where the black hole is orbited by a nearby companion star, which feeds gas from its atmosphere onto the black hole. Previous searches for such binaries near the centre of the Milky Way turned up nothing believable. Now Chuck Hailey of Columbia University and his colleagues have found a dozen X-ray binaries within 1 parsec of the radio source Sgr A*, which is presumed to be the central black hole of the Milky Way (see the April 5 issue of *Nature*). They argue that these dozen are the tip of an iceberg of black holes, with a population of hundreds of X-ray binaries, and many thousands of isolated black holes.

The concentration of massive objects at the bottom of a gravitational "well" has been studied for many years, starting in the 1970s with the evolution of globular clusters. The central concentration of mass is known in the trade as a "cusp," and it was applied to supermassive black holes in the 1990s. It was about this time that it became accepted in astronomy that supermassive black holes were responsible for the phenomena known variously as Seyfert galaxies, quasi-stellar objects, quasars, active galactic nuclei, and several other names now mostly lost in the mists of time as the nomenclature settled on quasar (at the luminous end) and active galactic nuclei (at the low luminosity end). As a side note on the quirks of science, the existence of supermassive black holes was questioned by a substantial fraction of physicists long after the astronomers accepted them.

In order to look for the X-ray binaries, Hailey and his collaborators went to the archive of the *Chandra X-ray Observatory*, which has spent a good bit of time—1.4 million seconds—observing the galactic centre region for various different projects over the period 2003–2014. There are lots of X-ray sources near the centre of the Milky Way, so they had to devise a method to sort out the low-mass X-ray binaries from the rest. This was the trickiest part of the project. Until Hailey and his collaborators tried this, it was thought to be too difficult a problem to distinguish the X-ray binaries from the much more numerous binary white dwarfs.

They eventually settled on a dozen sources that seem to be "quiescent" low-mass X-ray binaries, meaning that they are accreting mass at a rather low level, though they cannot rule out that six of them might be millisecond pulsars, which are neutron stars that have been spun up (rotation periods increased from a few tenths of a second to several milliseconds) by accretion of gas from a companion star.

Extrapolating those numbers, they estimate that within the central parsec of the Milky Way there are 600–1000 quiescent X-ray binaries, though if a third of their sample is millisecond pulsars, that number drops. Even so, that means that there are still more than 10,000 isolated black holes in the central parsec.

So, this summer, if you live in a part of Canada where the galactic centre is visible above the horizon, spare a thought for all those black holes. ✶

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

Binary Universe

Super Mars

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

In late July 2018, Mars will be super! While low in our Canadian skies, the red planet will be close to the Earth, hopefully making for some of the best views since the Great Mars Apparition of 2003. I will be trying to view the fourth planet (and its elusive moons) as much as possible.

Around opposition, when Mars is well within one astronomical unit, it will be large and brilliant—approximately 24 arc seconds in size and brighter than -2.7 magnitude.

Being so close means that we will be able to see features on the surface of Mars. While we know it is not traversed with water-filled canals and tripod aliens plotting against us, we should be able to pick off light and dark regions, the south pole, and perhaps dust storms in the thin atmosphere.

I will highlight some products to help you dive deep into our neighbouring world.

The Web Tool

A time-tested tool is from *Sky & Telescope* magazine, the *Mars Profiler*.

www.skyandtelescope.com/observing/interactive-sky-watching-tools/mars-which-side-is-visible/

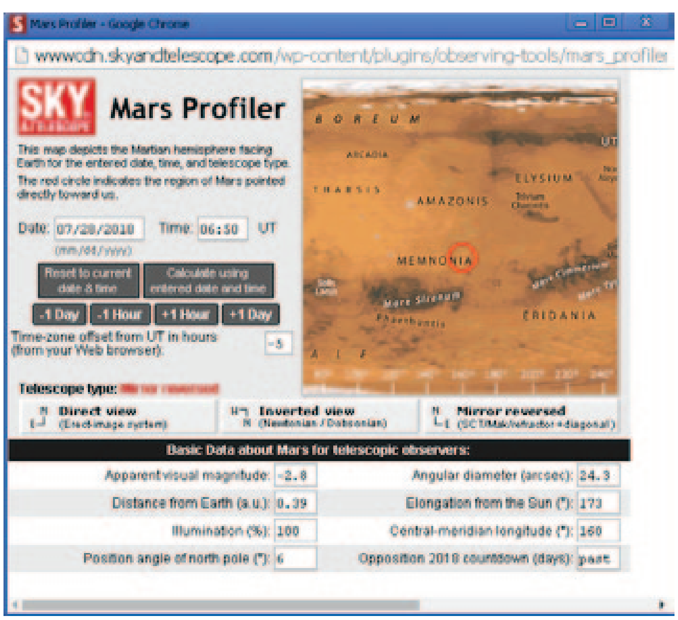


Figure 1 — Mars Profiler tool with rectangular map and control panel.

