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Journal

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PROMOTING ASTRONOMY IN CANADA

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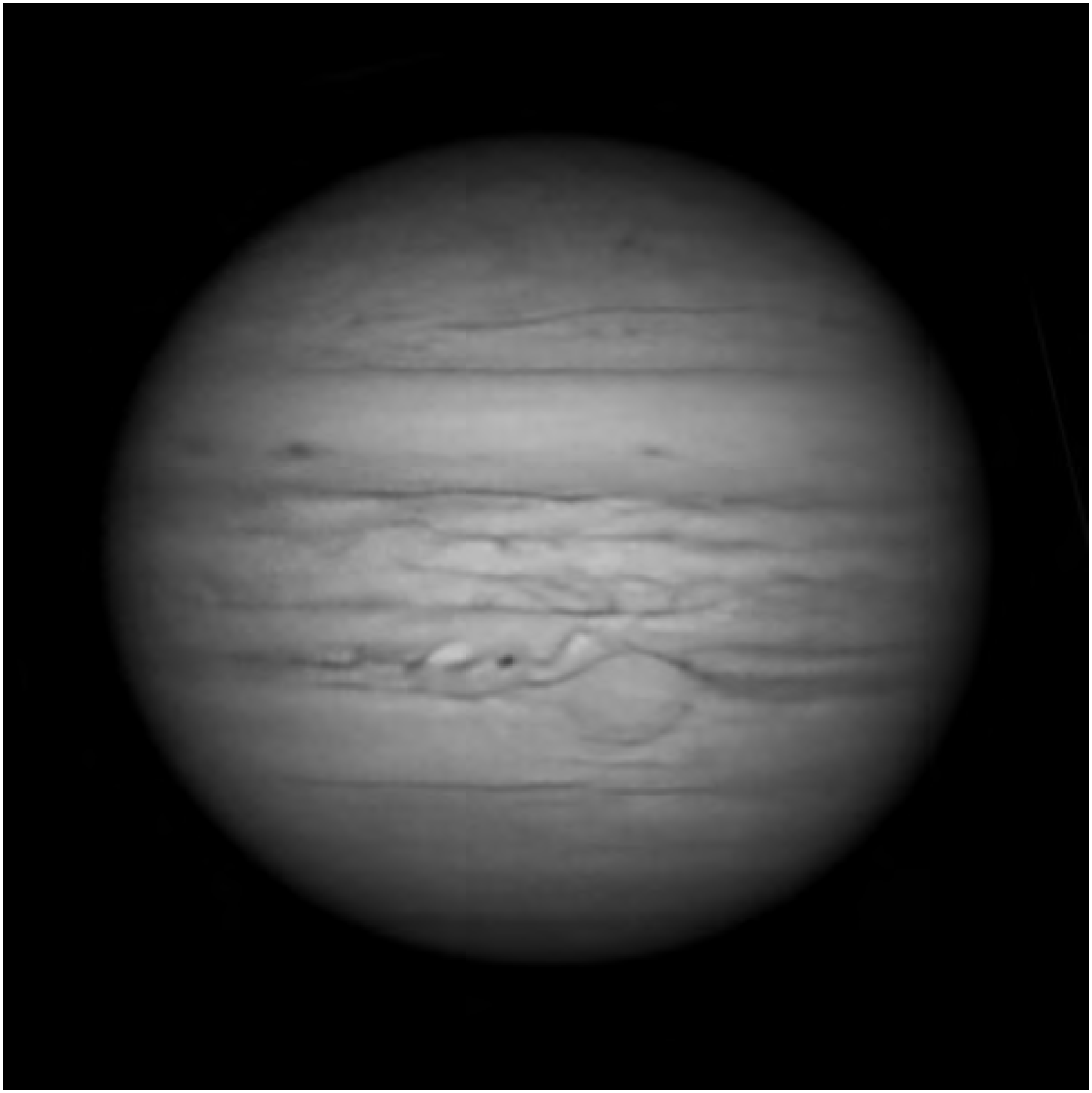
Inside this issue:

Trifecta

The Best of Monochrome



The mighty Jupiter, our Solar System's giant, was taken by Winnipeg Centre member Mike Karakas from his backyard in Winnipeg on the night of August 14. He used his C11 on an EQ6 mount. Focal ratio: ƒ/33. His camera was a ZWO ASI174mm with a 642nm IR-pass filter. Capture was done with FireCapture, stacking done with Autostakkert, wavelets with Registax and final processing in Photoshop. Best 1200 frames stacked.

Journal

October/ octobre 2021 | Vol. 115, No. 5 | Whole Number 810

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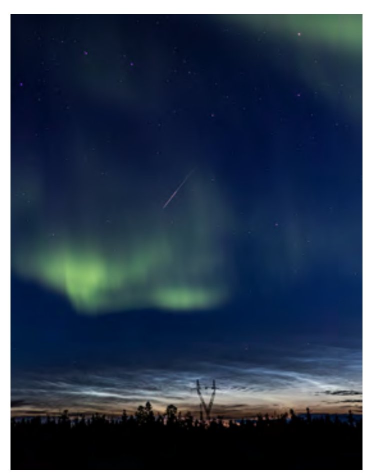
Société Royale d'Astronomie du Canada

contents / table des matières

Feature Articles / Articles de fond

Columns / Rubriques

Departments / Départements



Stephen Bedingfield had amazing timing for this shot where he captured a Geminid meteor along with aurora and noctilucent clouds in Yellowknife. Stephen says, "Capturing this image involved timing, luck and the presence of these three elements under good sky conditions. At the latitude of Yellowknife, the noctilucent clouds (NLC) are observed around local midnight during a brief window of a few weeks in late July/early August. Aurorae are common in Yellowknife, but relatively bright aurorae are needed to stand out with the night sky still in nautical twilight."

He used a intervalometer that took 1,000 exposures to catch the Perseid using a Canon 5D Mark III, 24 mm lens at ISO 400, ƒ/1.8, 4.0 sec.

Journal

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

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President's Corner

by Robyn Foret, Calgary Centre
(arforet@shaw.ca)

As we find ourselves in the 3rd quarter of 2021, with the promise of a return to normal and a guarantee of longer evenings and hopefully clear skies, bereft of cloud and smoke, we have much to look forward to and an opportunity to do things better.

Starting with news from the RASC, the Society's Board has two new Directors, each with three-year terms; Betty Robinson, a Member since 1981, and Malhar Kendurkar who joined the Society in 2016.

Betty Robinson, of the Mississauga Centre, has been very involved in a number of Centre Council and National Council roles and regularly contributes to the *Observer's Handbook*. Her professional career is in educational publishing. With Betty stepping up into the pinnacle Leadership and Governance role within the Society, we are very excited to see how all of this expertise and passion, combined with her 40 years of Society contribution, helps shape the ever-evolving RASC.

Malhar Kendurkar, of the Prince George Centre, became active in there as a Leader and supported their outreach efforts in his first year. As an observational astronomer and full-time researcher, presently the Principal Investigator from Canada on the Global Supernova Search Team, Malhar has established a broad network of collaborators and we are all keen to see how he can help us on our quest to provide value to the Scientific Community, value to Members, and also in the arena of Citizen Science.

The Society Office has seen some change too. We said goodbye to our beloved friend and colleague, Renata Koziol, who's moving on to new challenges. Renata has been a foundational member and Leader of the Society Office Team, surviving no fewer than three Executive Directors. I was honoured to bestow the Society's President's Award on Renata this year, recognizing her commitment and dedication beyond the job description these past 10 years. We will miss her greatly and wish her nothing but the best in all that she does.

Looking to the fall, we're all hoping that we can resume some degree of public outreach and begin to share our love of the night sky with the Canadian public again. We can only hope that our volunteers and their public audience have taken all available measures to keep themselves and each other safe from COVID-19.

On the exploration front, if all goes as planned, we should soon see the launch of the *James Webb Space Telescope*. As of this writing, its scheduled launch is October 31, and it should reach its home at the Earth-Sun Lagrange 2 point a month later, and then begin observations six months after launch. Considering the extraordinary contributions of the *Hubble Space Telescope* and the impact on our field of study, the ten-year planned life cycle of the JWST could be somewhat of a game changer. We don't know what we don't know yet, but it should be a fun ride regardless.

Closing this piece with the opportunity to do things better, how we manifest that is for each of us to decide. The past year and a half has challenged us in ways we did not imagine; it's changed how we view one another and most importantly how we interact with one another. Most of the country has adopted the attitude that we wear masks not for ourselves but for our loved ones and for our community. This care and compassion is something we believed we had before, but COVID-19 gave us the chance to demonstrate to others and to ourselves that this is true. I'm looking forward to seeing how that care and compassion for others continues on in our Society's efforts to safely teach and enlighten others about our Universe and our place in it. ✶

News Notes / En manchette

Compiled by Jay Anderson

Dwarf galaxies rotate with the best of them

An international team of astrophysicists from the Instituto de Astrofísica de Canarias (IAC), the University of La Laguna (ULL) and the Space Telescope Science Institute (STScI) has discovered the presence of transverse rotation (in the plane of the sky) in three dwarf spheroidal galaxies. These are very faint, small, low-luminosity galaxies with very little dust and an older stellar population. They are found in the Local Group as companions to the Milky Way and to the Andromeda Galaxy. Dwarf spheroidal galaxies are easily overlooked because of their faint luminosity, but may be important for what they can tell us of the formation and evolution of larger galaxies.

Figure 1 — Fornax dwarf spheroidal galaxy. Image: ESO/Digitized Sky Survey 2.

Though casually resembling globular clusters, dwarf galaxies offer characteristics that give them a distinct identity. They are faint, but seem to contain large amounts of dark matter. Dwarf galaxies are considerably larger than globular clusters, and their chemical composition does not resemble that of globular clusters; instead their makeup speaks of extended periods or bursts of star formation earlier in their lifetime. In the present epoch, dwarf galaxies are largely depleted in dust and gas and no longer engage in star formation.

Though the standard cosmological model suggests that this type of galaxy was the first to form, most have been absorbed and cannibalized by large galaxies such as the Milky Way. Those that remain contain valuable information about the early Universe.

One subclass of dwarf galaxies are the dwarf spheroidals. Spheroidals are very diffuse, with low luminosity, and seem to contain large proportions of dark matter. However, their internal kinematics are not well understood due to the technical difficulties involved in detailed study of their mechanics.

Various previous studies have shown that the dwarf spheroidals do not have patterns of internal rotation, but that their stars move on random orbits predominantly towards and away from the centre of the galaxy. The other major sub-class of dwarfs—the irregulars—have large quantities of gas, and in some cases do have internal rotation. These differences suggest a different origin for the two types of dwarfs, or at least a very different evolutionary history in which interactions with large galaxies, in our case with the Milky Way, have played a crucial role in eliminating the internal rotation of the spheroidals.

To carry out their present research, the research team used the latest data from ESA's *Gaia* to study the internal kinematics of six Milky Way dwarf spheroidal galaxies and have discovered the presence of transverse rotation in three of them: Carina, Fornax, and Sculptor. These are the first detections of this type of rotation in dwarf spheroidal galaxies, except for the Sagittarius spheroidal, which is strongly distorted by the gravitational potential of the Milky Way, and is therefore not representative of its type.

"The importance of this result is because, in general, the internal kinematics of galaxies, in this case their rotation, is an important tracer of their evolutionary history, and of the conditions in which the system was formed," explains Alberto Manuel Martínez-García, doctoral student at the IAC and the ULL, and first author of the article.

"Although the standard model of cosmology assumes that the dwarf galaxies were the first to form, it is not clear if they are simple systems or whether those we observe are formed by the agglomeration of other even simpler systems, smaller and older. The presence of rotation suggests the second option. It also suggests a common origin for all dwarf galaxies, those that are at present rich in gas (the irregulars) and those which are not" explains Andrés del Pino, researcher at the STScI and a co-author of the article.

"The *Gaia* satellite has revolutionized our knowledge of the Milky Way and its neighborhood, giving us very precise measurements of the positions and motions of almost two thousand million stars. Although the data from *Gaia* are used mainly to study our galaxy, this ESA mission has also opened a new window on the study of the satellite galaxies of the Milky Way, giving specific access to their internal kinematics," says Antonio Aparicio, a researcher at the IAC and the ULL and a co-author of the article.

Even so, according to the researchers, studies based on *Gaia* data entail many technical difficulties. In the first place, one must determine which of the stars in the database really belong to the satellite galaxies, and which to the Milky Way itself, as the latter tend to contaminate the sample. The problem is that although the data to be analyzed are limited to the region and the angular size of the spheroidal under study, which is the equivalent of one quarter of the angular diameter of the Moon, the vast majority of the stars detected in this area belong to the Milky Way and therefore indeed contaminate the sample.

In addition, the distance of the spheroidals studied, which is up to some half a million light-years, and the low intrinsic luminosity of their stars, imply that the measurements are affected by a considerable level of noise. For all these reasons the analysis of the data requires a thorough filtration and a deep analysis of the different observational parameters to be able to reach reliable conclusions.

Compiled in part with material provided by the Instituto de Astrofísica de Canarias.

Betelgeuse mystery solved

When Betelgeuse, a bright orange star in the constellation of Orion, became visibly darker in late 2019 and early 2020, the astronomy community was puzzled. A team of astronomers have now published new images of the star's surface, taken using the European Southern Observatory's Very Large Telescope (ESO's VLT), that clearly show how its brightness changed. The new research reveals that the star was partially concealed by a cloud of dust, a discovery that solves the mystery of the "Great Dimming" of Betelgeuse.

Betelgeuse's dip in brightness—a change noticeable even to the naked eye—led Miguel Montargès and his team to point ESO's VLT towards the star in late 2019. An image from December 2019, when compared to an earlier image taken in January of the same year, showed that the stellar surface was significantly darker, especially in the southern region. But the astronomers weren't sure why. The team continued observing the star during its dimming, capturing two other images in January 2020 and March 2020. By April 2020, the star had returned to its normal brightness.

"For once, we were seeing the appearance of a star changing in real time on a scale of weeks," says Montargès, from the Observatoire de Paris, France, and KU Leuven, Belgium. The images now published are the only ones we have that show Betelgeuse's surface changing in brightness over time.

In their study, published in *Nature*, the team revealed that the mysterious dimming was caused by a dusty veil shading the star, which in turn was the result of a drop in temperature on Betelgeuse's stellar surface. The team used the Spectro-Polarimetric High-contrast Exoplanet REsearch (SPHERE)

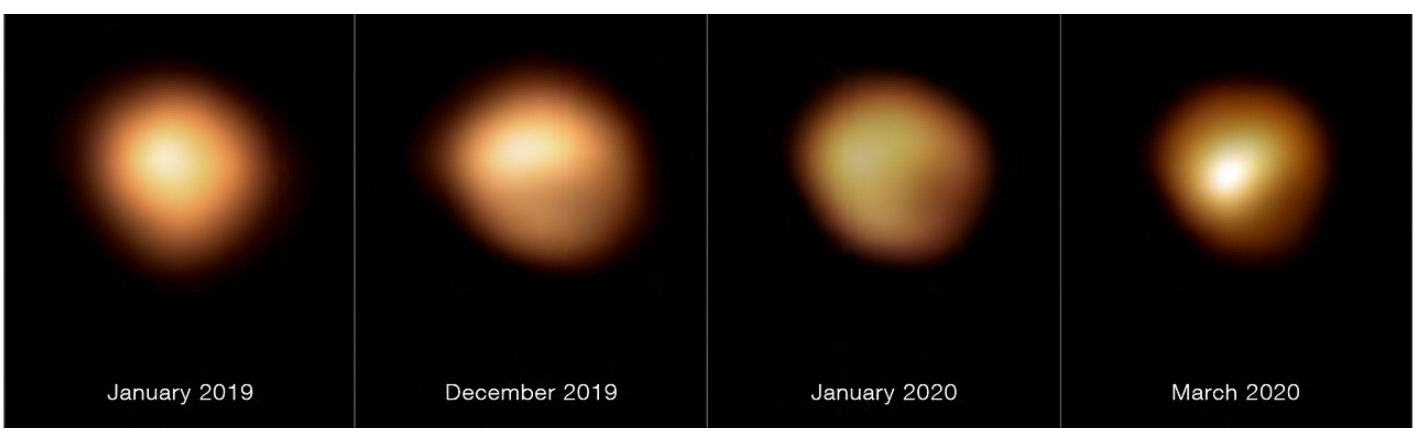

Figure 2 — Betelgeuse's surface before and during its 2019–2020 dimming. Image: ESO

instrument on ESO's VLT to directly image the surface of Betelgeuse, alongside data from the GRAVITY instrument (an interferometer operating in the near infrared) on ESO's Very Large Telescope Interferometer, to monitor the star throughout the dimming.

