

The Journal of The Royal Astronomical Society of Canada

Journal

Le Journal de la Société royale d'astronomie du Canada

PROMOTING
ASTRONOMY
IN CANADA

April/avril 2020
Volume/volume 114
Number/numéro 2 [801]

Inside this issue:

**Cepheid Variables
in Andromeda**
Supernova Redshifts
2019 Awards

Corona Australis

The Best of Monochrome.

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



The magnificent California Nebula was imaged by Ron Brecher's home observatory in Guelph, Ontario. It is a 16-hour exposure through a 106mm f/3.6 refractor, combining 12hr20m collected with a one-shot colour camera and 4hr30m collected with a monochrome camera.

contents / table des matières

Research Articles / Articles de recherche

56 **Cepheid Variables in the Andromeda Galaxy from Simon Fraser University's Trottier Observatory**
by Howard Trottier et al.

67 **Matching Supernova Redshifts with Special Relativity and no Dark Energy**
by Simon Brissenden

Feature Articles / Articles de fond

80 **Pen and Pixel: Orion / Comet PANSTARRS C/2017 T2 / Dumbbell Nebula / Cone Nebula.**
Blake Nancarrow / Klaus Brasch / Tom Owen / Gary Palmer

Columns / Rubriques

71 **Skyward: First Light and Something Old, Something New**
by David Levy

73 **CFHT Chronicles: Behind the Data at CFHT**
by Mary Beth Laychak

77 **Binary Universe: Take Control of Your Mount**
by Blake Nancarrow

89 **John Percy's Universe: Assassin: The Survey**
by John R. Percy

92 **Dish on the Cosmos: King of The Radio Sky**
by Erik Rosolowsky

94 **Celestial Review: Algol at Minimum**
by Dave Garner

96 **Imager's Corner: CGX-L Review**
by Blair MacDonald

100 **Observing: Springtime Observing with Coma Berenices**
by Chris Beckett

Departments / Départements

50 **President's Corner**
by Dr. Chris Gainor

51 **News Notes / En manchettes**
Compiled by Jay Anderson

101 **Awards for 2019**
Compiled by James Edgar

112 **Astrocryptic and February Answers**
by Curt Nason

iii **Great Images**
by Luca Vanzella

"Space is a pretty dynamic place, and there is a lot going on in this area called Corona Australis Complex," said Debra Ceravolo. Peter Ceravolo acquired the data from San Pedro de Atacama in Chile, using the Ceravolo 300 Astrograph at f/4.9 on a Paramount ME. Debra processed the image using MaximDL and PixInsight. Total exposure was 7.2 hours: LRGB: 285, 50, 30 and 35 minutes. "Some dust (blue reflection nebula) is getting lit up by nearby bright stars and the dark dust cloud is not. It is all about 500 light-years away except the globular cluster (NGC 6723) is 30,000 light-years away. Put that in perspective!" she says.



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 astronomical 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.

Editor-in-Chief

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

Associate Editor, Research

Douglas Hube
Email: dhube@ualberta.ca

Associate Editor, General

Michael Attas
Email: attasm1@mymts.net

Assistant Editors

Michael Allen
Martin Beech
Dave Chapman
Ralph Chou
Ralph Croning
Dave Garner
Patrick Kelly

Production Manager

James Edgar
Email: james@jamesedgar.ca

Advertising

Adela Zyfi
Email: mempub@rasc.ca

Contributing Editors

Jay Anderson (News Notes)
Chris Beckett (Observing Tips)
Mary Beth Laychak (CFHT Chronicles)
David Levy (Skyward)
Blair MacDonald (Imager's Corner)
Blake Nancarrow (Binary Universe)
Curt Nason (Astrocryptic)
John R. Percy (John Percy's Universe)
Randall Rosenfeld (Art & Artifact)
Eric Rosolowsky (Dish on the Cosmos)
Leslie J. Sage (Second Light)
David Turner (Reviews)

Proofreaders

Michael Attas
Margaret Brons
Angelika Hackett
Michelle Johns
Barry Jowett
Kim Leitch
Alida MacLeod

Design/Production

Michael Gatto, Grant Tomchuk
Email: gattotomatto@gmail.com,
granttomchuk@eastlink.ca

Printing

Cansel
www.cansel.ca

Her Excellency the Right Honourable **Julie Payette**, C.C., C.M.M., C.O.M., C.Q., C.D., Governor General of Canada, is the Viceregal Patron of the RASC.

The *Journal* of The Royal Astronomical Society of Canada is published at an annual subscription rate of \$93.45 (including tax) by The Royal Astronomical Society of Canada. Membership, which includes the publications (for personal use), is open to anyone interested in astronomy. Applications for subscriptions to the *Journal* or membership in the RASC and information on how to acquire back issues of the *Journal* can be obtained from:

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

Canadian Publications Mail Registration No. 09818
Canada Post: Send address changes to 203 – 4920 Dundas St W, Toronto ON M9A 1B7

Canada Post Publication Agreement No. 40069313

We acknowledge the financial support of the Government of Canada through the Canada Periodical Fund (CPF) for our publishing activities.

© 2020 The Royal Astronomical Society of Canada.
All rights reserved. ISSN 0035-872X

Canada



President's Corner

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

For most RASC members, getting together usually means some activity within a Centre, such as a monthly meeting, observing night, annual banquet, or even an informal activity like the weekly Astro Café that has become a popular event in my home Centre in Victoria.

Getting the Society together at the National level is more difficult because, as our former Prime Minister, William Lyon Mackenzie King, once observed, in Canada we have too much geography.

For much of its existence, the RASC's only National event was its Annual General Meeting, which, until 1960, always took place in Toronto. That event traditionally involved only dealing with Society business, but in 1959 the meeting was expanded to include papers on astronomy. The following year the enlarged event took place in Montréal, marking the beginning of our annual General Assemblies.

The GAs that followed over the past six decades have usually taken place on university campuses in various parts of the country, usually on either the Victoria Day or, more recently, the Canada Day long weekends. National Council meetings, Society banquets, the Annual General Meeting and paper presentations have been staples of every GA.

For many years Centres competed to host the GA, but in recent years interest in hosting these meetings has declined to the point where the 2019 GA was largely organized out of the National Office. There are several reasons for this change, but a major one is that General Assemblies based at universities have become more complicated to organize and less convenient for many people to attend.

A few years ago I asked for input from interested members and then wrote a report suggesting that we make some changes to the format of GAs. In 2019, we held the GA in the middle of June instead of on a long weekend, a change that was seen as successful.

Another idea was to move the GA away from universities. The 2020 General Assembly is taking place the weekend of June 5 to 7 at the Executive Plaza and Conference Centre in Coquitlam, B.C., which is conveniently located near a stop on Greater Vancouver's SkyTrain system. In a nod to our history, one evening's activities will take place at Simon Fraser University in Burnaby and include a visit to the Trottier observatory on campus.

While hotel accommodations are more expensive than university residences, meetings in hotels are generally easier

to organize since that is their business and not a sideline. We also believe that GA organizers should focus more on activities that will draw local audiences and help build their Centres. We hope that these changes encourage more Centres to consider hosting GAs and rebuild interest in this vital national activity.

The Vancouver organizing committee for the 2020 GA is doing a great job putting the weekend together with speakers

such as Bob McDonald, host of CBC's *Quirks and Quarks*, and top-flight astrophysicists including Michael Landry, Aaron Boley, Jess McIver, and Jaymie Mathews. More speakers and many exciting activities can be found on the 2020 GA website ga2020.rasc-vancouver.com.

I look forward to seeing many friends from Greater Vancouver and around Canada at the 2020 General Assembly! ✨

News Notes / En manchette

(Compiled by Jay Anderson)

Green dunes: A new form of aurora

Working together with space researchers, Finnish amateur photographers have discovered a new auroral form. Named “dunes” by the hobbyists, the origins of the feature were tracked to a wave guide formed within the mesosphere and its boundary, the mesopause. The study also posits that this new auroral form provides researchers with a novel way to investigate conditions in the upper atmosphere.

In 2018, Minna Palmroth, Professor of Computational Space Physics at the University of Helsinki, published a book entitled *Revontulibongarin opas* (A guide for aurora borealis watchers). The book was born out of Palmroth's cooperation

with northern lights enthusiasts and the answers she provided to questions about the physics of the phenomenon in the hobbyists' Facebook group.

Thousands of magnificent photographs of the northern lights taken by hobbyists were surveyed and categorized for the book. Each auroral form is like a fingerprint, typical only of a certain phenomenon in the auroral zone. During the classification, hobbyists pointed out that a certain auroral form did not fit into any of the pre-existing categories. Palmroth set aside these unusual forms for later consideration.

Just days after the book was published, the aurora watchers saw this unusual form again and immediately informed Palmroth. The form appeared as a green-tinged and even pattern of waves resembling a striped veil of clouds or dunes on a sandy beach. The most distant waves were more distinct than those closer to the camera, suggesting a thin layer of emission that became more prominent at larger slant angles. Video of the new phenomenon show a series of wispy waves, quasi-stationary or slowly moving, while a much more active auroral display dances on their northern edge.

The phenomenon was photographed at the same time in both Laitila and Ruovesi, southwest Finland, with the same structures observed in the



Figure 1 — (a) Auroral dunes captured on 2018 October 7, at 17:40.59 UT in Laitila. The stars in the background indicate that the field of view is toward the northwest. The dunes (marked by magenta circles and numbers) extend equatorward from the discrete bright arc in the north. The local magnetic-field direction is shown by the auroral pillars, the almost vertical purple structures. (b) Simultaneous picture of the dunes in Ruovesi, 172 km northeast from Laitila. The background star positions indicate that the field of view is roughly toward the west. Image: Palmroth et al., 2020.

auroral emission in both images. Maxime Grandin, a postdoctoral researcher in Palmroth's team, identified stars behind the emission and determined the azimuths and elevations of the stars with the help of the astronomy software program *Stellarium*. This made it possible to use triangulation to analyze the photographs and determine that the dunes were a monochromatic wave field with a wavelength of about 45 km within a thin layer at 100 km altitude.

A total of seven similar events—where a camera had recorded the same even pattern of waves—were further identified from the Taivaanvahti (Sky Watch) service maintained by the Ursa Astronomical Association.

“Due to the difficulties in measuring the atmospheric phenomena occurring between 80 and 120 kilometres in altitude, we sometimes call this area ‘the ignorosphere,’” Palmroth says. The dunes were observed precisely in that particular region of the auroral zone. The observed phenomenon guided the researchers toward a middle ground between atmospheric research and space research, as the usual methodology of space physics could not explain it alone.

“The differences in brightness within the dune waves could be due to either waves in the precipitating particles coming from space, or in the underlying atmospheric oxygen atoms,” says Palmroth. “We ended up proposing that the dunes are a result of increased oxygen atom density.”

Next, the team had to determine how the variability in the density of the oxygen atoms caused by gravity waves in the atmosphere results in such an even and widespread field of waves. Normally at the altitude of study there are many different kinds of gravity waves travelling in different

directions at different wavelengths, which is why they do not easily form the even wavefields exhibited by the dunes.

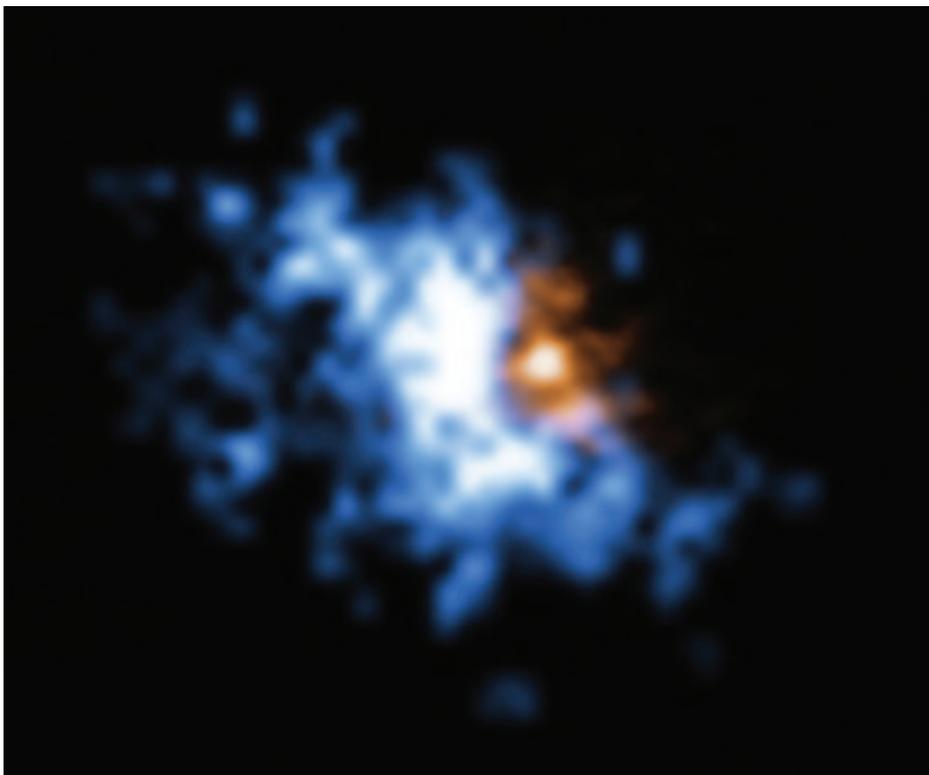
The study suggests that the phenomenon in question is a mesospheric bore, a rare and little-studied phenomenon that takes place in the mesosphere. Various types of gravity wave are born in the lower atmosphere and then rise to higher regions. In very rare cases, gravity waves can get filtered as they rise between the mesopause and a temperature inversion layer that is intermittently formed below the mesopause. The inversion layer makes the filtered waves bend and enables them to travel long distances through the channel without attenuation.

Mesospheric bores are usually found by their effect on airglow and have not been noted before at auroral latitudes. This may be due to an observational bias notes Palmroth, as “the auroral zone as a whole is usually discounted in studies focused on the bore, as auroral emissions impair the technique used to identify mesospheric bores.”

With the help of instruments operated by the Finnish Meteorological Institute, the dunes were found to occur simultaneously and in the same region where the electromagnetic energy originating in space is transferred to the “ignorosphere.”

“This could mean that the energy transmitted from space to the ionosphere may be linked with the creation of the inversion layer in the mesosphere,” says Palmroth. “In terms of physics, this would be an astounding discovery, as it would represent a new and previously unobserved mechanism of interaction between the ionosphere and the atmosphere.”

Compiled with material provided by the University of Helsinki and AGU100 (American Geophysical Union).



Black hole's breakfast at Cosmic Dawn

Astronomers using the European Southern Observatory's Very Large Telescope (VLT) have observed

Figure 2 — This image shows one of the gas halos newly observed with the MUSE instrument on ESO's Very Large Telescope superimposed to an older image of a galaxy merger obtained with ALMA. The large-scale halo of hydrogen gas is shown in blue, while the ALMA data is shown in orange. The halo is bound to the galaxy, which contains a quasar at its centre. The faint, glowing hydrogen gas in the halo provides the perfect food source for the supermassive black hole at the centre of the quasar. The objects in this image are located at redshift 6.2, meaning they are being seen as they were 12.8 billion years ago. Image: ESO/Farina et al.; ALMA (ESO/NAOJ/NRAO), Decarli et al.

reservoirs of cool gas around some of the earliest galaxies in the Universe. These gas halos are the perfect food for supermassive black holes at the centre of these galaxies, which are now seen as they were over 12.5 billion years ago. This food storage might explain how these cosmic monsters grew so fast during a period in the Universe's history known as the Cosmic Dawn.

“We are now able to demonstrate, for the first time, that primordial galaxies do have enough food in their environments to sustain both the growth of supermassive black holes and vigorous star formation,” says Emanuele Paolo Farina, of the Max Planck Institute for Astronomy in Heidelberg, Germany, who led the research. “This adds a fundamental piece to the puzzle that astronomers are building to picture how cosmic structures formed more than 12 billion years ago.”

Astronomers have wondered how supermassive black holes were able to grow so large so early on in the history of the Universe.

“The presence of these early monsters, with masses several billion times the mass of our Sun, is a big mystery,” says Farina, who is also affiliated with the Max Planck Institute for Astrophysics.

It means that the first black holes, which might have formed from the collapse of the first stars, must have grown very fast. But, until now, astronomers had not spotted “black hole food”—gas and dust—in large enough quantities to explain this rapid growth.

To complicate matters further, previous observations with ALMA, the Atacama Large Millimetre/submillimetre Array, revealed a lot of dust and gas in these early galaxies that fuelled rapid star formation. These ALMA observations suggested that there could be little left over to feed a black hole.

To solve this mystery, Farina and his colleagues used the MUSE instrument on ESO's VLT in the Chilean Atacama Desert to study quasars—extremely bright objects powered by supermassive black holes that lie at the centre of massive galaxies. The study surveyed 31 quasars that are seen as they were more than 12.5 billion years ago, at a time when the Universe was only about 870 million years old. This is one of the largest samples of quasars to be surveyed from this early on in the history of the Universe.

The astronomers found that 12 quasars were surrounded by enormous gas reservoirs: halos of cool, dense hydrogen gas extending 100,000 light-years from the central black holes and with billions of times the mass of the Sun. The team, from Germany, the US, Italy, and Chile, also found that these gas halos were tightly bound to the galaxies, providing the perfect food source to sustain both the growth of supermassive black holes and vigorous star formation.

The research was possible thanks to the superb sensitivity of MUSE, the Multi-Unit Spectroscopic Explorer, on the VLT, which Farina says was “a game changer” in the study of quasars.

“In a matter of a few hours per target, we were able to delve into the surroundings of the most massive and voracious black holes present in the young Universe,” he adds.

While quasars are bright, the gas reservoirs around them are much harder to observe. But MUSE could detect the faint glow of the hydrogen gas in the halos, allowing astronomers to finally reveal the food stashes that power supermassive black holes in the early Universe.

In the future, ESO's Extremely Large Telescope (ELT) will help scientists reveal even more details about galaxies and supermassive black holes in the first couple of billion years after the Big Bang.

“With the power of the ELT, we will be able to delve even deeper into the early Universe to find many more such gas nebulae,” Farina concludes.

Compiled with material provided by ESO.

How the corona got its hots

Place your hand near a heat source and you can feel the warmth. Move your hand farther away and the heat fades. This is the opposite of what seems to happen on the Sun. The Sun's outer layers get hotter the farther one gets from the surface.

For more than 60 years, observations of the Sun suggested that magnetic waves travelling away from the surface out into the corona could be a prime culprit in maintaining the super-high temperatures. Scientists have observed that these magnetic waves accelerate from a few hundreds of metres per second in the photosphere to several kilometres per second in the chromosphere—a behaviour that has proved difficult to explain.

Theory predicts that the greater umbral wave power found at chromospheric heights may come from the existence of an acoustic resonator, which is created due to the substantial temperature gradients experienced at photospheric and transition region heights. Until now there has been no solid observational evidence that would support this hypothesis. To further study the question, researchers formed a consortium called Waves in the Lower Solar Atmosphere (WaLSA) to carry out an investigation using advanced high-resolution observations from the National Science Foundation's Dunn Solar Telescope, located in Sunspot, New Mexico. The team included 13 scientists, spanning 5 countries and 11 research institutes, including University of Exeter; Northumbria University; the European Space Agency; Instituto de Astrofísica de Canarias, Spain; University of Oslo, Norway; the Italian Space Agency; and California State University, Northridge, USA.

By examining high-resolution spectra of the Sun, researchers were able to determine the behaviour of certain elements within its atmosphere, including silicon (formed close to the Sun's surface), calcium, and helium (formed in the chromosphere where the wave amplification is most apparent).

The variations in the elements allowed the speeds of the Sun's plasma to be uncovered. The timescales over which they evolve were benchmarked, which allowed the wave frequencies of the Sun to be recorded.

The researchers then used supercomputers to analyze the data through simulations. They found that the wave amplification

process can be attributed to changes in temperature between the surface of the Sun and its outer corona, which creates an “acoustic resonator.”

The edges of this resonance cavity are partially reflective and help to trap the waves, allowing them to intensify and dramatically grow in strength. The experts also found that the thickness of the resonance cavity—the distance between the significant temperature changes—is one of the main factors governing the behaviour of the waves.

“The effect that we have found through the research is similar to how an acoustic guitar changes the sound it emits through the shape of its hollow body,” says Dr. David Jess from the School of Mathematics and Physics at Queen’s University, Belfast, and leader of the team of researchers. “If we think of this analogy, we can see how the waves captured in the Sun can grow and change as they exit its surface and move toward the outer layers and exterior.”

“This new understanding of wave motion may help scientists uncover the missing piece in the puzzle of why the outer layers of the Sun are hotter than its surface, despite being further from the heat source,” explains Jess.

Next-generation telescopes, such as the NSF’s Daniel K. Inouye Solar Telescope (which has released its first

high-resolution images) will allow scientists to explore the Sun at incredibly high resolution. Such an unprecedented view of the Sun may help researchers solve the coronal heating problem and how the Sun affects the environment near Earth.

Mars’s layer-cake polar cap

In 1966, two Caltech scientists, physicist Robert B. Leighton and planetary scientist Bruce C. Murray, were ruminating on the implications of the thin carbon dioxide (CO₂) Martian atmosphere first revealed by *Mariner IV*, a NASA fly-by spacecraft built and flown by JPL. They theorized that Mars, with such an atmosphere, could have a long-term stable polar deposit of CO₂ ice that, in turn, would control global atmospheric pressure.

Carbon dioxide makes up more than 95 percent of Mars’s atmosphere, which has a surface pressure of only 0.6 percent that of Earth. One prediction of Leighton and Murray’s theory—with enormous implications for climate change on Mars—is that its atmospheric pressure would rise and fall as the planet wobbles on its axis during its orbit around the Sun, exposing the poles to more or less sunlight. Direct sunlight on the CO₂ ice deposited at the poles leads to its sublimation (the direct transition of a material from a solid to a gaseous



Figure 3 — The solar corona, seen here during an eclipse, has a temperature measured in the millions of degrees but arises from a surface that is much cooler, only 5800 K. The source of the heating may be the resonant enhancement of magnetic waves at the solar surface, which then feed energy into the corona. Image: Judy Anderson/Alson Wong.

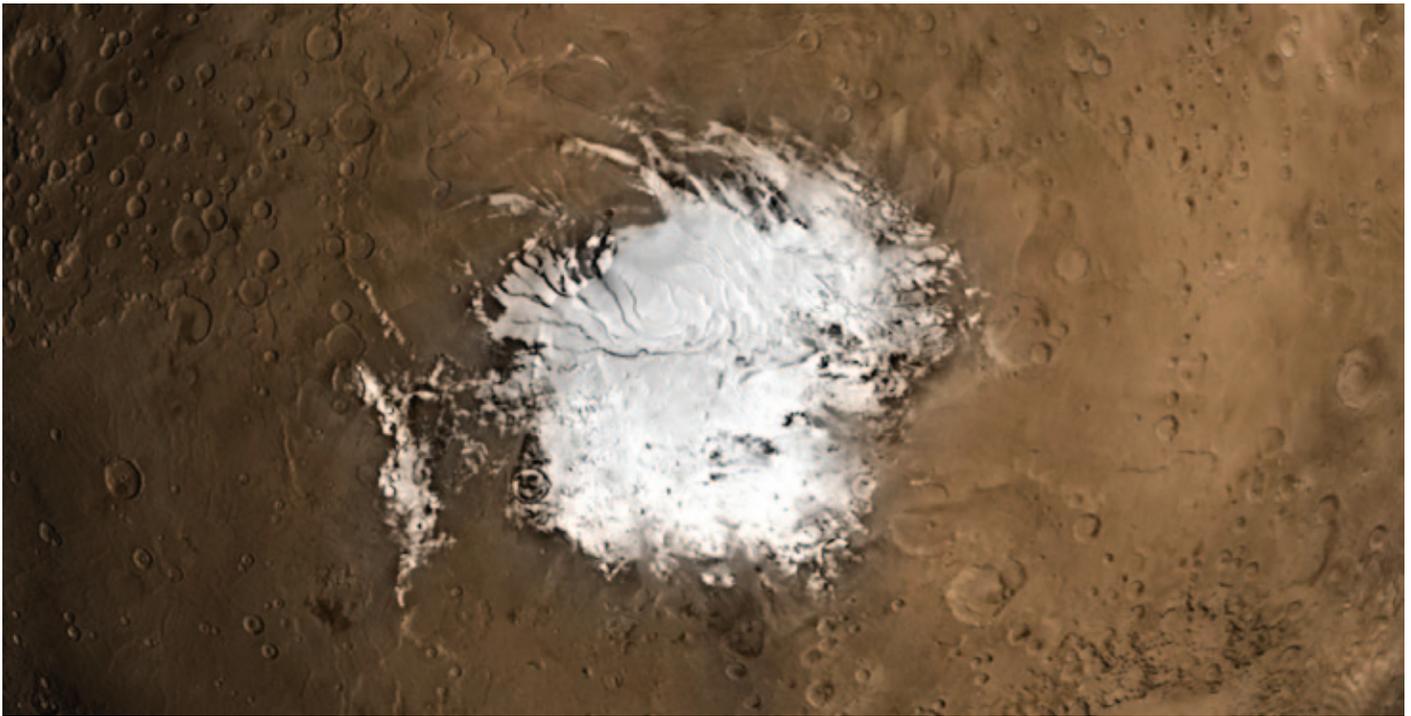


Figure 4 — A view of Mars's south polar cap acquired by the Mars Polar Orbiter. Image: NASA/Goddard Space Flight Center Scientific Visualization Studio

state, without melting). Leighton and Murray predicted that, as exposure to sunlight shifts over time, atmospheric pressure could swing from just one-quarter that of today's Martian atmosphere to twice that of today over cycles of tens of thousands of years.

Now, a new model by Peter Buhler of JPL, which Caltech manages for NASA, and colleagues from Caltech, JPL, and the University of Colorado, provides key evidence to support this hypothesis. The team explored the existence of a mysterious feature at the south pole of Mars: a massive deposit of CO₂ ice and water ice in alternating strata, like the layers of a cake, that extend to a depth of 1 kilometre, with a thin frosting of CO₂ ice at the top. The layer-cake deposit contains as much CO₂ as in the entire Martian atmosphere today.

In theory, that layering should not be possible because water ice is more thermally stable and darker than CO₂ ice. CO₂ ice, scientists long believed, would quickly destabilize if it was buried underneath water ice. However, the new model by Buhler and colleagues shows that the deposit could have evolved as a result of the combination of three factors: 1) the changing obliquity (or tilt) of the planet's rotation; 2) the difference in the way water ice and CO₂ ice reflect sunlight, and; 3) the increase in atmospheric pressure that occurs when CO₂ ice sublimates.

"Usually, when you run a model, you don't expect the results to match so closely what you observe. But the thickness of the layers, as determined by the model, matches beautifully with radar measurements from orbiting satellites," says Buhler.

Here's how the deposit formed, the researchers suggest: as Mars wobbled on its rotational axis over the past 510,000

years, the south pole received varying amounts of sunlight, allowing CO₂ ice to form when the poles were receiving less sunlight and causing it to sublimate when the poles were sunnier. When CO₂ ice formed, small amounts of water ice were trapped along with the CO₂ ice. When the CO₂ sublimated, the more stable water ice was left behind, where it gradually accumulated to form distinct layers within the ice cap.

But the water layers do not totally seal the deposit. Instead, the sublimating CO₂ raises Mars's atmospheric pressure, and the layer caked with CO₂ ice evolves in equilibrium with the atmosphere. When the sunlight starts declining again, a new CO₂ ice layer forms on top of the water layer, and the cycle repeats.

Because sublimation episodes have generally been declining in intensity, some CO₂ ice was left behind between the water layers—thus, the alternation of CO₂ and water ice. The deepest (and therefore oldest) CO₂ layer formed 510,000 years ago following the last period of extreme polar sunlight, when all the CO₂ sublimated into the atmosphere.

"Our determination of the history of Mars's large pressure swings is fundamental to understanding the evolution of Mars's climate, including the history of liquid water stability and habitability near Mars's surface," Buhler says. His co-authors are his former advisers Andy Ingersoll and Bethany Ehlmann, both professors of planetary science at Caltech; Sylvain Piqueux of JPL; and Paul Hayne of the University of Colorado, Boulder.

Compiled with material provided by Caltech. ★

Cepheid Variables in the Andromeda Galaxy from Simon Fraser University's Trottier Observatory

Authors: [SFU†] Dr. Howard Trottier, Rohan Abraham, Zina Aburegeba, Dr. Teresa Cheung, Matthew Cimone, Kyle Dally, David Dobre, Rohit Grover, Sarah Savić Kallesøe, Katherine Kelly, David Lee, Oleg Mazurenko, Christina Morley, Anja Rabus, Ryne Watterson, and Aidan Wright; [RASC‡] Ken Arthurs, Robert Conrad, Andrew Krysa, J. Karl Miller, Greg Sebulsky, and Paul Siniak.

Affiliations: †Simon Fraser University; ‡Royal Astronomical Society of Canada, Vancouver Centre

Mailing address: Simon Fraser University, Department of Physics, Burnaby BC V5A 1S6

Email: trottier@sfu.ca

Date: April 2018

Abstract

This is a report on observations of 17 Cepheid variable stars in the Andromeda Galaxy, from Simon Fraser University's Trottier Observatory. The observatory is a teaching and public outreach facility with a 0.7-m aperture telescope under suburban skies. The observations were done as a group project by a team that included students, staff, and faculty at the university, and members of the Vancouver Centre of The Royal Astronomical Society of Canada. The Cepheid periods range from about 7 to 44 days, and observations were made on 26 nights over the course of two years. Images were taken through a luminance filter, and the instrumental magnitudes were converted to the Johnson-Cousins V -band using a calibration procedure whose precision is thoroughly characterized. The mean apparent magnitudes range from about 19.3 to 20.7, and they exhibit a correlation with the period that clearly reproduces the famous period-luminosity relation discovered by Henrietta Leavitt. We estimated the distance modulus μ (difference between apparent and absolute magnitudes) using a well-established calibration of the Leavitt relation, along with a correction for interstellar extinction from a professional study of this region of M31. We obtained $\mu = 24.37 \pm 0.21$, which is in excellent agreement with the known value, and corresponds to a distance of 2.44 ± 0.25 million light-years.

I) Introduction

The combination of increasingly affordable large-aperture telescopes, and large-format cooled CCD cameras, has

revolutionized the capabilities of amateur astronomers. The abundance of amateur astronomical images of astonishing depth and quality is the most prominent sign of this technology shift. Amateurs also conduct original research with their own equipment, including supernovae searches, variable star measurements, comet hunting, asteroid photometry, and other investigations. However, a major impediment to the pursuit of original research is the long-term commitment in time and effort that is generally required, with no assurance that a lengthy investigation will produce a significant new finding.

For those who want to experience the excitement of doing real science, there is a much more accessible alternative to attempting original research, which is to *reproduce* important discoveries. "Rediscovery" projects can be as sophisticated and satisfying as original research, but they can be tailored to make successful completion much more likely, and to be achievable within a predictable time frame. Reproducing classic experiments is a routine part of university education in many branches of science, and university teaching observatories have long been used to this end.

A recent book by Robert Buchheim [1] details a remarkably comprehensive array of astronomical "rediscovery" projects, of varying degrees of sophistication. These projects can be done using modest equipment, and are well suited to amateur astronomers, and to implementation at university teaching observatories. The penultimate project in Buchheim's book is to measure the light curve of the first Cepheid variable star to be discovered in the Andromeda Galaxy, which Edwin Hubble recorded in 1923 on a now-legendary photographic plate (see e.g. Ref. [2]). The goal of Buchheim's project is to estimate the distance to M31. This is to be done by comparing the average apparent magnitude of Hubble's first Cepheid (hereafter referred to as "H1") with its absolute magnitude, as given by the famous period-luminosity (PL) relation, which was discovered by Henrietta Leavitt in 1912, and that was the basis of Hubble's historic estimate of the distance to Andromeda.

Prior to the publication of Buchheim's book, a sophisticated measurement of the ephemeris of H1 was done by a largely non-professional group that included Buchheim, working under the auspices of the American Association of Variable Star Observers (AAVSO) [3]. That study was undertaken at the request of the Hubble Heritage Project, which highlighted the work in an on-line press release [4]. A group from the AAVSO also published a follow-up study [5].

Buchheim's book, along with the Hubble Heritage and AAVSO publications, inspired the study that is the subject of this report. We undertook a much more ambitious project than the one suggested by Buchheim, by observing a large number of Cepheids in Andromeda, and our work differs in purpose and scope from the AAVSO studies. This work was done as a group project at the Simon Fraser University (SFU) Trottier Teaching and Outreach Observatory, by a team that included

SFU students, staff and faculty, and members of the Vancouver Centre of The Royal Astronomical Society of Canada. The project was conceived of and directed by the lead author, who also did the data analysis.

We monitored 17 Cepheids, including H1, with periods ranging from about 7 to 44 days. Our data set, accumulated over the course of two years, is large enough to independently observe Leavitt’s PL relation (also known as Leavitt’s Law), a dramatic “rediscovery” with a significance that would be hard to surpass! A data set that covers a wide range of periods is also required for a reliable determination of the distance, since the PL relation does not apply to individual Cepheids, but instead characterizes ensemble averages of these stars (see e.g. Ref. [6]).

The SFU observatory opened in April of 2015 and is the anchor of a high-profile public space devoted to science, situated near the centre of the Burnaby campus (see Figure 1). The facility is used for public outreach, student education, and as a resource for local amateur astronomers, especially members of the RASC Vancouver Centre. The observatory houses a PlaneWave Instruments CDK700 alt-az telescope system, with a 0.7-m aperture operating at $f/6.5$, under a 6-m Ash dome. Observatory equipment includes a Finger Lakes Instruments 16-Megapixel imaging camera, and a high-resolution echelle spectrograph made by Shelyak Instruments. Some images taken at the observatory have been published [7][8], along with a report on a “rediscovery” of exoplanet τ Boötis b from radial-velocity measurements [9]. Other images and studies have been produced by observatory users, including students from local high schools; some of this work is documented on the observatory website [10].

The rest of this paper is organized as follows. In Section II, we give a brief overview of Cepheid variables, emphasizing



Figure 1 — Nighttime view of the Trottier Observatory and Science Courtyard at Simon Fraser University. Image courtesy of PWL Landscape Architects, Inc.

properties that are relevant to our study. In Section III, we identify the Cepheids we studied, and the reference and comparison stars used for photometric calibration, and we summarize some parameters of the observing campaign. In Section IV, we detail the photometric reduction of the raw instrumental magnitudes, which were obtained with a luminance filter in order to maximize the signal-to-noise, and must be converted to a standard bandpass, here taken to be the Johnson-Cousins V -magnitude. In Section V, we analyze the reduced data: we estimate the periods, plot light curves, compute mean magnitudes, analyze the correlation between apparent magnitude and period (thereby reproducing Leavitt’s Law), and finally we estimate the distance to Andromeda, after correcting for extinction due to interstellar dust. In Section VI, we briefly summarize our results, and provide suggestions for further work.

We hope that these results will encourage amateur astronomers and other university teaching observatories to attempt similar projects. To that end, we have formulated this report as a comprehensive guide to the data collection and analysis techniques. We have also included enough theoretical background to put the work in context, and we have provided a fairly comprehensive set of references.

II) Cepheid variables: a brief overview

Cepheid variables form a critical “rung” in the so-called cosmic distance ladder, the sequence of techniques used by astronomers to determine the distances to objects that are at progressively greater remove (for a thorough and accessible introduction to these techniques, see Ref. [11]). These methods generally use one form or another of astronomical “standard candle.” These are classes of astrophysical objects all having the same luminosity, or luminosities that are strongly correlated with more readily measured attributes, and that are luminous enough to be seen at the distance scale of interest.