While not strictly a stand-alone smartphone app, the website resource can be run in a browser tab. I specifically tested it offline and found it worked fine, so you should be able to use it no matter where you go. Of course, it is free.

Mars Profiler uses Javascript technology and initially opens a new pop-up window, both of which you may need to enable.

On loading the S&T Mars tool, you will see a cylindrical projection of the red planet with a control panel (Figure 1). The red circle is the Earth-facing indicator alluding to what's toward us for a given date and time here on Earth. Major features of Mars are identified. The map also shows a longitude scale.

With the controls, it is easy to show Mars's face for the current time. Setting to a time in the past will be helpful when updating one's log book. Using a future period will help with planning. Handy buttons allow one to advance or retreat by one day or hour. You will note Universal Time is used, so if you manually enter values, do so in UT.

Below the map are buttons that allow you to indicate the telescope type. Three views are offered including Direct or normal like how binoculars work, the Inverted view for an even number of reflections within a telescope, and the Mirror Reversed view for an odd number of reflections. Of course, this may change if you're using a star or mirror diagonal or a camera.

Finally, there is a table with Basic Data of the fourth planet, such as the magnitude, the angular size, the distance, and the countdown to the next opposition.

The *Mars Profiler* sets the standard of what is useful. Being able to control the date, time, and telescopic view are important. This basic tool is limited, you can't zoom in, nor can you toggle the labels. The biggest issue is the map display, which you may find challenging. You must remember that things at the extreme left and right edges will be at the limbs of the disk and there is increasing distortion the further you move from the centre or the red circle. *Mars Profiler* does not have a red night-vision mode.

The Apple Tool

I tested a couple of apps for iOS and found *Mars Atlas* by Julian James to be the best. It is a very good application for simulations of Mars. He makes two editions, one for a full Macintosh computer and one for an Apple mobile device.

Mac app:
https://itunes.apple.com/us/app/mars-atlas/id429268403

iOS app:
https://itunes.apple.com/gb/app/mars-atlas/id303482394

After the acquisition for less than $10, I installed and tested version 2.6.0 on an iPad.

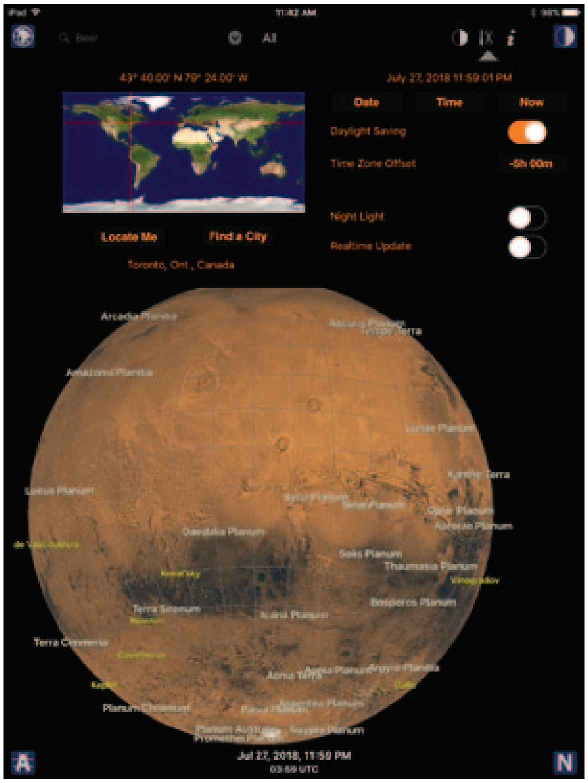


Figure 2 — Mars Atlas with Settings panel open.

Figure 3 — Mars Atlas with detailed feature pop-up.

The simulated view of the Mars globe from Earth appears with some features identified. The display can be zoomed to reveal more detail. By default, the sunlight effect is enabled, meaning it shows the sunward side of the red world illuminated and the hemisphere opposite in darkness. You can easily turn this on or off with the "phase" button. This may be moot during the Mars apparition when it will appear full to us.