Betelgeuse's surface regularly changes as giant bubbles of gas move, shrink, and swell within the star. The team concludes that some time before the Great Dimming, the star ejected a large gas bubble that moved away from it. When a patch of the surface cooled down shortly after, that temperature decrease was enough for the gas to condense into solid dust particles.

"We have directly witnessed the formation of so-called stardust," says Montargès, whose study provides evidence that dust formation can occur very quickly and close to a star's surface. "The dust expelled from cool evolved stars, such as the ejection we've just witnessed, could go on to become the building blocks of terrestrial planets and life," adds Emily Cannon, from KU Leuven, who was also involved in the study.

Witnessing the dimming of such a recognizable star was exciting for professional and amateur astronomers alike, as summed up by Cannon: "Looking up at the stars at night, these tiny, twinkling dots of light seem perpetual. The dimming of Betelgeuse breaks this illusion."

Compiled from material provided by the European Southern Observatory.

Supernova in the making

Astronomers have made the rare sighting of two stars spiraling to their doom by spotting the tell-tale signs of a teardrop-shaped star. The two stars are in the early stages of a spiral that will likely end in a Type Ia supernova.

The ominous shape is caused by a massive, nearby, co-orbiting white dwarf with its intense gravity distorting a second companion star that will be the catalyst for an eventual supernova that will consume both. Found by an international team of astronomers and astrophysicists led by the University of Warwick, it is one of only very small number of star systems that has been discovered that will one day see a supernova.

HD265435 is located roughly 1,500 light-years away and comprises a hot subdwarf star and a white dwarf star orbiting each other closely with a period of around 100 minutes.

Lead author Dr. Ingrid Pelisoli from the University of Warwick Department of Physics explains: "We don't know exactly how these supernovae explode, but we know it has to happen because we see it happening elsewhere in the Universe. One way is if the white dwarf accretes enough mass from the hot subdwarf, so as the two of them are orbiting each other and getting closer, matter will start to escape the hot subdwarf and fall onto the white dwarf. Another way is that because they are losing energy to gravitational wave emissions, they will get closer until they merge. Once the white dwarf gains enough mass from either method, it will go supernova."

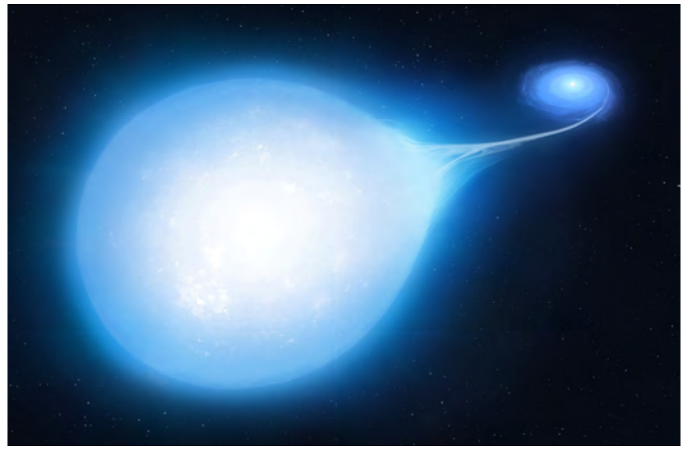

Figure 3 — Artist's impression of the HD265435 system at around 30 million years from now, with the smaller white dwarf distorting the hot subdwarf into a distinct "teardrop" shape. Image: University of Warwick/Mark Garlick.

Using data from NASA's *Transiting Exoplanet Survey Satellite* (TESS), the team was able to observe the hot subdwarf, but not the white dwarf as the subdwarf is much brighter. However, that brightness varies over time, which suggested that the dwarf star was being distorted into a teardrop shape by a nearby massive object. Using radial velocity and rotational velocity measurements from the Palomar Observatory and the W. M. Keck Observatory, and by modelling the massive object's effect on the subdwarf, the astronomers could confirm that the hidden white dwarf is as heavy as our Sun, but just slightly smaller than the Earth's radius.

Combined with the mass of the subdwarf, which is a little over 0.6 times the mass of our Sun, both stars have the mass needed to cause a Type Ia supernova. Already close enough to begin spiraling together, the white dwarf will inevitably go supernova in around 70 million years when the two combine to form a heavy single star. Theoretical models produced specifically for this study predict that the hot subdwarf will contract to become a white dwarf star before merging with its companion.

Dr. Pelisoli adds: "The more we understand how supernovae work, the better we can calibrate our standard candles. This is very important at the moment because there's a discrepancy between what we get from this kind of standard candle, and what we get through other methods.

"The more we understand about how supernovae form, the better we can understand whether this discrepancy we are seeing is because of new physics that we're unaware of and not taking into account, or simply because we're underestimating the uncertainties in those distances. ✶

Compiled with material provided by the University of Warwick.

Carolyn S. Shoemaker: 1929–2021

by David H. Levy

When Carolyn Shoemaker died on Friday, August 13, I was very surprised that after such a long life, she passed away rather suddenly. In the last year or more of her life, she lived in The Peaks, an assisted-living facility in her home of Flagstaff. I telephoned her every Monday, and she would usually begin, "It must be Monday! It is David." These brief conversations were important for both of us. They came to an abrupt end after she suffered a fall and passed away a few days later.

Carolyn Jean Spellmann was born on 1929 June 24, in the American town of Gallup, New Mexico. Her family relocated to Chico, California, when she was very young. After high school, Carolyn attended Chico State College (now the University of California at Chico), where she majored in history while also studying political science and literature. She later got a Master's degree. When her mother travelled to Caltech to attend Carolyn's brother Richard's graduation, she was introduced to his roommate, a young geologist named Gene Shoemaker. Although Mrs. Spellmann tried to bring her daughter and Gene together, Carolyn was just not interested. A few years later, Carolyn attended Richard's wedding. This time Richard joined the effort to introduce Carolyn to Gene—he bribed her. If she would go out once with Gene, he would give her a tablecloth. Carolyn accepted the offer, and the couple began dating. They married in 1951.

During the rich first year of their marriage, the couple did a lot of fieldwork together. Carolyn hated the geology course she had taken at Chico, but she changed her mind when she saw the passion and enthusiasm that Gene displayed for the history of our planet as written in page after page of rock.

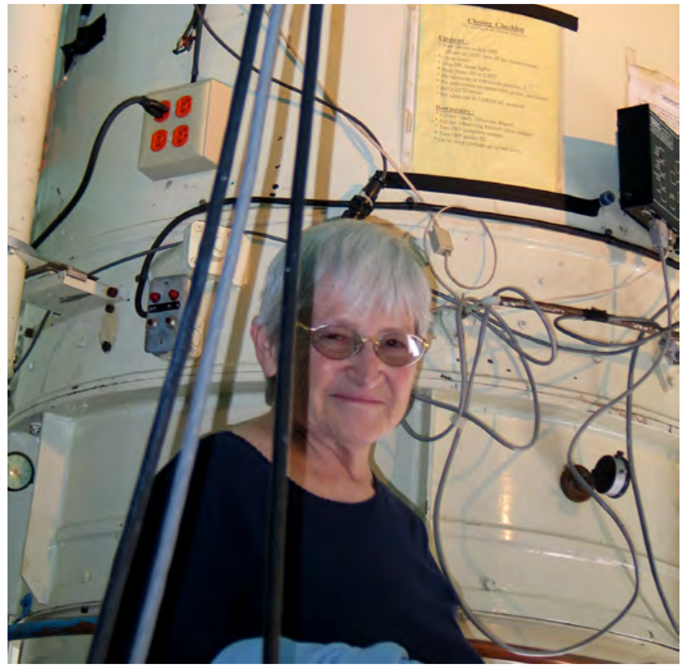

Figure 1 — Carolyn S. Shoemaker

Near the end of one of their field trips, they stopped for a late afternoon visit to Meteor Crater. He suspected the crater might have been formed, not in hours or days by a volcanic steam explosion, but likely in five seconds by the impact of an object from space. When Gene helped detect the presence of coesite—a mineral that can form only under very high temperature and pressure conditions—at the site, its identity as an impact site was confirmed.

Carolyn was a teacher, but only briefly. She left after a year to concentrate on raising her three children Christy, Linda, and Pat. After they were grown and began leading their own lives, Carolyn began searching for something to do. At about this time, Gene was organizing a project called Palomar Asteroid and Comet Survey, and he invited Carolyn to join him. Carolyn quickly became proficient at scanning the films using a stereomicroscope. It was not long before she found her first new asteroid. By the time the program ended in 1994, she had found 377 numbered asteroids; that is, 377 asteroids whose orbits had been determined well enough to have a permanent number assigned to them. Carolyn also claimed that if she added the asteroids that had not yet been numbered, the number goes up to about 800.

In 1983, Carolyn discovered the first of her 32 comets. She always told me that a new asteroid would always capture her interest, but a new comet would be a transformative experience. (I might have added that finding an asteroid was akin to having lunch at McDonald's; discovering a comet was having tea with the Queen.)

The purpose of the Shoemaker survey, which included Henry Holt and in later years, me, was specifically to find asteroids and comets that could someday pose a threat to the Earth. But all this changed with the discovery of a comet in March 1993. That comet, Shoemaker-Levy 9, was not a comet that was famous for what it was or what it looked like. It was famous for what it did. For the first time, humanity witnessed the collision of two objects in the Solar System, a comet and a planet, Jupiter.

Carolyn was honoured both before, and certainly after, the impact week of July 1994. In 1988, the Hilda asteroid 4446 Carolyn was announced by the International Astronomical Union. That asteroid was discovered by Edward Bowell, of the Lowell Observatory, in 1985. Carolyn won the Rittenhouse medal of the Rittenhouse Astronomical Society in 1988. She received an honorary doctorate from Northern Arizona University and was appointed Clops scholar at Johns Hopkins University in 1990. She was awarded scientist of the year in 1995 and was elected to the American Academy of Arts and Sciences in 1996. That same year, Carolyn was awarded NASA's Exceptional Scientific Achievement Medal. Not bad for a woman who started out with absolutely no interest in science. She won the James Craig Watson Medal of the U.S. National Academy of Sciences in 1998.

During one emotional conversation, Carolyn once admitted to me that she never really "got over" the sudden loss of her husband Gene in a car accident in Australia in 1997. When she added that she often wished she had been taken with him, I reminded her of all the people whose lives became richer and happier because of her continued presence on Earth. Carolyn's lively conversation, excellent sense of humour, and sheer joy of the work she did at Palomar, one of the world's greatest observatories, has enriched all of us. She is now with Gene.✶

Effect of Diffraction Halos on the Position and Size of Baily's Beads and Diamond Rings during Eclipses of the Sun

By Duval, M.† , Amyot N., and Chevrefils F.* Members of RASC and Amateur astronomy clubs of Montréal (SAM)* and Dorval (CADFS)†*
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Abstract

Photos taken during the eclipse of the Sun of August 21, 2017 have been used to evaluate the positions and sizes of Baily's beads (BBs) and diamond rings (DRs).

This paper shows that BBs and DRs are due to the diffraction of light around the tiny specks and arcs of the Sun rising above the lunar limb profile during eclipses. This is the same diffraction effect as during the transits of Venus and Mercury against the Sun.

It shows that DRs are formed, not "above small or deep valleys along the lunar limb profile" as generally believed by astronomers, but rather by thin arcs of the Sun sufficiently high and wide to rise above all peaks and mountains of the lunar limb.

The size of BBs and DRs in photos is considerably larger than generally indicated in software models, because of the very large diffraction halos around them and the overexposure of photos of DRs.

Résumé

Les photos prises pendant l'éclipse de soleil du 21 août 2017 ont été utilisées pour évaluer les positions et tailles des perles de Baily (PB) et anneaux de diamant (AD).

Cet article montre que les PBs et ADs sont dues à la diffraction de la lumière autour des minuscules éclats et arcs de Soleil apparaissant au-dessus du disque lunaire pendant les éclipses. Cet effet de diffraction est le même que pendant les transits de Vénus et de Mercure devant le Soleil.

Il montre que les AD se forment, non pas « au-dessus de petites ou profondes vallées sur le bord du disque lunaire » comme le pensent en général les astronomes, mais plutôt par des arcs de soleil suffisamment hauts et larges pour dépasser tous les pics et montagnes sur le bord du disque lunaire.

La taille des AD et PB est considérablement plus grande que ce qu'indiquent les modèles de logiciels, à cause des halos de diffraction très larges et de la surexposition des photos d'AD.

Introduction

The eclipse of the Sun of 2017 August 21 has been observed by millions of people across North America, and thousands of photos of it have been taken and posted on the internet or elsewhere in the following weeks and months. However, it is not always clear in these photos what are the relative positions and sizes of Baily's beads (BBs), rings of pearls (RPs) and diamond rings (DRs) along the lunar limb profile.

This paper uses the high-resolution lunar-limb profiles available today on the internet and the recent investigations on the formation of diffraction halos during the transits of Venus and Mercury, and the eclipsing Moon, against the Sun, in order to determine the positions of DRs, RPs, and BBs in photos and evaluate their relative sizes along the lunar-limb profile.

1. Diffraction Halos at the Sun/ Moon Interfaces

1.1 Diffraction halos during the transits of Venus and Mercury against the Sun

It has been established in previous publications (Duval et al., JRASC, 2005, 2012, and 2017) that the "black-drop effect" (BDE) during the transits of Venus and Mercury against the Sun is due to the formation of diffraction halos above and inside the real disks of the planets, and around the real disk of the Sun above the sky.

The apparent disk of Venus in telescopes and in photos is thus smaller than its real disk, while the apparent disk of the Sun is larger. At contact 3 of the transit, the apparent disks of Venus and the Sun are still far apart when their real disks come in contact. At that moment, however, the halos above Venus and around the Sun suddenly disappear, revealing the underlying black disk of Venus and creating the black-drop effect. The same occurs at contact 2 and during the transit of Mercury.

It has been shown that these diffraction halos are mainly due to the imperfect resolution of the amateur instruments used (telescopes, cameras). Even the high-resolution telescopes used by professional astronomers are not 100% perfect and display a small BDE.

BDEs have even been detected (Pasachoff, 2018) in photographs of a top model taken in a studio against a strong backlight by renowned artist Irving Penn.

1.2 Diffraction halos during eclipses of the Sun

An eclipse of the Sun can be viewed as a "transit of the Moon" against the Sun, or more precisely a transit of the Sun behind the Moon, since the Sun moves more rapidly through the sky than the Moon does.

The Sun first touches the Moon at contact 1 then moves more and more behind the Moon (first partial eclipse of the Sun). The first "diamond ring" (DR) occurs at contact 2, when only a very small arc of the Sun remains uncovered by the Moon. The Sun then is entirely covered (total eclipse). A second DR occurs at contact 3, when a very small arc of the Sun reappears on the other side of the Moon. The Sun then becomes less and less covered by the Moon (second partial eclipse), until last contact 4 where the Sun moves completely away from the Moon.

As during the transits of Venus and Mercury, at all contact points of the Sun and the Moon between contacts 1 and 4, diffraction halos are formed above and inside the real disk of the Moon, and outside the real disk of the Sun above the sky, as explained in Duval et al (JRASC2017-2).

This is represented schematically in Figure 1, where the real disk I of the Moon is in blue, the real disk J of the Sun rising above the Moon after contact 3 is in red, the diffraction halo L above and inside the real disk I of the Moon is in green, and the diffraction halo K outside the real disk J of the Sun above the sky is in orange.

These diffraction halos are produced by the bright light of the Sun "blurring" into the black disk ofthe Moon and into the dark sky. The apparent disk L of the Moon in contact with the Sun is thus smaller than its real disk I, while the apparent disk K of the Sun is larger than its real disk J.

In Figure 1, the real and apparent disks of the Moon and Sun are intersecting at points E and F.

1.3 Relationship between EF, IJ, and KL values in photos of the eclipse of 2017

The Excel program developed previously (Duval et al., JRASC 2017-2) has been used to accurately calculate the increasing values of segments IJ and EF in Figure 1 as the Sun progressively rises above the Moon during the eclipse of 2017 after totality. When EF is small, IJ is tiny, not detectable visually, and measurable only by Excel calculation.