Cepheid variables qualify as standard candles because their mean luminosities are strongly correlated with the period of pulsation, and they play a fundamental role in modern astronomical research. Cepheids are used to determine distances to relatively nearby galaxies, in order to calibrate the luminosity of Type Ia supernovae, which in turn are used for cosmological distance estimates (see e.g. Ref. [12]). A very notable study of Cepheid variables was one of the three principal initial objectives of the *Hubble Space Telescope* (known as “Key Projects”), which measured the Hubble constant H_0 [13][14].

Cepheids have a number of favourable attributes, in addition to the period-luminosity relation, which include [13]: large luminosities (as much as 100,000 times the luminosity of the Sun); light curves with large amplitudes and a distinctive saw-tooth shape, illustrated in Figure 2, which aid in their

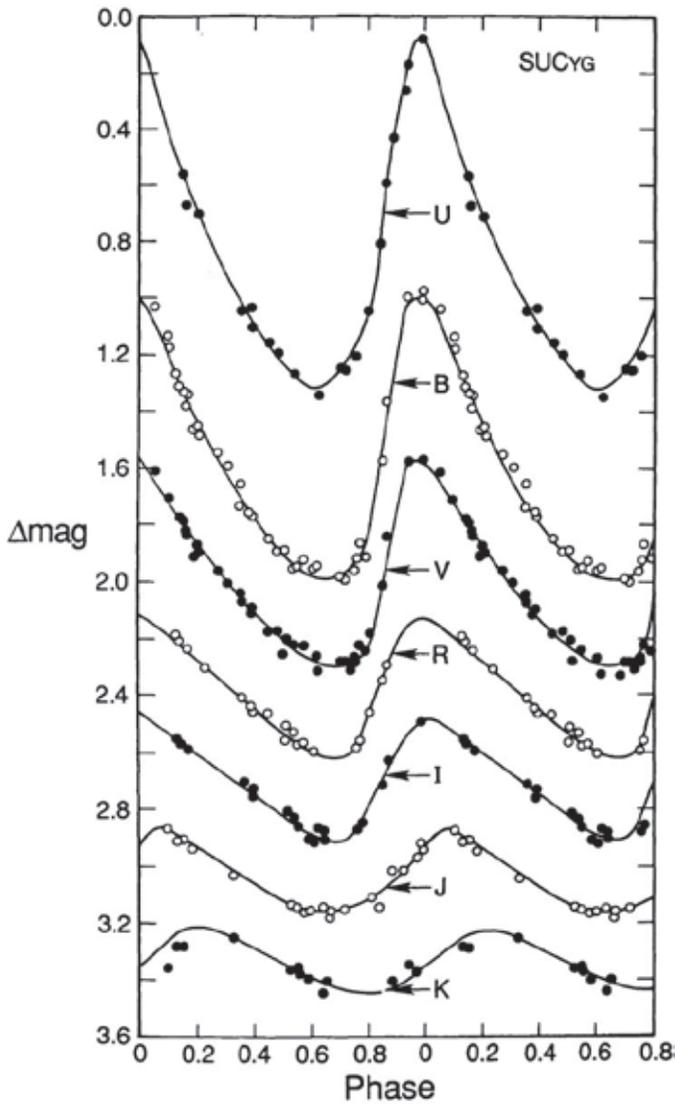


Figure 2 — Light-curves of a typical Galactic Cepheid variable star, in wavelength bands from the optical to the near-infrared [6]. Figure copyright *Astronomical Society of the Pacific*, reproduced with permission.

identification; and their relative abundance in spiral galaxies, which means that many independent objects in a given galaxy can be studied simultaneously. The use of the Cepheid yardstick also has challenges, which include [13]: significant extinction and reddening caused by dust along the line of sight through the Milky Way, and in the host galaxy (Cepheids are post-main-sequence stars associated with dusty star-forming regions); the dependence of the period-luminosity relation on the composition (metallicity) of Cepheids in different galaxies, and within different regions of the same galaxy; and uncertainties in the period-luminosity relation [12].

In its simplest form, the period-luminosity relationship, also known as Leavitt's Law, is given by

$$\langle M_X \rangle = -a_X \log_{10} P_d - b_X \quad (1)$$

where $\langle M_X \rangle$ denotes a mean absolute magnitude in wavelength band X (i.e. $X = B, V, R$, etc.), P_d is the period of pulsation in

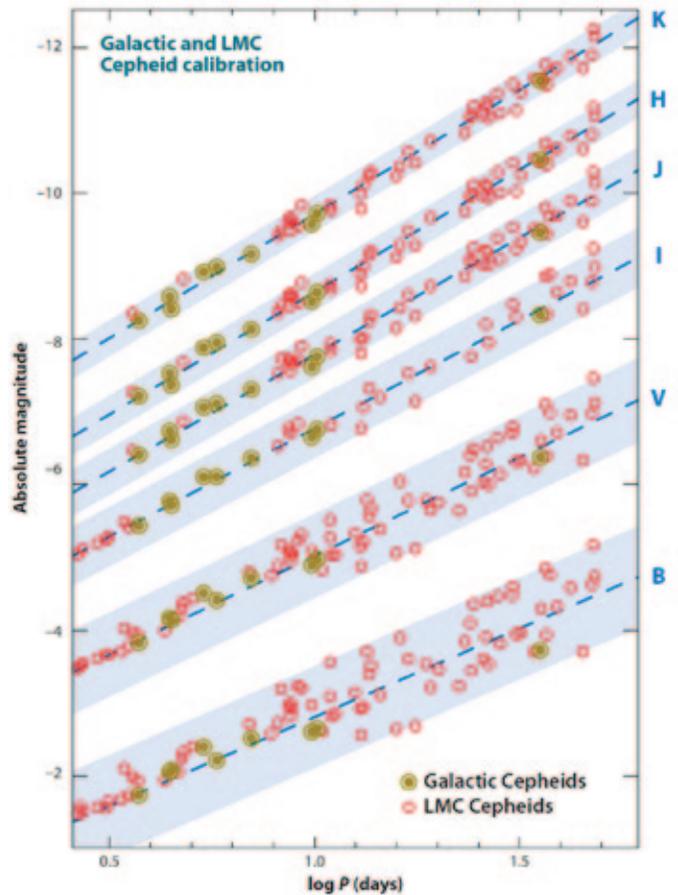


Figure 3 — Composite period-luminosity relations for Galactic and Large Magellanic Cloud (LMC) Cepheids [14]. Figure copyright *Annual Reviews*, reproduced with permission.

days, and a_X and b_X are constants that take on different values in different bands. The PL relationship in several wavelength bands is illustrated in Figure 3 [14]. The scatter in the data is not due to measurement uncertainties, but instead reflects a statistical property of Eq. (1), which applies to ensembles of Cepheids, not to individual stars, which can differ in luminosity for a given period due to intrinsic differences such as metallicity.

The *Hubble Space Telescope* Key Project to measure H_0 adopted the following PL relation for the visual band [13], based on studies of Cepheids in the Large Magellanic Cloud

$$\langle M_V \rangle = -2.76(3) \log_{10} P_d - 1.46(4) \quad (2)$$

where the numbers in parentheses are uncertainties in the last digit of the constants. The spread in the absolute magnitudes about the mean relation given by Eq. (2) has a standard deviation of approximately ± 0.16 magnitudes [13].

The mechanism that generates pulsations of Cepheid variables is well understood and is similar to a heat engine (see e.g. Refs. [11], [14]). During the contraction phase, energy is trapped in the star's interior and the pressure increases, until the contraction is reversed; the energy is then released as work is done to

expand the star's outer layers against gravity, while the pressure decreases until the expansion halts and the next contraction phase begins. Cepheid pulsations are driven by a region in the star of partially ionized helium, which traps energy during a contraction by producing further ionization of the gas. In an ordinary star, by contrast, the energy generated by a contraction causes the temperature of the gas to increase, which also increases the temperature gradient (i.e. the opacity is reduced), which allows the energy to escape, and damps the pulsation. Simple physical arguments can also be used to derive the form of the period-luminosity relation, including a reasonable estimate of the coefficient of the logarithm in Eq. (4).

III) M31 Cepheids: Observations

We did a literature search to identify Cepheids that could be observed with our facility. This led us to publications by Baade and Swope (B&S) from the mid-1960s, on hundreds of variable stars, in three regions of M31, which were observed with the Palomar 200-inch telescope [15] [16]. These papers include photographic plates with the locations of the variables, which we compared with our own images to identify possible targets. We note that a modern study of the B&S fields was

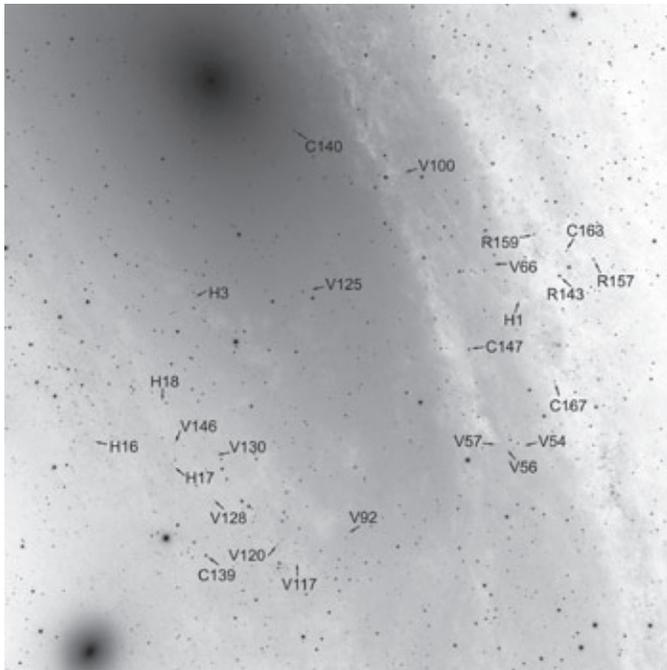


Figure 4 — Greyscale-inverted finder image for the 17 Cepheid variable stars that were monitored in this study (denoted by H# or V#), along with the 3 reference stars that were used for photometric calibration (R#), and 5 check stars that were used to monitor the quality of the photometry (C#). This image was taken on 2017 December 8 (UT). The J2000 coordinates of the centre of the field are RA 00h 42m 4s, and Dec +41° 06' 55". The field is “visually” oriented, with a position angle of 13° from North, an angular size of about 27.8' square, and a plate scale of about 0.81"/pixel. Contrast enhancement and sharpening were used here to aid in the identification of the targets (only dark subtractions and flat-field corrections were applied to images that were used for photometric analysis).

| Cepheid | Period (days) | ϕ_{shift} | $\langle m_v \rangle$ |
|---------|--------------------|-----------------------|-----------------------|
| V146 | 7.39 | 0.36 | 20.62(20) |
| V117 | 7.89 | 0.04 | 20.66(17) |
| V125 | 11.80 | 0.89 | 20.06(17) |
| V54 | 12.15 ^a | 0.73 | 20.46(15) |
| V92 | 14.35 | 0.21 | 20.29(13) |
| V56 | 14.40 | 0.61 | 20.04(10) |
| V57 | 14.62 | 0.78 | 20.08(14) |
| V100 | 16.71 | 0.63 | 20.15(25) |
| H18 | 18.52 | 0.74 | 20.04(11) |
| H17 | 18.77 | 0.74 | 19.82(11) |
| V130 | 20.19 | 0.59 | 20.18(14) |
| H3 | 27.03 | 0.58 | 19.38(7) |
| V128 | 27.24 | 0.20 | 20.39(16) |
| V66 | 29.01 ^b | 0.82 | 19.88(12) |
| H1 | 31.38 | 0.97 | 19.26(5) |
| H16 | 41.12 | 0.19 | 19.55(7) |
| V120 | 44.88 | 0.97 | 19.52(10) |

Table 1 — Cepheid variables observed in this study. The periods are taken from B&S [16], except for the two cases identified with a superscript, where our estimates differ appreciably (B&S period for a: 11.58 days; and for b: 28.16). ϕ_{shift} are phase shifts introduced in Eq. (7). $\langle m_v \rangle$ tabulates our final estimates of the mean visual magnitudes.

published by Freedman and Madore [17]; this paper contains a great deal of valuable information, including estimates of the extinction along the line of sight to each field.

B&S Field I [16] has Hubble's first Cepheid, and we identified 16 additional variables in that field that are bright enough to be detected from our suburban location, and that lie within a single field of view of our imaging system (about 27' square). Of the Cepheids in our study, four were identified by Hubble, which we label with an “H” prefix, and the rest by B&S, which we identify with a “V” prefix and their numbering scheme. We list some properties of our targets in Table 1, including our final results for the periods and mean magnitudes. The mean luminosities of these stars range from about 3000 to 20,000 solar luminosities.

A finder image that identifies the Cepheids is shown in Figure 4, along with eight photometric standard stars that we use, whose properties were taken from databases compiled by the American Association of Variable Star Observers (AAVSO) [18] [19]. AAVSO identifiers and data for these stars are listed in Table 2, along with identifiers that we use in Figure 4 and

| AAVSO ID | Our ID | m_v | $m_B - m_v$ |
|-------------|--------|------------|-------------|
| 000-BJV-791 | R143 | 14.272(38) | 0.680(64) |
| 000-BJV-794 | R157 | 15.679(32) | 0.624(64) |
| 000-BJV-795 | R159 | 15.858(29) | 0.686(53) |
| 000-BBB-973 | C139 | 13.813(49) | 0.546(80) |
| 000-BBB-974 | C140 | 14.000(18) | 0.587(30) |
| 000-BJV-792 | C147 | 14.704(9) | 0.772(22) |
| 000-BJV-798 | C163 | 16.285(49) | 0.914(96) |
| 000-BJV-800 | C167 | 16.672(44) | 0.805(74) |

Table 2: Photometric standard star data taken from the AAVSO Variable Star Plotter [18], except for C139, which is from the AAVSO APASS database [19].

later in the paper; we used three of these stars as calibration references (“R” prefix), and the others as check stars (“C” prefix).

This project traces back to an observatory imaging program that serendipitously imaged H1 on a night in the fall of 2015. Several months passed before we realized that H1 had been captured, so we had to wait until the fall of 2016 to continue taking data, and by that time we had conceptualized the full project. We took measurements again in the fall of 2017 and ended up with 26 nights in all; some of the observations are grouped in bunches of a few closely spaced nights, typically spanning about a week, owing to the short periods of good weather that are typical of the west coast in the fall season. Some information about the observation campaign is given in Table 3, including dates and exposure times, along with the averaged full-width at half-maximum (FWHM) of the imaged stars, as a measure of image quality.

Integration times ranged from as little as 20 minutes, to more than 90 minutes. A luminance filter was used in order to maximize the signal-to-noise. Single-frame exposure times of 2 minutes were typical, limited in part by sky glow. Seeing conditions varied widely, with star profiles typically less than about 2.5", and one extremely turbulent night at 3.6" that still yielded useful data. Sky transparency also varied widely, and a bright Moon was in the sky on some nights. Several variables were not imaged on the first five nights, as we had yet to determine the optimal coordinates for the field of view, and some of the fainter variables could not be detected on nights with poorer seeing and/or transparency. Targets that were not observed on a given night are listed in Table 3. Despite the widely variable observing conditions, differential photometric calibration produces consistent results for the magnitudes of check stars spread across nearly the entire field of view, over the entire observing campaign, as we demonstrate in the next section.

| Date (UT) | Exp. / FWHM | Not observed |
|-------------------|-------------|----------------------------------|
| 2015-11-16, 06:30 | 48m / 2.2" | V100, H16 |
| 2016-09-05, 06:30 | 42 / 2.2 | V146, V117, H17, V128, H16, V120 |
| -09-22, 06:45 | 36 / 2.0 | V146, V117, H17, V128, H16, V120 |
| -09-26, 05:45 | 98 / 1.8 | V146, V117, H17, V128, H16, V120 |
| -09-28, 04:50 | 54 / 2.9 | V117, V56, H17, V128, H16, V120 |
| -09-29, 07:10 | 82 / 2.1 | |
| -10-10, 03:45 | 76 / 2.1 | V100 |
| -10-11, 03:30 | 60 / 3.1 | V117, V54, V100, V128 |
| -10-29, 05:45 | 20 / 2.3 | |
| -12-01, 08:00 | 26 / 2.5 | |
| -12-05, 02:30 | 86 / 2.3 | |
| 2017-01-12, 03:30 | 76 / 2.8 | V100 |
| -01-13, 03:30 | 76 / 2.9 | V146, V100, H18, V54 |
| -01-24, 03:30 | 72 / 2.0 | |
| -02-01, 03:30 | 90 / 3.6 | V146, V117, V100 |
| -09-15, 07:30 | 86 / 2.2 | |
| -09-24, 05:00 | 88 / 2.3 | V100 |
| -09-27, 05:00 | 86 / 2.0 | |
| -09-29, 04:45 | 90 / 1.9 | V146 |
| -12-06, 03:15 | 86 / 2.5 | |
| -12-07, 03:45 | 77 / 2.8 | V117, H18 |
| -12-08, 03:15 | 87 / 1.9 | |
| -12-09, 03:00 | 47 / 2.1 | V130 |
| -12-11, 03:00 | 82 / 3.0 | |
| -12-23, 03:50 | 107 / 3.1 | V117, H18 |
| -12-24, 03:15 | 73 / 2.6 | V117, H18 |

Table 3 — Observation campaign parameters: Date at the mid-point of an imaging run; Exposure time in minutes / stellar FWHM in arcseconds; and variables that either were not in the field of view, or that could not be detected.

IV) Photometric reduction

Dark frames and twilight flats were applied to individual frames, which were then stacked to produce an integrated image. No other processing was applied to images used for photometry. To estimate stellar magnitudes, we used standard differential photometry, in which the brightness of a target

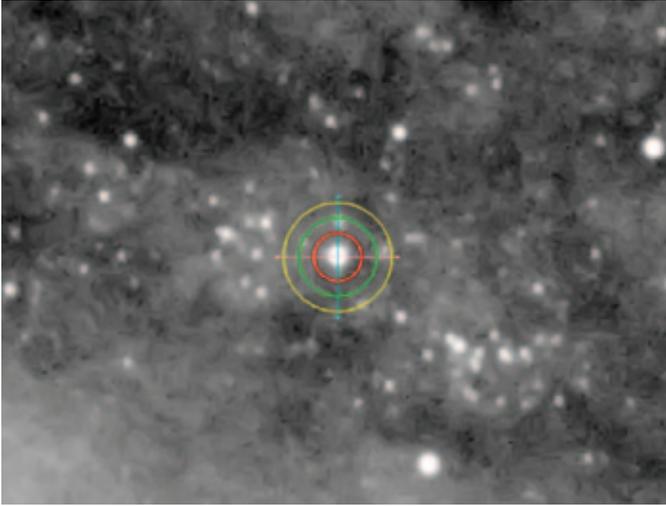


Figure 5 — Close-up of the region around reference star R159 (located in the top-right quadrant of Figure 4). Aggressive contrast enhancement was used to bring out dust lanes (in white in this greyscale-inverted image) and other structures. The “bullseye” is a sampling region with an inner radius of 8 pixels, and an outer annulus with interior/exterior radii of 13/18 pixels.

star is compared with one or more reference stars of known magnitude in the same field of view (for an introduction to photometry for amateurs, see Ref. [20]). This eliminates effects due to atmospheric extinction and variable sky conditions, to the extent that the field of view is small, and if the colours of the target and comparison stars are the same; in these circumstances, all of the sampled-star magnitudes are equally shifted by atmospheric extinction.

Two quantities must be extracted from an image in order to estimate each stellar magnitude. One quantity is the sum of the analogue-to-digital (ADU) counts from all the pixels in a region, or “aperture,” around the star of interest. The aperture readout includes contributions from the galaxy background and sky glow (cf. Figure 5), hence the total background must also be estimated; this is done using the readout of an annular region outside the aperture, with the ADU count scaled to match the area of the aperture.

Denoting the aperture readout by Σ_{aper} , and the scaled background by Σ_{back} , one defines an “instrumental” magnitude m_{inst} according to

$$m_{\text{inst}} = -2.5 \log_{10} (\Sigma_{\text{aper}} - \Sigma_{\text{back}}) \quad (3)$$

The standard magnitude $m_{\text{std,target}}$ of a target star is then estimated from the known magnitude $m_{\text{std,ref}}$ of a reference star according to

$$m_{\text{std,target}} = m_{\text{inst,target}} - m_{\text{inst,ref}} + m_{\text{std,ref}} \quad (4)$$

We computed $m_{\text{inst,target}}$ from an average of the values obtained using each of the three reference stars; we found that the individual results overlap within the Poisson-noise of the

readouts, which provides one overall consistency check of the results.

To maximize the signal-to-noise, we took our images through a luminance filter. However, we want to obtain magnitudes that correspond (as closely as possible) to the widely-used Johnson-Cousins “V”-band photometric filter, so that we can make use of the calibrated PL relation, Eq. (2). Equation (4) will produce an exact V magnitude for the target, with a reference star V-mag as input, only if the two stars have the same colour; in that case, the difference between their instrumental magnitudes will be independent of the filter used (strictly speaking, the stars must also be in the same luminosity class).

Equation (4) cannot give an exact conversion from instrumental to standard magnitudes for Cepheids, using a fixed reference star, since they vary in colour with pulsation phase. Cepheid colour indices ($B - V$ magnitude differences) lie within a range of about 0.4 to 1.6 (see e.g. Ref. [21]). On the other hand, we show below that Eq. (4) produces very precise V-mags for the check stars, which have colour indices ranging from about 0.5 to 0.9. This strongly suggests that we will likewise obtain good approximations to the V-mags for the Cepheids. We present additional explicit support for this conversion procedure further down, where we estimate a so-called photometric transfer function, which can connect instrumental magnitudes for target and reference stars with different colour indices.

One of the challenges of using Cepheid variables is that they are generally found in dust lanes where the galaxy background may change rapidly within regions of small angular size. This is evident in Figure 5, which shows a sampling region with a very inhomogeneous background. We initially tried to do the photometric analysis with the widely used *MaxIm DL* photometry tool [22], but in many cases the results were very sensitive to the size of the sampling region. Fortunately, we happened across a very powerful freeware program called *Aperture Photometry Tool* (APT) [23], which has many powerful features, and is very well suited to fields with inhomogeneous backgrounds. APT has an intuitive graphical user interface, can be used in interactive and batch modes, and has many tools for data visualization and analysis. For our purposes, the most important feature of APT is that it automatically generates a radial-intensity profile for the stars in an image, by sampling many unsaturated, isolated stars, and it can use the profile to correct for the flux that falls outside an aperture of a given size.

A widely quoted guide for the minimum aperture necessary for accurate uncorrected sampling is 2.5–3 times the FWHM. This guide implies, with our data, aperture radii upwards of 8 pixels would have to be used, along with a requisitely larger annular region; a sampling region of this size is illustrated in Figure 5. APT’s correction algorithm, on the other hand,

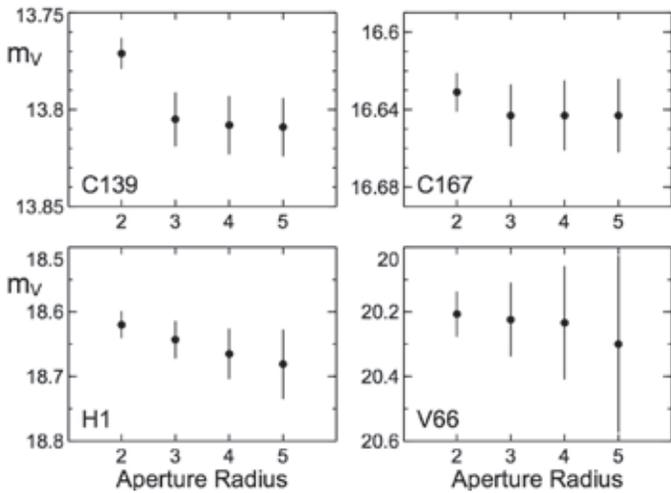


Figure 6 — Calibrated magnitudes for two check stars and two Cepheids, as functions of the photometric aperture radius, using the program APT. The annulus for background sampling had inner/outer radii of 5/6 pixels. Error bars are Poisson-noise uncertainties. This is from the data of 2016 September 29 (UT).

produced reliable estimates using an aperture radius of only 3 pixels. This is illustrated in Figure 6, which shows calibrated magnitudes for 2 check stars and 2 Cepheids, as functions of the aperture radius, using a fixed annulus of inner radius 5 pixels, and outer radius 6 pixels. The size of the correction depends on the image FWHM, and typically varied from around 50% for an aperture of 2 pixels, to 20% for an aperture of 3 pixels, and 5% for 5 pixels. The higher signal-to-noise that results from using smaller sampling regions is also evident in Figure 6.

We hereafter quote magnitudes estimated using an aperture radius of 3 pixels, and an annulus with inner/outer radii of 5/6 pixels respectively; the results are also insensitive to an increase in the size of the annulus.

APT also has a very convenient tool for dealing with crowded star fields, which can be used to eliminate user-selected pixels

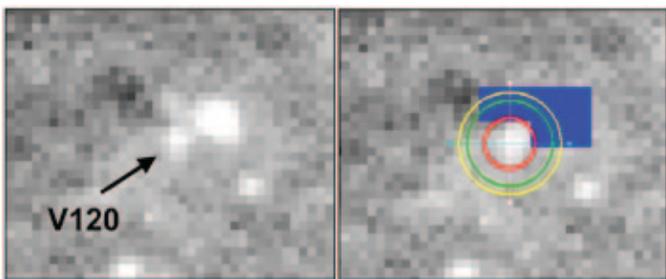


Figure 7 — Close-up of the region around Cepheid V120. Left: Note the much brighter star above and to the right of V120, and the fainter star directly above it. Right: The APT “zap” mask used to remove the neighbouring stars from photometric sampling is shown in blue. The “bullseye” is a sampling region with an aperture radius of 3 pixels, and a background annulus with inner/outer radii of 5/6 pixels.

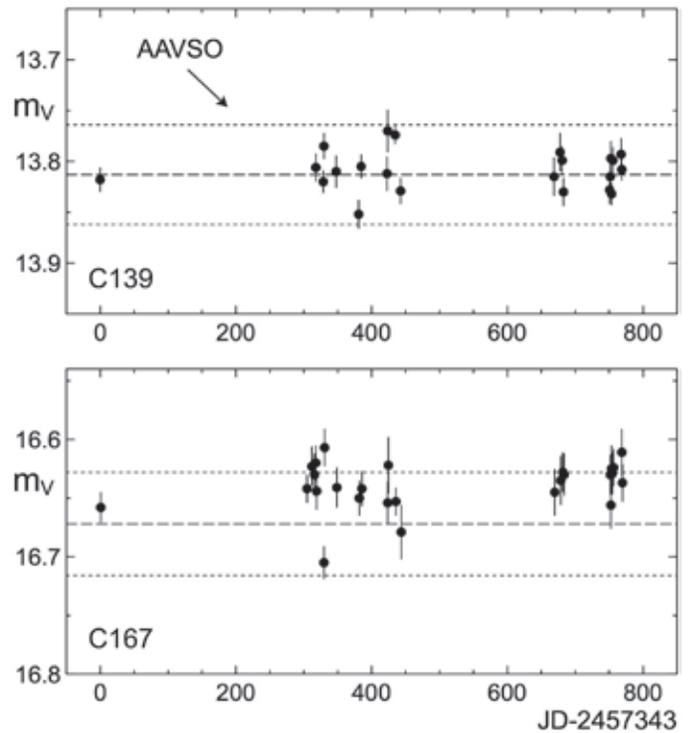


Figure 8 — Calibrated magnitudes of two check stars, versus observation date in Julian Days. The AAVSO magnitudes are also shown: dashed lines are central values, and dotted lines show the uncertainties.

from the calculation of instrumental magnitudes. We used this tool in the analysis of V120 (located in the bottom-left quadrant of the finder image in Figure 4), which has two stars in close proximity, one of which is much brighter than the target. The APT display of the field around V120 is illustrated in Figure 7, which shows the pixels we deleted in the region occupied by the neighbouring stars. We found that the magnitude of V120 can be significantly underestimated if the background stars are not removed.

Accurate results also depend critically on the reliability of our flat-field corrections, since the sky conditions varied greatly over the course of the observing campaign; moreover, some of the target stars are relatively far from the reference stars. To assess the stability of our results, we monitored the visual magnitudes of the 5 check stars. The results for the brightest check star and the faintest, which are widely separated in the image, are plotted in Figure 8, as functions of the observation date. There is no discernible systematic change with time in any of the check-star magnitudes, within typical Poisson-noise uncertainties of about ± 0.02 mag. Furthermore, our estimates of the check-star magnitudes are in good agreement with the AAVSO V -band values, which provides very strong support for the conversion of instrumental luminance magnitudes using Eq. (4).

We also obtained direct evidence for the reliability of our photometric conversion by measuring the transfer function for the filter that was used. This function converts the instrumental

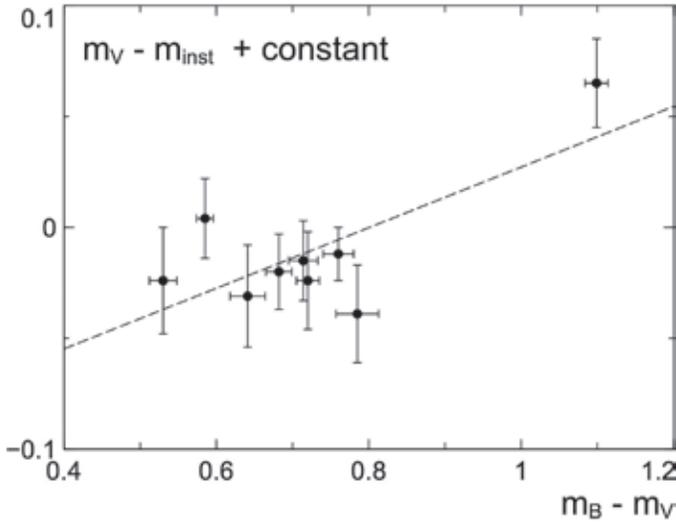


Figure 9 – Transfer function for the M31 field imaged on 2017 December 8 (UT), using an ensemble of stars from the NOFS database. The instrumental magnitudes were shifted by an overall constant for clarity. The dashed line is the result of a linear fit. Error bars are dominated by uncertainties in the reference data.

magnitude to a calibrated magnitude in a standard filter, taking account of the different band-passes, and of the wavelength-dependent atmospheric extinction. The bandpass/extinction correction is typically parameterized by a colour index; we used the difference between the B -band and V -band magnitudes, $m_B - m_V$. A linear dependence on the index often provides a good approximation [20], so we considered the connection

$$m_V - m_{inst} = a(m_B - m_V) + b \quad (5)$$

The coefficient a depends on the altitude at which the measurements are made, while the “offset” coefficient b drops out when taking the difference between instrumental magnitudes of target and reference stars, as in Eq. (4).

We estimated the transfer function using data for reference stars in our field of view that we took from the Naval Observatory at Flagstaff Station (NOFS) database, accessed via the AAVSO freeware tool *Seqplot* [24]: we selected all available stars with uncertainties in both $m_B - m_V$ and m_V of less than about 0.02 mag, yielding 9 stars with m_V ranging from about 12.6–15.4 (consistent results were obtained using the standard stars in Table 2, as well as with another set of stars taken from the APASS database, via Ref. [24]). The colour-index dependence of the instrumental magnitudes from one night of our campaign is shown in Figure 9. The data is well described by Eq. (5), and a fit yielded $a = 0.14(5)$. Analysis of our data from other nights showed that a has a negligible dependence on altitude, in the range covered during our campaign (which ran from about 50° to 80°).

We can’t actually use Eq. (5) to colour-correct our Cepheid data, since we do not have the target colour indices. However,

the small value of a shows that the colour corrections should be less than the typical statistical uncertainties in our instrumental magnitudes. In the case of the reference and check stars, where the differences in the respective $m_B - m_V$ values are less than about 0.2 mag, the colour corrections to the check-star V -mags are under about 0.03 mag. For the Cepheids, the expected colour corrections should generally be under about 0.15 mag.

V) Analysis and results

With the calibrated magnitudes in hand, our next step was to estimate the periods. Baade and Swope quote periods to three decimal places, but we cannot find how these values were obtained. A criterion that is typically used to identify candidate periods for Cepheids, which have light curves that are far from sinusoidal, is to minimize the following function of the period P , often referred to as a light-curve “string length” [25]

$$\Theta(P) = \frac{\sum_{i=1}^N (m_{i+1} - m_i)^2}{\sum_{i=1}^N (m_i - \bar{m})^2} \times \frac{(N-1)}{2N} \quad (6)$$

where N is the number of data points, \bar{m} is the average magnitude, $\bar{m} = \sum_{i=1}^N m_i / N$, and the data set $\{\varphi_i, m_i\}$ is arranged sequentially by phase (identifying $m_{N+1} = m_1$). In general, Θ fluctuates around 1 as a function of P , and if no periodic behaviour is present in the data, then $\Theta \rightarrow 1$ in the limit $N \rightarrow \infty$ [26]. Visual inspection of the light curves is often used as an additional subjective but very effective way to discriminate among candidate periods (see e.g. Ref. [27]).

Figure 10 plots our result for $\Theta(P)$ in the case of H1. The rapid fluctuations over intervals of much less than one day are mainly due to noise in the data, while the deepest local minima tend to repeat in intervals of roughly 3–7 days, a pattern that is likely due to aliasing (see e.g. Ref [26], and for useful reviews

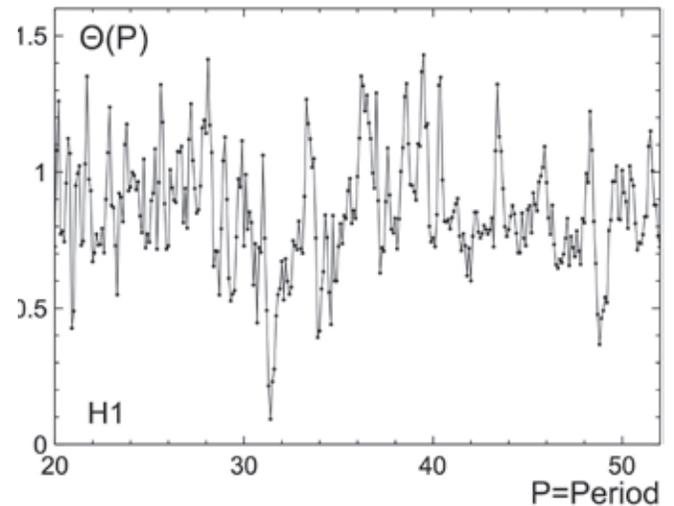


Figure 10 – String-length function $\Theta(P)$ vs. period for H1, using a step size of 0.1 days for clarity. The global minimum coincides with the B&S period of 31.38d.