Tapping on the tools icon shows the Settings panel that allows one to specify the user's location, set the date and time, daylight-saving option, and time zone. The Realtime Update switch is handy when you want to verify what you are seeing right now in the ocular or on the camera screen—I had to manually set time zone and choose my location as the Locate Me button didn't work. Regardless, I was able to easily adjust for the past or future.

I was very happy to see the Night Light control that turned the entire application interface red, including the controls.

There is a display mode button, which when tapped, shows a grid and/or features. The items shown include classic "albedo" surface details, the easily identified light and dark regions. If you zoom in, you will see smaller features identified by the US Geological Survey, and note spacecraft locations. If you double tap a feature (when the finicky option works), you will see a pop-up (Figure 3).

To simulate your view at high magnification, *Mars Atlas* supports the traditional telescope views (normal, mirror-reversed, and rotated) plus the unusual rotated-mirror.

The app has a couple of other interesting features. For example, you can perform a search action to quickly find a specific feature. The Globe Mode allows you to move around the planet as if in your own spaceship.

The developer was helpful and quick to respond to my questions. The app is not perfect, but I found it to be the best of all. It was fairly easy to use and the on-board instructions helped me understand the interface.

The Android Tool

I scoured the Google Play store as I researched Android options. I was most intrigued by *Physical Mars* from Requio Web Design. While it looked very thorough with topographic and temperature maps, it didn't seem to support all telescopic views, particularly mirror flipping. Still I purchased it for less than $3 and downloaded the app to my phone.

When I started *Physical Mars*, I was presented with the main screen (Figure 4). This shows a rectangular projection of Mars evocative of a Geochron clock. The sunlit face of Mars was emphasized with the light sinusoidal region along with the yellow dot. I presume the blue dot is to indicate the sub-Earth point over the Martian surface. The table below shows a number of values, including the central meridian, geocentric distance, and angular diameter, as well as the light-time to Earth.

For this map, labels can be shown by tapping the menu button and choosing from Craters, Monts, Landing Sites, etc., although I found the font terribly tiny on my small screen. The Wide Areas highlights a number of the albedo features, such as Syrtis Major. Selecting one set of labels clears the others. Tapping the Real-Time button allows one to choose a past or future date and time. Like the S&T *Mars Profiler* map, there is significant distortion in this type of projection.