Values IJ and EF have been expressed in km on the Moon, knowing that its diameter during the eclipse of 2017 was ~3474 km. The relationship between calculated IJ and EF values during the eclipse is represented in the graph of Figure 3 by the purple dots.

Around 90 photos taken during the eclipse of 2017 and posted on the internet or elsewhere have been collected for this paper. Typical photos taken at contact 3 in Oregon (Pasachoff, J. *Nova*, 2017) and illustrating the formation of Baily's beads (BBs), rings of pearls (RPs), diamond rings (DRs) and diffraction halos at various EF stages of the eclipse are indicated in Figures 2a to 2d.

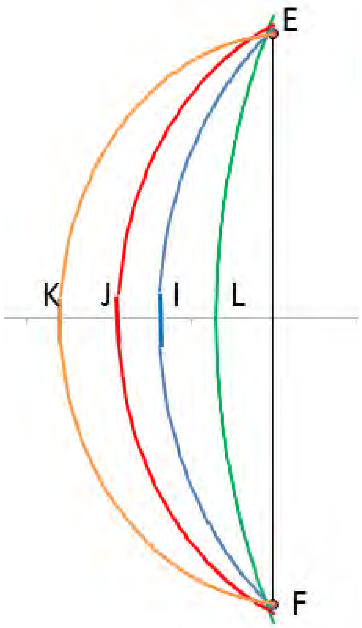


Figure 1 — Schematic representation of the diffraction halos produced by the Sun J rising above the Moon I. Diffraction halo L is inside the Moon. Diffraction halo K is outside the Sun

KL and EF values of BBs, RPs and DRs in each of these ~90 photos of the eclipse of 2017 have been measured, expressed in km on the Moon, plotted and represented in Figure 3 by the blue, red and green dots, respectively.

There is some dispersion in KL values in Figure 3, due to the differences in resolution of the various telescopes and cameras used for taking the photos, resulting in different sizes of diffraction halos.The lower the resolution of the instrument used, the larger the KL value at the same EF stage.

KL and EF values in photos of Venus and Mercury transiting the Sun (Duval et al, JRASC 2005–2017) have been calculated separately. These photos were taken with a solar filter, therefore they include only the diffraction halos around the planets, no overexposure of photos. KL and EF values of Venus and Mercury are aligned with the blue dots of BBs in Figure 3, meaning that these blue dots include only the diffraction halos, no overexposure.

KL and EF values of RPs and DRs due only to diffraction halos have also been calculated, and found to be slightly below the red and green dots of Figure 3, meaning that RPs and DRs in the photos of Figures 2b to 2d are due not only to diffraction halos but also to overexposure of photos between totality and the formation of the first crescents of Sun, where solar filters were reinstalled on cameras.

On the lower horizontal axis of Figure 3 are indicated EF values in km at various stages of the eclipse. Time in seconds after totality, calculated using the diameter of the Moon (3474 km) and the duration of the eclipse (~2.5 h), is also indicated. Time between the appearance of the first BBs (blue dots) and the last DRs (green dots) is ~ 20 seconds. On the vertical axis are indicated the corresponding values of IJ (calculated with Excel) and KL (measured in photos).

It can be seen from Figure 3 that BBs start forming when an arc of Sun IJ of less than one metre rises above the surface of the Moon seen from the Earth, which is remarkably small and impossible to detect with telescopes of any size. Also remarkable is that this tiny arc of Sun produces a diffraction halo KL and a BB of ~15 km high, fifteen thousand times bigger.

Figure 2 — Typical photos of BBs, RPs, DRs, and diffraction halos during the eclipse of 2017

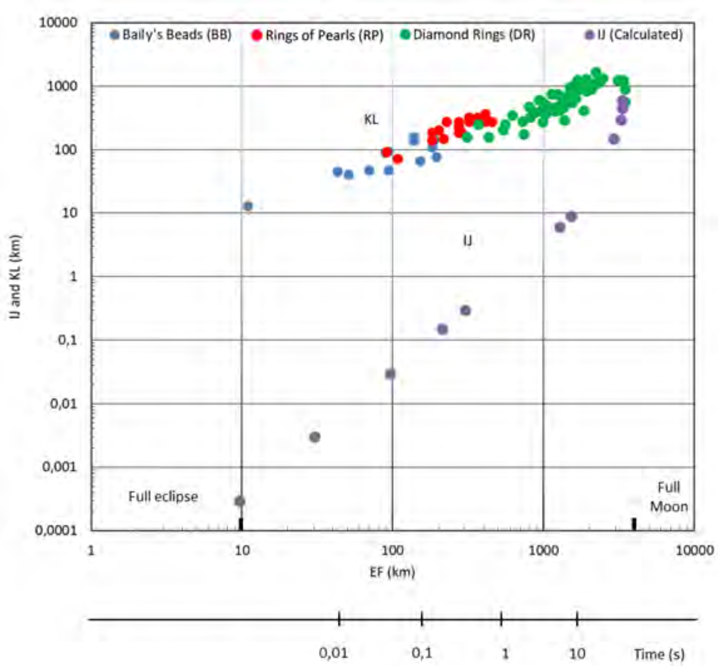


Figure 3 — Relationship between EF, IJ, and KL values in km during the eclipse

2. Lunar limb profiles

The surface of the Moon is composed of craters, mountains and valleys such as shown in Figure 4, resulting in an irregular limb profile of the Moon during eclipses of the Sun.

The *Solar Eclipse Maestro* software of Xavier Jubier (XJ), available on the internet and using limb-profile information provided by the *Kaguya* satellite and NASA's *Lunar Reconnaissance Orbiter* (LRO) missions, has been used to determine the exact lunar limb-profile and positions of contacts 2 and 3 during the eclipse of 2017 August 21 in Oregon (Figure 5).

Peaks and valleys on the limb profile at contact 3 have been extracted from Figure 5 and represented schematically in Figure 6, using a height exaggeration factor of ×75 (instead of ×15 in Figure 5) in order to get a better visualization of the height of peaks, notches and valleys on the lunar limb.

The average limb profile in Figure 6 is indicated by the blue line, contact 3 by the blue arrow in its centre. North is up. The peak/valley profile is in black. The highest peak south of contact 3 is about 2.9 km high, the lowest valley about 1.3 km deep.

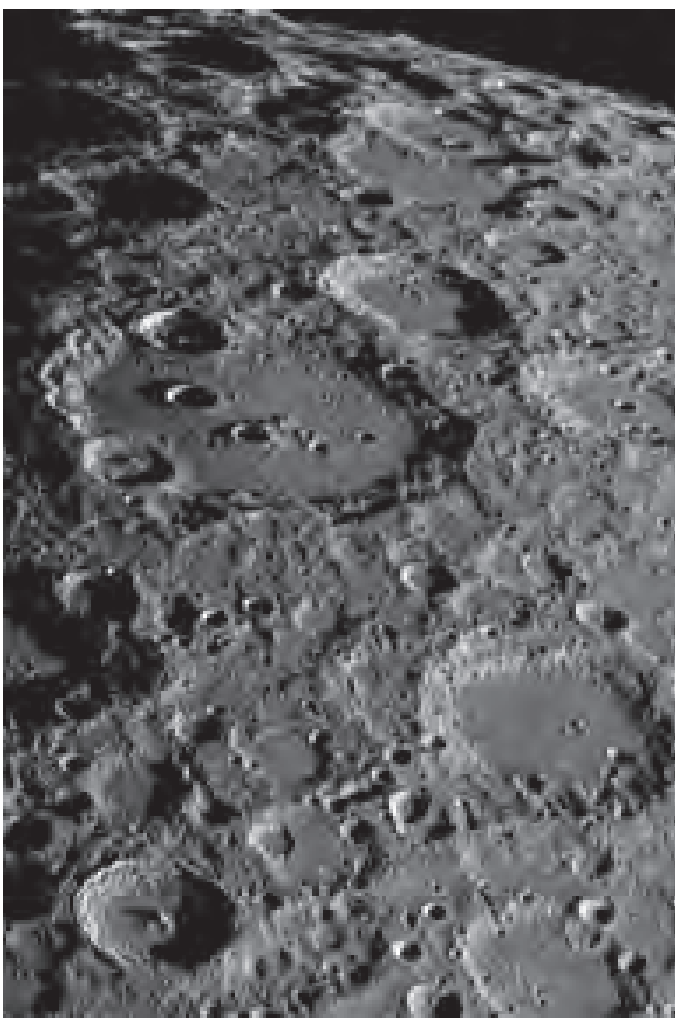


Figure 4 — Typical craters, mountains, and valleys at the surface of the Moon

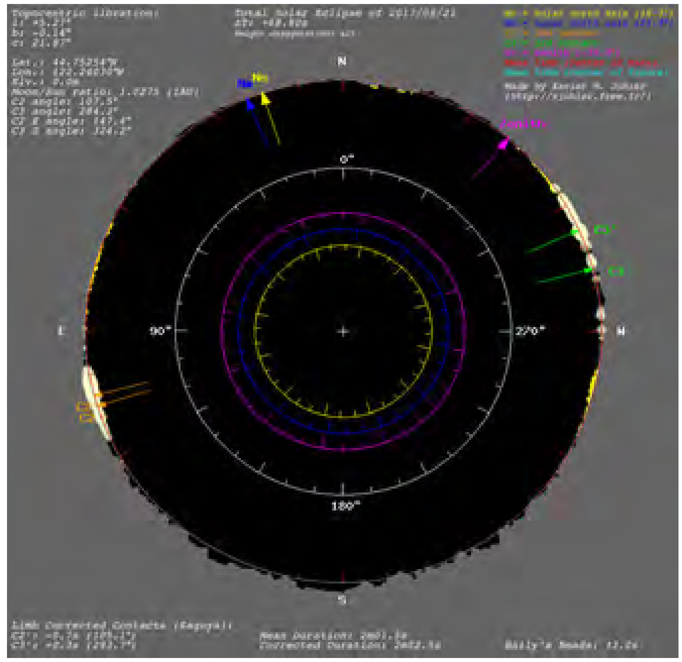


Figure 5 — Lunar limb profile during the eclipse of 2017 August 21, provided by XJ software

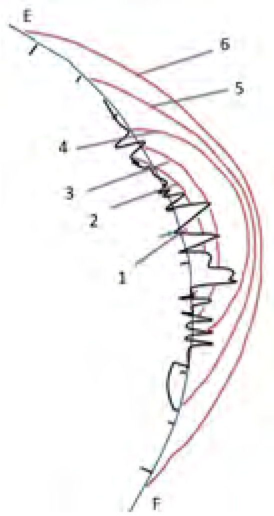
Also indicated in Figure 6 are six typical arcs of Sun J (in red) rising above the lunar limb. IJ and EF values of these six arcs, calculated by Excel as explained in section 1.3 and expressed in km on the Moon, are indicated in Table 1. IJ values in arcseconds seen from the Earth, and time in seconds after contact 3, are also given in Table 1.

An exaggeration factor of ×75 is used for the heights of arcs #1 to 4 in Figure 6, as for peaks and valleys. An exaggeration factor of only ×35 is used for arc #5, and of ×20 for arc #6, which are both entirely above all peaks.

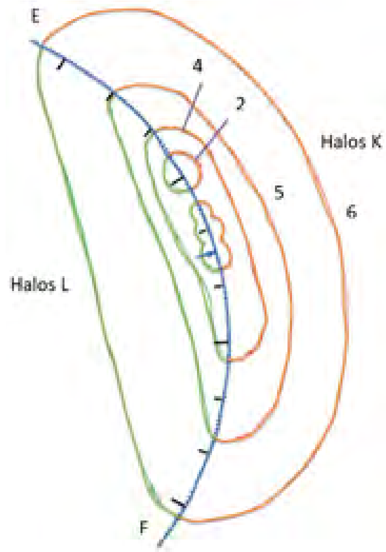
No exaggeration factor is used in Figure 6 for widths EF of arcs of Sun and distances between peaks. This is what creates the visual effect of deformation of arcs of Sun J in Figure 6.

Table 1 — Widths EF and heights IJ of arcs of Sun J #1 to 6 rising above the lunar limb profile of Figure 6

Arc of Sun J #	EF, km	IJ, km	IJ, arcsec	Time, sec
1	180	0.08	0.04	0.1
2	600	1	0.6	1,3
3	800	2	1	2.5
4	1000	4	2	5
5	1600	10	5.5	10
6	2200	50	28	20



Peak / Valley profile in black,
Arcs J of Sun in red



Diffraction halos L inside the Moon in green K
outside the arcs of Sun in orange

Predicted BBs and DRs
in orange

Average lunar limb profile I in blue
Contact 3 = blue arrow in centre of limb profile

Figure 6 (left) — Schematic peak/valley profile and typical arcs of Sun IJ rising above the Moon, with a height exaggeration factor of ×75 for peak/valley profile and arcs of Sun IJ #1 to 4; of ×35 for arc of Sun #5 and ×20 for arc #6; No exaggeration factor is used for widths EF of arcs of Sun and distances between peaks.

Figure 7 (centre) — Schematic representation of BBs, RPs, DRs and diffraction halos in Figures 2a to 2d.

Figure 8 (right) — Schematic representation of BBs predicted by XJ software in Figure 5.

3. BBs, DRs and diffraction halos during the eclipse

Widths EF and heights KL of typical BBs, RPs and DRs in the photos of Figures 2a to 2d, including their diffraction halos and photo overexposures and expressed in km on the Moon, are indicated in Table 2. They are schematically represented in Figure 7.

Table 2 — Widths EF and heights KL of BBs, RPs and DRs at stages #2 to 6 of Figure 7

Stage #		EF, km	KL, km	Photo in
2	BB	180	100	Figure 2a
4	RP	400	350	Figure 2b
5	DR	1600	600	Figure 2c
6	DR	2200	1200	Figure2d

The same colour code as in Figure 1 has been used in Figure 7, i.e., diffraction halos L above and inside the Moon are in green, while diffraction halos K outside the Sun and above the dark sky are in orange.

It can be seen in Table 2 that KL values with the diffraction halos are hugely higher than IJ valueswithout them in Table 1. Plotted in Figure 7 without the height exaggeration factor used in Figure 6, IJ values would totally disappear inside the blue line of the limb profile of Figure 7.

EF values for BBs and RPs in Table 2 are smaller than EF values of the corresponding arcs of Sun #1–2 in Table 1, because only a portion of these arcs peek through the notches between peaks and produce BBs.

A comparison of Figure 2 to 7 and Tables 1–2 indicates that:

3.1) BBs in Figure 2a and Figure 7 (stage #2) are formed by the arcs of Sun IJ #1–2 of Figure 6 peeking through notches between peaks. These arcs of Sun are less than ~1 km high (Table 1). As soon as parts of these arcs of Sun appear in notches, considerably larger diffraction halos are immediately formed, with KL values of more than 100 km high in Table 2, Figure 7 and Figure 3, which appear to observers as BBs. Parts of the arcs of Sun not appearing in notches remain hidden behind peaks. Because of the high mountain profile on the right side of contact 3, BBs form only on its left side.

3.2) BBs increase in size as arcs of Sun IJ #2–4 in Figure 6 and Table 1 rise further above the limb and are less and less hidden by peaks. They merge together at their base at stage #4 of Figure 7 and Table 2, forming "rings of pearls" (RPs) in Figure 2b.

3.3) when arc of Sun # 5 (~ 10 km high in Table 1) rises entirely above all peaks in Figure 6, a DR starts forming at stage #5 of Figure 7 and in Figure 2c, in a sudden flash of light, with a KL value of ~600 km and EF ~1600 km in Table 2. This DR then continues to increase in size with arc of Sun IJ #6 in Figure 6 and Table 1, subtly extending to both sides of contact 3 in Figure 7 and Figure 2d without observers really able to notice it.

3.4) moments later, the final DR becomes a crescent of Sun, as solar filters are reinstalled on cameras, with the apparent disk of the Moon L becoming slightly smaller than its real disk because of the diffraction halo inside and above the Moon, as shown in Figure 1. Here too, observers cannot visually detect this subtle decrease in size of the apparent disk of the Moon,**only photos can.**

4. BBs and DRs predicted by XJ software

In Figure 8 are indicated the positions and sizes of BBs predicted by XJ software, using the same scale in km as in Figure 7.