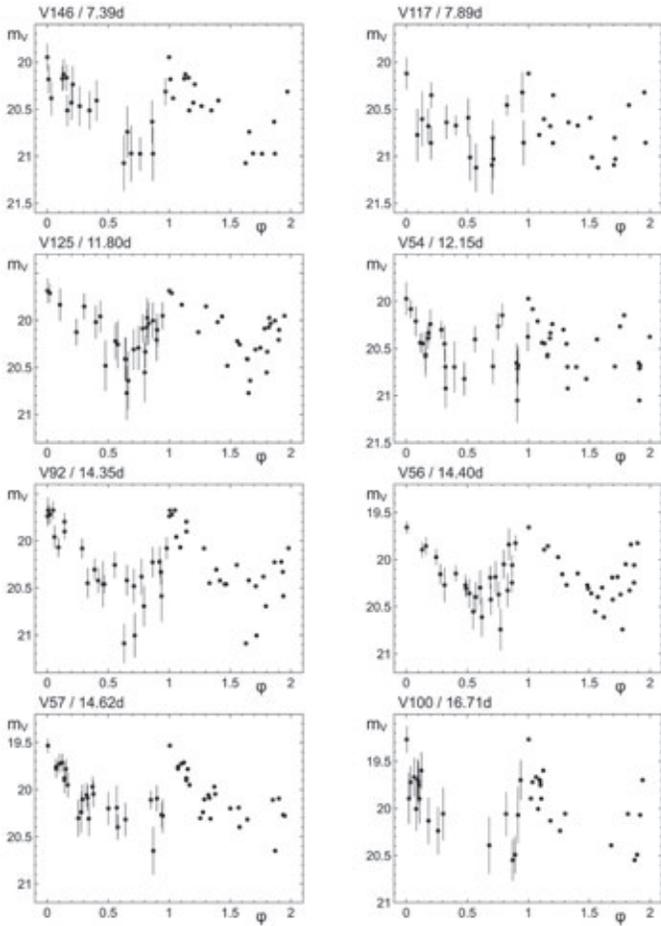


Figure 11 — Phased light curves for the first eight Cepheids, in order of period, starting with the shortest. The light curves are plotted for two consecutive cycles, the first with error bars, and the second without.

of time-series analysis of light curves, see Refs. [28] and [29]). In fact, removing some of the closely spaced nights from our data set generally results in a decrease in the depth of the local minima in $\Theta(P)$, relative to the global minimum, as one would expect from aliasing in data that is sampled at irregular intervals.

We estimated the periods of all our targets by scanning for minima in their respective $\Theta(P)$ functions, using a step size of 0.01 days, as is widely employed in the literature (see e.g. Ref. [27]). In some cases, our data are too noisy to produce a clear global minimum in $\Theta(P)$, and visual inspection of the light curves, using the B&S periods to guide the search, was needed to identify candidate periods. The results of our analysis are consistent with the B&S periods to about a tenth of a day or better, with two exceptions, V54 and V66 (see the caption of Table 1 for details); we therefore adopted the B&S periods but for those two cases. Our period for V66 has the largest difference with the B&S values, although only by 0.85d. Following common practice, we do not quote uncertainties in the individual periods (cf. Refs. [26], [27]). We note however that the minima in $\Theta(P)$ have narrow widths, typically no more than a few tenths of a day, and uncertainties at that level would

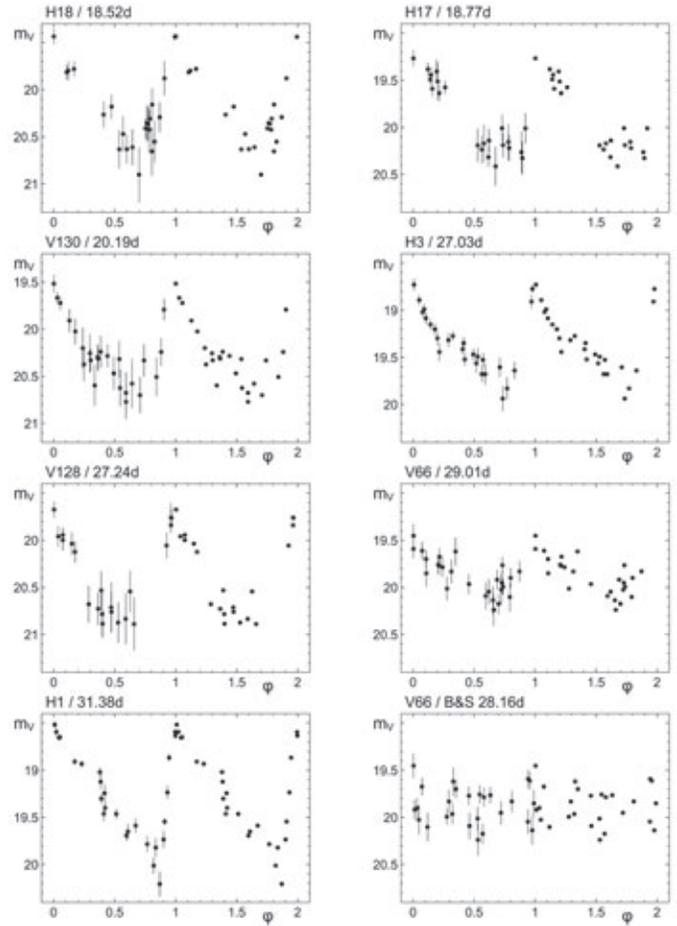


Figure 12 — Phased light curves for the next seven Cepheids in order of period, continuing from Figure 11, with V66 plotted twice (right column, last two rows), using our value of the period, and using the period given by B&S [16].

have a negligible effect on the absolute magnitudes obtained from Eq. (2).

We plot phased light curves in Figure 11, Figure 12, and Figure 13, with the phase φ defined by

$$\varphi = \text{frac} \left(\frac{t_{\text{obs}} - t_{\text{ref}}}{\text{Period}} \right) + \varphi_{\text{shift}} \quad (7)$$

where t_{obs} is the time of an observation, t_{ref} is an arbitrary reference time, $\text{frac}()$ is the fractional part of the expression in parentheses, and φ_{shift} is an additional phase shift. We fixed the value of t_{ref} in Eq. (7) to the time of maximum brightness of H1, given by the recent AAVSO study of the light curve [3]

$$t_{\text{ref}} = 2,455,430.5 \text{ Julian Days} \quad (8)$$

which is quoted with an uncertainty of ± 0.5 days. We then determined the additional phase shifts φ_{shift} in Eq. (7) such that the maximum brightness for each Cepheid is at zero total phase; we made rough estimates by inspecting the light curves by eye, with the results listed in Table 3. We note that the light curve for V66 is plotted twice in Figure 12, using our period, and the B&S period; the comparison shows a clear preference for our value.

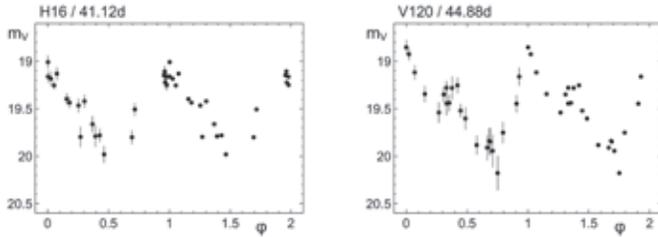


Figure 13 — Phased light curves for last two Cepheids in order of period, continuing from Figure 11 and Figure 12.

After determining the periods, we computed the mean magnitudes by averaging over intensities, employing the widely used definition [30]

$$\langle m \rangle = -2.5 \log_{10} \sum_{i=1}^N 0.5(\varphi_{i+1} - \varphi_{i-1}) 10^{-0.4m_i} \quad (9)$$

with the identification $\varphi_{N+1} = 1 + \varphi_1$ and $\varphi_0 = \varphi_N - 1$; the phase difference factor gives greater weight to data that are more spread apart in phase over data more closely bunched together. Results for the mean magnitudes are given in Table 3.

Figure 14 plots the mean magnitude versus the period. This plot is one of the major highlights of this work, as it clearly reproduces Leavitt’s period-luminosity relation, given that the Cepheids are at approximately the same distance. This is a very dramatic “rediscovery”!

After our analysis was complete, we found that the mean magnitudes of seven of our targets could be extracted from a plot in the paper by Freedman and Madore (F&M) [17] (numerical values are not given); our results are in agreement to within our Poisson-noise uncertainties in all of these cases, which include both the shortest- and the longest-period variables in our data set, V146 and V120, respectively.

To estimate the distance, we first estimated the apparent distance modulus μ_{app} , from a fit to

$$\langle m_V \rangle = \langle M_V \rangle + \mu_{\text{app}} \quad (10)$$

which amounts to a vertical shift in a line of fixed slope, as illustrated in Figure 14. We found $\mu_{\text{app}} = 24.98(9)$, unweighted by the errors in the mean magnitudes. This is in excellent agreement with F&M, who obtained $\mu_{\text{app}} = 24.99(8)$ [17], after correcting for a small difference in the zero-point of the PL relation that they used, compared with Eq. (2). The standard error in our value of μ_{app} corresponds to an RMS dispersion of 0.38 in the fit, which is illustrated in Figure 14, and reflects the inherent dispersion in the PL relation (cf. Figure 3), inflated by Poisson-noise fluctuations in our mean magnitudes.

We note that if we take the slope in the PL relation to be a free parameter, the fit returns an absolute value that is

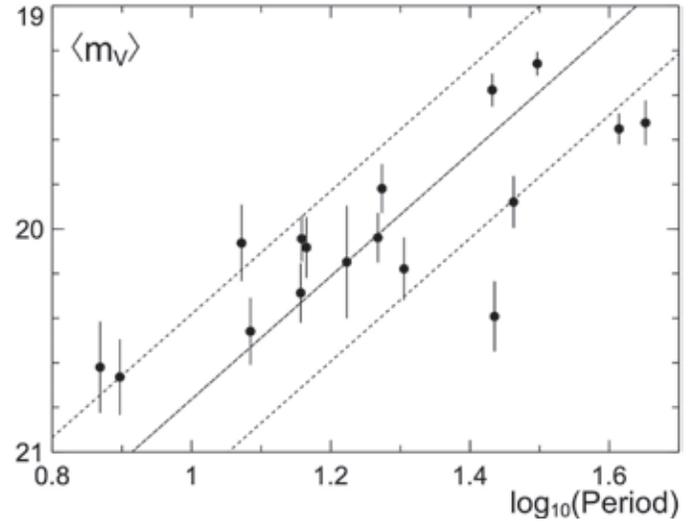


Figure 14 — Mean apparent magnitude $\langle m_V \rangle$ versus logarithm of the period in days. The dashed line is a fit to Eq. (10), unweighted by the errors in the mean magnitudes. The dotted lines show the RMS dispersion in the fit.

appreciably smaller than in Eq. (2). This is very likely due to a bias in our sample toward more-luminous shorter-period Cepheids, which is supported by the results of F&M, who measured several fainter targets than we could reach; other studies commonly fix the slope in order to avoid a similar bias (see e.g. Ref. [31]).

To obtain the true distance modulus μ , one must take account of extinction due to interstellar dust along the line of sight, through the Milky Way and into the target galaxy. The magnitude shift owing to extinction in a wavelength band X is denoted by A_X , so here we write

$$\mu_{\text{app}} = \mu + A_V \quad (11)$$

F&M estimated extinctions in the B&S fields by measuring the apparent distance moduli in several band-passes, and fitting the differences with a model of extinction due to galactic dust; they found $A_V = 0.61(12)$ for B&S Field I.

The uncertainty in our estimate of the true distance modulus is dominated by the systematic uncertainty in the photometric conversion from instrumental magnitudes, which we estimated in Sect. IV to be less than about ± 0.15 mag, along with the uncertainty in the extinction. We add these systematic errors in quadrature with the standard error in the fit to Eq. (10).

Our final result is $\mu = 24.37(21)$. This is in excellent agreement with a recent analysis of many studies of the distance to M31 [32], which recommends a robust mean value of 24.46(10). With the distance in parsecs given by

$$d(\text{pc}) = 10^{\mu/5+1} \quad (12)$$

our estimate of the distance to M31 is 0.748(76) Mpc, or 2.44(25) million light-years.

VI) Summary and outlook

We succeeded in reproducing Leavitt's Law from observations of 17 Cepheid variable stars in M31, over a two-year campaign. The precision of the magnitude estimates was enhanced by imaging with a luminance filter, and carefully validating a straightforward but precise photometric conversion to the standard V -band. By comparing with a widely used calibration of the PL relation, and taking account of interstellar extinction along the line of sight, we obtained an estimate of the distance to M31 with an uncertainty of 10%, and in agreement with the known value.

Other projects along these lines could include studying Cepheids in other regions of M31, and in the few other members of the local group of galaxies that are accessible to smaller telescopes, the Triangulum Galaxy M33 being a notable case [33]. A particularly interesting project would be to independently estimate the extinction due to galactic dust, although this would require imaging through at least two standard band-passes (e.g. B - and V -bands), which would have significantly smaller signal-to-noise levels relative to luminance images. ★

References

- [1] Buchheim, R.K. (2015). *Astronomical Discoveries You Can Make, Too! Replicating the Work of the Great Observers*. Springer Praxis.
- [2] Hubble Space Telescope website, *Snapshots of the star that changed the Universe*, www.spacetelescope.org/images/opo1115d.
- [3] Templeton, M. et al. (2011). Modern Observations of Hubble's First-Discovered Cepheid in M31. *PASP*, 123, 1374.
- [4] Hubble Space Telescope press release, *Hubble Views the Star that Changed the Universe*, www.hubblesite.org/news_release/news/2011-15.
- [5] Goff, B. et al. (2012). Photometry of Hubble's First Cepheid in the Andromeda Galaxy. *Proceedings for the 31st Annual Conference of the Society for Astronomical Sciences*.
- [6] Madore, B.F. and Freedman, W.L. (1991). The Cepheid Distance Scale. *PASP*, 103, 933
- [7] Dickinson, T. (2015). Editor's Report: New Canadian Observatory's First Colour Photo. *SkyNews*, Vol. XXI, Issue 4 (November/December).
- [8] Trottier, H.D. (2016). *JRASC*, Vol. 110, No. 4.
- [9] Trottier, H.D. (2017). Detection of exoplanet τ Boötis b at the Simon Fraser University Trottier Teaching and Outreach Observatory, *JRASC*, Vol. 11, No. 4.
- [10] Simon Fraser University Trottier Observatory, www.sfu.ca/science/trottierobservatory.html.
- [11] Webb, S. (1999). *Measuring the Universe: The Cosmic Distance Ladder*. Springer-Praxis.
- [12] Riess, A.G. et al. (2016). A 2.4% Determination of the Local Value of the Hubble Constant. *ApJ*, 826, 56.
- [13] Freedman, W.L., et al. (2001). Final Results from the Hubble Space Telescope Key Project to Measure the Hubble Constant, *ApJ*, 553, 47.
- [14] Freedman, W.L. and Madore, B.F. (2010). The Hubble Constant. *Annual Review of Astronomy and Astrophysics*, 48, 673.
- [15] Baade, W. and Swope, H.H. (1963). Variable Star Field 96' South Preceding the Nucleus of the Andromeda Galaxy. *ApJ*, 68, 435.
- [16] Baade, W. and Swope, H.H. (1965). Variables in the Andromeda Galaxy – Fields I and III. *ApJ*, 70, 212.
- [17] Freedman, W.L. and Madore, B.F. (1991). An Empirical Test for the Metallicity Sensitivity of the Cepheid Period-Luminosity Relation. *ApJ*, 365, 186.

- [18] AAVSO website for the Variable Star Plotter, www.aavso.org/apps/vsp/.
- [19] AAVSO website for the APASS database, www.aavso.org/apass.
- [20] Warner, B.D. (2016). *A Practical Guide to Light Curve Photometry and Analysis*, 2nd ed. Springer.
- [21] Moffett, T.J. and Barnes, T.G. (1984). Observational Studies of Cepheids. II. BVRI Photometry of 112 Cepheids, *ApJ Supplement Series*, 55, 389.
- [22] Diffraction Limited website for *MaxIm DL*, www.diffractionlimited.com/product/maxim-dl.
- [23] Aperture Photometry Tool website, www.aperturephotometry.org.
- [24] AAVSO *SeqPlot* site, www.aavso.org/seqplot.
- [25] Lafler, J. and Kinman, T.D. (1965). RR Lyrae Star Survey with the Lick 20-inch Astrograph II. *ApJ Supplement*, 11, 216.
- [26] Clarke D. (2002). String/Rope length methods using the Lafler-Kinman statistic, *A&A*, 386, 763.
- [27] Freedman, W.L. et al. (1994). The Hubble Space Telescope Extragalactic Distance Scale Key Project. I. The Discovery of Cepheids and a New Distance to M81, *ApJ*, 427, 628.
- [28] Foster, G. (2010). *Analyzing Light Curves: A Practical Guide*. Available from www.lulu.com.
- [29] Templeton, M. (2004). Time-Series Analysis of Variable Star Data, *Journal of the AAVSO*, 32, 41.
- [30] Saha, A., Hoessel, J.G., and Mossman, A.E. (1990). RR Lyrae Star in Local Group Galaxies. II. *ApJ*, 100, 108.
- [31] Ferrarese, L. et al. (1996). The Hubble Space Telescope Extragalactic Distance Scale Key Project. IV. The Discovery of Cepheids and a New Distance to M100, *ApJ*, 427, 628.
- [32] de Grijs, R. and Bono, G. (2014). Clustering of Local Group Distances: Publication Bias or Correlated Measurements? II. M31 and Beyond, *ApJ*, 148, 17.
- [33] Freedman, W.L., Wilson, C.D., and Madore, R.F. (1991). New Cepheid Distances to Nearby Galaxies Based on BVRI CCD Photometry. II. The Local Group Galaxy M33, *ApJ*, 372, 455

SERVING AMATEUR ASTRONOMERS FOR OVER 29 YEARS

toll-free 1-800-580-7160
info@khanscope.com
www.khanscope.com

ALL MAJOR BRANDS, INCLUDING:
AstroTrac • Meade • Celestron • Tele Vue • Kowa • Coronado • Levenhuk • ADM Sky-Watcher • Nikon • Kendrick • William Optics • Antares • Hotech • Farpoint Baader • iOptron • QSI • Telrad • TeleGizmos • Orion • Vixen • MoonLite • Lunt Explore Scientific • MallinCam • Rigel • Starlight Instruments • Vernonscope

SERVING BEGINNERS AND ADVANCED AMATEURS

WE SHIP CANADA WIDE | WE ACCEPT TRADE-INS
WIDE SELECTION OF NEW AND USED EQUIPMENT

We service and repair most brands of telescopes and binoculars

TO ORDER TOLL-FREE, CALL **1-800-580-7160**
OR LOCAL 416-783-4140
OR ORDER ONLINE VIA OUR SECURE WEB SERVER AT www.khanscope.com

KHAN SCOPE CENTRE
3243 Dufferin Street, Toronto, ON M6A 2T2
in Toronto: 416 783 4140
[facebook.com/khanscope](https://www.facebook.com/khanscope)

VISIT OUR SHOWROOM! OVER 70 SCOPES ON DISPLAY

Matching Supernova Redshifts with Special Relativity and no Dark Energy

by Simon Brissenden, Sunshine Coast Centre
sbrissenden@hotmail.com

Abstract

This analysis shows that a special relativity Doppler interpretation matches observed Type Ia supernova redshifts. Davis and Lineweaver reported in 2003 that a special relativity Doppler match to supernova redshift observations can be ruled out at more than 23σ , but MacLeod's 2004 conclusion that this finding was incorrect and due to a mathematical error is confirmed. MacLeod's plot of special relativity against observation has been further improved by using celerity (aka proper velocity) instead of peculiar velocity. A Hubble plot of Type Ia supernova celerity against retarded distance has a straight line of $70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ for as far back in time as we can observe, indicating that, with a special relativity Doppler interpretation of cosmological redshift, expansion of the Universe is neither accelerating nor decelerating, and it is not necessary to invoke the existence of dark energy.

Introduction

In 1929, Edwin Hubble[1] used observations of apparent magnitude and redshift of 24 extra-galactic nebulae to describe a linear relationship between their distance and radial velocity. His value for this linear relationship was $500 \text{ km s}^{-1} \text{ Mpc}^{-1}$. With better telescopes and more data, we now know that Hubble's estimates of extra-galactic distance were too small, and a more accurate value is $70 \text{ km s}^{-1} \text{ Mpc}^{-1}$. Hubble's discovery led to the concept of an expanding Universe that has become known as the Big Bang Theory.

Although the existence of a relationship between apparent magnitude and redshift for extra-galactic objects was clear, how to interpret this relationship was debated for many years. Interpretations that have been considered can be broadly categorized as either; (1) a special relativity Doppler explanation, where stars are moving through space, or (2) a general relativity explanation, where stars are embedded in expanding spacetime.[†]

Hubble's original analysis evaluated the observed redshift as a Doppler effect, which is consistent with a special relativity interpretation (although early redshift measurements didn't require relativistic correction). In due course, the popularity of this interpretation was superseded in the scientific community by the idea Le Maitre proposed in 1927[2] using Einstein's general theory of relativity, that expanding spacetime causes the extra-galactic redshift. Today, cosmological studies start with the assumption that a general relativity interpretation is correct. I am not aware of any professional cosmologists currently advocating a special relativity Doppler interpretation for cosmological redshift.

In 1998, Perlmutter[3] and Schmidt & Riess et al. [4] published papers on their measurements of Type Ia supernova redshifts. This led to them jointly winning the 2011 Nobel physics prize for establishing the existence of dark energy. Their papers and the Nobel Prize committee's award[5] implicitly assume a general relativity interpretation of cosmological redshift is correct and the possibility of a special relativity Doppler explanation for this data is not discussed.

Although the scientific consensus has swung decisively against a special relativity Doppler interpretation, there has been recurring inappropriate use of special relativity terminology to describe the cosmological redshift. In 2003, Davis & Lineweaver wrote a paper "*Expanding Confusion: common misconceptions of cosmological horizons and the superluminal expansion of the Universe*"[6] to clarify and correct the differences between general relativity and special relativity interpretation and terminology. This paper was subsequently adapted into a 2005 *Scientific American* article[7].

In the *Expanding Confusion* paper, Davis & Lineweaver attempted to show that special relativity cannot match cosmological redshift observations. In their Figure 5, they demonstrated a poor match between a special relativity Doppler interpretation and Perlmutter et al.'s published data. They stated that "*the interpretation of the cosmological redshift as an SR Doppler effect is ruled out at more than 23σ compared with the Λ CDM concordance model.*" This finding has not been challenged by the professional cosmology community.

However, a largely overlooked 2004 paper "*Redshift and Energy Conservation*" by MacLeod[8] did question the accuracy of this conclusion. MacLeod speculated that Davis & Lineweaver had omitted a $(1+z)$ correction factor when plotting the SR line in their Figure 5, and described how including this factor places the SR curve close to the Perlmutter $(\Omega_M, \Omega_\Lambda) = (1, 0)$ case and nearer to the measured redshift data than the reported 23σ discrepancy.

Special Relativity Analysis

Supernova cosmology is a challenging observational process that gives two key measurements; the redshift of observed supernova spectral lines z , and the supernova's observed intensity, represented as an effective or apparent magnitude m_B . Redshift is used to estimate the recessional velocity of the supernova and effective magnitude is used to estimate the supernova's distance from Earth.

Analyzing this data as a special relativity Doppler effect can be done in two ways:

The theoretical relationship between velocity and distance (assuming special relativity) is converted to z and m_B and plotted against measured supernova data.

Supernova measurements of z and m_B are converted to velocity and distance (using special relativity equations) and plotted in the format used by Hubble in 1929.

The benefit of the first approach is that it enables a special relativity interpretation of the data to be compared with a general relativity interpretation. This is the approach taken by Davis & Lineweaver, and subsequently MacLeod in his review.

The second method cannot be compared directly against general relativity models, as cosmological velocity and distance are different concepts in special and general relativity. However, it has the benefit of not requiring an a-priori assumption of the Hubble constant, which can be determined from the plot. Both approaches will be followed in this analysis, starting with the first, used by Davis & Lineweaver.

Redshift z is related to peculiar velocity $v_{pec}(z)$ using a special relativity equation (Davis & Lineweaver, equation 2):

$$v_{pec}(z) = c \frac{(1+z)^2 - 1}{(1+z)^2 + 1} \quad (1)$$

where c is the speed of light. Distance is derived from velocity by the Hubble relationship, $v = HD$, where H is the Hubble constant, to give (Davis & Lineweaver, equation 10):

$$D(z) = \frac{c}{H} \frac{(1+z)^2 - 1}{(1+z)^2 + 1} \quad (2)$$

Here $D(z)$ is the physical distance of the supernova, calculated from its redshift, using the Hubble relationship. However, with a special relativity model, the apparent intensity of a redshifted (i.e. receding) star is reduced by the relativistic Doppler effect. Distance $D(z)$ is converted to luminosity distance $D_L(z)$, because the supernova appears to be further away than it would be if it were stationary. Luminosity distance is then used to calculate effective magnitude. The special relativity Doppler intensity reduction therefore requires a $(1+z)$ correction factor (Davis & Lineweaver, section 4.2):

$$D_L(z) = D(z)(1+z) \quad (3)$$

Finally, effective magnitude $m_B(z)$ is calculated from luminosity distance using the following equation (Davis & Lineweaver, section 4.2):

$$m_B(z) = 5 \log(H_0 D_L(z)) + M_B \quad (4)$$

where $M_B = -3.45$ and $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$, both as per Davis & Lineweaver. (Davis & Lineweaver state that M_B is the “absolute magnitude in the B-band at the maximum of the light curve,” but I believe this parameter also includes corrections of $-5 \log(H_0)$ to balance the inclusion of H_0 in the $\log(H_0 D_L(z))$ term, and $+30 = 5 \log(10^6)$ for the conversion of $D_L(z)$ from parsecs to Mpc. Using a value $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ implies that a supernova Type Ia absolute magnitude of $M = -19.23$ is being used.)

Equations 1–4 and all input parameters are taken from Davis & Lineweaver. However, the resulting curve is not the same as Davis & Lineweaver’s Figure 5. In my Figure 1, it is plotted as an orange

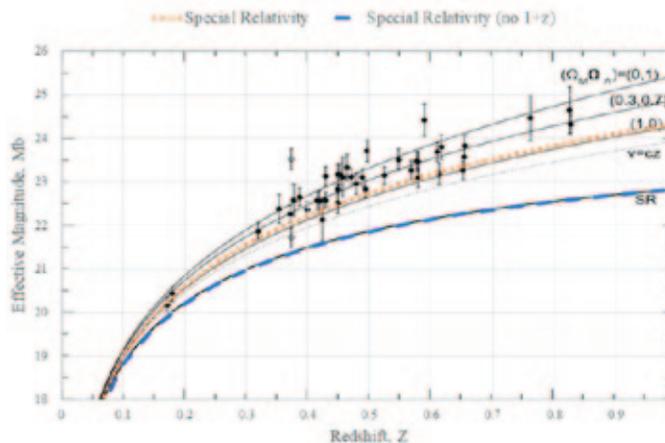


Figure 1 – Expanding Confusion fig 5; with and without $(1+z)$ factor.

line, labelled “Special Relativity,” which is superimposed on Davis & Lineweaver’s Figure 5 (which was itself taken from Perlmutter et al. Figure 2a). It can be seen that this curve is close to the Perlmutter $(\Omega_M, \Omega_\Lambda) = (1,0)$ case, as noted by MacLeod, and while still generally lower than the measured supernova data, visibly much closer than the 23σ discrepancy reported by Davis & Lineweaver.

To test MacLeod’s hypothesis that Davis & Lineweaver omitted a $(1+z)$ factor, the special relativity curve is replotted omitting the step described by equation 3, and using $D(z)$ rather than $D_L(z)$ in equation 4 to calculate $m_B(z)$. This is plotted as a blue line labelled “Special Relativity (no $1+z$)”, which overlays the curve labelled “SR” in Davis & Lineweaver’s Figure 5. This supports MacLeod’s finding of a mathematical error by Davis & Lineweaver. These results have been shared with Professor Davis and she confirmed the error[9].

Using Celerity instead of Peculiar Velocity

While the special relativity curve in Figure 1 is much closer to the supernova data than originally suggested by Davis & Lineweaver, it is still generally below the measured data points. A further correction, not discussed by MacLeod or Davis & Lineweaver, is required for a complete special relativity interpretation of cosmological redshifts.

The Hubble relationship is usually described as the radial velocity of stars away from Earth, relative to their distance from Earth. Implicit in describing the data this way is that the Earth is stationary. While a stationary Earth, embedded in spacetime, is appropriate for an expanding spacetime cosmological model, it violates the Copernican principle for a special relativity solution. It is just as accurate (Mach would perhaps have argued more so) to state that Earth is moving rapidly away from the distant stars.

With the high redshift measurements now being made, and assuming a special relativity solution, the velocity of separation between Earth and the most distant observable supernovae is

approaching the speed of light. Time dilation/distance contraction effects that would not be detectable in low z supernova redshift data become significant in high z redshift data. To use the analogy of the twins paradox, we are the astronaut twin seeming to cover huge distances in little elapsed time, not her twin left behind in the lab observing everything from a stationary position.

Incorporating this effect into the cosmological redshift analysis requires calculating the Lorentz factor γ with the standard special relativity equation:

$$\gamma = \frac{1}{\sqrt{1 - v_{pec}^2/c^2}} \quad (5)$$

This factor is used to convert peculiar velocity v_{pec} to celerity v_{cel} (aka proper velocity);

$$v_{cel} = \gamma v_{pec} \quad (6)$$

Using celerity rather than peculiar velocity in a special relativity analysis of supernova redshift data can be done by amending equation 3 to include the Lorentz factor;

$$D_L(z) = \gamma D(z)(1+z) \quad (7)$$

The result of equation 7 is used in equation 4 to calculate effective magnitude $m_B(z)$, which is plotted against redshift z as the solid line labelled “SR with celerity” in Figure 2.

There has been a significant increase in the number of Type Ia supernovae measurements available since Perlmutter et al.’s Figure 2a was accepted for publication in 1998. Figure 2 (below) uses 580 Type Ia supernovae from the Union2.1 database[10] with an expanded data range up to 1.4 in redshift and 26 in effective magnitude.

In Figure 2, the distance modulus ($\mu = m - M$) reported in the Union2.1 database has been converted to apparent magnitude m , using a value $M = -19.23$ for Type Ia supernova peak absolute magnitude, to be consistent with the value that appears to have been used in equation 4 by Davis & Lineweaver. (MacLeod used a value of $M = -19.33$ that came from Wang[11].)

A comparison with the dashed line labelled “SR with peculiar velocity” shows the significant improvement in the match against measured data when using celerity instead of peculiar velocity. The results of Figure 2 suggest that a special relativity Doppler interpretation of cosmological redshift, using celerity instead of peculiar velocity, is not inconsistent with Type Ia supernovae measurements.

Updated Hubble Plot

It is perhaps symptomatic of the move by the scientific community away from a special relativity interpretation of cosmological redshift, that I have been unable to find an updated version of Hubble’s 1929 plot in the literature that uses recent supernova redshift data. I have therefore made one myself (Figure 3).

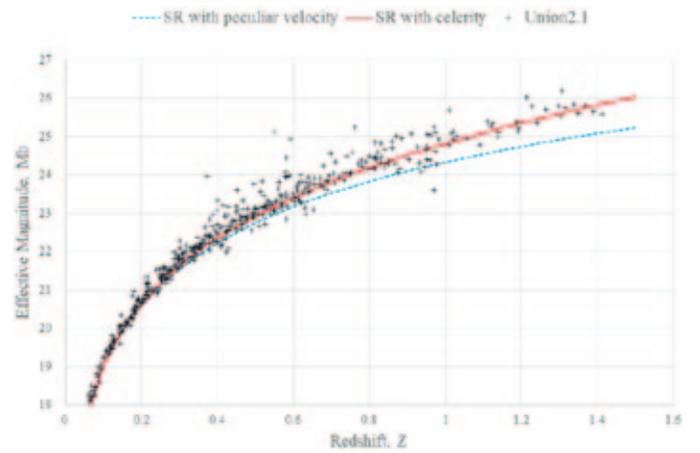


Figure 2 – Expanded Plot with 580 Supernovae; Celerity vs Peculiar Velocity.

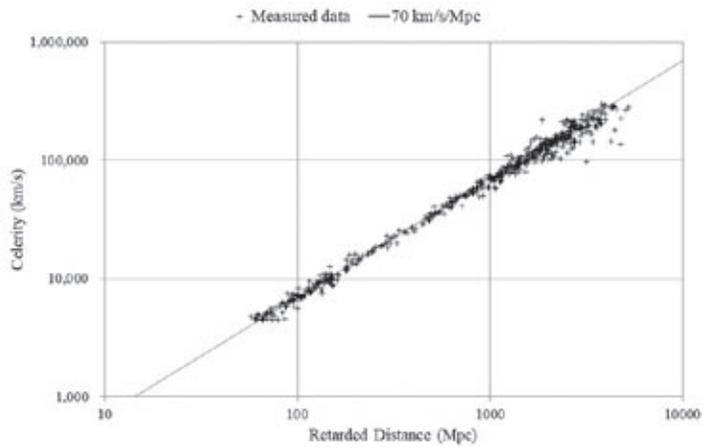


Figure 3 – Celerity vs Retarded Distance (using Union2.1 Type Ia supernova data)

The highest velocity discussed in Hubble’s original paper was 3910 km s^{-1} for NGC 7619. With today’s improved technology, measured supernova velocities are approaching a significant fraction of the speed of light. Using celerity instead of peculiar velocity means it is theoretically possible in future for radial velocity on a Hubble plot to exceed the speed of light.

The steps followed here to make an updated Hubble plot with the appropriate special relativity corrections are:

Observed redshift z is converted to peculiar velocity $v_{pec}(z)$ using equation 1.

Lorentz factor γ is calculated with equation 5.

Celerity v_{cel} is calculated with equation 6.

Distance modulus ($\mu = m - M$) reported in the Union2.1 database is converted into luminosity distance (D_L) in megaparsecs using equation 8.

$$D_L = \frac{10^{\left(\frac{\mu}{5} + 1\right)}}{1,000,000} \quad (8)$$

For a special relativity analysis, luminosity distance will be an overestimate of the actual supernova distance because of the reduced intensity of receding supernova sources caused by the Doppler effect. Following the terminology used by MacLeod, luminosity distance (D_L) is converted to retarded distance (D_R) with equation 9.

$$D_R = \frac{D_L}{(1+z)} \quad (9)$$

When celerity is plotted against retarded distance in Figure 3, the Union2.1 Type Ia supernova observations plot on a straight line, with a slope of $70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ extending as far as we have been able to observe.

Discussion

Figure 3 is an interesting and revealing plot. In one sense it is simply the same result that Hubble reported 90 years ago; a plot of velocity against distance has a linear relationship, but now with more data. However, the absence of deviation from a straight line is significant. The constant expansion rate means that, with a special relativity Doppler interpretation, the expansion of the Universe does not appear to be accelerating or decelerating for as far back as we can measure with Type Ia supernovae. Therefore, with a Doppler interpretation of cosmological redshift, dark energy is not required to reconcile theory with observation.

In physics, a straight-line relationship is normally viewed as evidence for an underlying physical reality. Matching Type Ia supernova redshifts with general relativity requires expanding spacetime, dark energy and results in a curved line on a plot. Matching Type Ia supernova redshifts with special relativity requires no expanding spacetime, no dark energy and results in a straight line. Occam's razor would seem to favour a special relativity Doppler interpretation.

When science, many years ago, chose a general relativity expanding spacetime explanation of cosmological redshift over a special relativity Doppler effect, it was based on astronomical measurements that were non-relativistic. With improvements in telescopes and technology, measurements are now venturing into a realm where relativistic corrections are required. Special relativity takes these new data points and puts them on the same straight line, while general relativity encounters a deviation between theory and data that requires the introduction of a new and mysterious form of cosmic energy. If this evidence had been available 90 years ago, would cosmology have made the same choice?

The Big Bang Theory, constructed on a foundation of general relativity, is a complex integrated story that has been developed over many years. There are several features of the Universe (cosmic microwave background, abundance of light elements, large scale structure) that support this interpretation. However, it was observations of the cosmological redshift-distance relationship 90 years ago that gave rise to the Big Bang Theory, and this

data is still the strongest experimental evidence available that it is correct.