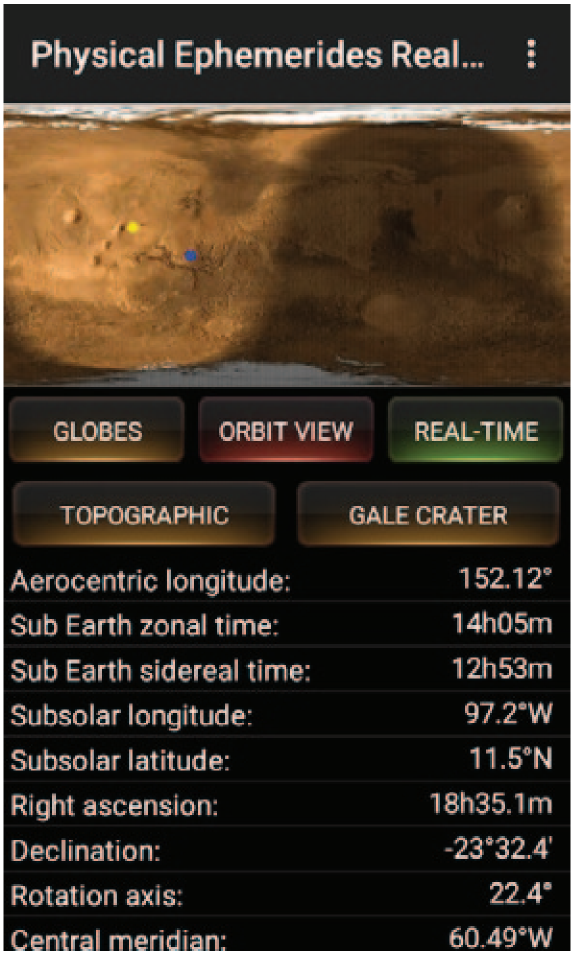


Figure 4 — Physical Mars *main Ephemerides screen.*

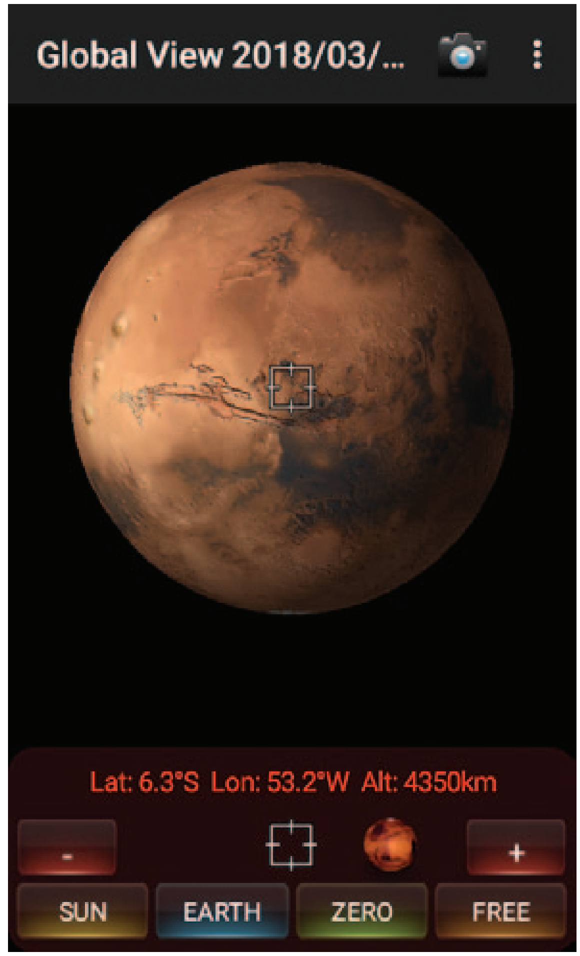


Figure 5 — Physical Mars *in Globes mode.*

Switching to a realistic spherical presentation is quickly done by tapping the Globes button. Initially, the Earth-facing side of Mars is shown (Figure 5). The Martian latitude and longitude appears, as well as your "altitude" above the surface. You can easily zoom, decrease, or increase your altitude. You can illuminate the dark side of Mars, if necessary, although I found the terminator very soft. When you drag or swipe on your screen the planet is rotated.

The fourth button in the toolbar, Free/Lock, allows you to lock on the current latitude and change only the longitude. Otherwise you can freely move about the fourth planet to examine the north and south poles.

I did not see a way to show labels in the Global View, which I thought somewhat strange. However, you can browse for a feature and have it centred.

The Global View takes the date and time from the main screen, so you will need to back up to the previous screen.

From the Global View menu, one can view the Earth or force the Mars display to be rotated. It is here I was hoping to find a mirror-reversed option, but it is definitely not available. You'll have to do some mental gymnastics, get out a pocket mirror, or flip the image in an image app.

There are a number of interesting additional features including the Orbit View diagram. *Physical Mars* lacks a red-light mode.

Overall the Android app is fair. Certainly, if you regularly use a Newtonian telescope or plan to photograph Mars, this app may prove very useful.

I never heard from the developer despite repeated attempts. I would like to know if version 1.12 last revised in 2014 would be updated for bugs and additional features. While not as feature-rich as other apps, the price of *Physical Mars* is reasonable.

Mars is coming. Be ready.

Bits and Bytes

There is a new edition of Aladin available, version 10, with an improved interface. ✶

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

John Percy's Universe

The Wonderful Words of Astronomy

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

Astronomy, like all subjects, has its own language—and jargon. Language is important. Language has power. My go-to reference on astronomical terminology is Jacqueline Mitton's *Cambridge Illustrated Dictionary of Astronomy.* The general public probably understands when we talk about planets or star clusters, but what about *right ascension*? And do they confuse *eclipse, ecliptic,* and *elliptic*? Or *astronomy* and *astrology*—heaven forbid? This column is a whimsical reflection on some of the odd or confusing or interesting terms that astronomers use.

Most astronomical terms come from Greek or Latin, with a few from Arabic (*almanac, azimuth, zenith, nadir*—the latter often encountered in crossword puzzles), French (*coudé* focus), German (*gegenschein*), or Italian (*neutrino*). Some bear the names of astronomers: *Drake's equation, Herbig-Haro object, Hubble's law, Oort cloud, Seyfert galaxy.*

Terms from Long Ago

Right ascension and *declination* are the astronomical equivalents of longitude and latitude. They are ubiquitous in astronomical publications such as the *Observer's Handbook*. But what are their origins? Is right ascension the opposite of left ascension, or wrong ascension? According to *Wikipedia,* "right ascension refers to the ascension, or the point on the celestial equator that rises with any celestial object as seen from Earth's equator, where the celestial equator intersects the horizon at a right angle" and the term declination "means a 'bending away' or 'a bending down.' It comes from the same root as the words incline and recline." Does that help?