It can be seen that the sizes of BBs predicted by the software are smaller than their actual sizes in Figure 7 and in photos. This is because the software does not take into account the large diffraction halos KL around BBs in telescopes.

Also, the software does not predict the actual sizes of RPs and DRs, which are considerably larger in Figure 7 and in Figure 2b–d than in Figure 8, because of the large diffraction halos and oversaturation of photos. Finally, the software indicates that their position remains on the left side of contact 3, while it actually extends to both sides of it.

5. Conclusions

5.1) Contrary to what is often mentioned by both amateur and professional astronomers, diamond rings (DRs) during eclipses of the Sun do not form "above a deep valley on the Moon's limb" (Pasachoff, 2017), or "above a small valley in the limb" (NASA's LRO).

This paper rather shows that DRs only form when sufficiently large arcs of the Sun J rise above all peaks and valleys of the lunar limb (with values EF > 1000 km wide, IJ > 4 km high and > 5 sec. after contact 3 in Table 1).

Small and deep valleys and notches (50 to 200 km wide, 10 to 150 metres deep) rather produce Baily's beads (BBs) with the first tiny arcs of rising Sun J (IJ < 1 km high; < 1 sec after contact 3 in Table 1) peeking through the notches.

5.2) X. Jubier's software is remarkably accurate for predicting the peak and valley profile of the lunar limb and the position of Baily's beads (BBs) during eclipses of the Sun.

However, photos taken during the eclipse of 2017 indicate that the actual sizes of BBs and DRs are considerably larger than predicted by the software, because it does not take into account the diffraction halos forming above the Moon and around the Sun, and the oversaturation of photos. Also, it does not always predict the exact position of DRs on the limb profile.

The next total eclipse of the Sun in the US and Eastern Canada around Montréal and the Maritime provinces, will occur on 2024 April 8. Observers are invited to program in advance the exposure time of their cameras with a small software as follows:

– during the total eclipse, remove the solar filter and use maximum exposure time to photograph coronal flares around the Sun.

– gradually reduce exposure time during the ~20 seconds between total eclipse and the last DRs,to photograph the diffraction halos around BBs, RPs, and DRs without oversaturating the photos. The minimum exposure time for the last DRs could be the equivalent of using a solar filter.

– reinstall the solar filter to photograph the reappearance of Sun crescents. ✶

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Looking Skyward at Night: Star Culture in a Colonized World

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Used to play pretend
Give each other different names
We would build a rocket ship and then we'd fly it far away
Used to dream of outer space
But now they're laughing at our face singing
"Wake up, you need to make money"

– Tyler Joseph, Twenty-One Pilots

Humans all live under the same night sky, our view of the stars varying only due to our geographical location on the planet. Not all humans, however, value the cultural significance and meanings that are derived from astronomy and the night sky equally. Our connection to the cosmos can be muted by time and our place in history, weather, light pollution, or just the habit of looking down rather than up. In western society, we live inside more than outside, and are connected to electronic devices more than to the natural world. Humans are tentatively taking steps to venture out into the cosmos, just as we have, as a species, explored around our planet.

The story of humans in outer space, while slowly becoming more diverse (from a workforce perspective), features predominantly white, male names, such as billionaires Elon Musk (SpaceX) and Jeff Bezos (Blue Origin). Rather than leading humanity toward a utopian, egalitarian science-fiction future where money has little meaning and we work together as a species, the current commercialization of outer space continues capitalist views of western society, whereupon private owners seek profit as opposed to trade being controlled by the state. This leads me to wonder, how is the commercialization of outer space and increasing light pollution going to affect humanity, and will it negatively affect marginalized populations and underrepresented BIPOC (Black, Indigenous, and people of colour) groups in STEM (science, technology, engineering, and mathematics) by omission?

Culture, according to Kenny and Smillie, in their book *Stories of Culture and Place: An Introduction to Anthropology,* "is a system of meaning; it provides the standards of value through which action is judged and is usually an unconscious, taken-for-granted reality for the people who share it." This meaning is shared by a group, and allows people to make sense of the world around them. Culturally, the night sky has different significance for different social groups, depending on socioeconomic status, location, race and power. Capitalists, such as Elon Musk, Richard Branson, and Jeff Bezos (currently the richest person on Earth) look for what is of commercial value, or how they can continue their current lifestyle elsewhere. For example, Musk, in a test of the Falcon Heavy Rocket on 2018 February 6 (powerful enough, when eventually operational, to get SpaceX beyond low-Earth orbit, which is as far as its current workhorse Falcon 9 rocket currently operates) sent, as a test payload (instead of a concrete block as ballast or scientific equipment), his cherry red Tesla Roadster sports car out into the cosmos. His company, his money, his risk, his choice, unlike the previous governmental way of doing things in space done inexorably over long periods of time with many cooks in the kitchen (lobbyist groups, senators representing their states, and so on. NASA facilities are spread over the United States). The billionaire, flinging his quarter of a million-dollar car into space sounds like the ultimate capitalist mid-life-crisis exercise in ego, while ground-based astronomers have to fight over every penny to have access to space. Or, as Alice Gorman puts it in her book *Dr. Space Junk vs the Universe* when she talks about the cultural meaning of a red sports car "the red sports car symbolizes masculinity….(and) how fragile that masculinity is… in which men rebel against perceived domestication" (p.75).

Astronomers, in contrast to capitalists, look to the sky to try to understand the Universe and our place in it, not profit from it. Their motivation is to gather knowledge for the betterment of our *Homo sapiens* species, not the accumulation of wealth. The amateur astronomer likewise looks to the heavens to find meaning and enjoyment (for myself, astronomy has always been my emotional port in a storm when life was swirling around me, knowing that my problems are insignificant in the grander scale, and many of my amateur astronomy friends share this perspective). The culture of the space nerd is similar the world over. Any amateur astronomer across the globe will ask you to use a red-light flashlight at night, for example, rather than losing their night vision with a white light, or love telling you about black holes, or sharing the view through their telescopes. Astronomical groups (such as the RASC) connect an amateur astronomy culture, and work toward education and light-pollution abatement. Many Indigenous groups and ancient cultures look to the sky for connection and meaning to understand life on Earth, for a spiritual connection, or instructions for the future (when to plant crops or celebrate an event), and meanwhile others may not give it a passing thought. This is regardless of the changing landscape or the appearance of the night sky as industrialization marches forth and the view of stars is slowly extinguished by light pollution. These different groups represent cultures that may have aspects in common, or that may clash if their values do not align.

Speaking to capitalist motivation, "Musk certainly wants to make money," says anthropologist David Valentine in *Exit Strategy: Profit, Cosmology, and the Future of Humans in Space*.

"He sees the free market as the way to get a return on his investments and being profitable as the natural condition of staying in business. … the desire to chart the course for human biological and social evolution into the deep future—to go and not return—is the reason for what they (so called New Space enterprises) are doing. It is an imperative." (p. 1061).

That is not why everyone wants to go to space. Should the desire of the capitalist subsume the desire and wellbeing of everyone else? Musk has been outspoken about anti-union sentiment in his factories, likewise with Jeff Bezos. Is a future commercialization of outer space going to be rife with danger and challenges? It would seem to set the stage for future exploitation, except in space, the workers would have nowhere to go. But perhaps this journey is inevitable. As Alice Gorman says, "Space is often seen as the very last frontier, ripe for conquest by daring adventurers. In this view, the trajectory of human evolution is a continual expansion into new territories, from the first steps our *hominin* ancestors took outside the African continent …to the 'high frontier' of space" (p. 219).

Musk and his billionaire friends may not give the changing view of the sky from Earth a second thought, for if they have little concern for the impact on astronomers, they will probably have less concern for those with less of a voice or influence in spaceflight circles. Satellites create transient streaks across the night sky, while generalized light pollution created by urbanization and lights pointing upward washes out the appearance of the sky in a more general way, dimming the appearance of stars. The impact can be catastrophic for Indigenous cultures. As Hamacher et al. state in their paper *Whitening the Sky; Light Pollution as a Form of Cultural Genocide*, "The erasure of the night sky acts to erase Indigenous connection to the stars, acting as a form of ongoing cultural and ecological genocide. Efforts to reduce, minimize, or eliminate light pollution are being achieved with varying degrees of success, but urban expansion, poor lighting design, and the increased use of blue, light-emitting LEDs as a cost-effective solution is worsening problems related to human health, wildlife, and astronomical heritage for the benefit of capitalistic economic growth."

This issue connects astronomers, indigenous communities, and those, like amateur astronomers, who care about the appearance of the night sky. It is perhaps an opportunity for collaboration.

There are also little outward signs that new spaceflight capitalists are bothered by structural inequities, and systemic racism. In May 2020, anthropologist and spaceflight enthusiast Professor Kimberley McKinson was watching SpaceX successfully launching a crewed capsule into space, while juxtaposing that with the horror of police violence toward black people.

The December 2021 *Journal* deadline for submissions is 2021 October 1.

See the published schedule at

rasc.ca/sites/default/files/jrascschedule2021.pdf

The SpaceX launch occurred on May 30, however the protests surrounding the death of George Floyd at the hands of police started on May 26 in Minneapolis and continued for days afterward. In an essay *Do Black Lives Matter in Outer Space?*, she talks about the new space race by rich white men as "narratives (that) are not unlike the ones of Euro-American colonization and imperialism on Earth…(during the) dawn of a new age of space colonization… Space exploration is not and has never been politically neutral." It's about greatness, domination, and perhaps there is some discovery and exploration in there somewhere, and a reminder that colonization is not just something that occurred in the past as a method of creating nations; it is happening now. In one instance of a hollow gesture regarding the history of slavery in the United States, Elon Musk designated the nineteenth of June a holiday at SpaceX and Tesla (the electric car company he owns). Juneteenth is the day that many black communities in the United States celebrate the emancipation of enslaved people. What he had to later clarify was that this was not a paid day off.

Our world is increasingly urban, integrated, connected, and polluted, and globalization—both economically and culturally—bridges people worldwide, but not always voluntarily or equally. This occurs through the items we purchase and entertainment or information we absorb that were created elsewhere that eventually arrive into our homes. These items can be practical and have substance, such as canned food or chocolate bars, or they can be virtual, such as Twitch streams, YouTube videos or the new age of online entertainment via companies like Netflix or Amazon Prime Video. Communication methods have evolved from just being on our planet via telegraphs and telephone lines over land and under the ocean, to outward into outer space as satellite communication became more commonplace. Cheaper, simpler satellite internet can be useful in remote locations in a large country like Canada, where having broadband internet can level the internet playing field, allow more access to education and online jobs and so on.

The sky is being used as just another resource to be utilized, just as the Earth and oceans were in the past, as our telecommunications methods have evolved. As countless satellites launch into low-Earth orbit (LEO) and light pollution due to urbanization and upward-facing lights worsens, the appearance of the sky at night changes, affecting cultures who value the extant view of the night sky, without light pollution. Light pollution washes out the appearance of the sky and extinguishes dim stars from view, but also negatively affects wildlife culture and human health. Light pollutes the sky in a similar way to garbage polluting the ocean or land; the problem comes in getting people to care about it, especially when it seems in conflict to worldwide accessible cheap internet, even though it does not have to be a single choice of either satellite internet or untainted skies. It can be achieved responsibly, if companies decide, and if people make responsible lighting and shielding decisions close to home.

In Laura Nader's work "Looking Up," she studied the top of the power pyramid, and made an anthropological rationale for

Figure 1 — A Tweet from Elon Musk on 2019 May 26; spouting incorrect information to millions.

studying decision makers, and "understanding the processes whereby power and responsibility are exercised in this country" (p. 284), referring to the United States. One company using the sky as a resource is SpaceX, a United States aerospace manufacturer and space transportation services company. One need go no further than its vocal and popular founder, CEO Elon Musk to understand its immediate local space-faring goals; to wit, to put up to 12,000 satellites in orbit as part of its plan for worldwide internet—the Starlink program. This is not all that SpaceX has been doing (talk about commercial crew, reusable spacecraft, etc.), but it is Starlink on which I will focus. As of January 2021, Elon Musk has more than 41 million followers on Twitter and is very active online. As well as having many detractors, he has many fans and likes, who support his initiatives loudly and vociferously, even if he is scientifically incorrect. For instance, in this image of a tweet from 2019, he underestimates the impact that his Starlink internet satellite constellation will have on the night sky by minimizing its impact to observers and astronomers (see Figure 1).

Contrary to what Musk is saying, people notice satellites flying overhead constantly (I see them from my yard in Toronto regularly, and I am but one person) and Starlink has, even in this early stage of its rollout, had significantly negative impacts on "advancements in astronomy."

Firstly, it interferes with images taken by observatories, and secondly, it is not a simple matter to move observatories to orbit. They are easier and cheaper to fix and maintain on Earth. It can take many years to develop and plan an observatory that goes to space. And while it is not prone to atmospheric effects, budgetary delays and political concerns can make launching astronomical observatories to space a challenge. For example, the *James Webb Space Telescope* (the successor to the ageing and popular *Hubble Space Telescope*) has experienced many delays and cost overruns, which are now into the billions of U.S. dollars. It may finally launch later in 2021 (after 14 years of delays. It was originally scheduled to launch in 2007). So not only is putting observatories in space not the simple answer, astronomers are fully aware of the effects of the atmosphere on observations and are dealing with it, using a technique known as adaptive optics. If one disagrees with Musk, his fan base goes on the attack, shouting down all detractors, even though he is incorrect in this case. How to use the night sky (if we should even use it at all) then becomes a popularity contest.

In terms of the use of space as a resource, Elon Musk and his ilk do not represent humanity, but sometimes the loudest voice in the room is who gets heard. Neither does a single astronomical group, or one group of Indigenous peoples represent humanity, although there are many cultures that have developed with conscientious thoughts of outer space at their core. It is a shared common resource that exists; it just IS, and connects a universal interest in the cosmos that many humans worldwide share, and have for thousands of years. Regulations and avenues of legal recourse are required to ensure that exploitation of under-represented peoples does not occur in space as it has on Earth. Or, as Hamacher et al. say, "Solutions to this must be transdisciplinary in nature and include Indigenous voices and philosophies that utilize a decolonizing framework." In space, as a new terrain, humans need to be mindful of the history of colonization and its negative effects on the colonized, including Indigenous cultures and other represented groups as we move forward, and learn to work together, lest we repeat these patterns in a new arena. ✶

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STEVE: A Look Back

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In the last decade, the atmospheric phenomenon given the unusual name of STEVE (Strong Thermal Emission Velocity Enhancement) continues to be documented. Modern digital imaging has made it possible for eyewitnesses to quickly record their sightings. Since the first images emerged, amateur and professional astronomers alike are continuing to explore this curious and fascinating display.

A brief definition is in order. According to analysis of satellite data from the European Space Agency's *Swarm Mission*, STEVE is caused by a 25-kilometre-wide ribbon of hot plasma at an altitude of 450 kilometres, with a temperature of 3000 °C (3270 K) and flowing at a speed of 6 km/s (compared to 10 m/s outside the ribbon). Our understanding of STEVE is still evolving, but there is enough familiarity to differentiate it from other atmospheric displays.

The characteristics of STEVE are known, and its identification can be confirmed. Research into archives can discover earlier reports that were, until recently, concealed. Historical observations are now being uncovered. The question is: Why? What made STEVE so elusive?

To answer that, it is helpful to source a modern, detailed eyewitness account where it is known beyond reproach that what was observed was STEVE.

RASC member Chris Beckett offers his report. Beckett is an experienced observer and a former chairperson of the RASC Observing Committee.

During a session near the town of Lajord, Saskatchewan, on 2011 May 1, Beckett's report contains the following;

> *At this point a large auroral arc formed overhead running up through Gemini through the zenith and disappearing into the west. It was like looking up at a giant green rainbow from underneath. It was narrow, only about 2–3 degrees across so I put my 40XW in, that gives me 3.6 TFOV in my scope and I swept the band noting how clearly defined the edges were through the telescope. I have observed frequently since 1996 but never experienced anything like what I saw last night, it was a remarkable sight.*
>
> *By 10:50pm the aurora appeared to cover nearly all the sky with faint glow…*

This eyewitness report confirms several of the physical characteristics of STEVE.

1) Crossed near the zenith at his latitude 50 degrees north
2) Narrow and distinct well-defined border and only 2–3 degrees wide
3) Described as an arc and like a rainbow
4) East–West orientation of the arc
5) Colour of bow was green
6) Aurora seen

Beckett's visual telescopic observation of the clearly defined border is rare. Furthermore, although earlier images exist, this observation predates the sharp rise in popularity of STEVE by the now famous Alberta Aurora Chasers imagers in 2016.