Expanding spacetime and dark energy are theoretical concepts that are poorly understood and have not been detected in the laboratory. The astronomical data that prompted these theoretical concepts to be introduced to science and constitutes the best available evidence that they exist, is the same data plotted in Figure 3, that can be interpreted using special relativity—a lab-verified theory—as evidence that they do not exist at all.

Acknowledgements

This is the second of three papers[12] that describe a “Big Bubble” cosmological model. I would like to thank Alasdair MacLeod, Tamara Davis, and Phillip Helbig for their help with the contents of this paper.

Simon Brissenden

PO Box 242, Lund BC, Canada V0N 2G0 ★

References

1. Hubble, Edwin, “A relation between distance and radial velocity among extra-galactic nebulae,” *PNAS* 15 (3), 168–173, (1929)
2. Le Maître, G., “Un univers homogène de masse constante et de rayon croissant rendant compte de la vitesse radiale des nébuleuses extra-galactiques,” *Annales de la Société Scientifique de Bruxelles*, 47:49, (April 1927)
3. Perlmutter, S., Aldering, G., Goldhaber, G., et al., *ApJ*, 517, 565, (1999)
4. Riess, A., et al., “Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant,” *Astronomical Journal*, 116, 1009–1038, (1998)
5. www.nobelprize.org/uploads/2018/06/advanced-physics-prize2011.pdf
6. Davis, T.M. & Lineweaver, C.H., “Expanding Confusion: common misconceptions of cosmological horizons and the superluminal expansion of the Universe,” [arXiv:astro-ph/0310808v2](https://arxiv.org/abs/astro-ph/0310808v2), (2003 November 13)
7. Lineweaver, C.H. & Davis, T.M., “Misconceptions about the Big Bang,” *Scientific American* (2005 February 21)
8. MacLeod, A., “Redshift and Energy Conservation,” [arXiv.org/pdf/physics/0407077](https://arxiv.org/pdf/physics/0407077), (2004)
9. Davis, T.M., personal email (2018 September 12)
10. Suzuki et al. “The Hubble Space Telescope Cluster Supernova Survey: V. Improving the Dark Energy Constraints Above $z > 1$ and Building an Early-Type-Hosted Supernova Sample,” [arXiv:1105.3470v1](https://arxiv.org/abs/1105.3470v1)[astro-ph.CO] (2011 May 17)
11. Wang Y., “Flux-averaging Analysis of Type Ia Supernova Data,” *ApJ* 536, 531, (2000)
12. Brissenden S.J., “Big Bubble Theory,” www.researchers.one/article/2019-09-21 (October 2019).

† While the terms “special relativity” and “general relativity” are used in this paper to describe the different interpretations of cosmological redshift, the relativity model is less at issue than the underlying mechanism; either a Doppler effect or expanding spacetime.

First Light and Something Old, Something New

by David Levy, Kingston & Montréal Centres

For those of us who are not astronomers, the phrase “first light” means dawn. If we are up early to go fishing, hunting, or to search for a missing person, we awake at first light. For skywatchers, first light has an entirely different meaning. Instead, it celebrates the first time starlight enters a new telescope or the inside walls of a new observatory. On Sunday evening, December 15, David Rosseter, one of the United States’ most famous amateur astronomers, celebrated first light for his new observatory, completed after he relocated to the Tucson area. Wendee and I were there, along with some neighbours, friends, and the new executive director of the International Dark-Sky Association.

The object David selected as the first thing to be observed from his brand-new observatory was Messier 15, one of the grandest globular star clusters in the entire sky. It is different from the object I traditionally use for my new telescopes, the planet Jupiter. Last fall, for example, I pointed Eureka, a brand-new telescope, at Jupiter for its first-light ceremony.

Jupiter shines at us from about 50 light-minutes away, meaning that light reflected from the Sun leaves the giant planet and takes about 50 minutes to reach us. The globular cluster Messier 15, is much, much farther away. It shines at us from well beyond the stars of its home constellation of Pegasus, from a distance of at least 33,000 light-years, and at magnitude 6.2, it is barely visible to the unaided eye on a very dark night.

I was very glad to see M15 using David’s giant 25” diameter reflector from his new observatory, for I recall seeing it frequently at our Adirondack Astronomy Retreat. At the first Star Night of the RASC Montréal Centre, my first one since becoming a member, I was assigned Messier 15, the globular star cluster that was discovered by



Figure 1 — Messier 15, taken by Tim B. Hunter.

Jean-Dominique Miraldi in 1746, and added by the comet hunter Charles Messier to his catalogue in 1764. I recently wrote about that experience in my autobiography:

At Star Night that September I was assigned to point my telescope at M15, the beautiful globular cluster in Pegasus. I recall doing my homework about that cluster. I learned that its distance was listed at about 33,000 light-years. We now know that M15 is also one of the oldest globular star clusters in the Milky Way, dating from at least 12 billion years ago. We also suspect now that the central portion of M15 underwent a collapse of its core deep in the past, and that its central core consists of a huge number of stars orbiting a massive black hole. Most of this information is more recent. Back then the pertinent facts were that the cluster had a membership of upwards of a hundred thousand stars.

—*A Nightwatchman’s Journey*, (p. 68)

Years later, I wrote:

On a beautiful clear night at one of our Adirondack Astronomy Retreats, I peered through Fritz, David Rosseter’s 25-inch Obsession Dobsonian reflector. The telescope was pointing at Messier 15 in the Pegasus constellation, but what I had was not just a view. It was an extended leisurely stroll among the stars of this cluster. I made some left turns, walked up hills, crossed bridges, and explored valleys all decked with uncountable stars.

—*A Nightwatchman’s Journey* (p. 289)

I thoroughly enjoyed another look at the beautiful and mysterious Messier 15 from David’s new observatory on that night. I especially enjoy showing younger people this fabulous cluster of so many stars. As each new generation is introduced to it, may Messier 15’s myriad stars shine for a distant and newer generation or from another observatory as it undergoes its first light.

Something old, something new: Eureka instead of Echo

This is the story of my first telescope, of the comet it did not discover (which later collided with Jupiter), and the telescope that replaced it. Although this story has been building for almost 60 years, it came to a head last fall. First, in late October, I got myself a brand-new telescope. It is a 12” reflector, with a fast f/5 focal ratio, which means that at low power I can get well over a degree field of sky when I gaze through it. That means more than two Moon diameters. I had some difficulty setting up the new telescope, and needed some help, but when it finally was ready, the views were a wonder to behold and a true joy.

I named the new telescope Eureka, after an asteroid I discovered, at Palomar with Henry Holt, in June of 1990. The asteroid turned out to be orbiting at the L5 point (Lagrangian 5) in Mars’s orbit, as it has been that way for much of the life of the Solar System. The asteroid is the first known Martian trojan, and our proposed name, Eureka, was accepted as an expression of joy in making a discovery. It was named for Archimedes’ expression of delight after discovering how objects displace water, and how he leapt out of his bathtub and ran down the



Figure 2 — Eureka, my latest telescope. If you look carefully, you might catch Venus at the top centre.

street yelling Eureka! (There is nothing in the story to suggest that Archimedes bothered to dry off and dress before he darted outside.) For my new telescope Eureka's first light (see February's column), I chose Jupiter, which is my choice for first-light objects ever since 1960 September 1.

That brings me to the second telescope, named Echo after a large passive communications satellite launched on 1960 August 12. Echo was my very first telescope, and it was the telescope through which I looked at Jupiter for the first time on that far-off night. On that distant night, Mom and Dad were with me and they were excited as well. An entirely new world was opening up for me, a world that has remained open and inviting ever since. For a few years it was my only telescope, replaced only when I upgraded to a 5-inch telescope while I was a patient at the Jewish National Home for Asthmatic Children in Denver, and an 8-inch a year later. Over the years Echo has provided a wealth of happy nights under the stars.

On Thursday evening, 2019 November 7, I formally donated Echo, my first telescope, to the Linda Hall Library of Science, Engineering, and Technology in Kansas City, along with more of my observing records. Echo began its new life that very evening. Under a clear sky, some people got the chance to look at the Moon through Echo, which still functions well after 59 years. May Echo get a lot of use at this wonderful library, one of the largest science libraries in the world.

All this brings me to the point of this article, Eureka instead of Echo. After all these years, I wanted a powerful telescope to replace my first



Figure 3 — Wendee and Echo, from White Sands National Monument.

telescope. With Eureka, I now have that instrument. Every time I look through it, my mind is filled with the magic and delight of that long-gone evening when I first set up a telescope and looked at Jupiter. On that night, I saw Jupiter, its belts, and its four big moons. One thing I did not see, and neither did anybody else, was a small comet moving close to the planet. That comet would remain undetected until 1993 March 23, when Gene and Carolyn Shoemaker and I set up a night's observing at Palomar that would include the field that revealed this comet. It was reported on the 25th. Sixteen months later, this comet, now known as Shoemaker-Levy 9, collided with Jupiter in one of the most dramatic explosions ever witnessed by humanity. May Eureka, instead of Echo, also reach for the stars. ★

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

Behind the Data at CFHT

by Mary Beth Laychak, Director of Strategic Communications,
Canada-France-Hawaii Telescope
mary@cfht.hawaii.edu

One of my first columns focused on the queue servicing observing mode (QSO) at CFHT. In this column, we are going to take another look at our QSO, remote observing, and remote observers.

In quick review—*In queue*, another name for QSO, the principal investigators (PIs) never set foot on CFHT. They do not go to the summit and operate the instruments themselves. In fact, they do not get assigned specific nights. Instead the time allocation committee (TAC) allocates them a ranking and a set number of hours. Each of CFHT's constituent countries has a separate TAC. For example, Canada A1 ranking with 36 hours means your program is the top-ranked program at CFHT from Canada and 36 hours of telescope time will be devoted to completing your observations.

Once a PI receives their ranking and time allocation, they use PH2, an online form designed and managed by CFHT, to detail their observations. Within PH2, the PI enters all the necessary information to complete their program efficiently; the image quality range (IQ), sky background, photometric vs non photometric conditions, etc. They can also schedule time-sensitive observations and leave comments for the QSO team to consider when observing or scheduling. All information for all programs is stored within a custom database.

From this database, the QSO team creates queues or plans for every night. Queues tend to be based around image quality, but the biggest defining quality of a single observation is its program ranking. This is the beauty of the queue system; we can discriminate based on weather and sky conditions. The highest ranked programs get observed in the optimal conditions for their science.

Because each instrument is unique and the observation strategies differ based on the science and the cameras, no one regularly queues coordinates for all five instruments. Rather the queue coordinators (QC) tend to specialize in imaging or spectroscopy. That is not a hard-and-fast rule, but most of the crossover occurs when people are on vacation or travelling for conferences.

Our two imagers, Megacam (optical) and Wircam (IR) tend to have the most queues. With Megacam in particular, the number of programs combined with the vast difference in IQ requests leads to 5–6 queues per night. The QC always creates a queue for suboptimal conditions, those roughly 65 nights a year of less-than-perfect conditions on Maunakea. These

queues contain programs that do not need sub-arcsecond seeing or can tolerate thin cirrus clouds. These “snapshot” queues are the secret weapon behind CFHT's amazing calendar images and the whole Hawaiian Starlight project. These images are taken during when we have poor seeing (>1.2”). Granted, many astronomers would consider killing for sky conditions that we deem “poor,” but it is all relative. The worst on Maunakea is the best almost everywhere else.

Our spectrographs tend to have fewer queues, on the order of 1–3 per night. In spectroscopy, IQ is less of an issue. Same with clouds. The defining characteristic of our optical spectrograph, Espadons, is mode—spectroscopic or polarimetric. We can switch modes once per night; new calibrations must be taken when that occurs. The QC needs to take that into account when creating the queues.

Similarly, 1–3 queues per night are created for SPIRou. Many of the SPIRou observations are long blocks for time-constrained programs like observing transits or longer observations needed to monitor stars for sensitive radial-velocity measurements. In the SPIRou queues, the time-sensitive and radial-velocity observations require consistent good seeing, with no clouds. If the weather is marginal, the observers need a backup plan in case they do not think they can complete the longer observations.

Then we have SITELLE, which doesn't fit neatly into the imaging/spectrograph boxes. As a reminder, SITELLE is an optical imaging Fourier transform spectrometer (IFTS) providing integral field unit (IFU) spectroscopic capabilities in the visible (350 to 900 nm) over an 11-by-11-arcminute field of view, with a variable spectral resolution from $R=2$ to $R>10^4$ which allows for low to high spectroscopic studies. Put simply, SITELLE combines high-resolution images and spectroscopy over an $11' \times 11'$ field of view, potentially providing 4 million spectra per observation. SITELLE observations (on average) are longer, 2–4 hours in duration. That does not leave the QC nearly as many options as we see with Megacam and Wircam. Much like SPIRou, the longer SITELLE observations require consistent skies with minimal variations in image quality or clouds. The combination of long observations and stable conditions limit the number of options the QC has, so a SITELLE night may only have 1–2 queues. The second queue is often shorter than a full night with a handful of options for changing sky conditions. Often the QC instructs the observer to observe through the changing conditions with the knowledge that they may have to repeat those observations another night.

Since 2010, our remote observers observe from Waimea instead of the summit. Our remote observers do everything they need to observe from the lower altitude and warmer conditions. At the summit, we have a two-person rule to ensure safety, but in Waimea, one person can operate the entire facility themselves. Visitors are always amazed when they

realize we can open the dome and mirror covers, turn on the dome and the telescope, adjust the windscreen and monitor the weather remotely.

One of the secrets behind remote observing is the vast number of cameras we have inside and outside the observatory. At the start of every night, about an hour before sunset, the RO starts

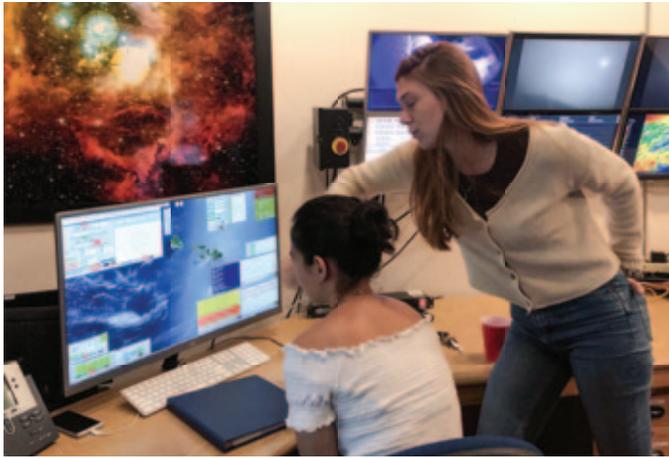


Figure 1—RO Helen in the remote observing room explaining how the telescope controls and weather monitoring works to a visiting student.

their shift by doing a visual inspection of the key systems. Many of the cameras have pan, tilt, and zoom features, allowing the RO to read the dials on our machinery.

When we open the shutter, the RO watches and listens. The entire dome is microphoned, which is also handy during



Figure 2—One of our cameras looking at the machinery room along with the complete listing of internal and external summit cameras.

evening summit tours, so the RO can hear the noises the shutter makes. To the untrained ear, the shutter opening sounds like loud noises, but our ROs know what the opening dome should and, more importantly, should not sound like. If an RO doesn't like a clang or bang from the shutter, he or she can report the noise in the nightly log so our operations group

can listen to the nightly dome-shutter recording and follow up in the morning.

Similarly, the RO monitors the weather. As I am writing this column, we have a winter storm on Maunakea (this column is due two months before publication, so it is February). Despite the high winds, snow at the Visitor Information Station at 3000 metres, and the icy summit conditions, tonight's RO stayed all night monitoring the conditions. Winter storms at the summit often mean extreme weather island-wide, making power glitches or outages a possibility. While all of our instruments text our technical staff alerts if something is out of constraints (occasionally you will attend a meeting, hear a bunch of text alerts followed by muffled curses, and a quick exit by technical staff), the RO is the first line of defense. Technical staff will call the RO with instructions or for more details.

Because the RO observes from Waimea, they are cautious about opening in poor conditions. Tonight, for example, the cold summit temperatures and high humidity made Callie, tonight's RO, request a visual dome assessment before opening tomorrow. During the week, our summit operations crew will make the dome assessment. On weekends, the support RO and support astronomer need to drive to the summit to conduct the assessment if the conditions are in question. We also have cameras pointed at CFHT from the Gemini Observatory allowing us to zoom in and inspect our dome from Waimea.

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

If the RO runs into a situation where they are unsure what to observe, something is wrong with the observations, or if the sky conditions take a huge swing, they can call the QC for advice. If they run into a technical problem, the RO calls one

The June *Journal* deadline for submissions is 2020 April 1.

See the published schedule at

www.rasc.ca/sites/default/files/jrascschedule2020.pdf

of our technical staff for assistance. Otherwise, they are on their own all night, observing and evaluating the images.

While our QCs generally work with one or two imagers, our ROs observe with all our instruments. That makes training a new RO a long process as they learn the quirks and programs associated with each instrument.

Now that I have described remote observing, I want to introduce the people behind the scenes.

One of our longest-tenured remote observers, Lisa Wells started at CFHT in 1999, the days of classical observing, when astronomers still visited and observed their own data. Lisa started as an observing assistant and worked as a support astronomer for several of our instruments.



Figure 3—Lisa in the RO room

Prior to working at CFHT, Lisa worked for five years at CTIO (Cerro Tololo Inter-American Observatory) and two years at Kitt Peak. She has a B.A. in physics, math, and computer science from Augustana College and an M.S. in astronomy from the University of Arizona. Her science passion is supernovae. She was a member of the Cerro-Tololo/Cerro-Calán supernova search project at CTIO. These collaborations were with a large team that included the astronomers who won the Nobel Prize for discovery of the expanding universe.

Lisa misses being at the summit at times because she loved going out on our catwalk and viewing the night sky, checking the weather firsthand, and watching the Moon rise or set over the Pacific Ocean. Her favourite part of the job is doing the observations, especially on an ideal night where everything is working correctly, the weather is not extreme, and the image quality is as sharp as you can get. She gets a great sense of satisfaction when she sees her name in a Central Bureau Electronic Telegram from an astronomer for whom she has taken data a night or two before announcing that a near-Earth asteroid will not collide with Earth.

She wants people to know that you need to be a night owl to do this job and also not mind being alone for the long Hawaiian winter nights. Working alone gives you complete control of the stereo system and the ability to play it as loud as you want.

Our newest RO is Helen Januszewski who has worked at CFHT for almost a year. I want to wish her a happy birthday because this column will run the day before her birthday. She most enjoys the way observing connects her to worlds near and far; while she expected to be awed by watching the night sky, an unexpected joy has been getting to know Maunakea. Even as a remote observer far from the mountain, following the tricks of the changing weather, keeping tabs on the sleeping island from summit cameras, and watching the Sun rise and set each night on a new sky has been a privilege.

Before becoming an RO, Helen knew she would be the one to take the observations for CFHT, and that the PI would turn it into published science. Over the past year, she's realized there are many more pieces to this puzzle, roles to fill getting everything ready for her to walk in at night and getting the best data possible for the conditions and constraints. Others may not realize just how diverse are the set of skills and jobs required by observational astronomy. The operational staff maintains the telescope and facility, which is no small task for a 40-year-old observatory! Instrumentation and software groups support the instruments as they cycle on and off the telescope, as well as every way the ROs interface with them. Astronomers rotate through the role of queue coordinator to prepare priorities and an observing plan for the night. Such a brief summary leaves out a multitude of other responsibilities claimed by each person, and all of the above are on call 24/7 in case he or she runs into trouble during a shift. The RO may be most concerned with the progress of the night, but behind a smooth night is a diligent team that have had a busy day.

Before coming to CFHT, Helen was an intern at the Gemini North Observatory in Hilo, reducing data taken by the Gemini Multi-Object Spectrograph. That summer got her hooked on Hawaii astronomy, and she feels lucky to come back as a full-time observer!

Our next RO, Callie Crowder has been at CFHT for three years. Her favorite part about being a Remote Observer is seeing cutting-edge research being published in the field of astronomy and knowing that she was the one who observed the target to collect the data. As an RO, Callie spends between 12 and 16 hours in the office during her shift depending on the time of year and the instrument on the telescope at the time. In her spare time, Callie is a planet handler for the CFHT Facebook, Twitter, and Instagram and likes to take the celestial buddies on photoshoots around the office. The stuffed planets offer people the opportunity to go behind the scenes at CFHT in a friendly and accessible way for most audiences. She wants everyone to follow CFHT on social media @CFHTelescope. Happy birthday to Callie (since I am writing this on her birthday)!



Figure 4—Callie in her Galaxy Cat Halloween costume volunteering at the Solar System Walk. She is with NASA Solar System ambassador Nancy Tashima at the Mercury booth.

Figure 5—Cam being a good sport and posing for me in his office.

Last, but not least is Cam Wipper, an RO since 2015. Cam's favourite part of being an RO is being on the cutting edge of science, conducting observations that expand our knowledge of the Universe. He wants people to know that CFHT has taken data to help navigate *New Horizons* (shout out to Stephen Gwyn and JJ Kavelaars at the CADC) to Pluto and other targets. Cam is our only Canadian RO; he grew up in Nanaimo, B.C., attending Vancouver Island University for 3

years. He then transferred to the University of Hawaii at Hilo to study astronomy and work on Maunakea. ★

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

All-Star Telescope
www.All-StarTelescope.com

FREE SHIPPING
on most items*
*see website for details

NOW AVAILABLE—ONLY FROM ALL-STAR!

"I've just sat through the first lesson, and I ABSOLUTELY LOVE what you've done. The information is clear, practical and very well thought out. Your presentation style is warm and inviting, and the production quality is superb! This is, without question, one of the absolute best (if not the best) photo tutorials I've ever seen."

Angelo Ioanides, *ExtraOrdinary Vision*.magazirfb

Canada's recipient of Celestron's Perspectives on Imaging award
1-866-310-8844
 Didsbury, Alberta

CELESTRON
 PREMIER SELECT
 CELESTRON
 TELE Vue
 Telenor
 Dealer
 Celestron's New CGX Mount

Nightscapes and Time-Lapses
 FROM FIELD TO PHOTOSHOP
 A VIDEO TUTORIAL BY ALAN DYER

Background photo: Flame Nebula by Ken From of All Star Telescope

Binary Universe

Take Control of Your Mount



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

Two Rows

The hand controller of the modern go-to telescope is absurd.

Think about it. A small monochromatic display with two lines. Few buttons or keys, some of which sport strange labels. Odd object catalogues with limited choices and some that don't use SAO star numbers! Peculiar star names or ones you've never heard of before. Where the heck is Maaz?! Worst of all, the mount's hand controller (HC) literally tethers you to the telescope (often with a mind-numbingly short cable).

This clearly shows the big manufacturers are unimaginative, stuck in a rut, or not prepared to invest in research. Some do things differently.

I've never used them but the Vixen SkyPod and Star Book HCs look interesting. With bigger and colour displays, they give the user an electronic chart right at the telescope! Shouldn't the operation of a mount be easy, fast, and a bit more fun?

I was intrigued when I successfully attached a NANJING IDEA GoToStar system to my old trusty Vixen Super Polaris. Here was an independent telescope company in the early 2000s shaking things up. The obvious difference is the display with eight glorious lines of text! Lots of clever controls and options in the menus. Not perfect but light-years better than Celestron, Meade, and Orion. I believe iOptron bought the technology as I see similarities in their new designs. But I still shake my head when I see brand-new telescopes with a teeny tiny display and confusing firmware.

If you find the HC display annoying, the menu options and controls lacking, the catalogues useless, and the buttons infuriating, know that you have options. If you're imaging and don't need to be near the telescope during the session, all the more reason to let go.

Let go of the hand controller.

Virtual Control

The broad idea is that you can use your computer and operate the mount like a robotic telescope. With a Windows computer and appropriate software, you can use a virtual HC. I like to use SkyTools 3 Pro with real-time mount control. With good polar alignment and good pointing, I ignore the HC for the evening.

For the Sky-Watcher owner, there's a very intriguing software solution. You can have enhanced mount control thanks to the EQMOD project. EQMOD also supports some Orion, Avalon, and Vixen mounts.

The EQMOD software is actually a suite of applications and works on the ASCOM platform.

The EQMOD app shows the all-important slew buttons. That's all you see when displayed in its miniature form (Figure 1). Expand to full-size to use all the controls and features (Figure 2).

Maybe you're already using a computer for imaging and guiding. Maybe you're using planning or planetarium software and keeping digital log notes. So, let the computer take over HC duties as well.

A quick note about the Software Bisque Paramount. This is a professional-grade robotic system of course and the mounts do not come with hand controllers. All operations are managed from a computer using the fully featured TheSky application. As a supervisor at the Carr Astronomical Observatory where we have a Paramount ME and MyT, I have come to enjoy this way of working. OK, I'm spoiled.

A few years ago, I used Celestron's NexRemote to operate a telescope. My recollection is that it looked and acted like



Figure 1 — The EQMOD app in smallest form works like a miniature hand controller.

the HC with no additional capabilities. But on reviewing the website, I see it supports audio, custom sky tours, and gamepads.

EQMOD essentially allows the operator to do anything they could with the HC but a number of things beyond what's built in. The active developer community is also adding new capabilities over time.

Beyond Basics

Here's a brief comparison between using a hand controller versus EQMOD.

You can see that EQMOD greatly expands on what you can do compared to using the stock HC. Using EQMOD with EQTOUR (Figure 3) or a compatible astronomy application allows you to slew to any visible object.

Considering that you can also be some distance from the mount, you can work in a more comfortable way, seated, out of the cold, or away from the bugs.

Still More Features

- The EQMOD apps use a dark mode with red text although there are some bright elements in the screens. Red film is still a good idea if you must stay dark adapted.
- The app can assist in polar alignment using an alternate technique different than drift alignment.
- There is support for joysticks, wireless mice, and gamepads and a wide range of global positioning system (GPS) devices for the mobile observer or imager.
- There are additional separate apps to provide still more functionality (e.g. focuser control).
- There is a simulator provided for evaluation and testing.
- The EQMOD app itself can be operated in different languages.

| Feature | Typical HC | EQMOD |
|-------------------------------------|---|--|
| Observing locations | Major cities. Can create a custom location. | Can create 10 custom locations. |
| Site altitude | Rare. | Yes. |
| GPS support | Yes. | Yes. |
| Initial star alignment | 1, 2, and 3-star alignment procedures. May be able to add calibration stars. | Advanced alignment control. Use one or more stars. Use any stars. Add more synchronized points for a rich pointing model. |
| Celestial objects | Certainly, many targets but limited. Awkward access for some entries. | Infinite choices for pre-built catalogues. Use a full astro app or EQTOUR. |
| User-defined objects | Rudimentary. Limited custom user slots. | Completely customizable and unlimited user objects. |
| Tracking rate | Sidereal. Might have lunar and solar. | Sidereal, lunar, solar, custom (comet or satellite). Current rate shown. |
| Stop tracking | Difficult or awkward to toggle tracking off and on. | Can easily turn off and on. Drift adjustment control available. |
| Slew rate | Slow through fast settings, 9 levels or speeds. May be able to reverse direction. | Can be finely adjusted, up to 800x sidereal, with pre-sets. Can also apply different rates to RA and Dec. Can reverse the direction. |
| Abort slew | Yes. Not obvious or easy. | Yes. Easy. |
| Periodic error correction | Yes. May require (purchased?) add-in. | Yes. May be recorded with a webcam. |
| Variable PEC | No. | Yes. |
| Current mount status | Limited. Awkward to retrieve. | Local sidereal time, current RA and Dec, Alt and Az, side of pier telescope is on and direction it is facing, message centre, graphical monitoring of PEC. |
| Mount collision and meridian limits | Rare. Rare that they can be altered. | Yes. Full control with a powerful editor. Flip controls. |
| Mount parking | Rudimentary, one location. | Easy to use. Can specify multiple park locations. Automatic timer available. |
| Evening sky tour | Some have. Automatically selects visible objects. Meade Audio Star provides spoken notes. | Can create a custom plan. With EQTOUR application. |
| Spiral search | No. | Yes. |
| Mosaic gathering | No. | Yes. With EQMOSIAC application. |
| Guiding control | Limited. | Extensive with graphical monitoring. Supports ST4 and pulse. |



Figure 2 — The full windows of EQMOD presents all the controls and features including guiding.

Get Rid of the Controller!

Using EQMOD, you can actually ditch your HC. OK, don't throw it out, don't sell it, just put it aside. Put it in the house to keep out dew and bugs.

In place of the HC, you use an adapter called EQDirect. There's a USB model and one for a serial cable. I also noted a wireless Bluetooth edition. This simple adapter can be purchased from a variety of vendors or the do-it-yourself person good with a soldering iron can make their own. The option you select may be governed by cable run lengths.

Minimizing Controller Use

I tested the software with SkyTools 3 Pro, SkyTools 4 Visual, and Cartes du Ciel with a Sky-Watcher HEQ5 Pro mount and a version 3 SynScan hand controller. I used the Sky-Watcher serial data cable and a Staples (Prolific) USB-serial adapter on Windows 10. I used EQASCOM version 2.00q (with ASCOM 6.4 SP 1).

Here's a brief session outline, going through the start-up and operation in advance of imaging or a sky tour outreach event. This assumes the mount is polar aligned.

1. power up mount and relevant accessories
2. on the HC, follow the prompts about location, date, time, etc. but cancel the alignment process
3. put HC into "PC Direct" mode, if necessary
4. at the computer, launch the appropriate EQMOD tools
5. launch planning or planetarium app
6. perform a multi-star alignment with astronomy app (acting as the object catalogue) and EQMOD (acting as the HC)
7. conduct astronomy session proper
8. end of session, disconnect from mount
9. home and park mount in EQMOD
10. power down observatory

Continued on page 82



Figure 1 — Blake Nancarrow photographed Orion—including the much fainter-than-normal Betelgeuse—as well as the Hyades and the Pleiades from Bradford West Gwillimbury. The photographs were stacked in Sequator 1.5.5. Gimp used for levels, curves, and saturation.



Figure 2 — Klaus Brasch photographed Comet PANSTARRS C/2017 T2 near the Double Cluster in Perseus. The image was a stack of several frames taken with his modified Canon 6D and a TMB-92 f/5.5 refractor shooting at ISO 6400 through an IDAS PLS-P1 filter. The comet, around 10th magnitude, appears as a small turquoise comma just above the cluster.



Figure 3 — Tom Owen imaged M27, the Dumbbell Nebula, a planetary nebula 3500 light-years away in the constellation Vulpecula. He shot 18 subs totalling about 1.5 hours on 2017 September 29 using a 1.6× focal extender on his Takahashi FS 102, and also used a Uv/Ir cut filter on a MallinCam VSS+. This image was one that Tom sent for his Astrophotography Certificate submission in the Deep-Sky category. See rasc.ca/astro-imaging-certificate See also all the submitted entries from when the program began in 2016 at rascastroimaging.zenfolio.com



Figure 4 — Gary Palmer imaged another favourite, the Cone Nebula. He used a Sky-Watcher EQ6 AZ-GT scope on an Altair Pier and a SharpStar 15028 HNT (Hyperbolic Newtonian Astrograph) 150-mm at $f/2.8$ with a ZWO ASI 1600GT and Altair filters. He also used Primaluce Lab Eagle 3 Pro and Sesto Senso with LRGB and a bit of $H\alpha$ blended in for 30 x 60 seconds per channel. Captured in Sharpcap Pro and processed in Pixinsight and Photoshop CC.

You will note that the physical controller was not touched during the astronomy session. The well-thought-out EQMOD application allows hands-free robotic operation of the telescope. In theory, you will not need to use the Sky-Watcher HC for the bulk of a session.

What's Required

You'll need to be savvy with Windows and get a few ducks in a row to make this work. I kept running into connection errors, but when I checked the connection and launched apps from the EQMOD toolbox, everything worked.

EQMOD is built on the ASCOM platform so that means, if you don't have it already, you first install the free core ASCOM software on your PC.

<http://ascom-standards.org>

Then head to the EQMOD home page.

<http://eq-mod.sourceforge.net/>

You'll find extensive information including details of the open-source project, software prerequisites, and all the free EQMOD apps. There are links to the [groups.io](#) space, the wiki, the FAQs, the documentation, and the files for download.

While ASCOM is growing to other environments including Linux and Mac OS, EQMOD proper is only available for Windows.

I was a little bewildered at the early stages and made assumptions. I should have reviewed the available documentation. There's lots (in English and French) including a helpful polar-alignment tutorial. When I found the "quick start guide," I finally connected to the mount. In my case, I had to put the HC into PC Direct mode. Curiously, I did not see this mentioned in the full 182-page user manual. I also found a very good detailed walk-through by Kayron Mercieca in Gibraltar with references to Stellarium and Cartes du Ciel.

www.lightvortexastronomy.com/tutorials.html



Figure 3 — Ready for a double-star sky tour with EQTOUR (on the left) and EQMOD (in its normal size).

Toronto Centre member Denis Grey is a big fan and told me "support is outstanding." And I noted that EQMOD is regularly discussed on the popular forums like Ice In Space and Cloudy Nights. Quirky interface issues aside, the EQMOD is a handy and powerful software tool to allow you to stop using your hand controller. Just about every Sky-Watcher mount is supported, so if you are already using a computer at or near the telescope, get EQMOD. As Mercieca says "Having computer-control of your mount is a very big deal. It unlocks many features that the hand controller cannot possibly provide." I concur.

Bits and Bytes

The Astrophpheric weather resource now shows kp index values. ★

Blake's interest in astronomy waxed and waned for a number of years but joining the RASC in 2007 changed all that. He supervises at the Toronto Centre Carr Astronomical Observatory, sits on the David Dunlap Observatory Committee, helps with volunteer coordination, and is a member of the national Observing Committee. In daylight, Blake works in the IT industry.



**Ontario Telescope
and Accessories**

tel. 905-487-6363

| | |
|--|---|
| <p>Proud seller of</p> <ul style="list-style-type: none"> iOptron Bresser Explore Scientific Antares Bob's Knobs Lumicon | <p>Your Online source for</p> <ul style="list-style-type: none"> "GoTo" EQ and Alt/Az mounts Telescopes Finderscopes Camera mounts Mechanical adapters and Accessories |
|--|---|

www.ontariotelescope.com

Ontario Telescope and Accessories, Where OTA means more!

Visually Reimagining the First Known Astronomical Use of a Telescope in “Canada”: Fr. Bressani’s 1646 Eclipse Observation at Sainte-Marie among the Hurons



R.A. Rosenfeld
(r.rosenfeld@rasc.ca)

Abstract

Since at least the 17th century, artistic recreations of ancient and remote landscapes, interiors, objects, and events based on the best available research have been used as tools to convey an understanding of the past to lay and learned audiences, providing both with vivid conceptions of what they could never experience directly. In modern practice these images can also aid researchers in critically evaluating the limits of their knowledge, bringing them face to face with deficiencies in theories and gaps in the evidential bases of their reconstructions. Artists’ conceptions of astrophysical phenomena involve exactly the same goals, and similar general methods.

This paper explores the challenges of reconstruction drawing through a recent graphic recreation of the first recorded astronomical observation with a telescope in “Canada.”

Historically speaking...

Many of us, when reading of an episode from the history of astronomy—an important observation, a vivid detail from an astronomer’s life, or a description of a now vanished observatory—form a mental image from the text, as if the past of this most visual of sciences cannot be conceived without recourse to our visual imaginations.

Visual reconstructions of the past have long been used in astronomical museum and planetarium displays to further what we would now call education and public outreach. They can also be found in astronomical publications aimed at audiences ranging from the popular to the learned, and as far back as the 17th century. In the 19th century and later, their use in astronomy followed general trends in museology and publishing. Since the 1920s they have been known as “reconstruction drawings” (*e.g.* Forestier 1920).