Contributions to Popular Culture

The *Big Bang* is the name given to the event in which our Universe came into existence, in a momentary state of extreme temperature and density. The name was coined by Sir Fred Hoyle who didn't believe a word of it. He promoted the Steady State Theory, in which the Universe has existed forever. In 1994, *Sky & Telescope* magazine ran a contest to find a new and better name for the birth of the Universe but, despite 13,099 entries, no better name was suggested. So today we even have a popular TV series called "The Big Bang Theory."

A *black hole* is an object whose gravity is so strong that nothing can escape, not even light. The name was given by the eminent physicist John Wheeler in 1967. It has been embraced by popular culture to mean anything where lots goes in, but little or nothing comes out. Unfortunately, many government reports seem to fit this definition.

Considering that *dark matter* and *dark energy* sound mysterious, and are the most abundant and puzzling constituents of the universe, I wonder how soon they will find a place in popular culture?

Unfortunate Terminology

In an earlier column (Percy 2015), I addressed the topic of misconceptions in astronomy. One of the most powerful is that there is no gravity in space—thanks to the term *weightless*. It's true that astronauts in orbit feel weightless, because they and their spacecraft are both falling freely toward the Earth, so the floor of the spacecraft is not pushing upward on them. Luckily, they are also travelling sideways at about eight kilometres a second, fast enough to avoid hitting the ground. But it's gravity that is pulling them both downward.

And consider the term *light-year.* It sounds like a unit of time, but it's actually the distance that light travels in a year, at a speed of ~300,000 km/sec, or approximately ten million million km. And for some reason, astrophysicists consider any elements heavier than hydrogen and helium to be *"metals."* That includes carbon, nitrogen, and oxygen. And *planetary nebulae* have nothing to do with planets. A *nova* may be a newly observed star, but it's actually an old one. *Shooting stars* have nothing to do with stars (but astronomers rarely use that term for a meteor). A comet *tail* is not necessarily on the back end, where a cat's is; it can be on the front end if the comet is receding from the sun. The media have become enamoured of the terms *supermoon* and *blue moon*, which are not very super, or very blue.

The Language of Two Different Worlds

One of my standard public lectures is called "The Birth, Life, and Bizarre Deaths of Stars." I have to tell the audience, at the outset, that the lecture has nothing to do with Hollywood celebrities. And *degenerate stars* (white dwarfs and neutron stars) are well understood by astrophysicists, but also have nothing to do with celebrities. Nor does the *Great Attractor*; it's a massive cluster of galaxies that causes deviations from Hubble's Law. Indeed, these deviations of a galaxy's recession velocity from Hubble's Law are called *peculiar motions*. This conjures up visions of Monty Python's Ministry of Silly Walks. And what about *proper motion*—the motion of celestial objects across the sky? Is it the opposite of improper motion, which can be the basis for claims of harassment, or for a penalty on the football field? And atoms can be in an *excited state.* So can astronomers. *Terminator* is well understood by observers of the Moon but, to most people, it's a movie franchise. I leave it to you to imagine how the public interprets the astronomical terms *aberration, white dwarf, brown dwarf* (sometimes referred to as a *failed star*), *red giant, eccentricity,* and *excretion disk.*

A particularly dangerous case is the word *theory.* To astronomers, it's a well-established, well-supported principle, like the *theory of evolution.* To many of the public, though, it's "just a theory" or conjecture.

There are a few astronomical terms that can be useful in everyday life. *Opacity*, for instance, is the resistance of matter to the flow of radiation. It can also be applied to the denseness of certain public figures, as can the term *principle of mediocrity*—the belief that our nature and place in the Universe are not unusual in any meaningful way.

Acronymania

Scientists love acronyms; see (1) for some strange ones. They can certainly be very efficient. But, with the possible exception of *NASA*, astronomical acronyms are opaque to the public. *AGNs* are *active galactic nuclei*, powered by supermassive black holes, and *FRBs* are *fast radio bursts*, the latest mystery in the cosmos. More picturesquely: *MACHO*s are *massive compact halo objects*, and *proplyds* are *protoplanetary disks.* These are more interesting than the usual mundane or obscure astronomical terms.

Quasars and Pulsars and Spinars, Oh My!