When an investigation is conducted to find earlier archived observations of STEVE, a theme becomes quickly apparent. Earlier observers often confused it with other natural phenomena, not all of them atmospheric in nature. The confusion generally lies in three areas of misinterpretation.

The zodiacal light during an outstanding display can create a "bridge" that can be seen from the horizon to the zenith of an observer. Some witnesses could not discount the zodiacal light from STEVE especially considering the common east-west orientation of both.

The aurora, obviously a very familiar feature in higher latitudes, can put on stunning displays. Often STEVE is seen during or shortly before and after an aurora display. It was usually presumed by witnesses of STEVE that it was related to or a part of the aurora.

Finally, it was suggested that STEVE could be cometary in nature. An eyewitness would be able to distinguish it from a comet if it is observable for a reasonable period of time. STEVE does not rotate with the stars. In any case, all doubt would be eliminated to its cometary nature in the following nights if it completely disappears.

Past observers were clearly perplexed to explain what they were seeing. That has changed. Knowledgeable observers are now aware of the phenomenon and are able with confidence to know what they are viewing if it materializes. As noted above, imagers are also quick to act.

A search into archives confirms that it was observed for centuries, but in virtually every instance its nature is questioned. Some reports are clearly describing STEVE. Others are missing enough elements to cause doubt. In these cases, it becomes a judgment call as to whether STEVE was being witnessed.

Highlighted here are a few examples of observations of STEVE starting from as early as mid-19th century. Most have a Canadian or RASC association.

One description comes from Walter Maunder (1851–1928) an honorary member of RASC, and famed solar observer. In his book *Astronomy Without a Telescope* 1904, the following reference is made.

> *From time-to-time, curious beams of light are seen in the sky, the exact nature of which it is difficult to determine. Thus, on March 4th, 1896, a curious light was seen stretching up from the horizon towards the Pleiades, which some observers were inclined to regard as auroral, some as the Zodiacal Light, and some actually regarded as being cometary. The fact that*

an unmistakable aurora was seen the same evening pointed strongly in favour of the auroral theory. On the other hand, as its direction coincided nearly if not precisely with that of the axis of the Zodiacal Light, and as similar beams have been seen in the same position on other occasions, the question cannot be regarded as absolutely decided. It would be a matter of the highest interest could it be shown that certain definite regions of the heavens were subject to recurrent flashes, and a careful collation of observations made at widely separated stations would soon Settle as to whether we should regard them as auroral or zodiacal, and could not fail to increase our comprehension of one or the other phenomenon.

Maunder is discussing an event that occurred on 1896 March 4. This occasion was witnessed from various locations in the U.K. by skilled amateur astronomers. Maunder is probably commenting on the reports collaboratively. The fact that it was widely viewed undoubtedly led to an increased credibility of the sighting.

As noted earlier, Maunder explores the possibilities as to the nature of being either auroral or related to the zodiacal light.

Garrett P. Serviss (1851–1929) was a well-known astronomy author and popularizer in the late 18th and early 19th century. A reference to STEVE can be found in his book, *Curiosities of the Sky*. The chapter "Marvels of the Aurora" gives the details.

Serviss recalls in the chapter an aurora display he witnessed from his childhood in New York State. Details seem to suggest that STEVE was witnessed. Below however, is another incident within the same chapter.

I remember another similar one seen from the city of New York in November 1882. On this last occasion some observers saw a great upright beam of light which majestically moved across the heavens, stalking like an apparition in the midst of the auroral pageant, of whose general movements it seemed to be independent, maintaining always its upright posture, and following a magnetic parallel from east to west. This mysterious beam was seen by no less than twenty-six observers in different parts of the country, and a comparison of their observations led to a curious calculation indicating that the apparition was about one hundred and thirty-three miles tall and moved at the speed of ten miles per second…

Like Maunder, Serviss notes an incident that was seen by multiple individuals from different locations. In this case Serviss is able to confirm it is atmospheric in nature, and even tries to calculate the height above the ground of the mysterious bow.

Another interesting account has a strong RASC connection. In fact, it can be found in the inaugural JRASC edition! Back in the January/February 1907 *Journal*, an article; "A remarkable Aurora on August 7, 1906" by J. McEachren contains the details. His location was Shebeshekong, Ontario, near Parry Sound at 45.5 degrees north latitude.

At the time the Aurora began a large bow of light appeared in the north-east, seeming to spring up from the Aurora, and gradually but slowly extending upwards across the sky to the zenith and down to the west until it reached the horizon. It was from 3 to 4 degrees in width, came up in the north-east through the dolphin, crossed the Milky Way at about right angles slightly south of the zenith, and slightly south of the head of Cygnus, covered Corona Borealis and Arcturus and extended westward where Venus had been two hours before in the ecliptic.

…It had no motion but remained in the same position all the time. It arched the whole sky without a break. Breaking up first at the zenith it gradually but slowly dissolved, and at 10:30 had disappeared.

McEachren enjoyed about a 90-minute-long display allowing him to observe the stationary nature of the phenomenon. McEachren presumably was baffled.

Just three years earlier than McEachren's observation, another account occurred in August and is remarkably similar in description.

"The aurora of August 21, 1903" by Judson B. Coit.

Coit observed it from Cape Porpoise, Maine at 43.5 degrees north latitude.

At 9h 40m my attention was called to a beautiful band of light rising from the western horizon at a point about 10° N. of W., passing a little south of Arcturus, thence on some 10° south of Vega (i.e. about 15° south of the zenith) and extending nearly to the horizon at a point a little south of east. When first seen the band was estimated to be about 2° wide but narrower near the horizon. At 9h 45m the portion extending from a little above Arcturus to near Vega was described as being decidedly the brightest, but in other respects at this time, the western half presented no marked peculiarities being essentially continuous and remarkably uniform in width. The part reaching eastward from Vega some 40° presented, however, at this time, as when first seen, a very different appearance. Here, the band, instead of being continuous, consisted of segments or sections seemed to lie absolutely parallel to one another and at an angle of 45° with the general direction of the band, i.e. they lay nearly in the direction N.W. to S.E.

By 9h 50m the entire arch had swung to the south a distance equal to it own width, but still rested upon the horizon at apparently the same points…

Again, with confidence, this case can be confirmed as another independent sighting. The Boston University Observatory at the campus on the Charles River in Boston is named after Judson B. Coit. There appears no resolution as to what Coit viewed.

Finally, another worthy observation, this one is witnessed from Canada before Confederation.

Henry Youle Hind (1823–1908) was an English-born geologist and explorer. Hind at the time of his report was

Figure 1 – This photograph of STEVE was taken on October 1, 2006, and strongly resembles the description provided by many earlier eyewitness reports. Credit: 2006 Alan Dyer/AmazingSky.com

an immigrant to Canada. Hind was designated to lead the scientific portion of the Red River Expedition of 1857 on a route from Lake Superior to Selkirk Settlement (Manitoba). While camped on the Height of Land Lake in Ontario (west of Thunder Bay) on the night of 1857 August 12, Hind records the following observation.

> *At our camp on the Height of Land (Aug. 12th) an atmospheric phenomenon of singular beauty occurred. The night was very beautiful and calm. The moon shone with, great clearness and brilliancy, and numerous meteors darted through the sky in the south and west. Early in the morning, before daylight, I noticed a distinct arch of what at first sight I mistook for an aurora, but, observing its position to be nearly due west, referred it to very elevated clouds illumined by the sun's light. Its appearance was like that of a dim auroral arch, well defined, and forming the complete segment of a circle to the height of 45 degrees, its form being persistent as long as observed. The remaining portion of the sky was clear, the moon and planets shining at the time with a very brilliant lustre. It occurred to me that it might be the forerunner of a storm, an idea which the rising sun, lighting up the tops of the trees beneath a perfectly cloudless sky about an hour afterwards, banished for a few hours.*

The observation is contained in the document "*Narrative of the Canadian Red River exploring expedition of 1857 and of the Assinniboine and Saskatchewan exploring expedition of 1858.*"

Clearly the meteors described were associated with the famous Perseid meteor shower known to peak on that date annually. Hind's description of the "distinct arch" contains enough other details to confirm a sighting of STEVE. It is a curious note that Hind seemed to have recognized that this arch was not associated with the aurora. Most early witnesses did not make that assertion.

Conclusion

The above examples are just a small sample of writings that either suggest or are confirmation of STEVE. There are many more known and even still more to be discovered.

In recent images and visual observations, the "picket fence" phenomenon is often captured or described adjacent to the bow. This feature does not appear to be described often in earlier archived eyewitness reports.

In most cases, the observer was bewildered as to what they were witnessing. It is equally true that most people reading the reports interpret them to be an unusual aurora display if not outright dismissing it. This is a mistake. It took digital images emerging in the 2000s to start the movement to convince astronomers that there was something else going on.

It is always a worthwhile endeavour to keep an open mind when reading any old texts or reports of an astronomical nature. Anyone interested in researching archives of observing records, including decades of RASC Centre newsletters, should keep a watchful eye for reports of STEVE.

Alan Dyer, a well-known Canadian astrophotographer, has the earliest photograph of STEVE that I have found. It is on film dating to April 1997. I am thoroughly convinced that sketches and more photographs of STEVE exist before the 21st century and before the era of digital photography. ✶

The author would like to thank Chris Beckett and Alan Dyer for their cooperation.

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AAVSO

Your Monthly Guide to Variable Stars

by Jim Fox, AAVSO

Many, if not most, of the stars we see change brightness over various periods of time for various reasons. Sometimes a star can dim, brighten, and dim again in less than a second! Other stars can take years to complete a cycle of brightness variation.

These stars are called "variable stars." One variable that YOU can see this month is Mira or Omicron Ceti in the constellation Cetus the Whale or Sea Monster. You can find it by imagining the "V" of stars in Pisces with Alfa Pisces at its tip to being an arrowhead pointing south to Mira. Another "V" of stars formed by the Hyades cluster in the face of Taurus, the Bull, also points the way to the west. Where the two pointing lines intersect, you will find the variable star.

Or maybe not! At its brightest, Mira is easily visible to the naked eye at magnitude 2. But at its faintest, it is over 1500 times fainter at magnitude 10. That may be a challenge, even for binoculars. Perhaps that is why Johannes Hevelius coined the name Mira (Latin for "wonderful" or "astonishing") in 1662.

David Fabricus thought it might be a nova when he saw it first brighten and then fade in 1596, but then he saw it brighten again in 1609. Today, we know the star's period is about 332 days and it spends about half its time fainter than naked-eye visibility.

Miras are a class of variable stars that have completed fusing their hydrogen fuel and are the coolest, largest, and most luminous red giant stars. Their brightness varies as the star pulsates. Recent Hubble Space Telescope images of Mira show evidence of mass streaming away from the star at a rate of one Earth mass per year.

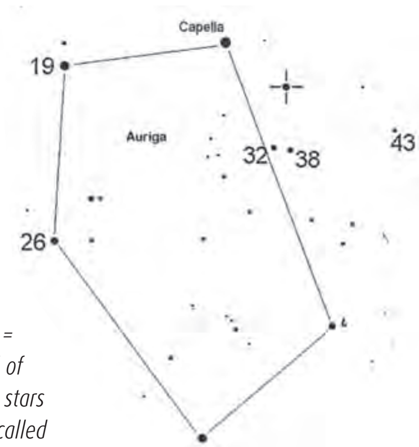

Figure 2 — This finder chart for Epsilon Aurigae will help you estimate its brightness. The image is not inverted so it is suitable for binoculars. Epsilon is the highlighted circle and magnitudes are in tenths with the decimal point omitted so as not to be confused with a star – so, 38 = 3.8. Given the "goat names" of Capella and Almaaz, the two stars labeled 32 and 38 are often called "the kids." Chart is courtesy of AAVSO.

November — Epsilon Aurigae

The variable that you can see during the month of November is Epsilon Aurigae, also recognized by the name Almaaz, "Billy Goat." It is located just west of the pentagon that forms the constellation Auriga, the Charioteer, and about 3 degrees southwest of the bright star Capella, the Latin word for "Nanny Goat." Every 27 years Epsilon dims from magnitude 2.9 to magnitude 3.8 and stays dim for about two years. This is an example of an "eclipsing binary" where a bright star is covered periodically by a dimmer object passing in front of it. But what is the dimmer object?

This question puzzled astronomers for years, but they mounted an extra effort during the eclipse of 2009–2011. Collaborations between professional and amateur astronomers collected enormous amounts of data and now they have a good idea of this mysterious body. The mystery object is another star, but that star is imbedded in an immense gas cloud and cannot be seen in visual light. The hidden star is a massive object that probably accumulated its gas cloud by capturing parts of the outer atmosphere and "stellar wind" of the visible star. Small brightness variations during the two-year eclipse may be due to variations in the opacity of material in the cloud.

For more than 100 years, the American Association of Variable Star Observers (AAVSO) has encouraged the observation and study of variable stars, maintaining databases of all submitted observations. Observing techniques include both visual and photometric (CCD/CMOS, DSLR and photoelectric) and now even spectroscopic. For more information on AAVSO and how you can contribute to astronomical science through variable stars, visit their website at www.aavso.org ✶

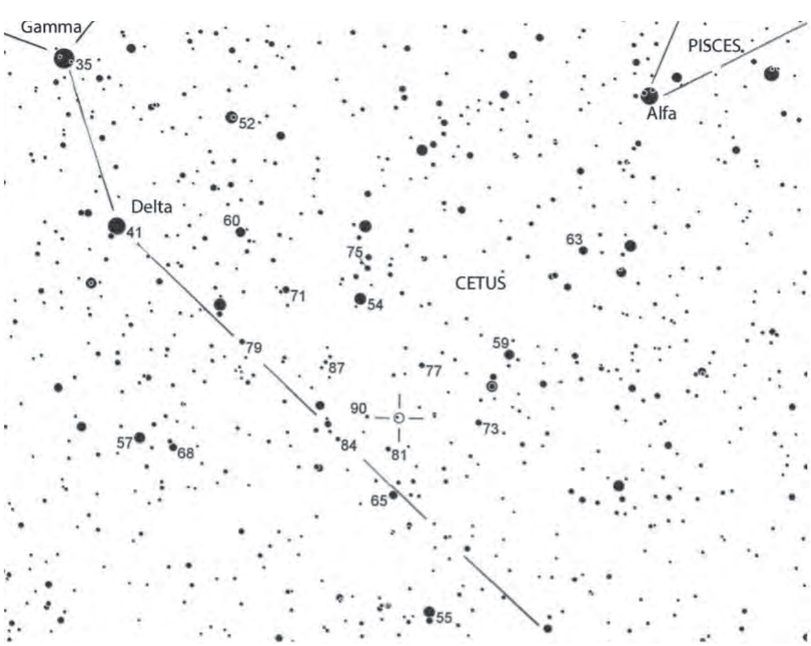

Figure 1 — This finder chart for Mira will help you estimate its brightness. The image is not inverted so it is suitable for binoculars. Mira is the highlighted circle and magnitudes are in tenths with the decimal point omitted so as not to be confused with a star – so, 54 = 5.4. Chart is courtesy of AAVSO.

Pen & Pixel

Figure 1 — We are delighted to have Ottawa Centre member Andrea Girones' incredible image of the Rho Ophiuchi region that she shot from her family cottage in Port Albert, Ontario, near Lake Huron.

"Even though it had been cloudy for most of the holiday the Astrogods gave me a stunning clear night on the new moon of July 9th," she says. Andrea used a WO RedCat51 250mm FL ƒ/4.9, with a ASI2600MC Pro cooled CMOS camera, on a Sky-Watcher Star Adventurer and guided with the ASI120MM camera. She took 48 120-second lights and 20 × 120s darks.

Figure 2 — This beautiful image of an astronomical favourite, the North America Nebula (NGC 7000), was taken by Shelley Jackson from Sarnia, Ontario. She used an 81-mm WO GT apo triplet on a Sky-Watcher AZ EQ5 pro mount with a ZWO ASI294MC Pro one-shot colour CMOS camera cooled to −10°C. She used L-eNhance and L-Pro filters from Optolong (L-eNhance data: 88 × 180-second lights; L-Pro data: 60 × 180-second lights) and processed and stacked the images in PixInsight.