In a recent review of the use of reconstruction drawings in Roman archaeology, one author defines them thusly: “Reconstruction drawings of the past are produced for a variety of purposes and audiences...All have the same objective: to put flesh on the bare bones of the past by restoring—on paper, at least—what time has taken away...In whatever format they are presented, reconstruction drawings are designed to help the public understand how archaeological or historical sites appeared in the past; they are a graphic recreation of a particular time and place” (Greaney 2013, 31).

It is interesting to note that conceptual renderings of astrophysical phenomena broadly share the same goals and methods, if not artistic techniques, as archaeological and historical reconstruction drawings. There is, in fact, at least one instance in the popular press of the 1930s of a well-informed attempt to portray an aspect of the Martian surface being termed a “reconstruction drawing” (Rudaux 1931, 644).

Beyond the sphere of public education reconstruction drawings can also aid researchers in critically evaluating the limits of their knowledge, bringing them face to face with deficiencies in current theories, and gaps in the evidential bases of reconstructions. In a related manner they can also be used in conjunction with a critical variety of experimental archaeology to test various solutions to understanding and reconstructing technologies (Connolly & van Driel-Murray 1991; James 2015, 1190-1191).

Several aspects intrinsic to the nature of reconstruction drawings call for caution in their responsible use, however. Firstly, while the success of the form requires that considerable effort be expended on securing the factual and historical accuracy of what is drawn, the very nature of the practice may be wholly ahistorical for the period being “reconstructed,” that is, the goals and appearance of a reconstruction drawing may be wholly alien and incomprehensible to the people alive in the culture being represented. Just because an image and the explanation it embodies makes sense in our time does not mean that it will make sense to viewers of all times.

Secondly, restraint is important in designing reconstruction drawings, because images may be more disarming than words in their appeal to the senses, particularly for those viewers more used to reasoning with words than with images. Someone may be convinced of the rightness of an image through its aesthetic appeal, and thereby ready to accept its historical accuracy at face value, without subjecting the drawing to the critical analysis which would be accorded a verbal statement. A reconstruction drawing based on good data, and purposefully designed to work on the historical imagination, is a powerful instrument. It presents a particular image of the past before the mind’s eye, an image that can become the dominant filter through which that past is seen coming into being in the present. This can directly or indirectly affect subsequent data selection and evaluation, interpretation of sources, and the formation of theories.



Figure 1 — Frontispiece from Kepler's *Rudolphine Tables* (1627). Public Domain, Google Arts and Culture.

The point of origin for “modern” reconstruction drawings is often placed vaguely in the mid-Victorian period, with a first efflorescence in the final years of the 19th and beginning of the 20th centuries, without too much consideration of the possibility of other antecedents (e.g. Greaney 2013, 32-33). The fullest treatment of origins to date (at least in English) occurs in Hodgson's thesis, in which he attempts to anchor the start in the 15th-century rise of history painting (2004). This is a reasonable argument, but the origin of reconstruction drawings is probably multiplex, including as well genre painting (with its attention to the material details of everyday life, and in some cases details of specialist technologies), and depictions of saints, mythological figures, and personifications (with their personal identifying attributes). The gradual development of the modern reconstruction drawing as reflected in the iconography of the learned at work—including historicizing pictures of working “astronomers”—has been pretty much ignored. This may be related to the paucity of attention in the secondary literature paid to the rise and role of reconstruction drawings in the history of science. That silence can hardly be addressed here, but it's worth looking at a few precursor examples.

Kepler's famous frontispiece to the *Rudolphine Tables* (1627) is a symbolic tableau of the author's conception of the history of astronomy, relying on portraits as models when they were available, and iconographic tradition otherwise, but used to craft something quite new (Figure 1). The representative figures range from an unnamed Chaldean (Babylonian) observer to modern astronomers Copernicus, Tycho Brahe, and Kepler himself (shown discreetly on a panel in the base; Gattei 2009; Jardine *et al.* 2014; Leedham-Green *et al.* 2014). An effort was made to particularize the contexts of work and achievement of the astronomers through the use of what Kepler thought were culturally appropriate material signifiers. Hence the astronomers are provisioned with symbolic instruments of their respective periods (e.g. the Chaldean uses the spacing of the features of his hand as an astrometric instrument, while Tycho appears with an up-to-date research quadrant and sextant for the same purpose), the columns assigned to each astronomer's sphere follow a typological progression of increasing decorative elaboration the closer they come to Kepler's lifetime (e.g. the Chaldean is assigned a barely dressed tree, whereas Tycho enjoys the support of the Corinthian order to lean on), and the astronomers appear in vestments fitting their respective places and times (Copernicus is dressed as a learned man of the first half of the 16th century, and Tycho as a nobleman of his and Kepler's period, whereas the Chaldean, Hipparchus, and Ptolemy are dressed to indicate they are from other places, and possibly other times).

This early 17th-century attempt to portray the astronomers with culturally correct instruments, historically progressing architectural supports, and culturally differentiated dress can be seen as a harbinger to the present requirements for precise fitness to time and place of the material objects in modern reconstruction drawings.

The frontispiece to the *Rudolphine Tables* was an expensive component in an expensive book, and was exceptional in many ways.

What of Canadian reconstruction drawings of notable “Canadian” astronomers, events, and past facilities? It would appear that few were ever executed for display, or publication. The earliest I know of, and the most widely disseminated due to their use in long-lived school texts, were produced by the prolific C.W. Jefferys (1869–1951; www.cwjefferys.ca). Jefferys became very influential in Canadian heritage circles, and, as historical consultant, his artifact and architectural drawings influenced as important a project as the recreation of the Sieur de Mons' Habitation at Port Royal (1605–1613) in 1939–1941. Over recent decades, some have wished to see greater recognition for Jefferys in the history of Canadian art. Whatever the merits of that effort, it cannot be said that Jefferys was particularly inspired when it came to handling science when it impinged upon his historical scenes. He was occasionally betrayed by the limitations of his technique, but more serious was his lack of control of the available sources.¹

Probably the best of his attempts to depict heritage minutes of colonial astronomy can be found in his drawings of Champlain shooting the Sun with his mariner's astrolabe (Figure 2), and David Thompson doing the same with his sextant. In the image of Champlain, Jefferys did show the instrument in the correct orientation, unlike the upside-down astrolabe in Champlain's hand in Hamilton MacCarthy's 1915 sculptural representation of him in Nepean Park in Ottawa. Jefferys ought, however, to have consulted one of the astronomers at his institution, the University of Toronto, who could have directed him to a 16th-century source such as Pedro de Medina's *Regimento de Navegacion* (1552) which would have illustrated the actual (safe) method of using the instrument (Waters 1966, 12, figure 1).

Even less felicitous is his illustration of the cross-staff and its use (Figure 3). The instrument Jefferys depicts looks more like a slight toy compared to the surviving examples (e.g. Greenwich, National Maritime Museum, Caird Collection, NAV0505, Thomas Tutell, ivory cross-staff, ca. 1700, London; de Hilster 2018, 160, 196–206). And the one-handed manner in which he has his figure support the instrument in observation does not inspire confidence, particularly in light of surviving 16th- and 17th-century images of the instrument in use.

In the final analysis, Jeffery's attempts at reconstruction drawings of early modern instruments and their use did nothing to advance the public understanding of the historical craft of practical astronomy in the first half of the 20th century. Quite the opposite, in fact.

The first recorded astronomical observation by means of a telescope in “Canada”

Jefferys did illustrate the Jesuits' mission settlement at Sainte-Marie among the Hurons, and the Jesuit martyrs, but steered clear of portraying any of their scientific work. Had he done so, he would have had the opportunity to depict the earliest known use of a telescope for an astronomical observation in what is now Canada. And, fittingly, the astronomer, Fr. Francesco-Giuseppe Bressani, SJ (1612–1672), was remarkable in his own right (Tessier, Bressani; Broughton 1981, 190, 192, 194–195—this classic paper is the starting point for any discussion of Bressani's astronomical work in Canada).

Fr. Bressani produced an interesting account of the missions in his day, including his own capture, torture, and disfigurement at the hands of the Iroquois (he lost most of his fingers), and a narrative of the martyrdom of his confreres, along with valuable ethnographic and geophysical observations (Bressani 1653). This activity also led to the production of an important early map, the *Novae Franciae Accurata Delineatio 1657* (conveniently reproduced in Anatrini 2018, 329). A copy of the map that surfaced in the early years of this millennium



Figure 2 — C.W. Jefferys, “Champlain with Astrolabe on the West Bank of the Ottawa River, 1613.” Library and Archives Canada, Acc. No. 1972-26-64.

was found to contain a unique printed dedication in which Bressani reveals how dedicated he was to active scientific endeavour:

Other maps of New France have appeared, but none with their true meridians, and parallels correct with the lands around the Mediterranean. Signor Champlain was a man but little intent on travel, and then only when he could slip away, without instruments, and the

time necessary for observations at night. The present author [Bressani] has travelled for ten years with compass and quadrant in hand, and observed various eclipses, with exactitude as to minutes and seconds, which when compared to those made at the same time by the most learned and very accurate



Figure 3 — A navigator using a cross-staff, from Jefferys and McLean 1942, 151.

Father Riccioli [1598–1671, author of the *Almagestum novum* of 1651] of the Company of Jesus observing in Bologna, were welcomed by the first rank of European astronomers, and ascertained to be beyond reproach (Antarini 2018, 341).²

That Bressani’s report of earned respect from Europe’s astronomical elite was not idle boasting is borne out by their printed treatment of his observations of the total lunar eclipse of 1646 January 30–31 (Espenak, Total Lunar Eclipse of 1646 Jan 31).

Riccioli reports that:

Eclipse of the Moon [in the year 1646]...on the 31st day of January...But in Canada, at the altitude of the pole 44 degrees, 20 minutes, Father Bressani observed it very diligently, and sent the observation to Father Athanasius Kircher [1602–1680], from whom I received it; he said, therefore, that he was there on the 30th day of January, and the beginning of the most tenuous encroachment of the shadow at the 10th hour and 25th minute after midday, the true beginning was seen with a telescope at the 10th hour and 44th minute, then nearly 6 digits were obscured at 11 hours and 12 minutes, and total immersion happened at the 11th hour and 41 minutes, and the rest was impeded by cloud cover (Riccioli 1651, 384).³

Kircher was one of the outstanding polymaths of the age, and Bressani couldn’t have chosen a more distinguished “astronomical telegram” service (Fletcher 2011).

Pierre Gassendi’s report of Bressani’s eclipse observation, besides its praise of the observer, is close in its essentials to Riccioli’s, except for its most valuable and tantalizing addition of a detail about the instrumental:

I received letters from the middle of the region of North America of the Hurons, from the house of the Society of Jesus, and the place called Saint Mary, sent by the excellent Bressani, mention of whom was made earlier, in which he reported that he had observed with an exceptional [*eximio*] telescope, the most delicate beginning of the darkening at 10 hours and 25 minutes, before the middle of the night; the perceptible darkening was at 10 hours, and 30 minutes. The beginning of the eclipse was at 10 hours and 45 minutes. Nearly six digits were eclipsed at 11 hours and 12 minutes. The totality of darkening was at 11 hours and 44 minutes. The rest was frustrated by clouds; unless that at two hours and 25 minutes after the middle of the night the Moon, presenting itself to view, exhibited no trace of obscuration (Gassendi 1658, 458).⁴

Cloud cover has remained a problem for observers in much of present-day Ontario, but it is the descriptor of the telescope

that is significant—the first telescope we know was used astronomically in Canada was an *exceptional* instrument. It is unfortunate that Bressani and his colleagues didn’t characterize it further, and more unfortunate still that it doesn’t survive. A few of the questions we’d like answers to are, “Who made it? How did Bressani acquire it? What was its focal length, and aperture? How did Bressani have it mounted?”

Not surprisingly, many of Bressani’s observations also made it into the great Enlightenment compendium of 17th-century astronomical observations compiled by Fr. Alexandre-Guy Pingré and published as the *Annales célestes du dix-septième siècle* (1901).⁵

A better candidate for a reconstruction drawing than the first known astronomical use of a telescope in “Canada” would be hard to find, particularly in light of the fact that the RASC is in the process of building a museum devoted to the story of astronomical optics in Canada.

The graphical challenge

Difficulties attend most attempts at reconstruction drawings, the most significant of which are attributable to the poor or variable survival of relevant historical data. Reconstructing graphically the first known astronomical use of a telescope in “Canada” is no exception (Figure 4).

In this case the chief hurdles to cross are:

1. the lack of surviving authentic images of Fr. Bressani (similar to the case for Samuel de Champlain);
2. the want of knowledge as to the exact, or even approximate, site of his observing station at Sainte-Marie among the Hurons;
3. the absence of nearly all information about his telescope, other than that it was “exceptional”;
4. the silence about his technologies for timing the event “accurately,” and making a record of his observations.

Examining how these challenges were met will provide readers with some insight into the process of creating a reconstruction drawing.

For 1, recourse was had to Jesuit tradition, namely the iconographic tradition of the order. While there are no surviving images of Bressani, there are many of the founder of the order. As Loyola naturally became a model for the life of his confreres (de Castro Valdés 2014, 73), it seemed fitting to use Loyolan iconography as a model for depicting Bressani. For his dress, the imagery of other Jesuits was used as a model, such as the Francesco Villamena portrait of Christoph Clavius (1606; Portrait of Cardinal⁶ Christopher Clavius 1606), and the image of Christoph Scheiner and his assistant at the bottom of the engraving of solar observing spaces in *Rosa Ursina* of 1630 (Scheiner, Christoph).



Figure 4 — R.A. Rosenfeld, reconstruction drawing of Fr. Francesco-Giuseppe Bressani, SJ, making the first recorded astronomical observation by means of a telescope in “Canada,” of the full lunar eclipse of 1646 January 30–31, at Sainte-Marie among the Hurons. Reproduced courtesy of the *Specula astronomica minima*.

Regarding 2, the decision was made to place Bressani’s observing station within the present recreation of the 17th-century settlement of Sainte-Marie among the Hurons, in the north court of the “European Compound” facing north, with a view to a version of the present reconstructed cookhouse across the courtyard to the west. Feeding the eclipse circumstances into Alexander E. Zavalishin’s StarCalc 5.73 for that geographic location indicated that there would be no difficulty observing the eclipse over the palisades from that location.

For 3, surviving smaller telescopes from the second half of the 17th-century provided models—few if any instruments from as early as the 1640s seem identifiable in collections (e.g. Van Helden 1999, 40–42 [2552 Divini], 52–53 [2556, Campani]; Louwman & Zuidervart 2013, 85–86 [60–61, Campani]). Images of telescopes from the first half of that century (such as the engraving of Scheiner at work cited above, and the instruments in Hevelius’s *Selenographia* of 1647) indicate that, as far as outward appearance is concerned, a certain conservatism ran through much of the century. Instruments from the 1660s–1670s can probably model the appearance of what Bressani could have used.

For mounting the telescope, the detailed engravings of Hevelius proved useful. Some viewers may recognize that the mount in the reconstruction drawing is based on that illustrated in the *Selenographia* (1647, Figure V).

As to 4, clocks could have been used, but that technology was still specialized, and expensive in the 1640s. If Bressani used a clock, he could have had a confrere watch it and shout out timings during crucial stages of the eclipse, as he could have had a confrere enter his observations by dictation in a logbook of some sort. For the reconstruction, it was elected not to show these stages, allowing viewers to imagine them happening nearby, but out of the frame! It is a bit of a cheat.

The lamp would only be necessary if illumination were needed for reading a timepiece or recording the observation. Seventeenth-century iconographic examples served as models (Gerard Dou, *The Hermit*).

Lessons

It can be said that it is only in the doing that we realize our mistakes, or choices that would have been better. Certainly a good case can be made for showing Bressani actually *observing* through the telescope, rather than standing by it and looking at the eclipse with his naked eye as here. If justification were needed one could cite the images of Jesuit astronomers in China in the 17th century, who appear with their astronomical instruments (as attributes), but not using them. That leads immediately to the question, “should a modern reconstruction drawing be echoing a 17th-century convention?” The instrument ought probably to be raised as well, unless one posits the observer sitting, but then where’s the chair? (I tend to stand when observing, so perhaps it’s an unconscious reflection of my observing habits.) And would someone observing in near northern Ontario in late January of 1646 have been out observing around midnight in only the standard Jesuit vestments, a carelessly crossed scarf, and a cloak?

More significant is what is not shown. I elected to omit Bressani's procedures for timing and recording his observations, which were certainly a crucial part of his observational protocol. I did so partly because they are unknowable, but I could have made a decision about them through analogy with other observers of his period. It was only when planning and executing the drawing that I became fully aware of that lack of knowledge, and the various questions it raised about the availability or not of advanced European technology so far from Europe, and possible ways of making up for its absence. An avenue for research was thus revealed via this reconstruction drawing.

As it stands, there is now a reconstruction drawing to make this event in the development of Canadian astronomy better known, when an observer far from the centres of European science produced data of note in Europe. After all, the first known astronomical use of a telescope in Canada is worth celebrating. ✱

Acknowledgements

This research has made use of NASA's Astrophysics Data System.

References

Manuscripts, Books, and Articles

- Anatrini, L. (2018). Mediators, Scientists and Informants Military and Ecclesiastical Between Scientific Research, Mnemotechnic Tradition and Evangelical Mission: the Role of Francesco Giuseppe Bressani S.J. in the History of Canadian Cartography. In (Ed.) D'Angelo, F., *The Scientific Dialogue Linking America, Asia and Europe Between the 12th and the 20th Century. Theories and Techniques Travelling in Space and Time*, Collection Curatele, 1 (pp. 324–352). Naples: Associazione culturale Viaggiatori
- Bessani, F.-G. (1653). *Breve relatione d'alcune missioni de' PP. della Compagnia di Giesù nella Nuova Francia*. Macerata: Per gli Heredi d'Agostino Grifei
- Binkley, L.J. (2011). Absences, Bias, and New Identities: the Representation of Aboriginal Peoples in Ontario Textbooks and Curricula 1988–1999. M.A. thesis, Queen's University
- Broughton, P. (1981). Astronomy in Seventeenth-Century Canada. *JRASC* 75, 4, 175–208
- Cardinal, L. (2009). Bressani: "Io dedico la nuova Francia... I dedicate New France... Franc.Gius. Bressano... Bologna 11th January 1657." Analysis of a Recently Identified Copy of Father Francesco Giuseppe Bressani's Map Including Dedication, Authorship, Place and Date of Printing, Notes. *The Portolan: The Journal of the Washington Map Society* 76, 33–42
- Connolly, P., & van Driel-Murray, C. (1991). The Roman Cavalry Saddle. *Britannia* 22, 33–50
- de Castro Valdés, J.G. (2014). Ignatius of Loyola and His First Companions. In (Ed.) Maryks, R.A., *A Companion to Ignatius of Loyola Life, Writings, Spirituality, Influence*, Brill's Companions to the Christian Tradition, 52 (pp. 66–83). Leiden Boston: Brill
- De Hilster, N. (2018). *Navigation on Wood. Wooden Navigational Instruments 1590–1731: An Analysis of Early Modern Western Instruments for Celestial Navigation, Their Origins, Mathematical Concepts and Accuracies*. Castricum: Nicolàs de Hilster
- Fletcher, J. (2011). *A Study of the Life and Works of Athanasius Kircher, "Germanus incredibilis": with a Selection of his Unpublished Correspondence and an Annotated Translation of his Autobiography*. (Ed.)

- Fletcher, E., Aries Book Series: Texts and Studies in Western Esotericism, 12. Leiden–Boston: Brill
- Forestier, A. (1920). Neolithic Man as Wrestler: A Rock-Painting "Vivified." *The Illustrated London News* (May 29) 156, 4232, 923
- Gassendi, P. (1658). *Astronomia...*, IV. Lyons: Laurent Anisson & Jean Baptiste Devenet
- Gattei, S. (2009). The Engraved Frontispiece of Kepler's *Tabulae Rudolphinae* (1627): A Preliminary Study. *Nuncius* 24, 2, 341–365
- Greaney, S. (2013). Reconstruction Drawings: Illustrating the Evidence. In (Eds.) Mills, N., *Presenting the Romans: Interpreting the Frontiers of the Roman Empire World Heritage Site* (pp. 31–39). Woodbridge–Rochester, NY: The Boydell Press
- Hevelius, J. (1647). *Selenographia...* Danzig: the author
- Hodgson, J. (2004). An Analysis of the History, Development, Motivations and Current Practice of Reconstruction Illustration, with Recommendations for its Future Development. Ph. D. thesis, Bournemouth University
- James, S. (2015). 'Visual Competence' in Archaeology: a Problem Hiding in Plain Sight. *Antiquity* 89, 347, 1189–1202
- Jardine, N., Leedham-Green, E., & Lewis, C., (2014). Johann Baptist Hebenstreit's Idyll on the Temple of Urania, the Frontispiece Image of Kepler's Rudolphine Tables, Part 1: Context and Significance. *Journal for the History of Astronomy*, 45, 1, 1–19
- Jefferys, C.W., & McLean, T.W. (1942). *The Picture Gallery of Canadian History. I: Beginning to 1763*. Toronto: The Ryerson Press
- Leedham-Green, E., Jardine, N., Lewis, C., & Fay, I. (2014). Johann Baptist Hebenstreit's Idyll on the Temple of Urania, the Frontispiece Image of Kepler's Rudolphine Tables, Part 2: Annotated Translation. *Journal for the History of Astronomy*, 45, 1, 21–34
- Louwman, P.J.K., & Zuidervaart, H.J. (2013). *A Certain Instrument for Seeing Far: Four Centuries of Styling the Telescope Illustrated by A Selection of Treasures from the Louwman Collection of Historic Telescopes*. Wassenaar: Louwman Collection of Historic Telescopes
- Pingré, A.-G. (1901). *Annales célestes du dix-septième siècle*. (Ed.) Bigourdan, G. Paris: Gauthier-Villars
- Riccioli, G. (1651). *Almagestum Novum...*, I. Bologna: Haeredes Victorij Benatij
- Rudaux, L. (1931). An Explorer of Mars: His Impressions. *The Illustrated London News* (April 18) 178, 4800, 642–644
- Van Helden, A. (1999). *Catalogue of Early Telescopes, Istituto e museo di storia della scienza Firenze*, Cataloghi di raccolte scientifiche 4. Florence: IMSS
- Waters, D. (1966). *The Sea or Mariner's Astrolabe*, Agrupamento de estudos de cartografia antiga, 15. Coimbra: Junta de investigações do ultramar

Websites

- Albert Tessier, Bessani, François-Joseph, *Dictionary of Canadian Biography* www.biographi.ca/en/bio/bressani_francois_joseph_1E.html (consulted 2019 December 20)
- C.W. Jefferys www.cwjfjfferys.ca (consulted 2020 February 13)
- Fred Espenak, Total Lunar Eclipse of 1646 Jan 31, *EclipseWise.com* www.eclipsewise.com/lunar/LEprime/1601-1700/LE1646Jan31Tprime.html (consulted 2020 February 16)
- Gerard Dou, The Hermit, *National Gallery of Art* www.nga.gov/features/slideshows/gerrit-dou.html#slide_12 (consulted 2020 February 16)
- Portrait of Cardinal Christopher Clavius 1606, *The Met* 150 www.metmuseum.org/art/collection/search/342372 (consulted 2020 February 16)
- Scheiner, Christoph. Rosa Ursina siue Sol. 1630. Folding plate opposite page 151, *Linda Hall Library* lhdigital.lindahall.org/cdm/ref/collection/cosmology/id/84 (consulted 2020 February 16)

Endnotes

- 1 It has to be noted here that the particular colonial stance of Jefferys's reconstruction drawings will now strike many viewers

as jarring, and offensive. First Nations people appear too often in them as savages, or at least, as childishly overwhelmed by European superiority, often to the point of graphic caricature. Times have changed, but he was preceded by Paul Kane, and was an exact contemporary of Edward S. Curtis, who portrayed First Nations people as people through the mist of colonialism, rather than as Jeffery's cartoon caricatures. Binkley 2011 explores some of these themes in relation to Jefferys.

- 2 *Sono uscite altre carte della nuoua Francia, ma nessuna co' suoi veri meridiani, e parallelli ne co' paesi Mediterranei giusti. Il Sig. Champelin huomo intendente ne caminò poca parte, & alla sfuggita, senza istromenti, e temp neccessario per le denute osseruationi. L'Autore di que ita vi hà passato da dicci anni con la bussola, e quadrante in mano, & osseruando varie Ecclissi, con esutezza di minuti, e secondi, che conferite con quelle, ch' allo stesso tempo il dottissimo, & accuratissimo P. Riccioli della Compagnia di Giesù osseruò in Bologna, e riceuè da' primi Astronomi di Europa, si è accertato di non essersi male apposto.* The translation presented above is different from that offered by Antarini. All the translations in this paper are by the present author. Unfortunately, I have been unable to consult Cardinal 2009, the discovery paper.
- 3 *At Canadae in altitudine Poli. Gr.44.20'. Obseruauit eam P. Bressianus per diligerter, scripsitq[ue] obseruationem ad P. Athanasium Kircherum, à quo eam accepi; ait itaq[ue] ibi fuisse diem 30.*

Ianuarij, & initium tenuissimae inumbrationis hor.10.25'. post merid. initiu[m] verum Telescopia visum fuisse hor.10.44'. digitos iam 6. ferè obscuratos hor.11.12'. totalem immersionem hor.11.41'. reliqua nubibus impedita.

- 4 *Litteras accepi è media Huronum Septentrionalis Americae regione, ac hospitio Patrum Societatis IESV, locoque Sancta Maria dicto datas ab optimo Bressano, cuius iam antè est facta mentio. Quibus perscribit vsum se eximio Telescopio, obseruasse. Initium unumbrationis leuissimum hor.10 min.25. ante mediam noctem, sensibiliorem unumbrationem hor.10.min.30. Initium Eclipseos hor.10.min.45. Digitos Eclipseos ferè sex hor.11.min.12. Totalem obscurationem hor.11.min.44. Caetera nubibus praepra: nisi quòd hor.2. min.25. post mediam noctem praebens se in conspectum Luna nullum vestigiuationis habuit.*
- 5 The 1646 eclipse observation is at Pingré 1901, 180.
- 6 The Metropolitan Museum webpage is incorrect; Clavius was never raised to the cardinalate.

John Percy's Universe

Assassin: The Survey

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

Astronomers have been surveying the starry sky for millennia. Think of Hipparcos's star catalogue, the giant star globe at the Beijing Ancient Observatory, Bayer's *Uranometria*, the never-completed *Carte du Ciel*, and, in the middle of the 20th century, the National Geographic *Palomar Observatory Sky Survey*. Wikipedia lists about 50 astronomical maps, catalogues, and surveys, starting with a Babylonian star catalogue c. 1800 BCE.

These were snapshots of the sky. Movies of large portions of the sky, aiming to reveal objects' motions and variability, required sensitive, accurate, wide-field digital cameras and powerful computers. These came later in the 20th century and included projects such as the original All-Sky Automated Survey (ASAS: Pojmański 1997) as well as surveys of smaller areas of the sky, such as the MACHO project (Cook *et al.* 1991) and the Optical Gravitational Lensing Experiment (OGLE: Udalski *et al.* 1992). MACHO and OGLE were needle-in-a-haystack projects, specifically designed to detect rare gravitational microlensing events from "massive compact halo objects" (MACHOs) in our galaxy—black holes, neutron

stars, white dwarfs, and even exoplanets. These surveys have revolutionized the study of variable stars in general by providing thousands of long-term light curves of many other types of variable stars as a by-product.

For decades, my students and I have been mining the century-long archive of (mostly) visual observations of thousands of variable stars maintained by the American Association of Variable Star Observers (AAVSO: www.aavso.org). It's the best tool for studying very long-term variability of stars. But it's not perfect; visual observations have limited accuracy, and various systematic errors, and are not always as systematic and sustained and dense as we would like.

I've been aware, for many years, of the large, automated surveys of star brightness mentioned above, but have not been motivated to use them. Inspired by a colloquium at the University of Toronto by Chris Kochanek (Ohio State University), I was introduced to an extension of ASAS—the All-Sky Automated Survey for Supernovae (ASAS-SN); Kochanek is Project Director.

The ASAS-SN Survey

ASAS-SN (colloquially pronounced "assassin") surveys the entire visible sky each night, down to about 18th magnitude. It is powered by a network of 24 telescopes, distributed around the globe. It began with a set of four robotic 14-cm Nikon telephoto f400/2.8 telescopes, with 2048² ProLine CCD

cameras with 8" pixels, and it expanded from there. Though designed to look for supernovae and other transients (which it has done very successfully), it has also observed hundreds of thousands of other variable stars—666,502 as of January 2020—and has discovered 50,000 of them. Light curves and data on these stars can be freely accessed at asas-sn.osu.edu/variables. If there is a target that is not in the variable-star database, you can go to asas-sn.osu.edu and query all of the original images at the target position and, after a few minutes, see the light curve and download the data.

What My Students and I Have Done with ASAS-SN

Kochanek's talk reminded me that the ASAS-SN data were dense and accurate, largely unanalyzed, and therefore potentially useful for undergraduate student research projects, as well as for my own. I began by studying the small-amplitude pulsation of R CrB stars at maximum, since the pulsation may be responsible for triggering the mass ejections and spectacular fadings of these rare, bizarre stars (Percy 2019). This was a follow-up to an interesting project on these stars by my student Kevin Dembski (Percy and Dembski 2019).

We then turned to my main interest: pulsating red giants (PRGs). Undergraduate math major Lucas Fenaux carefully analyzed several dozen PRGs that had been automatically analyzed and classified by ASAS-SN, and he found that the majority of the automatic analyses and classifications were clearly incorrect and/or incomplete! Some periods were in error by factors of up to five! His results were presented at the 2019 RASC GA, and subsequently published in a refereed research journal (Percy and Fenaux 2019).

We are continuing our studies of PRGs using ASAS-SN data, studying complex stars with two different pulsation periods and/or that have mysterious "long secondary periods" of unknown nature and origin. We are also studying short-period Mira stars—the transition between long-period, large-amplitude Mira stars (like Mira itself) and their smaller-amplitude semiregular cousins. I'm also using ASAS-SN data to study about 100 "orphan" irregular PRGs in the AAVSO observing program that have sparse data and have never been adequately analyzed and classified.

This summer, my students and I will be moving in a different direction—using ASAS-SN data to determine rotational periods and their amplitudes in young stellar objects—primarily T Tauri stars.

ASAS-SN has identified dozens of these on the basis of their slow variability but has not measured rotation periods. It is this rotation that produces the sort of "activity" we observe on the Sun and other Sun-like stars—magnetic fields, starspots, flares, and hot coronas.

You Can Be a Data Miner

You may just want to be a "recreational light curve observer," go to the ASAS-SN variable-star database (asas-sn.osu.edu/variables) and look at the light curves of the 666,502 stars in the database to see what variable stars do. If the stars are periodic, then ASAS-SN also provides a phase curve.

On the other hand, you may want to be a "citizen scientist" and analyze or re-analyze ASAS-SN data. Most of the ASAS-SN variable-star data have been only partially analyzed at best, or not at all. As Percy and Fenaux (2019) have shown, the ASAS-SN automatic analyses and classifications are not always correct or complete, especially if the star varies on two or more time scales, as PRGs do, or is otherwise complex. There is much still to be done. And if you have a basic understanding of math, computing, data analysis, and variable stars (see Percy [2007] or the AAVSO website), there is much that *you* can do.

Start by downloading the ASAS-SN data that you want to analyze. You can find data on specific stars by entering the variable-star name or coordinates on the Sky Patrol input form asas-sn.osu.edu. Or you may want to find data on stars with specific characteristics. You can select candidate stars by variable-star type, period, amplitude, or mean magnitude. Avoid stars that are too bright or too faint; the optimal range is $V = 8$ to 16. Look at the light curve first. It will give you a sense of the time scale and amplitude and complexity of the variability. Also: the data may be ratty, or there may be spurious faint data points, arising from astrometric errors (Percy and Fenaux 2019, Figure 4). If you use VSTAR, there is a filter function (click on "view") that you can use to filter out these data points from the analysis.

For analysis, my students and I use the AAVSO VSTAR package (Benn 2013), which is freely available on the AAVSO website (www.aavso.org/vstar). It runs on Java. There is an excellent manual, and various tutorials and other resources. Read these and read Percy and Fenaux (2019) first; I have posted it on my website (1).

Convert your ASAS-SN data to a .txt file of Julian date and magnitude. Display and inspect the light curve. You will then want to look for periodicity, in which case you will use VSTAR's DC-DFT (date-compensated discrete Fourier transform) routine. Click on "analysis" and choose either the standard scan or a period range appropriate to the time scales in the data. Then a plot of amplitude versus frequency (1/period) will give you a sense of whether there are any periods that are significantly above the noise level. Warning: time-series analysis of complex stars is a "black art"! Play around with VSTAR to get used to it. Join the AAVSO!

As for possible projects: I do not have the space to list and discuss all of them, but you could:

- continue the work of Percy and Fenux (2019), who analyzed only a few dozen stars from among the thousands of PRGs in the database
- analyze stars that ASAS-SN has classified as non-periodic or irregular; I suspect that many of them have some degree of periodicity (Percy and Fenux 2019, Figure 6)
- search for light curves that are highly unusual, such as ASAS-SN-V J144304.69-753418.9 (Percy and Fenux 2019, Figure 9), or Figure 1 accompanying this column.

This figure shows the ASAS-SN light curve of HV 2112, a proposed Thorne-Żytkow object—a red giant that has absorbed a neutron star now residing in its core (Levesque *et al.* 2014).

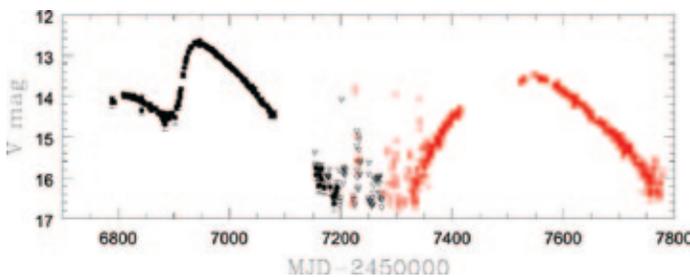


Figure 1 — The ASAS-SN light curve of the proposed Thorne-Zytkow object HV 2112 in the Small Magellanic Cloud (Levesque *et al.* 2014). Different colours are data from different cameras. Triangles are upper limits. Source: Kochanek *et al.* 2017.

Indeed, one way in which citizen scientists can contribute, in the era of massive surveys like ASAS-SN, is to find the “needles in the haystack”—the rare, unusual objects worthy of further study. This type of project will continue to be useful in the coming age of even larger surveys, such as the Large Synoptic Survey Telescope. ★

Acknowledgement

I thank the students who have worked with me on projects using ASAS-SN data: Kevin Dembski, Lucas Fenux, Patricia Golaszewska, and Anthony Mark Wallace. We are grateful to the ASAS-SN team for undertaking this remarkable project, and for making the data publicly available. We are also grateful to the AAVSO for developing VSTAR, and making it available in user-friendly form.