Quasi-stellar radio sources are point-like radio sources, discovered in the 1950s. We now know that they are powered by supermassive black holes at the centre of galaxies. Not surprisingly, their name was shortened to *quasars* by 1964. There were already *spinars*—rapidly rotating, massive stars. When Jocelyn Bell and Anthony Hewish discovered pulsing radio sources in 1968, the name *pulsars* was coined, apparently by British science journalist Anthony Michaelis. And according to ADS, the Astrophysics Data System, the first use of the term in the abstract of a scientific paper was by Canadian astronomers John Galt and Ann Gower. The term has caused some confusion, because the term *pulsating stars* was already used, but pulsating stars pulsate or vibrate, they don't really pulse. So pulsars pulse, and spinars spin, but quasars don't quase. In 1996, Canadian astronomer Chris Thompson co-discovered and co-named intensely magnetic neutron stars as *magnetars.*

The Funny Side of Astronomical Language

Great minds think alike. I was well started on an earlier version of this column when I received a message from Andy Fraknoi, one of my favourite astronomers, and certainly one of the funniest. He is one of the world's foremost astronomy educators, and an Honorary Member of the RASC. His "daffy-nitions" (2) are meant to amuse astronomers, but they may also reflect what the public thinks when they hear them. Examples: *antiproton*: whom Uncle Proton is married to; *contact binary*: tango partners; *Great Red Spot:* a popular night club in Beijing. Groan.

In any case, I invite you to think about the astronomical terms that you use, and how they might be perceived by the public. Be sure to explain them—light-heartedly, perhaps—when you talk with the public. And assure the public that most astronomers have a good sense of humour. You could regale an audience with stories of the names of constellations such as *Antlia*, the air pump. Introduce them to terms such as *spaghettification*—the stretching of objects into noodle shapes by tidal effects of strong gravitational fields, such as those of black holes. *Shepherd satellites* keep the rings of Saturn in order. And *galactic cannibalism*, the devouring of small galaxies by larger ones, and *galactic mergers* remind us of certain processes in the modern corporate world. My field of research is variable stars, and the arcane nomenclature of variable stars leads to star names, such as that of the young stellar object *RU Lupi*. Mike Simonsen's blog (3) includes many more, including some less polite ones. ✶

References

Percy, J.R. 2015, "Astronomical misconceptions," *JRASC 109*, 183.

Notes

1 www.space.com/28244-strange-astronomy-acronyms.html

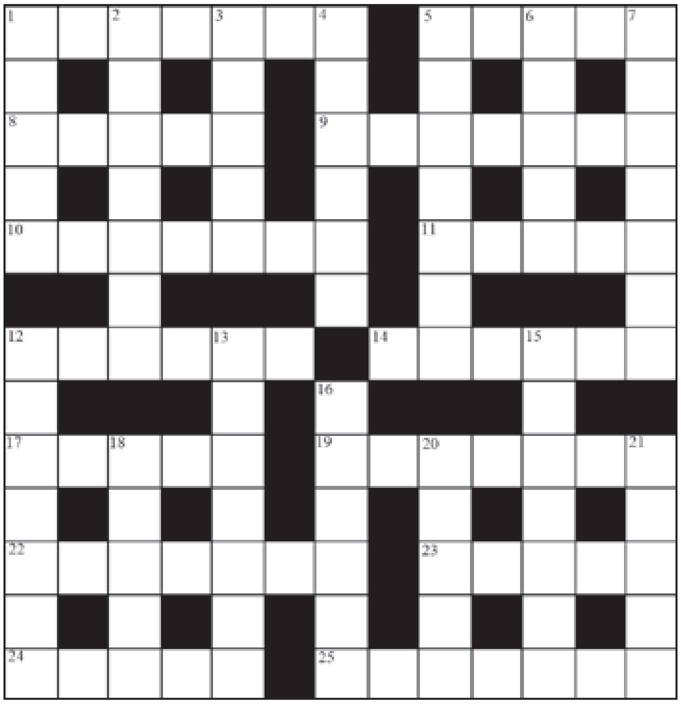
2 www.researchgate.net/publication/320099739_Andrew_Fraknoi%27s_Decidedly_Demented_Definitions

3 http://simostronomy.blogspot.ca/2009/01/variable-star-names-for-fun.html

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

Astrocryptic

by Curt Nason



ACROSS

1. Leo's showpiece often seen in an apochromat (7)
5. Society leader was part of the Merchant Marines (5)
8. Issued from Venus, it was seen around Uranus (5)
9. Rainy basin rim I bum around (7)
10. Society's place to stand and grow, with no ratio disturbed (7)
11. How Calgary members capture Taurids in this astronomical association? (5)
12. Osmium-infused CMOS chip captures the whole universe (6)
14. Please decipher how one often falls during a minor meteor shower (6)
17. Temperature loop for a camera coupler (1-4)
19. Pioneer of celestial mechanics discovered Capella rotates (7)
22. What we look through to see Selene twisting around the gym (3,4)
23. Romer's first turned to Rome's second satellite galaxy (3,2)
24. Mislabel a catalogue of galaxy clusters (5)
25. Sails around and about Romania's capital to a tour around Neptune (7)