Figure 3 — Ron Brecher imaged the B110 region in Scutum, a small constellation that he describes as "overflowing with dark nebulae," from his SkyShed in Guelph, Ontario. For luminance, he used a Sky-Watcher Esprit 150 ƒ/7 refractor and QHY600M camera with Optolong UV/IR filter. For chrominance, he used a Takahashi FSQ-106 ED IV at ƒ/5 and QHY367C Pro one-shot colour camera with Optolong UV/IR filter. Ron took 48 x 600-second luminance and 104 × 600-second chrominance.

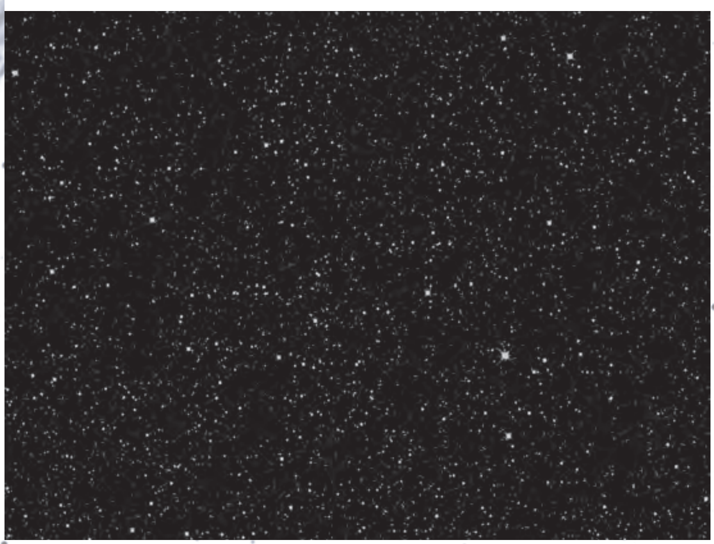

Figure 4 — In early August, astronomers around the world were surprised when the recurrent nova RS Ophiuchi went into an outburst for the first time in 15 years. It went from magnitude 11.2 to 4.8 from August 8 to 9. In the first image, you can see RS Ophiuchi before the nova, taken from the STScI Digitized Sky Survey. In the second, Toronto Centre member Kevin Watson — who has been involved with the robotic telescope since 2018 — used the RASC robotic telescope to capture the nova on the night it went into an outburst. Nice capture!

Skyward

Astronline

by David H. Levy, Kingston & Montréal Centres

During the last almost two years I have been busier than ever, meeting many new people, giving lectures, quoting poetry, and advocating observing the night sky.

And Wendee and I have barely left home.

Obviously, I have not been able to give lectures in person since the COVID-19 pandemic began. On the home front for me, our local Tucson Amateur Astronomy Association meets the first Friday of every month online over the Zoom cloud. (see www.tucsonastronomy.org) But almost every day, I reconnect with friends in astronomy clubs around the world. On Tuesdays, I am a part of Scott Roberts' weekly Global Star Party. (For more about this, visit https://explorescientificusa.com/products/explore-alliance-global-star-party) Scott has now had more than 60 of these wonderful events, and I enjoy each one. On Wednesdays and Saturdays, I am part of the Montreal Centre of the Royal Astronomical Society of Canada, where I meet people I've known for years, especially Carl, one of my best friends since we were teenagers in 1964. As a graduate student at Queen's University in the 1970s, I also was active with the RASC's Kingston Centre. I have also reconnected with the Denver Astronomical Society, a group I joined in 1963 when I was a patient at the Jewish National Home for Asthmatic Children. That experience was precious back then, and it is even more delightful now!

One of the groups, the Warren Astronomical Society in Michigan, does not use Zoom. Instead, they have WebEx, which is just as simple to use. I have even participated in sessions sponsored by Kansas City's Linda Hall Library, one of the largest science libraries in the world.

Not all of the online sessions are related to astronomy. Our local synagogue has a weekly Torah study session, and Wendee and I are regulars there. They also graciously listen to my poetry quotations, which range from Shakespeare to Chaucer, to this ancient one (from 1556) from Robert Recorde's *The Castle of Knowledge*:

> *If Reasons reach transcend the Skie,*
> *Why should it then to earth be bound?*
> *The wit is wronged and led awrie,*
> *If mind be married to the ground.*

When the sessions drag on, as they sometimes do, I can get fatigued since I am not as young as I was in 1963 or 1979. But it is worth the effort, and I sincerely hope that the Zoom/WebEx experience will outlive the pandemic when it finally ends. Seeing friends so often like this is wonderful. And on some occasions, I have joined online meetings from a remote site in southeastern Arizona.

Figure 1 — The author using his computer inside the observatory.

Sometimes, my quote tradition is something from scripture, like this gem from the Book of Isaiah:

> *Thou stretchest out the heavens as a curtain,*
> *And spreadeth them out as a tent to dwell in.*

My goodness—I never realized how a few words from the Bible could affect me as much as these do. They describe my experience perfectly—outside, I am peering at the curtain of the night sky. Moreover, the observatory out of which I look at the sky, or the observing pad upon which I stand, is the cosmic tent in which I dwell. ✶

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

Observing

Gegenschein, Mars, and a Mystery Solved

by Dave Chapman, Halifax Centre
(dave.chapman@ns.sympatico.ca)

Columnist Chris Beckett writes: Dave Chapman and I were communicating about his gegenschein observation and he offered to be a "guest" contributor for the Observing Column this month. I'm always excited to read other observers' observations and especially a phenomenon I have yet to see for myself.

"God bless you!" At least that's what I think Tony said—or words to that effect—after I exclaimed "gegenschein!" Tony Schellinck (a fellow Halifax Centre member) and I were casually reclining in our camp chairs, just after midnight, gazing up into the heavens after observing some "spring" double stars in our binoculars. It was 2017 February 25, and we were dressed in our summer clothes, enjoying the balmy night of the Florida Keys at the Winter Star Party (24.7ºN, 81.3ºW). Leo was high overhead, around 80º altitude, and I was wondering about the misty patch that seemed to be hanging in the body of The Lion. It was neither light pollution, nor a passing cloud, and certainly not the Milky Way. Then it struck me—if I were looking at the anti-solar point (which it turned out to be), the patch might be the elusive gegenschein, which I had heard of but never seen.

"Gegenschein" (German for "countershine") is akin to zodiacal light. Both are part of the zodiacal band of sunlight scattered by micrometre-sized grains of dust in the plane of the Solar System. Both are difficult to spot, requiring dark, transparent skies unpolluted by artificial light and free of moonlight. From our mid-northern latitudes, zodiacal light is typically spotted in the west after dusk within a month of the spring equinox, or in the east before dawn within a month of the autumn equinox. In contrast, gegenschein is best seen in the dead of night, opposite the Sun, where the glow is enhanced by a physical effect called "opposition surge" whereby the particles are fully illuminated, providing an enhanced backscatter overall (a similar effect makes the full Moon extra-bright). Gegenschein is hard to spot if the background sky is "busy" with stars (such as where the ecliptic crosses the Milky Way).

Checking the ecliptic longitude of the patch centre relative to that of the Sun (using *SkySafari* on my iPhone), I confirmed the sighting as gegenschein, and then I decided to record it. That was a fairly simple matter of taking a tracked photo with my Canon SL1 camera with a SamYang 14-mm lens (ISO 800, *ƒ*2.8, 238 s) which gave a respectable 77º × 56º field of view. As the lens has a bit of vignetting, I corrected for that using a "flat" frame. Figure 1a above right shows Leo right of centre with the gegenschein embedded (it is very subtle and may not reproduce well, so here's an online version www.dropbox.com/s/3v846jh8uvm4tvd/Figure1a.jpg?dl=0).

In Figure 1b, I have added a couple of labels to orient the reader, and a circle 20º across containing the brightest portion of the glow as I see it, centred on the star 52 Leonis. At the time of the photo, that star was 14 minutes short of culmination at 79º altitude, at ecliptic coordinates (158º longitude, +6º latitude), while the Sun was at (337º longitude, 0º latitude), a longitude difference of 179º—the patch I spotted definitely included the anti-solar point.

Figure 1a — The author's photo of gegenschein in the constellation Leo at the Winter Star Party, 2017 February 25.

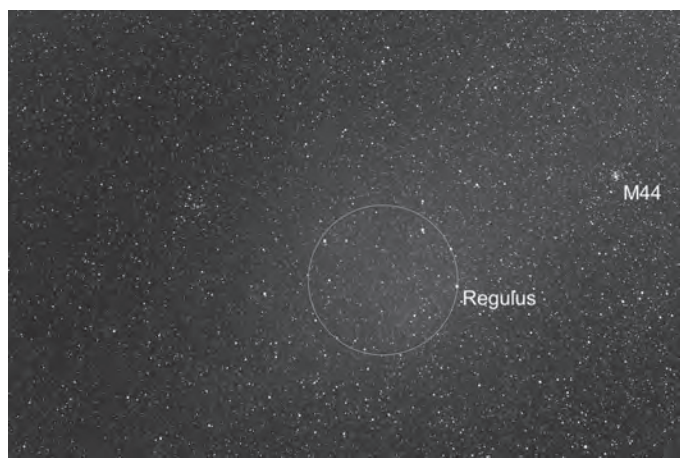

Figure 1b — The image from Figure 1a with annotations. The 20º circle is centred on the star 52 Leonis.

I had satisfied myself that I observed the gegenschein, and that I had located it fairly well, but I was bothered that it appeared to be centred 6º above the ecliptic. I reckoned that it should be *on* the ecliptic. I did a bit of research at the time, and I found that indeed there were existing scientific observations of systematic variation of the ecliptic latitude of the zodiacal band with longitude. I did not think more about it at the time, until just recently. Read on!

On 2021 March 9, NASA announced that data from the interplanetary probe *Juno* confirmed earlier hypotheses on the connection between zodiacal light and the orbit of Mars* (www.nasa.gov/feature/goddard/2021/serendipitous-juno-spacecraft-detections-shatter-ideas-about-origin-of-zodiacal-light). If you type "zodiacal light Mars" into your web browser, you will find all manner of popular accounts of this finding, but the peer-reviewed paper is here: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020JE006509

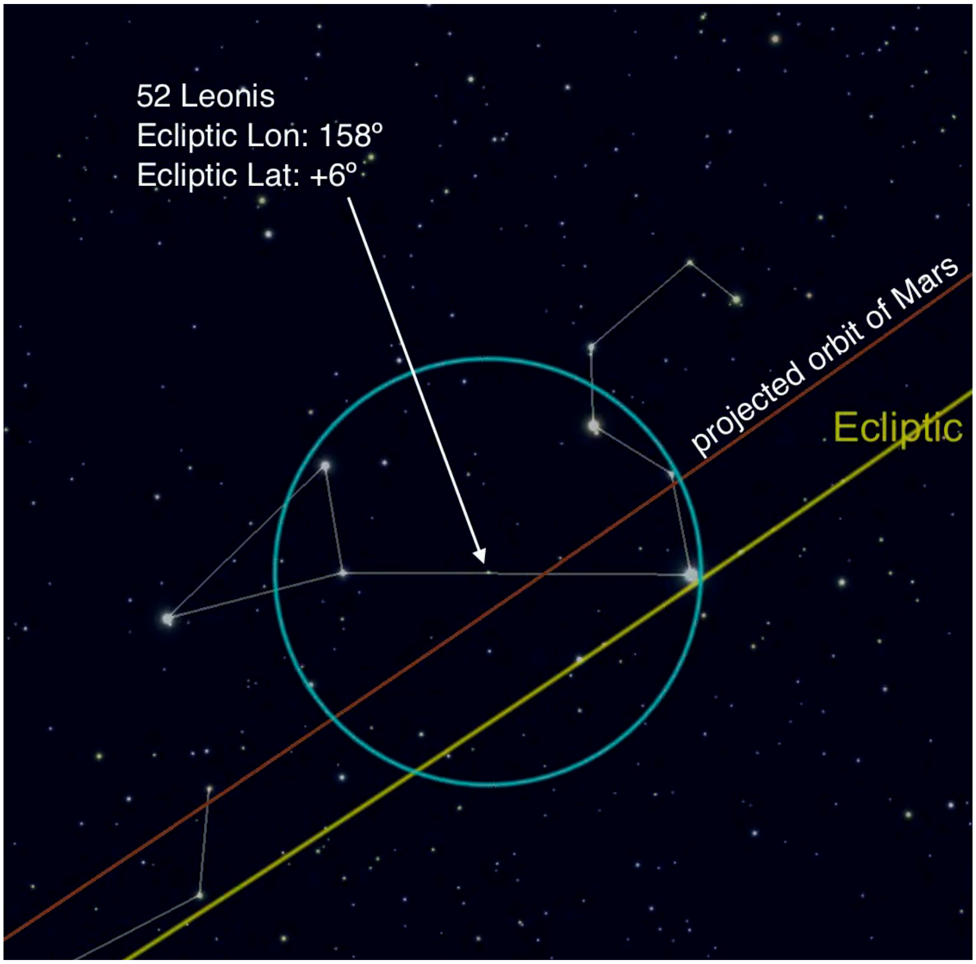

Figure 2 — The geometric relation between the observed gegenschein of 2017 February 25, the ecliptic, and the projected orbit of Mars.

The "why?" of that connection is not fully understood, but it tweaked my memory about my own observation of gegenschein in 2017 (it is interesting to note that the cited paper does not mention gegenschein, only zodiacal light). It was a simple matter in *SkySafari* to project the orbit of Mars (as seen from Earth) onto the background sky at the time. Figure 2.

I have reproduced the 20° circle from Figure 1b centred on 52 Leonis that captures most of the gegenschein. The first thing to note is that the gegenschein was significantly displaced from the ecliptic (about 6° give or take one degree). The second thing to note is that the orbit of Mars (think of it as a giant hula hoop) is also displaced from the ecliptic in the same direction (about 4.5° at that longitude). If that sounds large compared to the 1.8° orbital inclination of Mars, remember that the smaller number is from the Sun's point of view, while we on Earth are 2/3 of the way to the orbit of Mars, so the angle of view would be enhanced. The ascending node of the orbit of Mars is at ecliptic longitude 50°, so the largest apparent displacement of its orbit (at opposition) would be at longitude 50°+90°=140°. That position is near the boundary between Leo and Cancer, about halfway between Regulus and M44 in Figure 1b, only 18° away. If you do the math (a homework assignment), 4.5° is about right. As an aside, on 2027 February 19, Mars will be at opposition within that 20° circle.

In conclusion, the recent news about Mars and the zodiacal light appears to solve the mystery of why my gegenschein observation in February 2017 seemed to be "off." My analysis above is really only a sketch; a better job could probably be done. However, I am pleased that my chance observation of the gegenschein on that night is consistent with the recent scientific results. Going one step further, I wonder if my observation of the displaced gegenschein might be a small contribution to the science of this phenomenon. ✶

Dave Chapman FRASC has been an amateur astronomer for 60 years. When he bought his first RASC Observer's Handbook *for $1 in 1963, little did he know that he would be editor of that publication for issues 2012–2016. He earned the RASC Simon Newcomb award in 1986, the Service Award in 2015, and the Fellowship Award in 2020. Currently he is Observing Chair of Halifax Centre, member of the RASC Observing Committee, and member of the RASC Editorial Board. He thanks friend and mentor Emeritus Professor Roy L. Bishop (Acadia) for helpful comments on this article.*

* Distribution of Interplanetary Dust Detected by the Juno Spacecraft and Its Contribution to the Zodiacal Light, J. L. Jorgensen *et al.*, *JGR Planets 126(3),* March 2021.

Solar Monitor

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

Monitor our Star

I continue to search for good mobile apps to alert us of interesting activity at our nearby star. I don't see excellent options for Android users. A popular choice for the iOS platform is *Solar Monitor* and some amateur astronomers I know regularly use it. *Solar Monitor* culls near-real-time data about the Sun and possible auroral activity from official sources maintained by NASA and the European Space Agency. I downloaded and tested the iPhone app.

Main Monitor

On starting *Solar Monitor*, you are shown the main *Monitor* screen, which I quite like. This mode offers one-stop shopping to get a sense of what's going on now and what's coming up (see figure 1).

The top of the screen sports recent images of the Sun in different spectra courtesy the *Solar Dynamics Observatory* (SDO). Tapping a Sun image switches to a high resolution, zoom-able, full-screen display. You might spot active regions or solar flare sites.