Endnotes

- 1 www.astro.utoronto.ca/~percy/percyfenux2019.pdf

References

- Cook, K.H. *et al.* (1991). A feasibility study for detection of gravitational microlensing by baryonic dark matter via CCD photometry, *Bull. Amer. Astron. Soc.*, 23, 952.
- Kochanek, C. *et al.* (2017). The All-Sky Automated Survey for Supernovae (ASAS-SN) light curve server V1.0, *Publ. Astron. Soc. Pacific*, 129, 104502.
- Levesque, E.M. *et al.* (2014). Discovery of a Thorne-Żytkow object candidate in the Small Magellanic Cloud, *MNRAS*, 443, L94.
- Percy, J.R. (2007). *Understanding Variable Stars*, Cambridge University Press.
- Percy, J.R. and Dembski, K. (2018). A Study of pulsation and fadings in some R Coronae Borealis (RCB) Stars, *JAASO*, 46, 127.
- Percy, J.R. and Fenux, L. (2019). Period analysis of All-Sky Automated Survey (ASAS-SN) data on pulsating red giants, *JAASO*, 47, 202.
- Percy, J.R. (2019). ASAS-SN observations of the pulsation of some RCB stars, arxiv.org/abs/1903.05166
- Pojmański, G. (1997). The All-Sky Automated Survey, *Acta Astronomica*, 47, 467.
- Udalski, A. *et al.* (1992). The Optical Gravitational Lensing Experiment, *Acta Astronomica*, 42, 253.

John Percy FRASC is Professor Emeritus, Astronomy & Astrophysics and Science Education, University of Toronto, and a former President (1978–1980) and Honorary President (2013–2018) of the RASC.

RASC Internet Resources



Like us on facebook



Follow us on Twitter @rasc

www.rasc.ca

Visit the RASC Web site

www.rasc.ca/discussion

Email Discussion Groups

www.rasc.ca/contact

Contact the Society Office

www.rasc.ca/news

RASC eNews

Dish on the Cosmos

King of The Radio Sky



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

Most people who own optical telescopes quickly turn to observing Jupiter since it's one of the brightest objects in the night sky.

When I was young and received a long-begged-for telescope for my birthday, the first thing I pointed it at was Jupiter. Seeing the Galilean moons and the resolved disk of the planet was incredibly exciting. The light that we see from the planet comes from the upper clouds in Jupiter's atmosphere reflecting the Sun's light back to us. Jupiter is big, relatively nearby, and highly reflective leading to it being bright. In radio wavelengths, Jupiter also shines brightly, but the light it is emitting comes from its own internal heat and magnetic field rather than the reflected sunlight. Recent observations of Jupiter have used the radio emission from the planet to study an unfolding storm in great detail, giving a glimpse down into the depths of the planet.

Jupiter played a prominent role in the history of radio astronomy because of its brightness. It was observed on early telescopes that were little more than telephone wires strung across fields. This sort of radio emission is long-wavelength and comes from the strong magnetic activity in the planet and surrounding region. Jupiter has a strong magnetic field because of its high mass. The self-gravity of the planet compresses its interior, which is mostly hydrogen and helium, into a dense enough state that hydrogen becomes a metallic fluid. It may be surprising, but this strange behaviour has been in front of anyone who has looked at a periodic table and seen hydrogen over on the left side with all the other metals. However, hydrogen only becomes a metal under the high pressures like those found in the interior of Jupiter. Jupiter is also rapidly spinning with a rotation period of 10 hours. The combination of fast rotation and a metallic core leads to strong magnetic

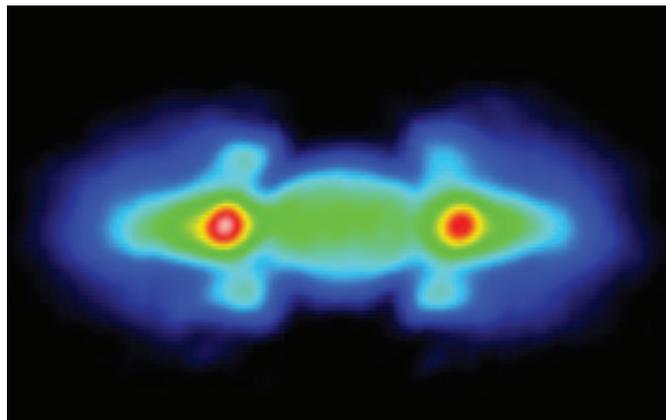


Figure 1 — Radio emission from the plasma torus in the equatorial orbital plane around Jupiter. This emission forms a strong radio source in the low-frequency radio sky. Image credit: Australia Telescope National Facility (A. Dulk, Y. Leblanc, R. Sault, and R. W. Hunstead)

fields. Charged particles trapped in these magnetic fields give off long-wavelength radio radiation, which is readily detectable even with the earliest telescopes. Figure 1 shows a map of Jupiter at relatively low frequencies (1 GHz) where the radiation from the magnetic effects is readily visible. The image shows the torus of plasma in orbit around the equator of the planet.

At higher radio frequencies, the radio emission of Jupiter comes from its own internal heat. This thermal emission comes from all hot, opaque objects. Because stars are hot, they give off thermal emission that is a high enough frequency to be seen as visible light. Since planets are cooler, their thermal emission is primarily visible in the infrared and radio wavelengths. Your own heat is what makes you visible in the infrared. Jupiter's surface is cooler, so its emission comes out at even lower frequencies, making it a good target for radio telescopes like the Atacama Large Millimetre/submillimetre Array (ALMA, relatively high frequencies) and the Very Large Array (VLA, lower frequencies). Figure 2 shows a map of Jupiter made recently with ALMA. The bright emission is from where Jupiter is relatively warm, which is where we are seeing through the colder cloud decks at the top of the atmosphere down to the warmer layers below.

Observations like these are really telling us about how the chemistry and the temperature of the atmosphere changes with depth. The chemical composition sets the opacity of the atmosphere, regulating how easily infrared and radio light moves through the gas. In peering into the planet with long-wavelength radiation, we see through the atmosphere until the point where the opacity of the material for that frequency of light gets large enough to block the light from below it. The brightness of the emission that we see depends on the temperature at the layer where the atmosphere becomes opaque. Radiation from lower levels of the atmosphere is trapped by the opacity and must diffuse upward until it

Is your address correct? Are you moving?

If you are planning to move, or your address is incorrect on the label of your Journal, please contact the office immediately. By changing your address in advance, you will continue to receive all issues of SkyNews and the Observer's Handbook.

(416) 924-7973 www.rasc.ca/contact

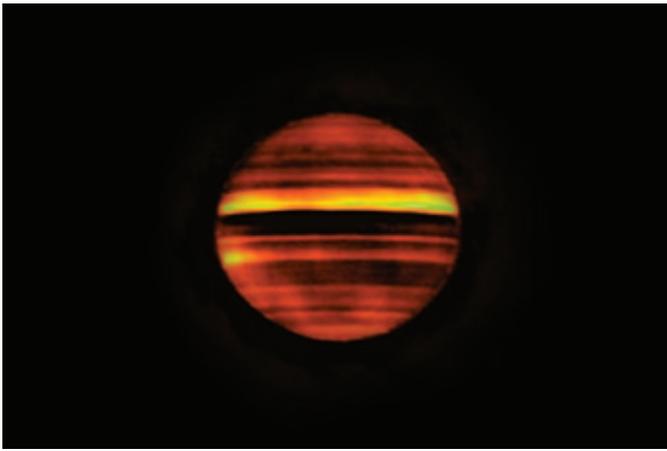


Figure 2 — Image of Jupiter in 100 GHz radiation traced by ALMA showing warm emission from the depths of the planet. The dark regions show where the atmosphere is opaque so the telescope only sees into the cooler outer layers. Image Credit: ALMA (ESO/NAOJ/NRAO), I. de Pater et al.; NRAO/AUI NSF, S. Dagnello

reaches this transition layer from transparent to opaque. This effect is also at the heart of the “greenhouse effect” on Earth. In changing the chemistry of Earth’s atmosphere by adding carbon dioxide and methane, we make it more opaque to infrared radiation, so infrared radiation builds up near the surface of Earth and slowly diffuses upward. The side effect of this radiation building up near the surface of the planet is that the surface layers get warmer, which is a driver for climate change.

We can see the contrast between what radio and optical observations are telling us in Figure 3, which shows an “unwrapped” view of Jupiter from ALMA and the *Hubble Space Telescope*. The most striking effect in these images is that the ALMA image appears bright where Hubble image is dark. This relationship tells us that the dark bands are made of chemical compounds that are less opaque than the light bands, allowing us to see deeper into the atmosphere to where the lower levels of clouds are warmer. The difference in depths is small; we only see 50 km further into the cloud deck in the ALMA observations compared to the visible.

The real scientific power in these data comes from two features that the images cannot convey. First, Jupiter is changing so these still images do not show how the planet is spinning and the storms on the surface of the planet are evolving with time. Second, the radio observations are taken at a wide range of different frequencies, analogous to different colours of radio light. The actual ALMA data, when combined with those from the VLA, make a rich radio-colour image of the planet. The brightness of the radio light at different colours provides a sensitive probe of the temperature and opacity (i.e. chemistry) of the atmosphere down into the cloud deck. Since this picture also changes with time, astronomers can see how the storms of Jupiter reshape the radio light emerging from the planet.

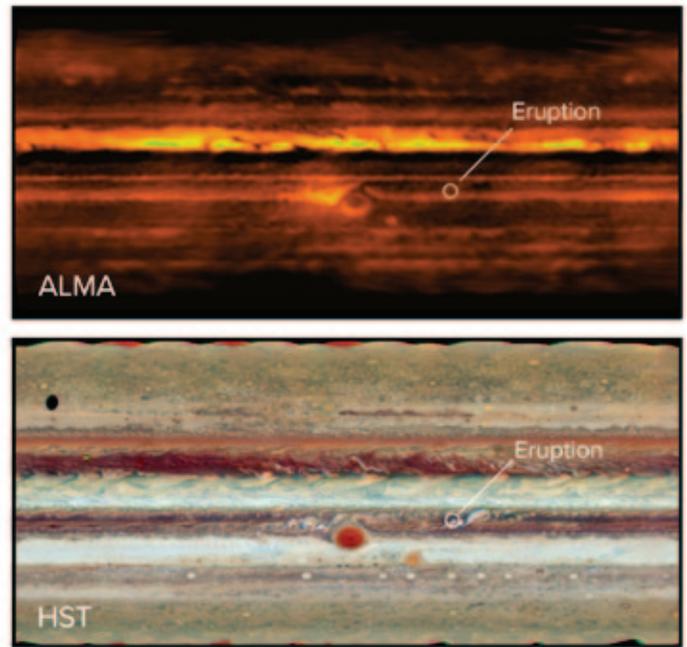


Figure 3 — Comparison of ALMA and Hubble Space Telescope imaging of Jupiter during an eruption event in 2017. The ALMA image is bright where the Hubble image is dark, showing these are regions where ALMA sees deeper into the atmosphere. The eruption feature highlighted is the beginning of a large-scale instability in Jupiter’s atmosphere. Image credit: Credit: ALMA (ESO/NAOJ/NRAO), I. de Pater et al.; NRAO/AUI NSF, S. Dagnello; NASA/Hubble

In Figure 3, a small feature is labelled “Eruption,” which was the focus on this particular study with Hubble, ALMA, and the VLA. In January 2017, an amateur astronomer first noticed an “outbreak” in Jupiter’s South Equatorial Belt. These outbreaks indicate the start of large-scale disruptions and changes to the storms in the atmosphere. With ALMA and the VLA, astronomers could finally see below the eruption plume to study what was driving the instability. They find that the eruptions are driven by a warm upwelling of ammonia gas, which condenses at the top of the plume into the white clouds seen in the HST images. The now “dry” cool gas then falls back down into the interior of the planet. This convective cycle follows the pattern of thunderstorm complexes here on Earth but scaled up to a huge size on Jupiter. These storms, when combined with Jupiter’s fast rotation and high winds, lead to the broad atmospheric instability across the planet. These insights just small parts of the mystery of Jupiter’s atmosphere, but these new radio views on the planet show how we can gain more insights by studying the planet across the electromagnetic spectrum. ★

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.

Celestial Review:

Algol at Minimum



by David Garner, Kitchener-Waterloo Centre
(dgarner@celestialreview.space)

I'm sure many of you have noted this entry in the *Observer's Handbook* section entitled *The Sky Month By Month*, or perhaps you have seen it in the magazine *Sky & Telescope*. Observing the variable brightness of Algol can become a part of your regular night-sky checks just as easily as observing the Moon and the planets. At mid-northern latitudes, this star can be seen for many nights of the year, but best from late summer, throughout the winter and into spring. Algol is the second brightest star in the constellation Perseus, after Mirfak. It is a bit over 92 light-years away and has an apparent magnitude that varies between 2.1 and 3.4.

Algol is relatively easy to find because it is located in the constellation Perseus, along the Milky Way between Cassiopeia and Auriga. Use Cassiopeia to star-hop to Mirfak, the brightest star in Perseus, then on to Algol the second brightest. The coordinates of Algol are: Right ascension $03^{\text{h}} 08^{\text{m}} 10^{\text{s}}$ and Declination $+40^{\circ} 57' 20''$.

Algol is a well-known eclipsing variable star and is the prototype for the class of stars known as Algol-type eclipsing variables. Algol is actually a triple-star system typically composed of Beta Persei Aa1, Aa2, and Ab. Beta Persei Aa1 is a B-class main-sequence star (B8V), Beta Persei Aa2 is an orange subgiant (K0IV) and Beta Persei Ab a dimmer A-class star (A7m).

Beta Persei Aa1 has an estimated mass 3.59 times our Sun and 2.88 times its diameter, resulting in as much as 98 times the Sun's visual luminosity. Beta Persei Aa1 is hotter, brighter, and bluer than Vega or Sirius. Beta Persei Aa2 is larger in size but less massive and cooler than Aa1.

Algol - Beta Persei - β Per

R.A. = $03^{\text{h}} 08^{\text{m}} 10^{\text{s}}$ Dec = $+40^{\text{d}} 57^{\text{m}} 20^{\text{s}}$ mag(v) $+2.1 \rightarrow +3.4$

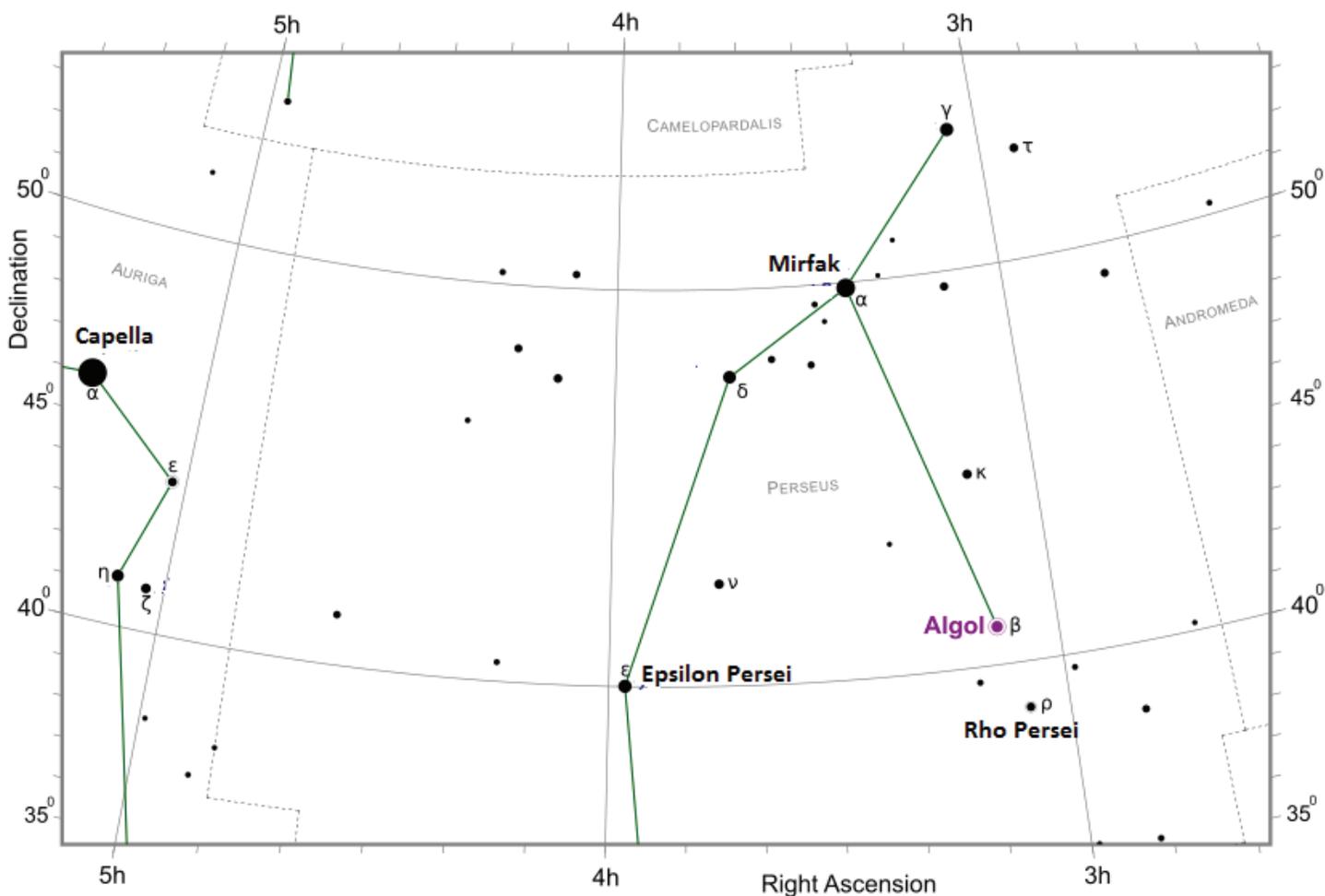


Figure 1 – Algol star chart.

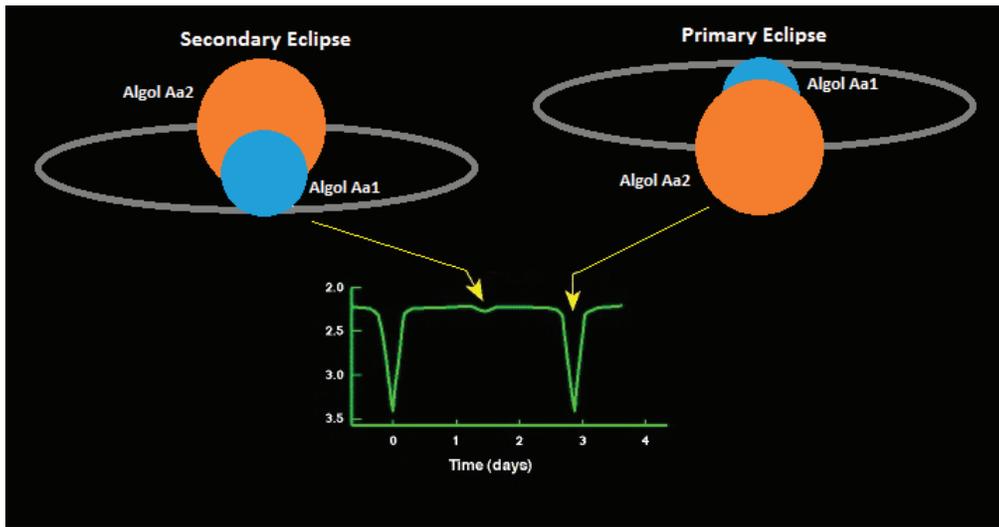


Figure 2 – Algol Eclipses.

Algol’s primary eclipses can be observed without a telescope, just with the naked eye. The star’s brightness can sometimes be seen falling and rising on the same night. Two nearby stars, Epsilon Persei (mag. 2.88)

and Rho Persei (mag 3.39) can be used for reference when watching the progress of the eclipses.

The third star in the system Beta Persei Ab, is a magnitude-2.3 A-type star that is separated from the pair by a distance of 2.96 AU, taking nearly 681 days (1.86 years) to complete an orbit. In addition, the orbit is inclined by 83.98° from Earth’s line of sight.

The name Algol comes from the Arabic phrase “*raūs al-ghūl*,” meaning the “head of the ghoul” or “head of the demon,” a monster who had snakes instead of hair, that was so terrifying in appearance that merely looking at it would turn people to stone. So, if you dare, the next time you go out to check the sky, keep an eye on Algol! ★

The pair are separated by only 0.062 astronomical units (AU). Algol Aa1 and Algol Aa2 form an eclipsing binary because their orbital plane is within the line of sight to Earth. The hot luminous primary, Beta Persei Aa1, and the larger, but cooler and fainter, Beta Persei Aa2, regularly pass in front of each other, causing eclipses. The overall apparent magnitude of the system regularly dips from magnitude 2.1 down to magnitude 3.4 every 2.867 days (2 days, 20 hours, and 49 minutes) followed by a roughly 10-hour-long eclipse. The secondary eclipse when the brighter primary star occults the fainter secondary is very difficult to detect, requiring advanced instrumentation. For visual observation of the primary eclipse, just keep adding 2 days, 20 hours, 49 minutes to each date and time to go from one primary eclipse to the next one.

These are the dates of Algol’s minima for March and April as published in the *Observer’s Handbook* (see section *The Sky Month By Month*):

| March 2020 | | April 2020 | |
|------------|-----------|------------|-----------|
| Day | Time (UT) | Day | Time (UT) |
| 3 | 1:36 | 3 | 14:35 |
| 5 | 22:25 | 6 | 11:24 |
| 8 | 19:14 | 9 | 8:13 |
| 11 | 16:03 | 12 | 5:02 |
| 14 | 12:52 | 15 | 1:51 |
| 17 | 9:41 | 17 | 22:40 |
| 20 | 6:30 | 20 | 19:29 |
| 23 | 3:19 | 23 | 16:18 |
| 26 | 0:08 | 26 | 13:07 |
| 28 | 20:57 | 29 | 9:56 |
| 31 | 17:46 | | |



Figure 3 – The Demon Star, Medusa.

Dave Garner teaches astronomy at Conestoga College in Kitchener, Ontario, and is the recipient of the 2017 President’s Award. He enjoys observing both deep-sky and Solar System objects, and especially trying to understand their inner workings.

Imager's Corner

CGX-L Review



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

As many of you know, I'm a big fan of masked stretching. Ever since Mike Unsold introduced the *Feature Mask Tool* in Images Plus, making these masks became quick and easy, just a simple mouse-click away.

Now, with *StarNet++* there is finally another tool for generating them that is easy, but not necessarily quick, for non-Images Plus users. The benefits of masked stretching are great star and background noise control, and while imparting the mask detail on the stretched image. The downside is that a lot of the colour is removed in the process, requiring sometimes tedious iterations of noise reduction and saturation boosting. In this edition, I'll demonstrate a nice layer technique to maintain colour when stretching your images.

The first step is a simple starless masked stretch. See Figure 1.

Keep the stretch gentle so as to not remove too much colour. The idea is just to get a starting point that has some detail and colour. Add a small saturation boost to bring the colour to the point where you are happy with it— call this image C.

The next step in the processing would be another masked stretch to further brighten the image, but this removes much of the colour in the image. See Figure 2.

From here you would normally reduce the noise a bit so that the saturation boost will not increase the chrominance noise. While this approach works, it results in a slight loss of detail because of the multiple iterations of noise reductions required. A better approach would be to apply the masked stretch in a way that doesn't lose as much colour in the first place. Layers to the rescue... See Figure 3.

Instead of simply applying the second masked stretch directly to the image, apply it and make a greyscale image of the result—call this image B. See Figure 4.

Next, make a greyscale version of the initial masked stretched image shown in Figure 1 and invert it to produce the image shown in Figure 5 and call it image A.

Now comes the layer magic, make a stack of the original masked stretched image (C), the second masked stretched greyscale image (B) and the original masked stretched greyscale image (A). The image order in the stack is C on the bottom, B in the middle and A on top. Set the blend mode of B to multiply and A to colour dodge to produce the layer stack shown in Figure 6.

Flattening the stack produces the final stretched colour image shown in Figure 6.

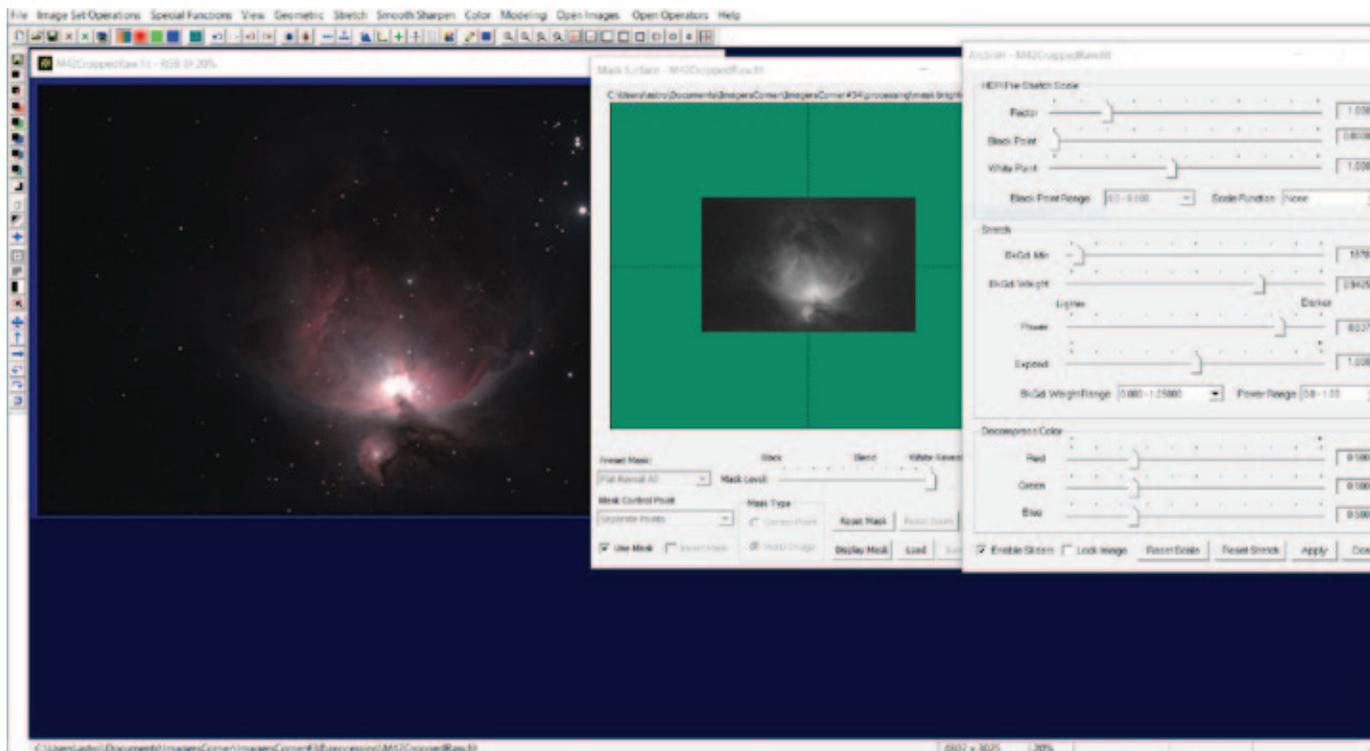


Figure 1 — Initial masked stretch

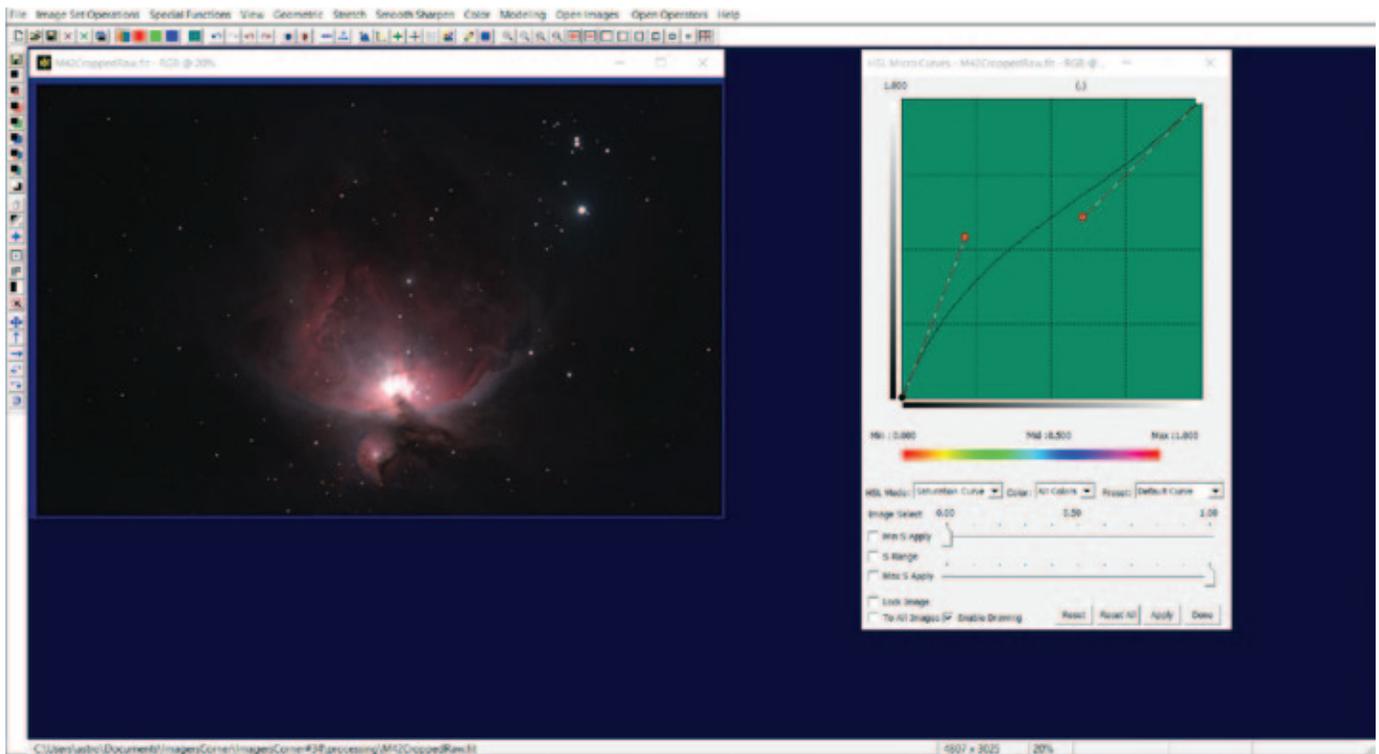


Figure 2 – Saturation boost. Concentrate on getting close to the final colour balance here (image C).

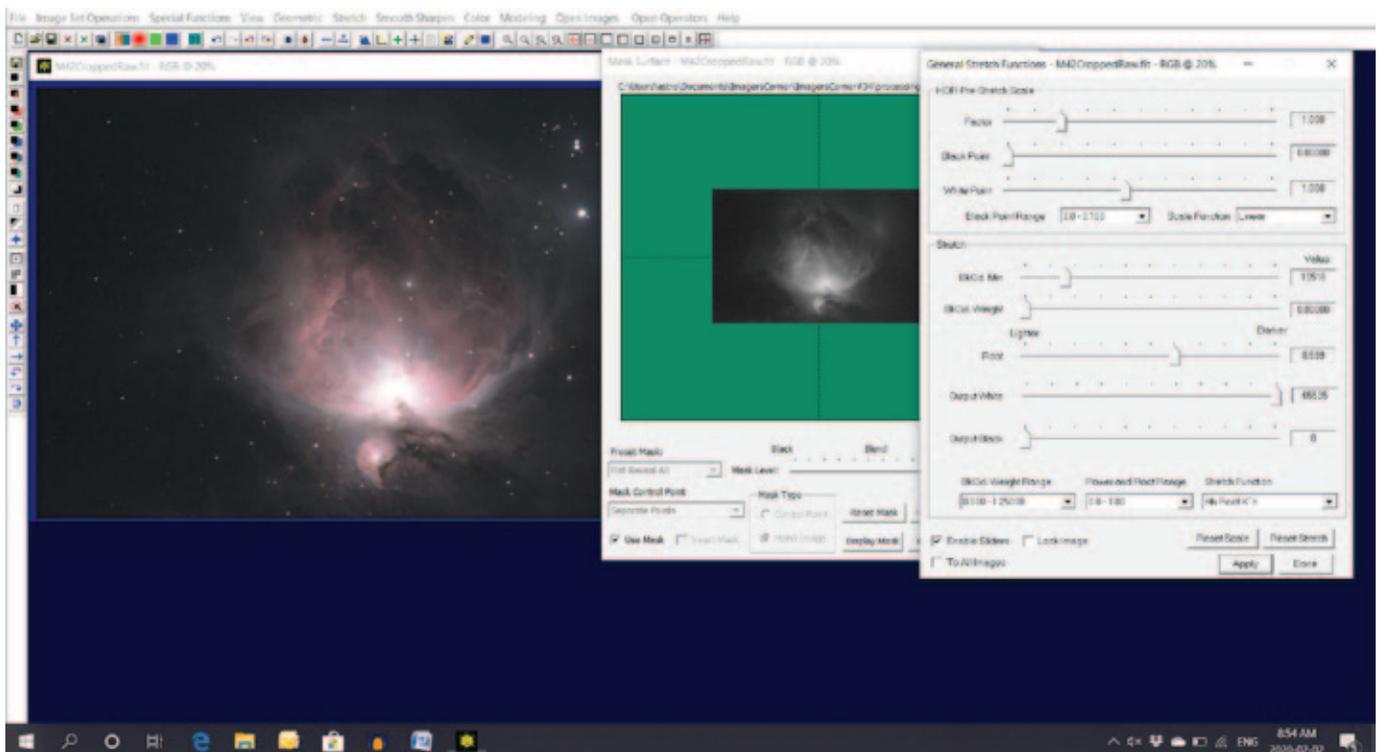


Figure 3 – Additional masked stretches bring out more detail at the expense of colour saturation.

RASC members receiving this *Journal* in electronic format are hereby granted permission to make a single paper copy for their personal use.