DOWN

1. Lunar rays emitted from here possibly seen by him (5)
2. In confusion I set up a two-toned satellite (7)
3. Used to measure distance with asteroid in lower extremes (5)
4. Do trip around but not over your telescope support (6)
5. Young pitcher to be with the French group in the outer belt (7)
6. Erstwhile equinoctial point varies without a beginning (5)
8. Tomboy almost very quietly discovered a comet (3,4)
12. Wild, racy orbit around the home of Venus (7)
13. Urge to boil in oil a French carbonaceous chondrite (7)
15. First eagles claws to be used in solar filters (7)
16. Initially, Percival Lowell covered the loss of an eyepiece (6)
18. In Hind's sight a peaceful asteroid (5)
20. North Star is missing this alignment (5)
21. Rix sketched an area where I rake around (5)

Answers to April's puzzle

ACROSS

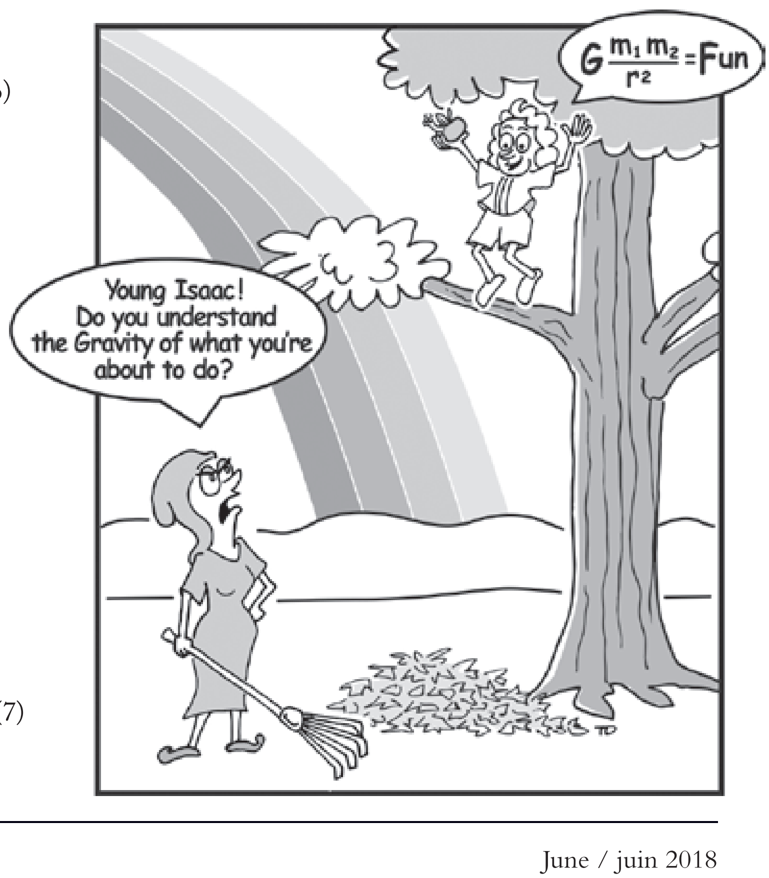
1 ALCOR (hid); **4** CATHODE (c(a Th)ode); **7** LARISSA (hid); **8** MODEL (2 def); **9** TOTAL (T(ot)al); **10** ETALONS (anag); **11** RENATA (anag); **13** PLANCK (homophone); **16** CONTOUR (C + on tour); **17** COLIN (co(l)in); **19** MAGUS (anag); **20** PODCAST (pod + cast) **21** SYNODIC (hid); **22** SONIC (ions (anag) + c)

DOWN

1 ALL-STAR (2 def); **2** COROT (Co + rot); **3** RESOLUTIONS (2 def); **4** CRATER (2 def);
5 OLD MOON (2 def); **6** ELLIS (2 def); **8** MIAPLACIDUS (anag); **12** NONAGON (no(anag)on);
14 KINETIC (kin + cite(rev)); **15** TRPOIC (anag); **16** COMES (co(me)s); **18** LEARN (anag)