You can adjust the centre portion or *Dashboard* to show different content. Tapping the "hamburger" menu lets one select a preference, alerts, or a chart display.

X-Ray Flux data can be shown along with the all-important colour-coded Planetary K-Index values. If the Kp-Now indicator is yellow or red along with high estimated values, start the car!

Figure 1 — The informative main screen of Solar Monitor *with useful Kp-Index indicators.*

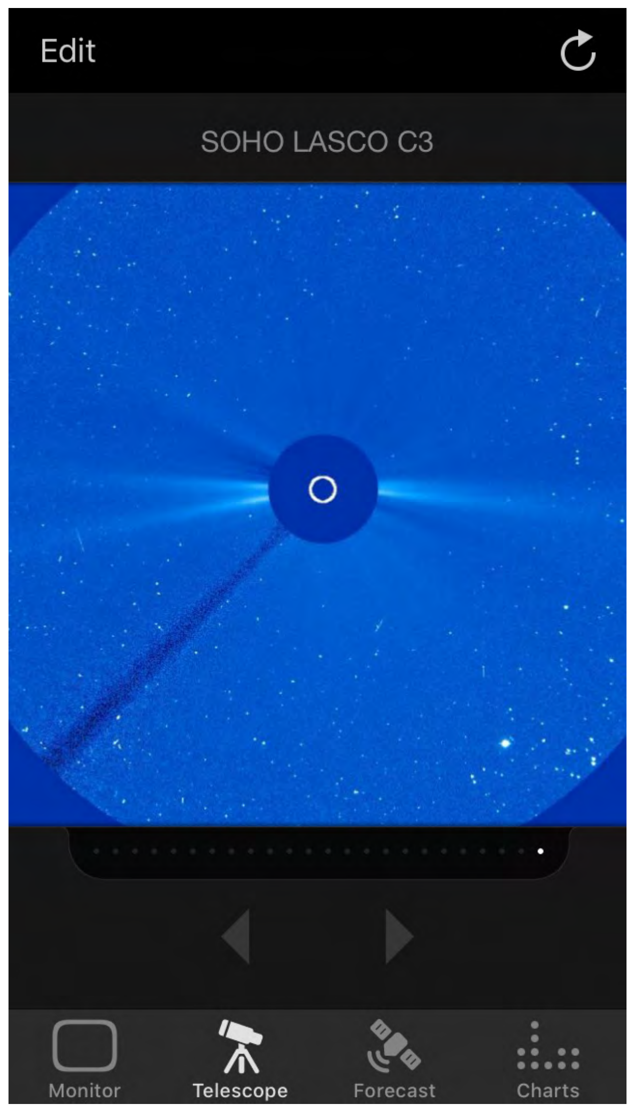

Figure 2 — Recent coronograph image from the SOHO space probe. Watch for CMEs.

Analogue gauges can show Solar Wind and Interplanetary Magnetic Field (IMF) Bz information, and you can tap here to flip between the label or value.

A toolbar at the bottom of the screen offers four different operational modes.

Live Probe Views

Telescope mode shows images from the *Solar & Heliospheric Observatory* (SOHO), which can reveal coronal mass ejections (CMEs) from the Sun and sungrazer comets (Figure 2). Triangle buttons below the image allow switching the Large Angle and Spectrometric Coronagraph (LASCO) display. You might notice inner planets Mercury and Venus in the coronograph images.

At the Poles

The *Forecast* mode can show images from the OVATION Aurora Model system (Figure 3) with infographics for auroral activity, borealis or australis. Watch for intense green in your region. If yellow or red, grab the camera, tripod, and intervalometer!

The Edit button at the top lets you choose the display and configuration, while the up and down arrow buttons flip the image and associated text to the upper and lower panels.

Watch for Trends

Finally, the *Charts* screen (Figure 4) can be used to show various line and bar charts as produced by the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center (SWPC).

You can show these charts with white or black backgrounds with the arrow buttons toggling full screen mode.

Set Reminders

Tapping the circled "i" button from the main screen shows a long page (Figure 5) with general information. It reminds us to set up Push notifications via the iOS device Settings.

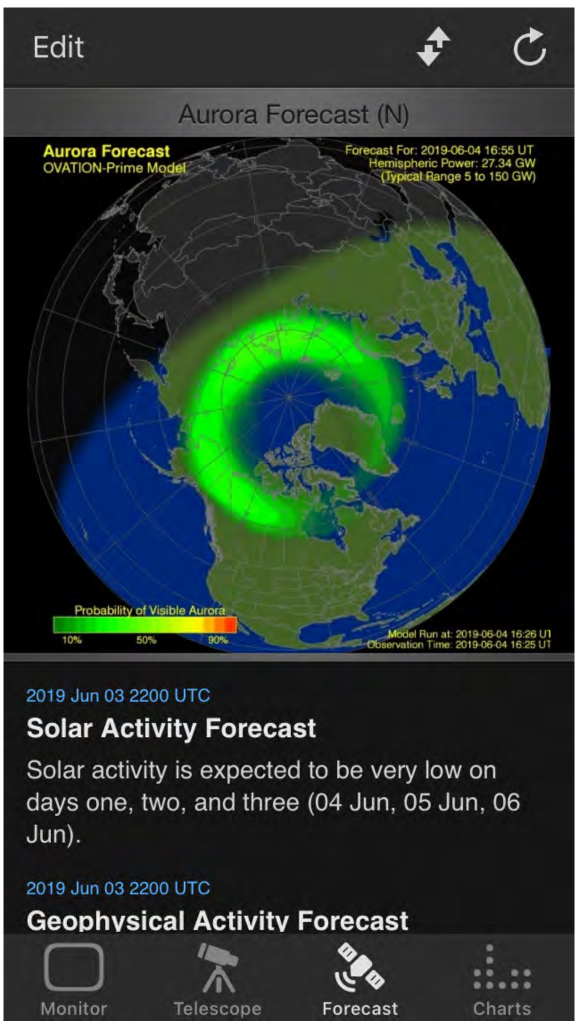

Figure 3 — Recent image from the OVATION model indicating aurora at the poles.

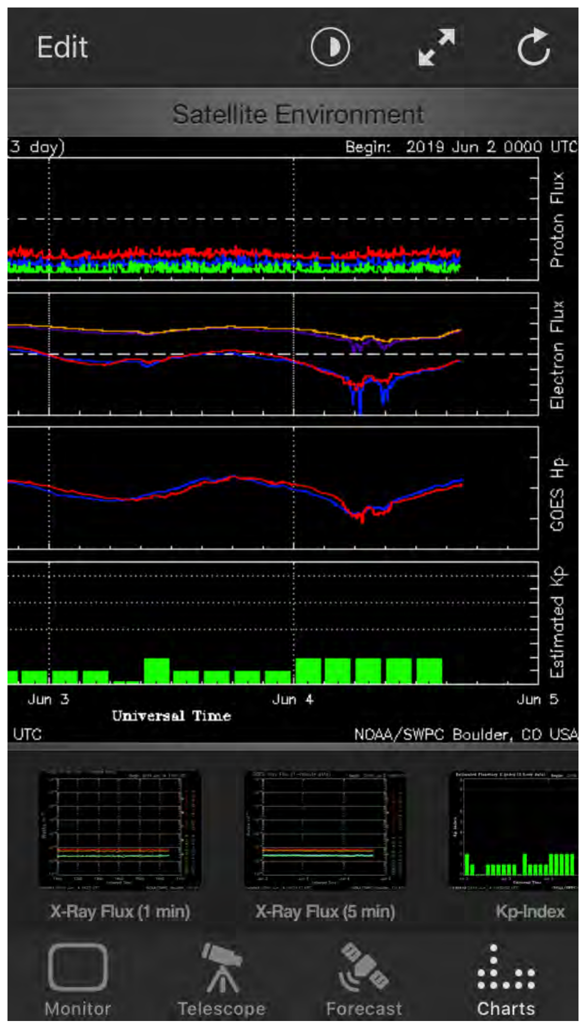

Figure 4 — Line and bar graphs with dark backgrounds from NOAA SpaceWeather source.

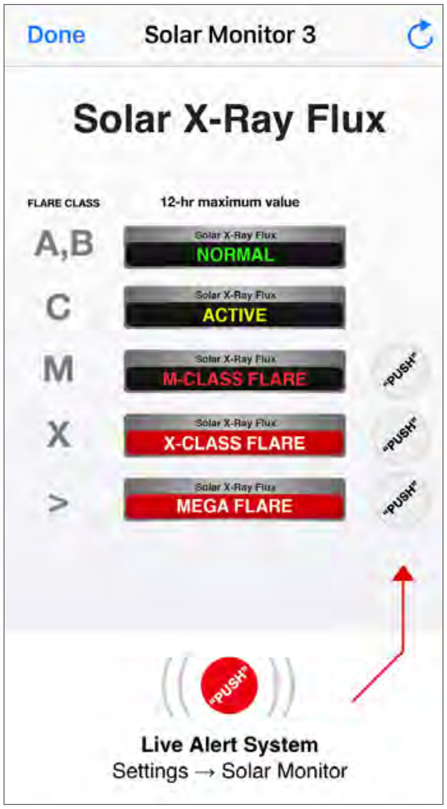

Figure 5 — The "information" screen reminding how to configure alerts from the app.

While this "information" screen provides some additional instructions, I thought I'd find some help and guidance information here, particularly definitions. A great number of acronyms are used in the *Solar Monitor* app, so it is up to the user to learn these terms and how to interpret the many displays.

More Info

Visit the developer's web site for product information and links to the product pages.

www.solarmonitor-app.com/

Solar Monitor version 3.1 runs on an iPhone and requires iOS 11 or later. It costs $7 at the App Store and has a rating of 3.8 out of 5 stars with 19 reviews. A handful of languages are supported.

Unfortunately, there's no help on the website. You'll likely need to visit NASA and ESA websites for technical information and explanations.

You must have an active internet connection to use the mobile app, as it dynamically pulls graphs and images from its sources, but you can force a refresh if necessary. Given the instantaneous nature of the app, you'll want to keep tabs on the NOAA graphs to get a sense of trends.

The iPhone app only works in portrait orientation.

Unique iPad Product

There seems to be a slightly different, and perhaps older app for the iPad, with a unique set of toolbar buttons.

www.solarmonitor-pro.com/ipad/

If I understand correctly, the iPad product is specifically called *Solar Monitor Pro*. Version 2.0 requires iPad OS 6.0 or later. It is listed at $7 as well.

The SOHO images look spectacular on the large display of an iPad. I've seen screen snaps and videos of *Solar Monitor Pro* and curiously it appears to have a detailed help screen with explanations!

Stale

The app (apps?) appears to have not been updated recently. At the store pages, Apple says the developer has not provided details about privacy practices. With some questions in hand, I tried to contact the developer Thomas Ebbert directly using info@egrafic.net but the email bounced. I found a working address but did not receive a reply. These are not good signs.

The website's pages show an active embedded Twitter feed with "alerts." I tried to DM the owner on Twitter—no go.

The app looked and worked fine for me. The iPhone app is a little pricey but offers a very helpful dashboard-like display with current information for the knowledgeable solar observer and aurora hunter.

To be frank, I'm not happy. I had high expectations with this app. It should work when off-line, at least showing the most recent data. I'd like to see a feed to identify Active Region sunspot groups. It doesn't make sense to me that the phone app excludes help information.

Just means I'll have to keep searching.

Here's hoping you'll catch many sunspots, filaments, and prominences at the Sun and aurora activity on Earth in the coming years surrounding the 2025 solar maximum.

Acknowledgements

I thank Chris Vaughan for being my eyes and ears while testing the iPhone app and Rhonda Gribbon for quickly proofing my bungled grammar, spelling, and punctuation.

Bits And Bytes

If you know me, you know I love the *SkyTools* software. I procured *SkyTools 3 Professional* in the summer of 2010 and have been drinking the Kool-Aid ever since. In the spring of 2020, the version 4 beta testing program spun down. The *Skyhound* developer ended version 3 technical support on 2021 August 31.✶

Blake's interest in astronomy waxed and waned for a number of years but joining the RASC in 2007 changed all that. He helps with volunteer coordination in the RASC Toronto Centre and is the interim chair of the national observing committee. In daylight, Blake works in the IT industry.

CFHT Chronicles

Planets and Weird Exploding Stars

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

This month's column is all about Tau Boötis b followed by a reader request for more information on electron-capture supernova, a big story that came out of our friends at the W.M. Keck Observatory, Las Cumbres Observatory, *Hubble*, and *Spitzer*.

Figure 1 — Artist's rendering of Tau Boötis b and its host star. Credit: ESO/L.Calcada

Tau Boötis b

(Author's note: Much of the content of the Tau Boötis b section of this article is based on a joint news release by CFHT, Université de Montréal, and the Institute for research on exoplanets (iREx). I wanted to acknowledge the efforts of the lead author Stefan Pelletier, co-author Björn Benneke, iREx EPO coordinator Marie-Eve Naud, and everyone else involved in this release. It's not my own original work, so credit should be shared with everyone.)

Astronomers using SPIRou at CFHT measured the atmospheric composition of the hot Jupiter Tau Boötis b and uncovered some surprises. Tau Boötis b is a scorching hot world that orbits its host star in three days.

A quick reminder about SPIRou: It's a spectrograph/spectropolarimeter used by astronomers to look at the light from a single object; star, planet, etc… SPIRou takes the light from a single object and breaks the light into its component infrared colours—colours our eyes are unable to detect. The observations allow astronomers to study the object's characteristics: temperature, motion, composition. When we most often talk about SPIRou, it's in the context of planet hunting, identifying the tiny gravitational wobbles in a planet's spectra caused by the gravity of an orbiting planet. SPIRou can also be used to study known planets in greater detail, exactly how Stefan Pelletier and his team did for Tau Boötis b.

Let's take a closer look at Tau Boötis b, the planet in question. It is 6.24 times more massive than Jupiter and 8 times closer to its parent star than Mercury to the Sun, thus classifying it as a hot Jupiter. Its host star, Tau Boötis, is located 51 light-years from Earth, is 40-percent more massive than the Sun, and one of the brightest-known planet-bearing stars in the sky.

Discovered in 1996, Tau Boötis b was one of the first exoplanets ever detected thanks to the radial-velocity method, which studies the slight back-and-forth motion of a star generated by the gravitational tug of its planet. The planet's atmospheric composition has been studied a handful of times before, but never with an instrument as powerful as SPIRou.

"SPIRou's high resolution and infrared wavelength range open a new window into the atmosphere of planets like Tau Boötis b," says Dr. Luc Arnold, CFHT resident astronomer and SPIRou instrument scientist. "These are the kinds of observations that the instrument was designed for, and we look forward to seeing what SPIRou uncovers next."

The team's detailed analysis, presented in a paper published in the *Astronomical Journal*, shows the atmosphere of the gaseous planet contains carbon monoxide, an expected result. Surprisingly, the team did not detect water, a molecule that was anticipated to be prevalent and should be easily detectable with SPIRou.

"Hot Jupiters like Tau Boötis b offer an unprecedented opportunity to probe giant planet formation," said co-author Björn Benneke, astrophysics professor and Pelletier's Ph.D. supervisor at Université de Montréal. "The composition of the planet gives clues as to where and how this giant planet formed."

The key to revealing the formation location and mechanism of giant planets is imprinted in their atmospheric composition. The extreme temperature of hot Jupiters allows most molecules in their atmospheres to be in gaseous form and detectable with current instruments, enabling astronomers to precisely measure the content of their atmospheres.

"In our Solar System, Jupiter and Saturn are much colder," continues Benneke. "Some molecules such as water are frozen and hidden deep in their atmospheres. Thus, we have a very poor knowledge of their abundance. Studying exoplanets provides a better way to understand our own giant planets. For example, the low amount of water on Tau Boötis b could mean that our own Jupiter is drier than we had previously thought."

Tau Boötis b is one of the first planets studied with SPIRou, which started observations at CFHT in 2018.

"This spectropolarimeter can analyze the planet's thermal light—the light emitted by the planet itself—in an unprecedentedly large range of colours, and with a resolution that allows for the identification of many molecules at once: water, carbon monoxide, methane, etc.," explains iREx researcher Neil Cook, a co-author who is an expert on the SPIRou instrument.

The team spent 20 hours observing the exoplanet with SPIRou between April 2019 and June 2020. This exquisite dataset allowed the researchers to make a detailed analysis of the molecular content of the hot Jupiter's atmosphere.