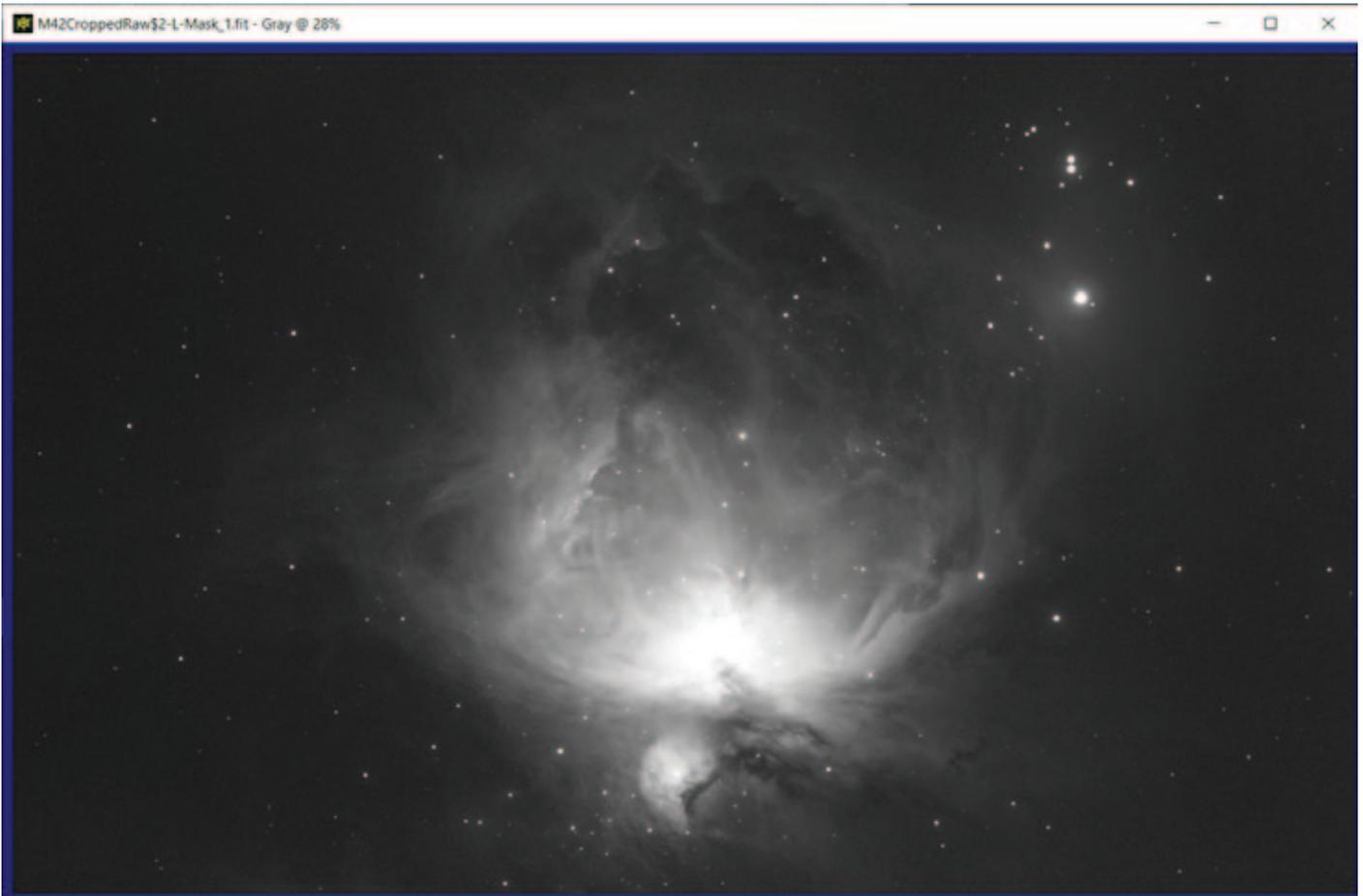


Figure 4 — Greyscale image made from the stretched image in Figure 3 (image B)

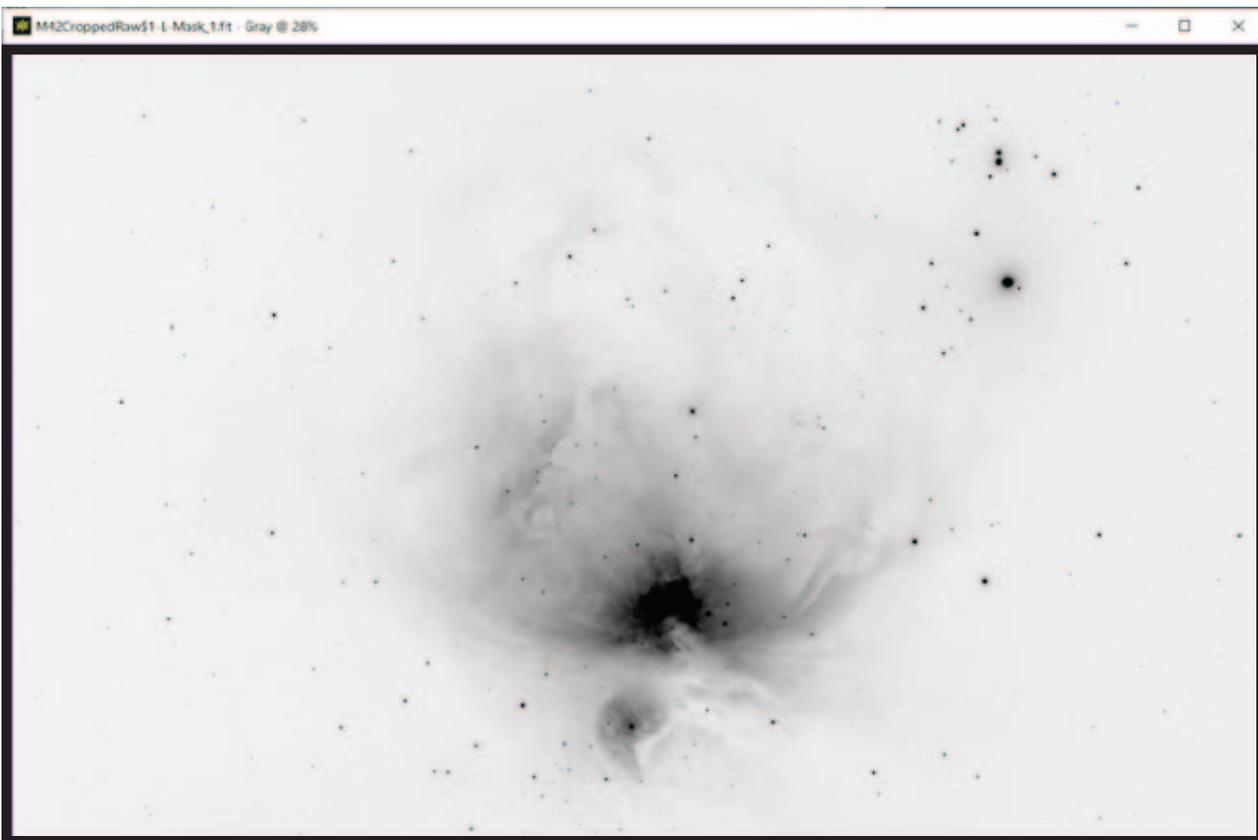


Figure 5 — Greyscale image made from the initial masked stretched version (image A)

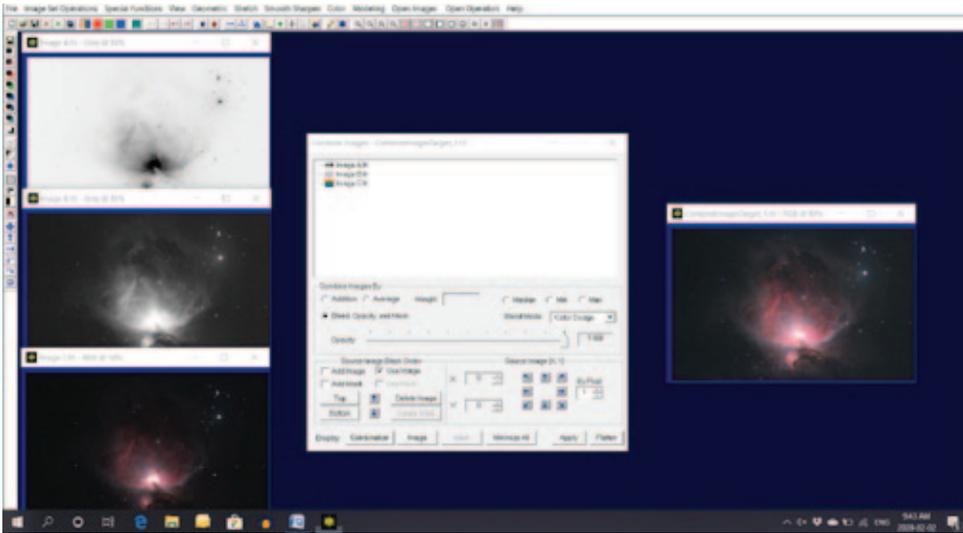


Figure 6 — Image stack and the final colour image.

This image has all the detail of the masked stretch shown in Figure 3, but without the colour loss or the excessive chrominance noise caused by boosting the saturation. Compare this layer approach to the more straight forward masked stretch in Figure 7.

The same technique can be used to preserve the colour using any stretch, whether masked or not, and is a great way of maintaining colour without excessive saturation boosts. This prevents the build up of chrominance noise and keeps the image detail, since you don't have to use multiple applications of noise reduction, blurring the image a bit each time. See Figure 8.



Figure 7 — Final stretched image

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

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



Figure 8 — Layered approach versus straight forward masked stretch

Observing

Hairy Springtime Observing with Coma Berenices

by Chris Beckett, *Unattached*
cabeckett@gmail.com

“On a line between Denebola and Arcturus, and somewhat nearer to the former, you will perceive a curious twinkling, as if gossamers spangled with dew-drops were entangled there.”

– Garrett P. Serviss

The Coma Berenices open star cluster, also catalogued as Melotte 111 (Mel 111) and Collinder 256, is arguably the best Northern Hemisphere open cluster that never made it into Messier’s Catalogue and among the three nearest clusters; only the Ursa Major moving group and the Hyades are closer.

The Coma Berenices open cluster’s 273 stars (Archinal & Hynes 2003) combine to make it one of the brightest open clusters, magnitude 1.8, while its size of 5 degrees places it among the largest, so big as to impede any confusion when viewed through the small field of Messier’s telescopes. Or, perhaps Messier simply decided it was too well known an object to be of any use for inclusion in a list meant to ferret out the comets from imposters ... or perhaps it didn’t meet with his odd sense of symmetry for selective cuts to his catalogue.

Back in 2017, Randall Rosenfeld and I penned our annual *Observers Handbook* feature constellation around this enigmatic region of sky. However, due to space constraints, some text and a sketch were left in the editor’s recycle bin. For those interested in the free download of that article please see the *Observers Handbook* Feature Constellation for 2017 available on the rasc.ca *Journal* page:

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

To recap, Coma Berenices is the only constellation named after a real person and not based on myth. After promising her hair to the gods upon her husband’s safe return from battle, the golden locks were subsequently lost at the temple. A quick-thinking court astrologer, likely wishing to avoid his own haircut, drummed up the story of the gods placing them among the stars.

Throughout history the Coma Cluster has been called a “tuft” of Leo’s tail and a “sheaf of wheat” among other dewy comparisons. However, it was Kepler’s Rudolphine tables of 1602 that solidified Berenice’s connection to the cluster.

“Most northerly part of the cloudy convolutions which are called Coma Berenices, between the borders of Leo and Ursa Major.”

– Line 494 Ptolemy’s *Almagest*

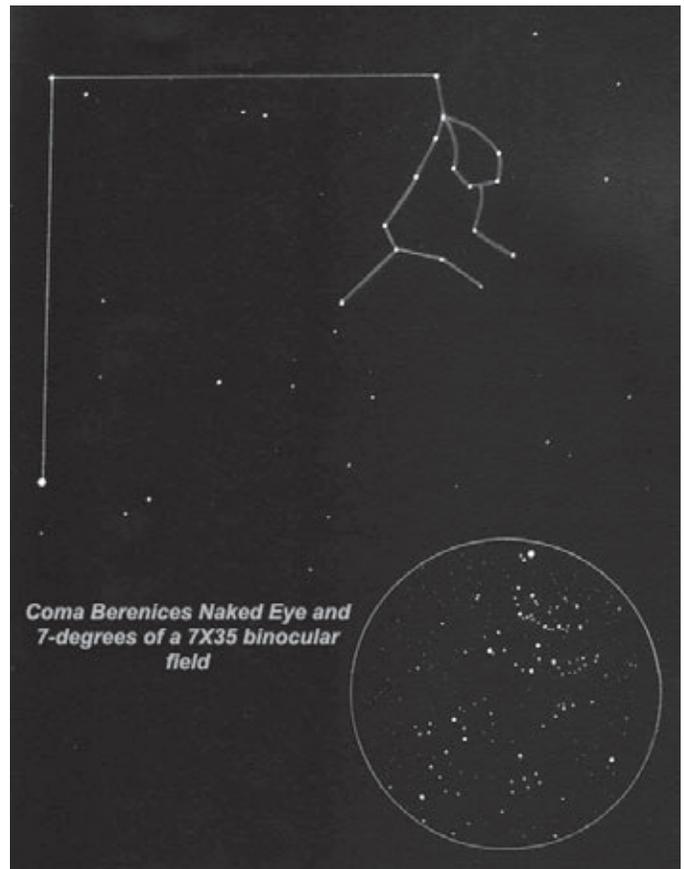


Figure 1 – Coma Berenices Constellation and Cluster sketched at Grasslands National Park East Block May 2016.

Eristothenes first mentioned this “swarm of hair” five centuries before Ptolemy described the cluster as “a nebulous mass, called the lock,” and detailed the nebulous area contained within 3 stars, Gamma, 7 Com and 23 Com, adding to the last, “shaped like an ivy leaf.” However, my attempt to find an ivy leaf among those stars more closely stemmed from 7 Com than 23 Com.

In addition to Messier neglecting the cluster, there exists a little confusion where Coma Berenices refers to both the constellation plus the large open cluster Melotte 111 contained within, and there is also a Coma Berenices Galaxy Cluster to add.

In fact, the cluster doesn’t appear in either the NGC or IC catalogues, and it wasn’t listed in a catalogue until Melotte added it as the unheralded 111th entry in his 1915 *Melotte Catalogue of Star Clusters*. Perhaps one reason for Mel 111’s neglect was that it wasn’t viewed as a real cluster until 1938, when Trumpler discovered that more than three dozen stars were associated in the region of the concentration. I point out this “non-cluster” prejudice as something of a minor travesty for modern amateur astronomers, where several early asterisms were eliminated from catalogues as time wore on.

Coma Berenices (Mel 111) is among four other objects we now know as deep-sky objects catalogued as pre-telescopic

nebulae; δ Persei (Double-Cluster), Praesepe (M44), Lambda Orionis (Col 69), Ptolemy's Cluster (M7), and Al Sufi's *sababi* (M31) (Glyn Jones 1975).

Serviss's *Astronomy with an Opera-Glass* popularized astronomy during the late 19th century by encouraging casual stargazers to pick up their basic 3.6× optics and turn them skyward and he details the fanciful description at the opening of this article as among the first of many inspiration objects to view with such modest equipment. Modern manufacturing and DIY advances, such as 3-D printing and online file sharing, allow us to create modern 2–3× “opera-glasses,” spawning a mini-resurgence in such small instrument usage (Serviss 1890). However, our slightly lower-power binoculars now sport 25° fields allowing observers to take in the entire constellation of Coma Berenices with just enough power to resolve the cluster.

My observations under the darkest skies of Grasslands National Park indicate I can clearly make out many of the 5th- and 6th-magnitude stars as detailed in the accompanying sketch. This is in conflict with Webb who wrote “Nebulose to the naked eye” (Webb 1917), while famed binocular observer Phil Harrington claims 22 stars can be viewed without optics and provides a detailed list in his book *Cosmic Challenges* (Harrington 2011). In the *Bedford Catalogue* description Admiral Smyth mentions Herschel's observation of a “weaver's shuttle shape.” I note if I had closed off the stem of my “ivy”

leaf it would possibly resemble the asterism Herschel wrote about (Smyth 1844).

7×35 binoculars completely resolve the cluster down to the faintest stars in the region approaching 10th magnitude. Of note are “waves” and “chains” of stars flowing perhaps like wavy hair or some dewy cobwebs someone forgot to sweep away.

*“Who spans the bright machinery of the skies and plots
the hours of star-set and star-rise
By you this soft effluence first was seen
Who knew at once the inglets of the Queen”*

– Conon of Samos ★

References

- Archinal, Brent A. & Hynes, Stephen J. (2003). *Star Clusters*. Richmond, VA: Willmann-Bell.
- Burnham, Robert (1978). *Burnham's Celestial Handbook: Vol 2. Chameleon Through Orion*. New York, NY: Dover.
- Harrington, Phil. (2011). *Cosmic Challenge*. New York, NY: Cambridge.
- Jones, Kenneth Glyn (1975). *The Search for the Nebulae*. New York, NY: Alpha-Academic.
- Serviss, Garrett P. (1890). *Astronomy With An Opera-Glass*. New York, NY: B. Appleton and Company.
- Smyth, Admiral William H. (1844). *The Bedford Catalogue*. Richmond, VA: Willmann-Bell.
- Webb, Rev. T.W (1917). *Celestial Objects for Common Telescopes: Vol 2. The Stars*. New York, NY: Dover.

2019 Awards *(compiled by James Edgar)*

The Service Award is a major award of the Society given to a member in recognition of outstanding service, rendered over an extended period of time (at least 10 years), where such service has had a major impact on the work of the Society and/or of a Centre of the Society.

Joanne Burns – Belleville Centre

Joanne is the only remaining founding member of the Belleville Astronomy Club which was formed by a small group who had attended a local community college astronomy course. Certainly, without the enthusiasm of Joanne and a few others, the Belleville Centre of the RASC would not exist.

From the beginning Joanne appointed herself club historian and organizer, a role that was formalized when she was elected secretary in 1990 and has served in this capacity for the past 28 years. Having Joanne as a core of the executive made our becoming an RASC Centre in 2003 a smooth transition as she readily took on the additional requisite responsibilities.

Joanne is quick to take on responsibilities well beyond the office of secretary. She has ensured that the group has always had a meeting place and is generally the first to volunteer for club events such as public outreach, provincial park partnerships, astronomy day activities, bus trips, as well as social events like club dinners and barbecues.

Joanne has always been the key Belleville Centre organizer for the annual Fall'N'Stars

event, south-eastern Ontario's only autumn star party, co-sponsored with the Kingston Centre, for the past 18 years.

Joanne has graciously volunteered her time over a large number of years to keep the Centre operating. Her personal contribution has been invaluable in helping deliver countless programs and activities to both the public and members of the Centre.

As representatives of the Belleville Centre, we submit Joanne Burns to be a well deserving recipient of the RASC Service Award.

Don Town, Belleville Centre, National Council Representative

Greg Lisk, Belleville Centre, President Emeritus (2006–2018)

Randy Boddam, Belleville Centre, Vice-President

David Cotterell, Belleville Centre, President

Robyn Foret – Calgary Centre

Robyn has been a very active Calgary Centre member, and has held multiple positions within the Calgary Centre Council over the past several years, including Secretary, President, Past President, and now Treasurer.

He has also served as one of three astronomy instructors for the Calgary Centre's Youth Group.

Robyn has also been heavily involved in public outreach. Starting initially as one of the volunteers running the telescopes on the observing deck of the TELUS World of Science (TWOS) in downtown Calgary at our Friday night public viewing events, Robyn took over as Deck Volunteer Coordinator, and eventually assumed the role of Volunteer Coordinator for all public outreach events for the Calgary Centre. Given that the Centre runs more than 50 public outreach events throughout the year with multiple volunteers needed for each event, this is a very busy role. All of this has not stopped Robyn from continuing to volunteer at outreach events himself, be they in Calgary or as far afield as Banff.

Robyn also applied to the Alberta Gaming and Liquor Commission (AGLC) on behalf of the Calgary Centre for Casino fundraising. We have now run two successful Casino events to raise money for our Centre's public outreach events, with another casino tentatively scheduled for next year. This money has allowed us the funds to invite high profile speakers such as Dr. Carolyn Porco (planetary scientist and leader of the imaging team for the Cassini mission to Saturn) to engage the general public in astronomy education at free events.

Robyn was also instrumental in ensuring that Calgary would be the host for the 2018 RASC General Assembly, which was held this past summer. As the Chair of the GA Committee, he provided oversight for the entire process, from the initial planning stages through to the final financial reckoning, and it was in large part due to his leadership that the event was so successful.

On the National level, Robyn has served and continues to serve on the RASC Board of Directors, initially as a Director, then as 2nd Vice President, and currently as 1st Vice President.

It is for his sustained volunteer activity with the RASC for many years, at both the Centre level as well as the National level, that we are pleased to nominate Robyn Foret for a National Service Award.

Sincerely,

Roland Dechesne, President, Calgary Centre
Steve Donaldson, Past President, Calgary Centre
Peter Brackett, Councillor, Calgary Centre

Roger Nelson – Calgary Centre

Roger's service to the RASC spans many roles, two RASC Centres, as well as the National Council and Board. His breadth of contributions is so large that it is almost insulting to try to fit it all on one page.

Roger joined Regina Astronomical Society in 1986 and shortly thereafter he was President, reinvigorating and thus saving the Regina Astronomical Society from collapse. He was a driving force in the push to reestablish ties with the RASC, which occurred in 1989. He led the efforts to move the club's meeting space and a new observatory to the Saskatchewan Science Centre. Roger was instrumental in creating what was to become the Saskatchewan Summer Star Party when he invited the Saskatoon, Calgary, and Edmonton Centres to the Cypress Hills Star Party. This kick-started the enduring partnership between the Regina and Saskatoon Centres who continue to run the SSSP to this day.

After Roger's move to the Calgary Centre, he quickly became active in the Calgary Centre's programs and council. He was the Observing Committee Chair for many years, but also contributed as Councillor and the time-consuming role of Centre Secretary.

On the national front, Roger was a Centre Representative on National Council and played the role of co-chair of that body. He is currently on the RASC Board, where he fills the position of Secretary, and is also the Chair of the Information Technology Committee.

Roger's prowess in information technology was never so welcomed as when he scratch-built the 2018 RASC General Assembly website under an impossibly tight deadline when it became clear the legacy web program that all assumed was going to work, simply did not. Without Roger's efforts, the General Assembly would not have been possible to host properly.

Roger is also an active observer, with a meticulous log book. He encourages members and the public alike to go observe the heavens, whether for simple enjoyment, observing certificate programs or, perhaps, to attempt some science.

Roger is also comfortable on television, and in both Regina and Calgary he used that medium to promote astronomy to the public in special community broadcasts or on news programs of major television network affiliates.

Roland Dechesne, President, Calgary Centre
Pierre Schierle, President, Regina Centre
Ross Parker, Historian, Regina Centre

Luca Vanzella – Edmonton Centre

It gives us great pleasure to nominate Luca Vanzella for the RASC Service Award. Luca has been the driving force behind some of Edmonton Centre's most successful activities that benefit both the public and RASC members.

Over the last decade, Luca has played an important role in the organization of events and providing the administrative backbone to keep Edmonton Centre's programs running smoothly. Luca has contributed to Edmonton Centre in a variety of administrative roles, taking on the positions of National Council representative, secretary, vice-president, president, and now past president. In addition, he has also

stepped up to organize our biannual casinos that fund most of our activities. He played an important part of the committees that organized activities for the 2009 International Year of Astronomy, and the RASC GA hosted in Edmonton in 2012. He has provided all members of Council with advice on Edmonton Centre bylaws, policies and procedures. In recognition of his many contributions to Edmonton Centre, he was awarded the Edmonton Centre's Annual Service Award in 2017.

The Queen Elizabeth II Planetarium, opened in 1960, was Canada's first public planetarium. It was an important part of Edmonton Centre's activities for many years until it was closed in the 1983. After 1983 the planetarium slowly decayed until the City of Edmonton decided in 2016 to restore the building. Luca Vanzella spearheaded a new Edmonton Centre committee to work on programming ideas for the planetarium once the renovations are completed in 2019. He worked hard as a liaison between RASC, the City of Edmonton, and Telus World of Science Edmonton (TWOSE). TWOSE will serve as the official tenant of the planetarium, and Edmonton Centre will provide programming for the public and members one evening each week. This will be a major focus of Edmonton Centre's outreach efforts once the building is reopened.

Edmonton Centre received a donation of a 32-inch mirror from a former member, Bob Drew. This donated mirror catalyzed a group within Edmonton Centre to build a telescope using this mirror as well as an observatory at a dark site East of Edmonton at Black Nugget Lake. The observatory, known as the Black Nugget Lake Observatory (BNLO) will be a premier observing site when it is completed in 2019. This project required an enormous amount of planning and administrative support, which Luca provided. Luca took care of applying for grants to fund the project. He wrote the application to the Government of Alberta to get permission to use the land for this purpose. He applied for the building permits to build structures on the land. He helped negotiate agreements with the group that manages the campground located at the site. The amount of bureaucratic hoops that were required for this project were daunting, however Luca kept the BNLO committee on track, both with the paperwork and the budget. The project is on target for a first light event in Fall 2019 for both the telescope and observatory at the Northern Prairie Star Party held at this location.

Sometimes one hears about an interesting initiative taking place at another RASC Centre, but it requires the right person to actually make it happen. When we learned about Victoria Centre's Astro Cafe events, Luca is the sort of person who decided that we needed to make something similar happen in Edmonton. He organized the first Astro Cafe in September 2015, and has continued to run these informal meetings on elementary topics for beginning astronomers on an approximately monthly basis. Luca had to investigate different venues until he found a local community hall that was an appropriate size and price, as well as starting a committee that decides on programming for these events. The Astro Cafes have been very successful, and we plan to continue holding them in the Queen Elizabeth Planetarium once it has reopened.

An important part of any organization is how it presents itself to the world through its webpages. Our webpage was at one time poorly organized, unprofessional looking, and difficult to update. Luca worked hard with a small committee to design a new website which premiered in 2014. The resulting website, edmontonrasc.com is easy to use, easy to navigate, and both members and the public can find information about our programming.

In addition to the outstanding service contributions to RASC, Luca is an excellent visual astronomer and creative wide-field astrophotographer. He serves on the National astroimaging certificate committee, as well as acting as a mentor to Edmonton Centre members on many aspects of wide-field astroimaging. He is well-known for his long-term photographic projects including his Moon rise and set time lapses, Sunrise azimuth sweep (from Summer to Winter Solstices), Edmontonhenge sunrise and sunset images (featured on Astronomy Picture of the Day), and his film photography analemma project.

Luca Vanzella has been a cornerstone of many Edmonton Centre activities. In general, his organizational skills, diplomatic abilities, and positive personality have enabled us to provide outstanding astronomy programming and infrastructure. We feel that Luca Vanzella's outstanding service to the RASC make him most deserving of the RASC Service Award.

Alister Ling, Edmonton Centre National RASC Council Representative

Sharon Morsink, President, Edmonton Centre RASC

Ed Mizzi – Hamilton Centre

Ed is an extraordinary volunteer, and became engaged in all aspects of the Centre, and encouraged both new and long-standing members to get actively involved in the Hamilton Centre.

If Ed was curious, he would learn a new skill, but as a natural leader, he would bring along the entire Centre to take part. From his natural teaching ability, he re-energized many Centre programs, and served in many positions on the Board, volunteered on AstroCATS and eventually became Centre President. He is very much enthusiastic and engaged now that he is enjoying retirement from his professional career.

Ed actively attends other RASC Centres when he can. He is a regular reporter and feature writer for RASC Hamilton Centre's newsletter, *The Orbit*. Among his contributions, he also authored a multi-page feature on how to conduct successful Outreach. He provided detailed and hands-on information on how to become an effective presenter, gleaned from decades as a professional teacher. He regularly, if silently, assists National Youth Outreach Co-ordinator Jenna Hinds' efforts to circulate educational material across his network of teaching contacts. He has taken new -- and young -- Board members under his wing to teach them the importance of their roles and to give them first understanding of vital leadership concepts such as Governance and Duty of Care. When

Hamilton Centre launched its online Forum, in 2016, a review of Forum activity revealed that in those first weeks and months, Ed Mizzi was the second-most-frequent poster, after the Newsletter Editor and that he spent the 5th-most time online, after the Editor, the Webmaster and two other Board members.

Besides RASC, Ed spends 6 weeks each year counselling at a Grade 7-8 kids' camp in Algonquin Provincial Park and this always includes astronomy. At Starfest, Canada's largest annual amateur astronomy conference and star party, "he helps everyone." This includes the visitor who—unknowingly—totally messed up Ed's already-aligned and already plate-solved imaging rig. (Adrian Aberdeen, Director RASC Toronto Centre, writes that Ed "went the extra mile" on this visitor.) He also actively promotes non-RASC astronomy-related events, such as presentations by McMaster University's Origins Institute and the University of Toronto's "Astronomy on Tap," a social/education event, held at a trendy brew-house-cum-lecture-theatre by the astrophysics community. A regular speaker on things astronomical to groups such as the Rotary Club, the Bronte Creek Project (a Halton District-run 1 semester, 4-credit, environmental leadership program for Grade 11-12 students) and even to teachers during their PA days, among others.

He is, at every turn, a gentleman and a gentle man. Modest, too. Several years ago, Ed wrote: "I do it for the students and because it is so rewarding... We are all teachers in our own way." He sees the best in people and encourages them to be better even if it means he ends up having less time than he would like for his own passions, such as astrophotography.

"He's a big reason I joined the Club because of his Outreach efforts and general kindness and I'm sure I'm not the only one he's got interested in astronomy."

Mark Smith, RASC Hamilton Centre Member and RASC National Robotic Telescope team contributor

"Last StarFest, it being my first time camping as an adult, Ed took me under his wing to show me the ropes of getting setup. I honestly believe that my trip was as enjoyable because of him. I would say that Ed is a selfless person who has dedicated himself to the betterment of the Society."

Adrian Aberdeen, RASC Toronto Centre Board Director

"Ed's always had a keen interest and desire in astrophotography in both his personal journey as well as helping with the maintenance and of the club's observatory to ensure club members are able to enjoy the facility. Ed's enjoyed using his DSLRs for astrophotography and sharing the knowledge he's learned over the years with the many people he meets at his outreach events. He has constructed an observatory in his backyard that has increased his ability to enjoy the night skies. Recently he added a monochrome camera and narrowband filters to help with pursuing his astrophotography hobby. Ed's always approachable and willing to share what he's learned to newcomers."

Martin Palenik, Hamilton Centre Member

Rick Saunders – London Centre

John Richard "Rick" Saunders was born in 1956 and joined the RASC London Centre in 2004. Rick distinguished himself right away with his technical competence and willingness to work on London Centre projects. He brought with him the special skills he had acquired in a career with the Canadian military and the weather service at London Airport. A lot of the work done to develop the London Centre observing site near Fingal, Ontario, was organized or performed by Rick. In particular, Rick took the lead in acquiring the structure for the second observatory at the site. He also played a key role in putting up the current arrangement of telescopes, one optimized for imaging and the other for visual observing, and Rick organized a barbecue and star party for the grand opening on 2012 October 21.

Rick's formal service on the London Centre executive began as Secretary from 2007 to 2009, continued as Webmaster in 2010 and 2011, then culminated as 34th President from 2012 to 2017. Under Rick's leadership, the London Centre regular meetings returned to Cronyn Observatory on the campus of Western University, where the meetings had been held in the decades before 1970. His jovial and informal style as chair of club meetings was very popular, and no less so the regular feature he presented called "Cheap Stuff from China," which highlighted useful or quirky hardware items that could be ordered online in our modern world. For the transit of Venus on 2012 June 05, Rick helped organize a major event at Western University, which almost 2000 persons attended.

One of Rick's most interesting achievements was the return of H.R. Kingston's refractor to London. H.R. Kingston was the founder of London Centre who passed away in 1963. Kingston's grandson lives near Seattle, Washington, and Rick made arrangements with him to have the refractor presented to the club membership at a banquet Rick organized on 2012 July 28 for London Centre's 90th anniversary, and now it resides in the 1940s "Period Room" at Cronyn Observatory.

As a key member of the 2016 General Assembly organizing committee, Rick's responsibilities included arranging the program of guest lecturers, including astronaut Jeremy Hansen, Erika Rix of Astronomy Magazine and Ann Hornschemeier of NASA's Goddard Research Center. In late 2018, Rick began to serve as editor of *Polaris*, the London Centre newsletter.

Since 2009 Rick has been involved in 26 outreach events, including participation in Astronomy Day events, displays for McKittrick's camera shop in Cherryhill Village Mall and in Masonville Mall and for Scouts at Camp Timken, near London, for Beavers & Cubs near Sparta, Ontario, at Camp Orenda, at Quai du Vin winery, at the London Regional Children's Museum and at Longwoods Conservation Area. Often these events involved Rick setting up his 20.3cm AstroTech F/4 Astrograph or 102mm Stellarvue 102 ED refractor, and sometimes with solar viewing apparatus for daytime events. On 2017 September 16, Rick presented astronomical images at Metropolitan United Church as part of London Symphonia's ambitious performance of Gustav Holst's famous suite "The Planets." Months in planning, this event required working with the musical director of the

orchestra and the technical staff of the venue. The images were shown on large screens in the main hall of the church while the orchestra and choir occupied the stage. Rick's work garnered wide praise from the audience.

It is a pleasure for London Centre executive to authorize and to support this nomination.

Mike Hanes – London Centre

Michael Francis Hanes (b.1959) joined the London Centre of the Royal Astronomical Society in January 1995, after receiving a large refracting telescope from his wife for Christmas. He soon became a leading force in the Amateur Telescope Making group, first with a six-inch scope to learn the basics and progressing up through 8 inch, 12.5 inch, 15 inch, 17.5 inch, and ultimately a 24 inch mirror. His telescopes are known for their quality, precision, attention to detail, craftsmanship, and functionality.

Mike was ATM Chair for London Centre from 2004 to 2016, often hosting a group of enthusiastic telescope makers in his large basement with up to six grinding tables operating simultaneously. Mike built a large motorized rough grinding table in his garage and another for polishing in his basement, to reduce the problem of grit contamination, and these machines have been used by several London Centre members to reduce the hand work required in mirror making. He donated one of his small scopes to the Centre and has also made telescopes for several other members of London Centre.

Mike joined the small observing group that met at Sharron Creek, and after several interactions with passing motorists Mike was first to promote observing from the Fingal Wildlife Management Area. He arranged to get keys to the FWMA gates and was later instrumental in gaining approval from the Elgin County Stewardship Council to observe from the park interior where passing cars and local lights do not disturb observers. When London Centre decided to build a Warm Up Room at the FWMA observing site for the comfort of observers, Mike did a large part of the framing, roofing, cladding, installing fibreglass insulation, vapour barrier and drywall. He fabricated a concrete "bunker" to store and protect the heater propane tank outside the building and built a welded steel frame to support a solar panel on the roof with which to charge storage batteries for the 12V and 120V AC off-grid power system.

London Centre's largest project was the building of Observatories One and Two on the FWMA concrete pad, which also houses the Warm Up Room.

Mike helped frame the foundations and cut three large holes in the existing and very hard WWII concrete pad so that isolated concrete piers could be installed for Centre telescopes. Mike provided much of the leadership in the group effort to frame in and clad the first roll-off-roof observatory, which was accomplished over a single weekend.

Mike also obtained and assisted with the installation of the secure steel door.

Mike was involved with the Society's Property Committee regarding the former headquarters building on Dupont Street and provided guidance and advice when the decision was made by National Council to relinquish the landlord role.

For the 2016 General Assembly, Mike worked tirelessly with conference staff at Fanshawe College and other committee members to ensure that the facilities were set up properly for all General Assembly events and for the AstroCATS event.

Mike's service to London Centre rose to a new level when he became President for 2018. His term was marked by a new format for club meetings and a well-organized program of Guests of Honour. Mike's outgoing personality and inclusive approach made it easy for other members to contribute, too.

As an avid observer, Michael has benefited from the experience of others, and he is quick in turn to assist new observers in finding their way around a busy sky.

It is a pleasure for London Centre executive to authorize and support this Service Award nomination.

Leslie Strike – Mississauga Centre

After joining the Mississauga Centre in September 2006, **Leslie Strike** quickly became an important and integral part of the Mississauga Centre.

Leslie immediately became active in the running of the Centre by joining the Council. She served as Vice-President from 2008 to 2012, then took on the role of Centre President for four years starting in 2012. Beginning in 2012, she also assumed the role of National Council Representative for the Mississauga Centre, only recently finishing six years of National Council service.

Leslie earned the Explore the Universe Certificate in 2006.

Another important contribution from Leslie is her assistance in setting up the Centre awards as Chair of the Awards Committee and participating in having the awards made and presented annually. In fact, in 2016, the Mississauga Council presented Leslie with the Centre's prestigious Attwood Award for her contribution as President, only the second time that this award has been given since its inception in 2012. The Attwood Award is given to a member of the Mississauga Centre who has demonstrated superior commitment to the goals and aims of the Centre, has devoted significant time to its endeavours, and has had a substantial impact on the vitality of the Centre.

Leslie is also active in reviewing and updating the Centre's By-Laws.