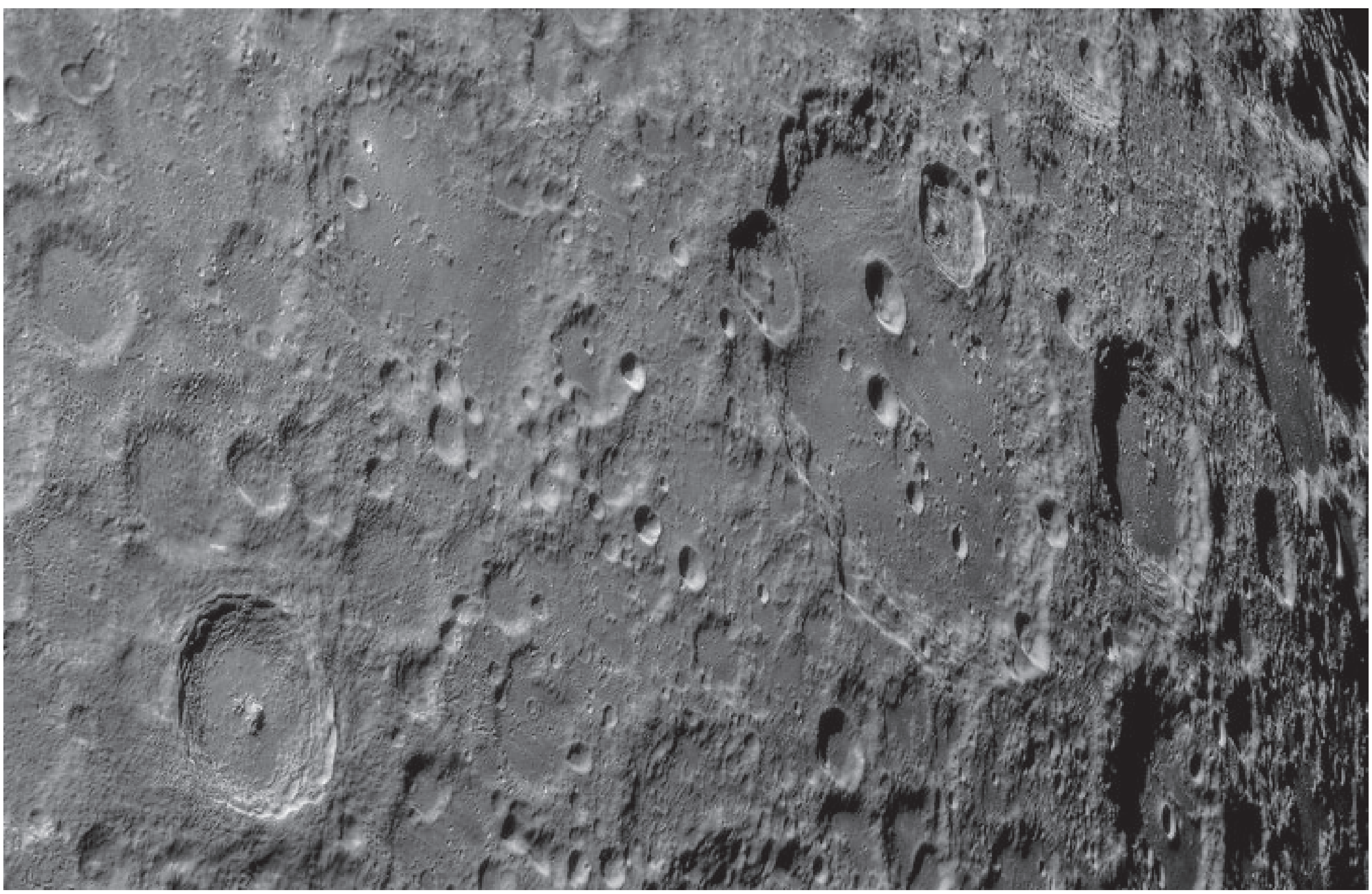
It's Not All Sirius

by Ted Dunphy



Great Images

by Mike Wirths



The beautiful lunar crater of Clavius was taken by Mike Wirths using his 18-inch Starstructure Dobsonian with an ASI 174-mm camera, 4x Barlow, and a red-filter stack of 500.

Journal

Great Images

Meet Steve, the phenomenon making waves in the astronomical community. Alan Dyer captured the unique display here in 2016. The single 13-second shot was taken through a 20-mm lens at f/1.4 and a Nikon D750 at ISO 3200.