Leslie is an active member and attends all the meetings, sometimes hosting and oftentimes making presentations on Centre activities as well as her own activities, such as astrophotography, eclipse-chasing, and astronomy trips to Tahiti, Atacama, Australia, Alaska, Svalbard, Chile, Peru, Bolivia, Indonesia, Nebraska, and Iceland. She plays an important role in Centre fundraising activities by running the meeting raffle and selling RASC merchandise. Leslie also attends the

Centre's outreach events, such as working with Girl Guide groups, helping teach astrophotography at the Centre's annual astronomy course, giving talks at libraries, and showing the sky to the public at the Centre's regular events at the Riverwood Conservancy. She rarely misses an opportunity to share her experience and knowledge with the public, not only by sharing her skills and enthusiasm as an astrophotographer and eclipse chaser, but by answering questions from the membership as well.

Leslie has proven to be an invaluable member of the Mississauga Centre, as well as the RASC itself. For all the reasons described above, we nominate Leslie Strike for the Service Award.

Betty R. Robinson, Mississauga

Allan Connery, Mississauga

Vance Petriew – Regina Centre

Vance Petriew developed a passion for astronomy as a youth while growing up on the family farm northwest of Saskatoon, Saskatchewan. Vance joined the Saskatoon Centre while attending the University of Saskatchewan where he spent his evenings teaching first year astronomy labs and working at the campus observatory. In 1999, Vance transferred to the Regina Centre where he has been in leadership positions ever since.

From 2000 to October 2008 he was the Centre's webmaster supporting our public presence. During this time, he conceived and implemented a redesign of the Centre's website.

- In October 2001, shortly after his discovery of Comet 185P/Petriew, he became the Centre President serving until October 2004. This was a very active time and Vance was a leader on several initiatives including:
 - leading a team of 4th year University of Regina engineering students that developed the mechanical and computer systems to drive the Centre's Saskatchewan Millennium Telescope (SMT) and Kalium Observatory dome via the internet.
 - providing "outstanding work ethic and dedication" along with "expertise and encouragement" to the Cypress Hills Interprovincial Park in obtaining their Dark-Sky Preserve (DSP) designation.
 - driving a major revision to the Centre's Bylaws.
- From October 2004 to October 2005 Vance served as Past President. During this time, he mentored the new President in his role. He also continued in his role as Centre webmaster.
- In October 2006 Vance was elected Vice President and held that role until October 2008 when he once again became the Centre President. He held that position through October 2009 and then served three years as Past President through October 2012.
- In February 2015 the Centre was experiencing turnover in some leadership positions and Vance came back as the Centre Secretary filling that role until November 2015

when he accepted the role of Centre President once again. He served his maximum three-year term until November 2018 and is now the Centre Past President. His focus during this time was:

- re-establishing and mentoring a new Centre leadership team.
- developing a Centre Operations Manual to capture the critical knowledge necessary to run the Centre.

Over the last two decades, Vance has also been the driver behind several other initiatives. These include but are by no means limited to:

- being the single largest source of revenue for the Centre through his fundraising activities. He runs the Office Recycling Program that obtains surplus government equipment and sells it. He also designs the logos, procures the t-shirts, and manages the Saskatchewan Summer Star Party (SSSP) t-shirt fundraiser.
- recruiting and coordinating the Regina Centre team that leads the solar viewing and night-time public observing programs at SSSP. That program has reached more than 10,000 people who visit the Cypress Hills DSP. He also is very active in local Centre outreach events reaching thousands of people through Astronomy Day, Canada Day observing, speaking at Public libraries, and in the school system.
- frequently presenting at the Centre's monthly meetings on topics such as: selecting your first telescope, selecting eyepieces, Dobsonian telescope design, the structure of the Solar System / galaxies / Universe, how to complete the Messier Marathon, the AAVSO and variable star observing, astrophotography and CCD photometry, and light-pollution abatement to name a few.
- acting as the Centre's primary media (television, radio, and newspaper) interface as well as responding to email and voicemail inquiries from the public.
- setting an example for others by completing the Messier list (2002), Finest NGC list (2002), the Deep-Sky Challenge list (2014), the Deep-Sky Gems list (2014), and being the only person to have ever completed every single object on the Explore the Universe list (2017).
- mentoring new observers and frequently contributing to the Centre's *Stargazer* newsletter, where he passes along his knowledge and experience.
- organizing work days to maintain the Centre's Davin Deep Sky Observatory and the Kalium Observatory which is used for public outreach.
- researching the weather and ideal locations for the Regina Centre group who travelled to the Casper, Wyoming, area for a very successful view of the 2017 Solar Eclipse.

Along the way, Vance also contributed significantly to the broader astronomy community beyond the Regina Centre. The following are a selection of his contributions and honours:

- the RASC Ken Chilton Prize (2002) and the IAU Edgar Wilson Award (2002) for the visual discovery of Comet 185P/Petrew, which provided the impetus to obtain the DSP designation for Cypress Hills.
- 2007 recipient of the American Association of Variable Star Observers (AAVSO) Director's Award "for his leadership of the Comparison Star Database Team, devoting numerous hours in the documentation of every comparison star currently used by the AAVSO. Vance also utilized his database skills in the creation of the Variable Standards Database, a masterful relational database of the comparison stars that can be updated in perpetuity."
- Leading the research and authoring a scientific paper titled "Photometric Analysis of HD 213616: a Multi-modal Delta Scuti Variable Star" published in *The Journal of the AAVSO*.
- contributing well over 1,800 visual and 310,000 CCD variable-star observations to the AAVSO.

Vance's love of astronomy has compelled him to almost two decades of selfless service to the Regina Centre. While he could justifiably be proud of his many accomplishments, nothing quite fills his heart with the same joy as the excitement and wonder in the eyes of people as they view the Universe. More than the 20-inch aperture of his telescope, this undoubtedly explains why he always has a lineup at SSSP.

Submitted by: Pierre Schierle, James Edgar

Danny Sklazeski – Sunshine Coast Centre

Danny Sklazeski is one of the founding members of our Sunshine Coast Centre, being one of the members of the original Sunshine Coast Astronomy Club that started in 1988. Danny is one of our Centre's most reliable volunteers, despite an ongoing battle with cancer. Danny is "Mr. Public Outreach." For thirty years Danny has shown up for all our Centre's outreach events with his telescopes, both night and solar, and takes great pride and pleasure in showing the public the skies. Since 2010 Danny has been a regular at our monthly "Astro Café" event. Danny shows up for all observatory events with his personal telescopes and was one of the most active volunteers in building that observatory and maintaining the observatory grounds. Danny assisted our observatory manager in his many site surveys seeking a final site for our observatory. Danny regularly mows the fields around our observatory, built the pathways, and maintains the portable toilet at the observatory site. Danny makes signage for outreach events. Danny sets up the coffee and snacks and cleans the kitchen afterwards at all of our monthly meetings. Danny is always there with tools and generator when needed. In 2018 Danny became our National Representative. Danny is our unofficial archivist, saving clippings and information of historical interest.

Submitter: Charles Ennis, 2nd Vice-President, RASC, Past President, Sunshine Coast Centre

Submitter: Bill Clark, Past President, Sunshine Coast Centre

Bruce Fryer – Sunshine Coast Centre

Bruce Fryer is one of the founding members of our Sunshine Coast Centre and one of the members that joined the Sunshine Coast Astronomy club in 2004 that became the Sunshine Coast Centre 4 years later. Bruce served for several years as the Treasurer on the Board of our Centre, the best treasurer we've ever had, and an accomplished conflict mediator. He has been active in working on grant applications to fund our Centre's activities and observatory. In October 2018 Bruce became our Centre's President. Bruce regularly presents a "Skies this Month" PowerPoint presentation at each of our Centre's monthly meetings. Until his retirement in 2017, Bruce was a high school science teacher and took astronomy into the classroom. Bruce helped write scripts and host the third and fourth season of our Centre's "Night Lights" community TV program, which we produce in partnership with Eastlink/Coast Cable. He went on road trips to the Okanagan Centre, the Dominion Radio Astrophysical Observatory, LIGO Hanford, the Museum of Flight, and the total solar eclipse in Oregon to capture footage for the Night Lights show. He is a Qualified Operator at our Centre's observatory.

Submitter: Charles Ennis, 2nd Vice-President, RASC, Past President, Sunshine Coast Centre

Submitter: Bill Clark, Past President, Sunshine Coast Centre

Michael Bradley – Sunshine Coast Centre

Michael Bradley was one of the original members of the Sunshine Coast Astronomy club when it reformed in 2004 and joined the RASC when the club became the Sunshine Coast Centre in April 2008. From 2004 to the 2015, Mike was one of the people working to make our observatory a reality, making presentations to various local governments and organizations. Mike was the President of the Sunshine Coast Centre 2012-2014. Mike is currently our Vice President and webmaster. Mike is one of our most reliable and creative volunteers. He shows up for all the outreach events with his telescopes, both night and solar. Mike shows up for all observatory events. Mike was the first Observatory Director and is currently on the Observatory Committee, having put in countless hours building and maintaining our observatory. Mike has spent many hours doing collimation, alignments, and other maintenance on the observatory's telescope and other club telescopes. Mike is our most notable in-house "maker": Much of the electronic equipment on the pier of our observatory's telescope is equipment he designed and built for it, such as dew suppression systems, timers, scintillation detectors, etc. Mike devised the system to monitor the power usage in our solar powered observatory created a wireless system to connect our observatory to the internet through a shared wireless link with one of the flying clubs at the airport where we have our observatory. This link gives us real-time information on conditions at the observatory building. Mike has made a lot

of display equipment for our information booth at outreach events, such as solar viewers, display stands and boards, solar projectors, and sky cameras. Mike is our point man in successfully pursuing many government and community grants to support the observatory and has made many presentations to community organizations to promote our Centre. He's taught many astronomy classes for our Centre as well as for the local Elder College. Michael helped write scripts and host two seasons of our Centre's "Night Lights" community TV program, which we produce in partnership with Eastlink/Coast Cable. He also appears in an episode of the Aboriginal People's Television Network youth science program "Coyote Science" and helped us film our Bravo Factual documentary, "Starry Nights". Mike is an avid astrophotographer who donates his pictures to the Centre's various projects. Many of the photos used by me in writing *Building a Small Observatory* and the *Solar Observer's Handbook* came from Mike or show Mike in action.

Submitter: Charles Ennis, 2nd Vice-President, RASC, Past President, Sunshine Coast Centre

Submitter: Bill Clark, Past President, Sunshine Coast Centre

David Thompson – Sunshine Coast Centre

David Thompson was one of the original members of the Sunshine Coast Astronomy club in 1988 and has served the club for thirty years. He was one of the people behind our club becoming the Sunshine Coast Centre of the RASC in 2008. David has served several times on our Centre's Board of Directors and was responsible for drafting the club's original bylaws and constitution.

David worked on our application to the CRA to become a registered charity and has worked on parts of all of the Centre's grant applications over the years. David is the current Observatory Director for our Centre and has served for 6 years on the Observatory Committee. David did two detailed surveys of the Sunshine Coast (2009 and 2011), taking Sky Quality Meter readings (which he submitted to the Light-Pollution Abatement Committee in 2009) and surveying possible sites for our observatory. He wrote several proposals and support documents for the observatory project to assist the club presenting the concepts to local governments and organizations. David is a philanthropist at heart: I long ago lost track of the number of things he has donated to our Centre, including telescopes, telescope accessories, and many fixtures for our observatory. Every year he makes a substantial matching donation to the Centre. David probably has spent more hours working on building and maintaining our observatory than all the other volunteers in our Centre combined. David has been there for every phase of the construction, and he is one of our in-house "makers." All the wiring and mechanical installations in the observatory are his work, and he created and installed the motorized retraction system for our observatory's roll-off roof. David is always at the observa-

tory when adjustments, alignments, or collimation need doing on the main telescope. David has spent many hours maintaining the Centre's loaner telescopes. Crowds aren't his thing—he's the man behind the scenes making sure everything works for those who are in the public eye. Despite this, he attends all the monthly meetings and has many times taught classes including a popular Christmas Astronomy Quiz at our December meeting.

Submitter: Charles Ennis, 2nd Vice-President, RASC, Past President, Sunshine Coast Centre

Submitter: Bill Clark, Past President, Sunshine Coast Centre

Phil Chow – Toronto Centre

Phil Chow has been an active member of the RASC Toronto Centre since 2003. He has served since then starting as the assistant membership secretary by managing the Centre's membership rolls with member renewals, changes of information, tax receipt issuance and more. He continues to serve as the Centre's Membership Secretary.

It also didn't take very long for Phil to discover the Centre's E.C. Carr Astronomical Observatory on Blue Mountain and he quickly became a familiar—and welcoming—face to members there. Phil dove into the volunteer pool at CAO and began participating in the public outreach and member activities offered there. He continues to contribute to group events and has significantly ratcheted up his commitment in the intervening years.

Phil currently serves as the CAO's Observatory Director and chair of the CAO Committee, which oversees the operation and management of the site. Aside from that position, he is an active volunteer with boots on the ground at CAO in many facets of its operations. He is a regular participant at CAO work parties and is currently the work party co-coordinator responsible for planning and conducting the day's activities, which entails detailing the tasks of about 20 volunteers' duties for the day.

A question regarding those events may be posed: What would it be worth to you if you could have 20 volunteers come over to your house one Saturday and they would do whatever chores you asked? Well, that is the situation that the Centre enjoys at least twice annually at CAO with its generous volunteers and a good part of the reason that they continue to step forward is because of the welcoming manner of the managing volunteers like Phil Chow.

Phil just has a way of setting folks at ease and genuinely appreciating them for who they are yet his style does not interfere with his focus or compromise the discharge of his responsibilities. His character has proven to be an important contributor to the harmony in his committee and the growing commitment of the CAO volunteers; and it is noticed.

Phil also serves the Centre as a scheduled CAO Supervisor in welcoming public and members alike to the CAO and facili-

tating their experience there. Being an effective supervisor and ambassador for the Centre at CAO is not for everyone, but Phil's easy style makes him a natural; the Centre is grateful for that.

Phil served as Editor of the Centre newsletter *'Scope* from 2006 to 2008 and has participated in the conducting of many Centre workshops such the popular astrophotography series held at CAO. He also continues to enjoy his long running participation in the Centre's city public outreach events as well. Phil can often be found mentoring newer members and is passionate about sharing his enthusiasm for astronomy.

We are very pleased to nominate Phil Chow for the National Service Award.

B. Ralph Chou, President, Toronto Centre

Tony Horvatin, Past President, Toronto Centre

Charles Darrow, Past President, Toronto Centre

Blake Nancarrow – Toronto Centre

Immediately upon his joining the Toronto Centre in 2007, Blake set about volunteering to support the information technology needs of the Centre. As a computer trainer, he used his extensive knowledge of computer hardware and software to improve the experience of our members in support of our then email list server and also the technology needs of various committees in the Centre. Blake has assisted our web team and provided software training as an assist to our volunteers in carrying out their duties. He is an excellent author of operations and training manuals and it is safe to say that the majority of existing Centre technical documentation has been created and maintained by Blake. He has also served as our IT Committee chair.

Blake is an enthusiastic volunteer in our public outreach efforts. He has participated in both our daylight and evening telescope outreach events at many of our regular venues such as the Ontario Science Centre, E.C. Carr Astronomical Observatory and the David Dunlap Observatory over the past decade. He has also delivered polished astronomy presentations of his own creation to various groups, both to members and to the public.

Blake is also very knowledgeable in both observational telescopes and imaging systems and shares his knowledge freely with both our members and the public. He often mentors beginner members who are looking for guidance in learning these systems and technology. For example, he organized and ran a workshop at the DDO for our members designed to assist them with operating new equipment they may have received over the holidays but were a bit overwhelmed with the learning curve before them. He maintains a personal blog with a wealth of useful astronomical information at blog.lumpydarkness.com.

Blake has also served in the Centre's administration as an effective and well-informed Councillor. He is a past Director of the Centre's E.C. Carr Astronomical Observatory and continues to serve as a CAO work party captain where he is present and contributes at nearly all such events. He remains the CAO IT Chair and a CAO site supervisor where he serves as an ambassador and facilitator to site visitors. Blake currently serves on the DDO Committee.

Blake continues to be a regular presenter at our Centre meetings with the monthly *The Sky this Month* segment, which provides members a summary of the coming month's observing points of interest and other topics. These presentations are valuable aids and reach many as meetings are now live streamed and archived on the Centre's YouTube channel.

His current passion for double star study invigorates the imagination of members through his online postings and contributions via his *Journal* column, Binary Universe.

We believe that Blake Nancarrow has and continues to make his mark on both members and the public and we are pleased to nominate him for the National Service Award.

B. Ralph Chou, President, Toronto Centre

Tony Horvatin, Past President, Toronto Centre

Charles Darrow, Past President, Toronto Centre

A.W. Scott Masterton – Toronto Centre

Scott Masterton has been a member of the RASC Toronto Centre since 1996 and a volunteer for most of that time. He is a long-time volunteer at Centre public outreach events by bringing his telescopes out to meet the public at the Ontario Science Centre, E.C. Carr Astronomical Observatory and David Dunlap Observatory.

Scott began serving on Council as Councillor in 2007. It is difficult to fathom the amount of service that Scott has actually provided to the Centre in his current role as treasurer. He is in his ninth, and final, year of service in that post! In this capacity, Scott has done a great service to the Centre in several ways. He shepherded the conversion of our electronic bookkeeping from the former New Views software to the more intuitive Quick Books, which was no simple feat. Scott also dealt with the complex bookkeeping requirements of managing our own property at the E.C. Carr Astronomical Observatory and then also the record keeping of managing the property of the David Dunlap Observatory when the Centre was responsible for all costs of operating the site between 2008 and 2016. Scott has consistently kept the Centre's finances in tip top shape and liaised well with our auditors.

Scott has been a primary driver of efforts to create Centre policy documents to control and regulate matters such as due diligence and conflict of interest considerations of our Council, and charitable donations assessments protocols so as

to be in compliance with CRA's charities requirements. He has liaised with our property insurers faithfully keeping our ever-changing information up to date in their files but also haggling on our behalf on the premiums charged. Scott has successfully navigated our auditor's requirements and relayed these often-cumbersome rules to the Centre's active volunteers to ensure that our finances remain on the straight and narrow. It is truly a thankless job but we recognize Scott's commitment to a job very well done!

Drawing on his work experience in the insurance industry, Scott designed the required fire-safety plans for both our own E.C. Carr Astronomical Observatory property, and the David Dunlap Observatory during the time that the Centre was its manager from 2008 to 2016.

Scott has also been a regular volunteer at CAO work parties over the years and generously contributed his skills where he could. Scott continues to serve and represent the Centre as a volunteer judge at high school science fairs where Centre prizes are awarded.

The undersigned are pleased to nominate Scott Masterton for the RASC National Service award.

B. Ralph Chou, President, Toronto Centre

Charles Darrow, Past President, Toronto Centre

Linda Pulliah – Unattached

RASC Member Linda Pulliah has been a member of the Sudbury Astronomy Club since the early 2000s, when she first met some club members at their astronomy dome site adjacent to a camp where her Girl Guides were spending some time. Linda came up to the dome to find out what they were doing there. She was shown the telescopes that the group had, and what the astronomers were viewing. Linda was hooked on astronomy.

Linda is a recently retired nurse whose passions include camping, astronomy and Guiding. Known as "Guider Freckles," she would include astronomy lectures as a part of numerous national Jamborees with the Girl Guides as well as presentations too numerous to count at local schools where the curriculum for Grade 6 students includes astronomy.

Linda has always been available on short notice to head out and look at the stars in large or small groups. She has increased the mutual participation in events with the North Bay Astronomy Club and Sudbury Astronomy clubs and she regularly attends meetings held in North Bay.

Star Parties fill Linda's calendar throughout the summer months. She regularly attended the Frozen Banana and Gateway to the Universe star parties and has built a strong relationship with Ontario Parks. She started the star party titled "Half the Night at Halfway Lake" and every year gets

Sudbury Astronomy Club members to attend with her in order to educate the campers on all things astronomical. Since that start, she has increased her contacts and now we have star parties in Samuel de Champlain Provincial Park and Grundy Lake Provincial Park.

Linda has completed her Messier Objects list and is also working on the Finest NGC Catalogue whenever clear skies allow.

In 2017, Linda reached out to Science North in Sudbury to offer her support for their free monthly star parties. She promoted the Science North events within the Sudbury Astronomy Club and welcomed Science North staff to SAC meetings. "Linda and the Sudbury Astronomy Club enriched the free programs offered at Science North by providing lectures, equipment and expertise at these events", according to Dr. Olathe MacIntyre, Staff Scientist, Space Place and Planetarium at Science North. "During the 2017 Solar Eclipse, Linda and members of the club helped to enrich the viewing experience for approximately 900 visitors. The success of that collaboration led to us partnering on a public event called 'Stars over Killarney' to celebrate the 150th anniversary of RASC, the Dark Sky Preserve Status of Killarney Provincial Park and the Killarney Provincial Park Observatory, which is available for public use."

The Killarney event attracted over 300 participants, and Bob McDonald from CBC Radio's *Quirks and Quarks* attended the event and spoke about the importance of dark skies in his blog that has a reach of ~65,000 people.

The Sudbury Astronomy Club was the recipient of Science North's Volunteer Organization Award due to Linda's tireless commitment to increasing public understanding and appreciation of astronomy.

Linda is so committed to educating the public about astronomy that she took a first-year astronomy course at Laurentian University just to be more knowledgeable with her Star Party presentations.

She has made presentations to seniors' groups, Cub Scouts, Church Groups, and others in the area, and does a marvelous job teaching about the night skies. She has a unique way of presenting complex astronomical phenomena in a way that everyone can understand, and she can adapt quickly to different ages in her audience.

Linda's contributions and outreach activities should be recognized with the 2018 Service Award.

Robert Pothier, President, Sudbury Astronomy Club

Pete Marshall, Vice President, Sudbury Astronomy Club,
RASC Member

Luc Boulard, Chair of the Observatory Sudbury Astronomy Club, RASC Member

Bob O'Daiskey, Director at Large, Sudbury Astronomy Club

Dr, Olathe MacIntyre, Staff Scientist, Space Place and Planetarium, Science North

Paul-Émile Legault, Director of the Doran Planetarium

Steve Dodson, Sudbury Astronomy Club and RASC Member

Richard Robert, Sudbury Astronomy Club and RASC Member

Laurie Roche – Victoria Centre

Laurie Roche has been a member of RASC since 1995. She was an elementary and middle school teacher for many years, using her Master of Education from Carlton effectively to support kids with a wide range of disabilities as a special education teacher. Laurie switched to teaching grade 7-8 math and science through to her retirement, and she continues to substitute teach those subjects, plus she tutors students.

Laurie has been active in Victoria Centre, volunteering for or leading countless public outreach events, including: International Astronomy Day, public nights at the Dominion Astrophysical Observatory (DAO), International Year of Astronomy (IYA 2009), Vancouver Island Regional Science Fairs, numerous public observing events, and bringing astronomy to the very popular Saanich (agricultural) Fair.

Laurie is also active at the National level of RASC, contributing to the Education and Public Outreach (EPO) committee. During 2018, she co-hosted a national contest in honour of the RASC sesquicentennial called *Imagining the Skies*. This online contest highlighted astronomical media through photography, sketching, art and crafts.

Serving terms on Victoria Centre's Council as Treasurer, Vice-president, and President, Laurie has shown great leadership through collaboration with many Centre members. Her past efforts to involve RASC members in public outreach have resulted in many members who continue to support this most important mission to engage the public in science and especially astronomy. Her support of others' leadership of events speaks to her excellent collaborative approach to public outreach, and using volunteerism as a fun, social activity to get members involved in RASC's main mission.

As one of the lead members of the Victoria Centre's *School Telescope Program*, Laurie has lent her considerable expertise in interacting with students of all ages (kindergarten to high school), and has helped make this program the most sought after by teachers beyond the local area schools. In the 2017-2018 school year more than 2,000 students took advantage of this program, involving 80 presentations and night sky viewing sessions.

Laurie's support of astronomy outreach to the public on Observatory Hill through Saturday night events during the summer months at the Centre of the Universe and the historic Plaskett telescope predates her involvement in the Friends

of the Dominion Astrophysical Observatory (FDAO). That said, she joined the board of the FDAO very soon after its inception and has been one of its strongest resources for outreach and education ever since, as the FDAO strives to revitalize EPO on Observatory Hill.

Laurie has almost single-handedly kept FDAO's fledgling volunteer daytime tours program running, not only by being lead presenter and educator, but also by organizing other volunteers to participate. She has also been a mainstay of regular Saturday star parties for the public every summer, and unstintingly gives her time on other evenings of the week to give talks on basic astronomy and about Canadian observatories around the world to all ages and levels of knowledge. Finally, Laurie is a strong advocate on the Board for enhancing public outreach offerings and their accessibility to the widest possible public.

Collaborating with and encouraging RASC members to get involved has been the hallmark of Laurie's approach to public outreach. Laurie's contagious enthusiasm for astronomy and science, and her active support outside the classroom of young women choosing science careers can't help but support astronomy being more inclusive. There is no doubt that her outreach in the classroom has helped younger people to consider scientific endeavours as cool and desirable career choices.

Reg Dunkley, President, Victoria Centre

Chris Purse, Past President, Victoria Centre

Dr. Chris Gainor, National President

Sid Sidhu, Victoria Centre

Dr. Ben Dorman, Chair, Friends of the DAO and
Joe Carr, Victoria Centre

Qilak Award

RASC—Chris Curwin (New Brunswick Centre)

CASCA—Dr. Jan Cami (Western University)

FAAQ—Hugues Lacombe (Club d'astronomie de Charlevoix)

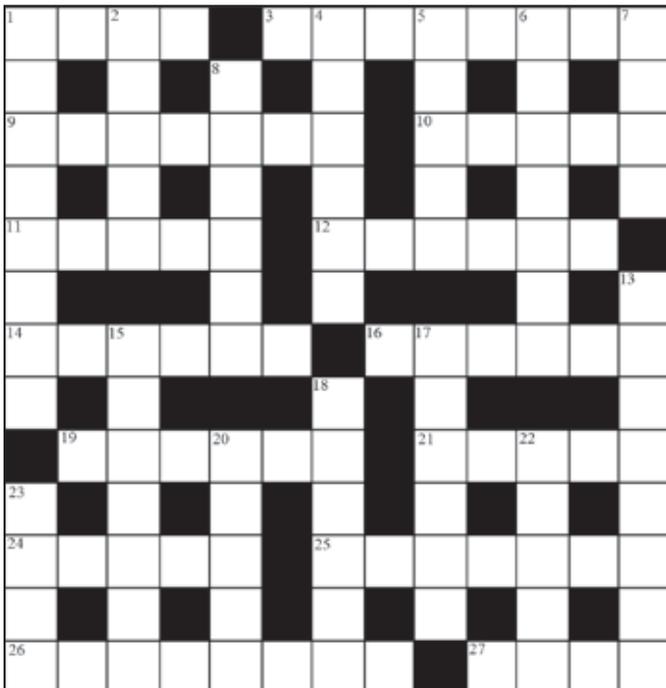
President's Award

Michael S.F. Watson, Unattached

Michael Watson is being awarded the RASC President's Award for 2019 in recognition of his major contributions to the governance of the Society as a member of the Board of Directors. Mr. Watson provides important legal perspectives on issues affecting the Society, and thanks to his long experience in the RASC, he is a source of great advice to his colleagues on the Board. ★

Astrocryptic

by Curt Nason



ACROSS

1. Etna erupts near Earth orbit (4)
3. Politician broke rule in extreme terror of cluster classification (8)
9. Regular change of argon for us in the Zodiac (7)
10. Level in the sky but not quite normal (5)
11. Lunar highland material will move slowly, soundly (5)
12. She was wise to study cosmic X-rays (6)
14. Comet discoverer was a part-time worker to the Spanish (6)
16. Zero age main sequence didn't end after a space station shone in Canis Major (6)
19. Conjunction or quadrature determined in a spectral analysis (6)
21. Zealous actor Al starred in Aries (5)
24. Russian Dog Star? (5)
25. I chased around it, as does Hypatia (7)
26. Smoothed interval, somehow name it after me (4,4)
27. Harpo's star eventually gave out (4)

DOWN

1. Algonquin sky binary is still distant (8)
2. Nebula not really in Aquila (5)
4. Libra scales provide balance for a member of Society (6)
5. Luna one crosses north about every lunar synodic period (5)
6. With a look to tear red shift, a physicist inspired relativity (7)
7. Peruse his 50 things to see (4)
8. Time will pass slowly when asleep at sea (6)

13. Jupiter's nurse follows him around (8)
15. Bad music leads to Russian agreement in the Great Bear (7)
17. His art strangely resembles Venusian terra (6)
18. Eccentric master of a chain of stars drawn from a galaxy (6)
20. Eastern agreement for lunar calculation of Easter (5)
22. Corn belongs to Starmus star, I hear (5)
23. Primordial matter seen in biphenyl emission spectra (4)

Answers to February's puzzle

ACROSS: 1 RUCHBAH (R(anag)ah); 4 GROFF (anag+f); 7 GRIGG (G(rig)G); 8 PETRIEW (pe(anag)w); 9 EBOLA (hid); 10 TUNER (rev+er); 12 DIGITALLY (digit+ally); 14 TEETH (2 def); 16 SCUTI (anag); 18 BARLOWS (an(Ar)ag); 19 OVULE (O(Vul)E); 20 SPRAY (2 def); 21 EYE LENS (an(y)ag)

DOWN: 1 ROGUE (brogue-b); 2 CRINOID (cr+1+no id)); 3 BIG BANG THEORY (anag); 4 GO-TO TELESCOPE (2 def); 5 OTION (or+ion); 6 FAWARIS (fa+a war is); 8 PANSTARRS (Pan(Starr)s); 11 SETEBOS (anag); 13 YOUTUBE (anag+e); 15 ERROR (terror-t) 17 IDEAS (anag)

The Royal Astronomical Society of Canada

Vision

To be Canada's premier organization of amateur and professional astronomers, promoting astronomy to all.

Mission

To enhance understanding of and inspire curiosity about the Universe, through public outreach, education, and support for astronomical research.

Values

- Sharing knowledge and experience
- Collaboration and fellowship
- Enrichment of our community through diversity
- Discovery through the scientific method

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

Board of Directors and appointed officers for 2020 | Conseil d'administration et membres attirés pour 2020

Honorary President

Doug Hube, Ph.D., Edmonton

President

Chris Gainor, B.A., M.Sc., Ph.D., Victoria

1st Vice-President

Robyn Foret, Calgary

2nd Vice-President

Charles Ennis, Sunshine Coast

National Secretary

Eric Briggs, B.A. Hon., Toronto

Treasurer

Catherine Carr, B.A. Hon., Toronto

Director and Past President

Colin Haig, B.Sc., M.Sc., Hamilton

Director

Michael Watson, B.A., L.L.B., Unattached

Executive Director

Philip Groff, B.A. Hon., M.A., Ph.D.

Editors

Journal

Nicole Mortillaro, B.A.A., Toronto

Observer's Handbook

James Edgar, Regina

eBulletin and National Newsletter

Eric Wickham, B.A., Communications and Marketing Coordinator, Mississauga

Observer's Calendar

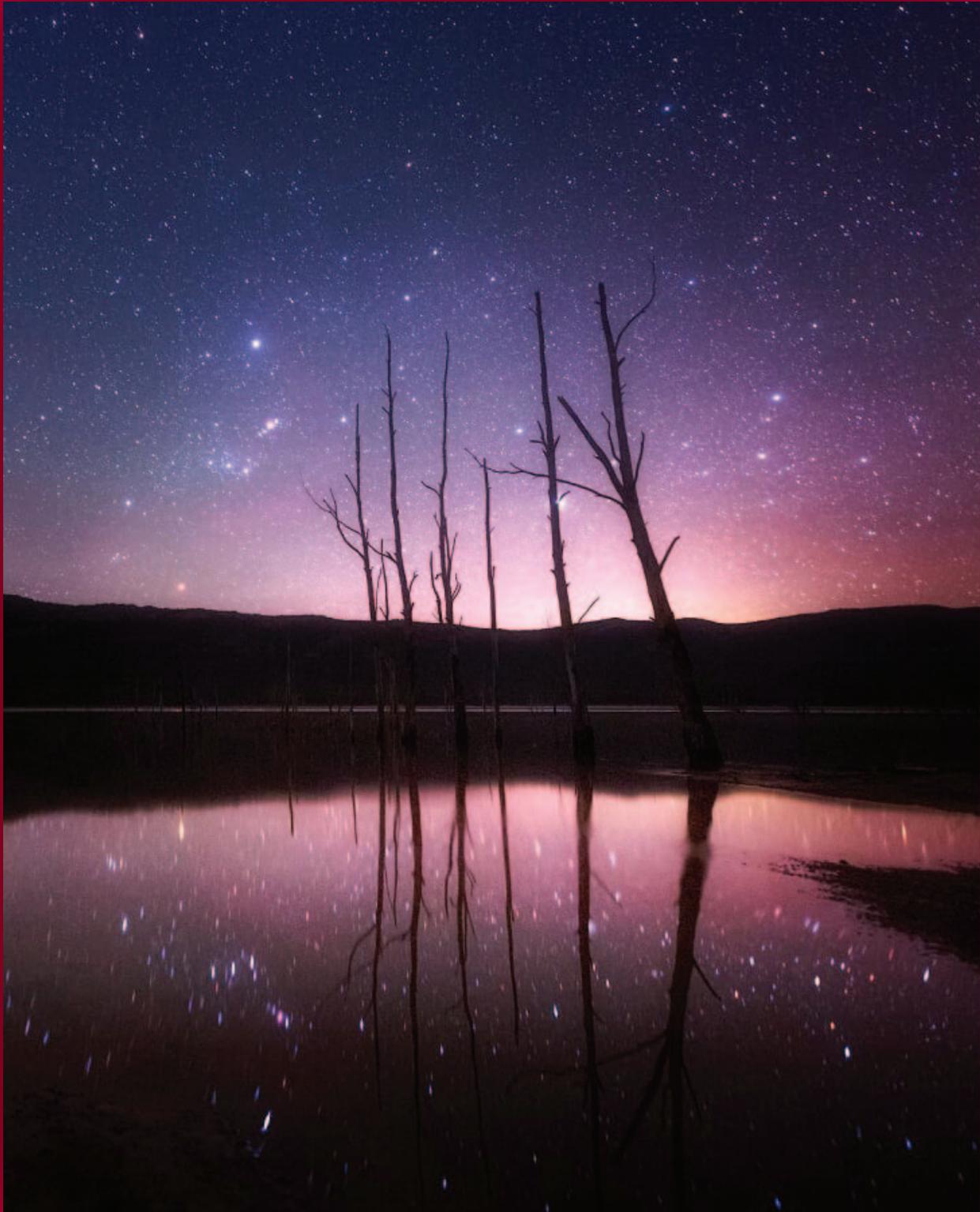
Paul Gray, Halifax

Great Images

by Luca Vanzella



Throwback to the glorious Comet Hale-Bopp from 1997. Luca Vanzella said, "I drove through a snowstorm to a country road north of Edmonton and got this shot—on Fuji film. I have shots that show more of the comet, but this one represents the naked-eye view best. Scanned negative and curved a bit in GIMP." The 20-second image was taken north of Gibbons, Alberta, on a Canon A-1, $f/2.8$, 50-mm, Fuji 800 film. Even though Luca shot in colour, the subject displays very nicely when converted to a greyscale image. This image was one that Luca supplied for his Astrophotography Certificate submission in the Wide Field category. See rasc.ca/astro-imaging-certificate See also all the submitted entries from when the program began in 2016 at rascastroimaging.zenfolio.com



Journal

Kerry-Ann Lecky Hepburn photographed the Milky Way from Grampians, Victoria in Australia. This is a single cropped image she shot using a Canon 6d, at ISO 6400 using a Sigma 14mm lens at f/1.8 and 25 sec.