"We measured the abundance of all major molecules that contain either carbon or oxygen," explains Pelletier. "Since they are the two most abundant elements in the Universe, after hydrogen and helium, that gives us a very complete picture of the content of the atmosphere."

Tau Boötis b, like most planets, does not pass in front of its star as it orbits around it, from Earth's point of view. Previously, the study of exoplanet atmospheres has mostly been limited to "transiting" planets—those that cause periodic dips in the brightness of their star when they pass between us and the star, blocking some of the light.

"It is the first time we got such precise measurements on the atmospheric composition of a non-transiting exoplanet. This work opens the door to studying in detail the atmospheres of a large number of exoplanets, even those that do not transit their star," explains Ph.D. student Caroline Piaulet, also a co-author of the study.

The team assumed the composition of Tau Boötis b would be similar to the composition seen in the Solar System. Based on those Solar System models, they expected to see large quantities of water vapour in the planet's atmosphere along with carbon monoxide. Water vapour should be easy to detect with an instrument such as SPIRou.

"We expected a strong detection of water, with maybe a little carbon monoxide," explains Pelletier. "We were, however, surprised to find the opposite, carbon monoxide, but no water."

The team worked hard to make sure the results could not be attributed to problems with the instrument or the analysis of the data.

"Once we've convinced ourselves the content of water was indeed much lower than expected on Tau Boötis b, we were able to start searching for formation mechanisms that could explain this," says Pelletier.

The analysis by Pelletier and colleagues allowed them to conclude that Tau Boötis b's atmospheric composition has roughly five times as much carbon as that found in the Sun, quantities similar to that measured for Jupiter.

This may be a hint that hot Jupiters could form much further from their host star, at distances that are similar to the giant planets in our Solar System, and simply experienced a different evolution, which included a migration toward the star.

"According to what we found for Tau Böotis b, it would seem that, at least composition-wise, hot Jupiters may not be so different from our own Solar System giant planets after all," concludes Pelletier.

Congratulations to Pelletier and the entire team!

A Third Type of Supernova?

Rarely do I receive a reader's request for content, so I was delighted to receive one for this column. The question—please explain more about the new, third type of supernova announced in June.

This new, third supernova is known as an electron-capture supernova, hypothesized by Ken'ichi Nomoto from the University of Tokyo in 1980. Before we dive into the new SN, let's talk about the two established types of supernova—Type I and Type II. Type I supernovae lack hydrogen in their spectra, while Type II have hydrogen. Each type has subcategories, Type Ia being the most famous, based on other elements found in the spectra.

For the most part, stars on the main sequence balance the force of gravity pushing inward by the energy created in the core of the star by fusion pushing outward. When I explain this concept to 5th graders, I have them imagine a seesaw—energy out balancing gravity in.

Type II supernovae occur in very massive stars, those with a mass greater than 10x the mass of the sun. These are known as core-collapse supernovae and occur when iron is created in the core through fusion. Iron essentially shuts off the energy production, leaving the force of gravity unbalanced. The core collapses into a neutron star or black hole, the rest of the material in the star is ejected at high rates of speed.

A Type Ia supernova forms differently. When a star eight times the mass of the Sun or less reaches the end of its life, the energy production in the core slows. Gravity causes the star to contract, which raises the temperature of the core, triggering one last burst of energy production. The star expands, the core cools, and contracts to form a white dwarf. For stars like the Sun, white dwarfs are the final result. However, white dwarfs in a close-orbiting binary pair can accrete matter from their companion. If this accreted mass results in the white dwarf exceeding the Chandrasekhar limit of 1.44x the mass of the Sun, the white dwarf begins to collapse inward, triggering a Type Ia supernova.

Obviously, these are simplifications of very complex astrophysical phenomena, but they set the baseline for discussion of the electron-exchange supernova. Looking at the stellar masses mentioned above, one notices a gap—what happens to stars 8–10x the mass of our Sun, known as massive super-asymptotic giant branch stars or super AGB stars?

In 1980, Ken'ichi Nomoto hypothesized that these super AGB stars undergo another process in their core—electron capture. In the core of super AGB stars we find ionized oxygen, neon, and magnesium atoms. As a star ages, it begins to produce less energy, allowing gravity to contract the star's size, which raises the density of the core. The free electrons bouncing around the core begin to be absorbed or captured by the ionized atoms. Normally the free electrons help to keep the pressure of the core up, but as they're absorbed, the pressure reduces. As in our previous supernova examples, a lower core pressure leads to a supernova.

For 40 years now, Nomoto's hypothesis lacked observational evidence. Until Supernova 2018zd…

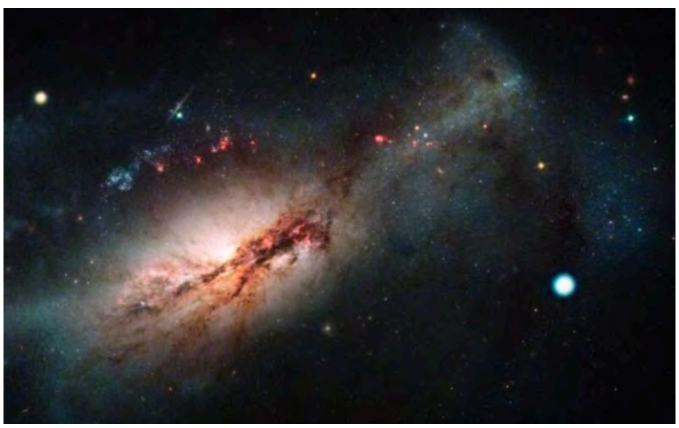

Figure 2 — Las Cumbres Observatory and ***Hubble Space Telescope*** *colour composite of the electron-capture supernova 2018zd (the large white dot on the right) and the host starburst galaxy NGC 2146 (toward the left). Credit: NASA/STSCI/J. Depasquale; Las Cumbres Observatory*

A team led by Daichi Hiramatsu from UC Santa Barbara and Las Cumbres Observatory collected data a mere three hours after the explosion of supernova 2018zd. The early observations allowed the team to develop an exquisite data set tracing the increase and decrease in the supernova brightness. The team continued to observe 2018zd over the next two years, discovered the progenitor star in archival *Hubble* and *Spitzer Space Telescope* data, and used the W.M. Keck Observatory to observe its spectrum.

The Keck data revealed that 2018zd met all six criteria for an electron-capture supernova: an apparent progenitor star of the

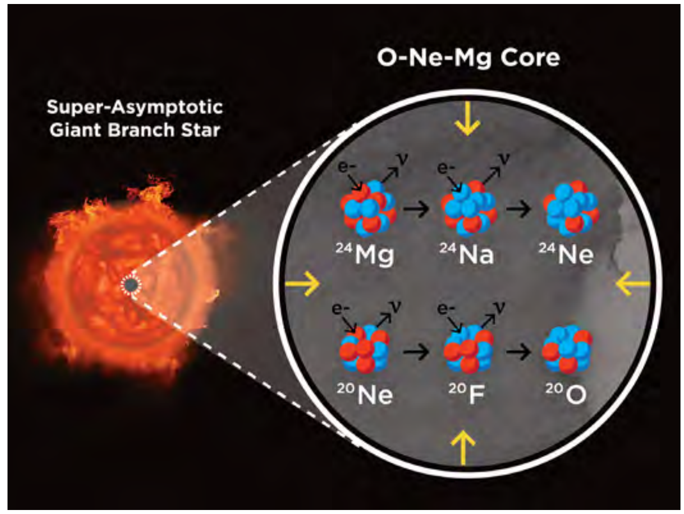

Figure 3 — Artist impressions of a super-asymptotic giant branch star (left) and its core (right) made up of oxygen (O), neon (Ne), and magnesium (Mg). A super-asymptotic giant branch star is the end state of stars in a mass range of around 8–10 solar masses, whose core is pressure supported by electrons (e-). When the core becomes dense enough, neon and magnesium start to eat up electrons (so called electron-capture reactions), reducing the core pressure and inducing a core-collapse supernova explosion. Credit: S. Wilkinson; Las Cumbres Observatory.

super-asymptotic giant branch (SAGB) type; strong presupernova mass loss; an unusual stellar chemical spectrum; a weak explosion; little radioactivity; and a neutron-rich core. The team looked at all published data on supernovae and realized that only 2018zd met all six.

The news about 2018zd opened up a new window of understanding into the Crab Nebula. Astronomers have long wondered if the supernova at the origin of the Crab Nebula fell into the electron-capture category. Historical records report the supernova was visible in the daytime for 23 days and visible at night for 2 years.

"I am very pleased that the electron-capture supernova was finally discovered, which my colleagues and I predicted to exist and have a connection to the Crab Nebula 40 years ago. This is a wonderful case of the combination of observations and theory," said Nomoto, who is also an author on the current paper.

Mahalo to our friends at the W.M. Keck Observatory for sharing the images from their news release. ✶

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.

John Percy's Universe

CASCA at 50

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

The Canadian Astronomical Society, our sister society for professional astronomers, celebrated her 50th birthday in May 2021. She is usually called CASCA, an acronym based on her names in the English and French languages. Explore her website (casca.ca), and catch up on the latest news about Canadian astronomy!

A century ago, there were only a handful of professional astronomers in Canada. Their organizational needs were met by the Royal Society of Canada, founded 1882, and the American Astronomical Society (AAS), founded 1899. Most were also active in the RASC. Their observatory reports, and some of their research papers, were published in this *Journal*.

Figure 1 — The Long-Range Plan for Canadian Astronomy 2020–2030, an almost-200-page document created by CASCA and its many partners, provides a road map for astronomy in Canada in the next decade.

After WWII, government interest in and support of science gradually increased, especially with the Cold War and the Space Age. Astronomy expanded into radio wavelengths, and into space. International cooperation in astronomy increased, especially through the International Astronomical Union (IAU), founded in 1918. The IAU National Committee for Canada, and later the federal National Research Council (NRC) Associate Committee for Astronomy, provided mechanisms for senior Canadian astronomers to meet regularly together. Some of these meetings are reported in *JRASC* in a series of 44 articles in which "Canadian Scientists Report."

As the post-war "baby boom" reached the 1960s, university enrolments also boomed, as did the popularity of astronomy with students and the public. New campuses were built. Many young astronomers were hired by the universities, including me. There was an increasing interest in and need for a Canadian professional astronomical society. Planning meetings were held. An organizational or "founding" meeting was held in Victoria in May 1971, and the first regular meeting was held in Toronto in November 1971 (Millman 1972). I was there. There were 138 charter members; 44 have passed away, and 24 of us are still dues-paying CASCA members. The Heritage Committee has prepared short bios of those charter members who have passed away (1). For more on the history of CASCA, see the CASCA history webpage (2). For even more, see Richard Jarrell's (1986) excellent history of astronomy in Canada. CASCA/RASC Archivist Randall Rosenfeld describes CASCA's archives, in the Spring 2020 edition of the CASCA newsletter *Cassiopeia.* History and archives are important!

CASCA's founding president was the late Helen Sawyer Hogg, Canada`s best-known and most beloved astronomer. Not until 2002, though, was there another female president—Gretchen Harris. Now, three of the past five CASCA presidents have been women. This statistic has been clouded, however, by the resignations of the current CASCA president and vice-president—both women—on 2021 August 5. The reasons are confidential, and presently unknown. This is very concerning.

CASCA and its Board have a strong committee structure, which provides both expertise and member engagement. Committees deal with the advancement of sub-fields of astronomy, such as ground-based, radio, space, and theory. Recently, committees on Equity and Inclusion and Sustainability have been added. Re sustainability: given the success of CASCA's virtual conferences in 2020 and 2021, is it really necessary for members to fly across the country to meet each year?

I served several terms as chair of the Education Committee, and I presently serve on the Heritage Committee. Almost from the beginning, there was also a strong Graduate Student Committee, which organized useful workshops by and for graduate students at CASCA meetings. They make up a significant fraction of CASCA membership. As of this year, there is also provision for undergraduate astronomy students to join CASCA. There is a quarterly newsletter *Cassiopeia*, presently edited by Joanne Rosvick, which you are welcome (and encouraged) to read (3). The CASCA-Westar Lectureship brings Canadian astronomers to smaller centres in Canada—perhaps including yours (4). CASCA is also a supporter of Canada's national bilingual education program *Discover the Universe* (5). Why re-invent the wheel when such a commendable program already exists? The annual Helen Hogg Public Lecture is jointly sponsored by CASCA and RASC, and alternates between the two societies' annual meetings.

In 2009, CASCA, RASC, and FAAQ spearheaded the celebration of the International Year of Astronomy in Canada, under the inspired leadership of Jim Hesser in Victoria. Together, we reached almost two million Canadians, in over 3,700 events. That doesn't include the engaging transit posters in Toronto and Montreal, and many other media events. Partnership works!

CASCA has a charitable arm, CASCATrust (6) to support these and other education and outreach activities, including student travel and presentation awards. It deserves more support. Many generous donors have also helped to endow a set of eight awards to honour the outstanding work and achievements of Canadian astronomers, including the Qilak Award for excellence in communicating astronomy to the Canadian public.

CASCA was born in tumultuous times. In the 1960s, Canadian astronomy was bitterly divided by "the Mount Kobau controversy." Plans had been developed to build a 4-m telescope—to be named the Queen Elizabeth II Telescope—on this site in B.C. But a significant segment of the astronomical community was concerned about the low amount and poor quality of clear sky at this site, and favoured a site under the pristine skies in Chile, where other large observatories were being built. The QEII telescope was cancelled in 1968. Feelings ran high. Fortunately, a scientific cooperation agreement between Canada and France led to the building of the Canada-France-Hawaii Telescope, which opened on Mauna Kea in 1969. Canada was in the astronomical big leagues.

One thing that has brought the Canadian astronomical community together has been CASCA's leadership in a series of decadal Long Range Plans (LRPs) for Canadian astronomy. The first was in 2000, with a mid-term review a few years later. The most recent was published this year (7). It was the result of extensive member and committee input, white papers, virtual discussions, and town-hall meetings on every aspect of astronomy. It "sets out priorities and recommendations that will ensure that Canadian astronomy sits at the forefront of knowledge and discovery over the next ten years, that the associated community of scientists, staff, and students will succeed and flourish, and that this work benefits the Canadian economy and Canadian society." The 2021 LRP includes a very strong commitment to broad-based professional development for young astronomers, and to equity, diversity, and inclusion, focused on making significant structural changes to our workplaces and communities. Recognizing and supporting the connections between astronomy and Canada's Indigenous peoples was another focus. We owe a great debt to the LRP 2021 co-chairs Pauline Barmby and Bryan Gaensler, and the other members of the planning committee. Their 89 recommendations are bold and ambitious.

But how to implement these decadal plans? LRP 2000 led almost immediately to the Canadian Coalition for Astronomy, which brought in government and private sectors. The Association of Canadian Universities for Research in Astronomy (ACURA), founded a few years later, linked the university sector. Subsequent LRPs also included the participation of the Canadian Space Agency (CSA) and the Canada Foundation for Innovation (CFI) which, along with NRC and the Natural Sciences and Engineering Research Council (NSERC), play key roles in supporting astronomical research.

With 581 members, CASCA is small enough so that its annual conferences can be held on university campuses, unlike the much larger AAS whose meetings have to be held in cavernous conference centres. CASCA 2020 was to be held at York University, but the planners quickly pivoted to put the conference on-line, which they did very successfully. CASCA 2021, originally planned for Penticton but also necessarily virtual, was even better. It included the full range of oral and poster papers, prize lectures, discussions about facilities, projects, and other issues—even social events, and attracted about 500 participants. It ended with a celebratory birthday "banquet," to which we charter members were invited. It was great to see so many old faces there, including many who also played important roles in the RASC. Many thanks to Dennis Crabtree and his team for their fine organizational work. Virtual conferences have many advantages!

For me, CASCA is just the right size—big enough to do great things (like LRP 2021) but small enough to connect with its members. Read the Executive Summary of LRP 2021. You will agree that astronomy in Canada, and CASCA in particular, have a very bright future. ✶

Endnotes

1 casca.ca/?page_id=193
2 casca.ca/?page_id=53
3 casca.ca/?cat=4
4 casca.ca/?page_id=7598
5 discovertheuniverse.ca
6 casca.ca/?page_id=63
7 casca.ca/?page_id=11499lrp202

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John Percy FRASC is Professor Emeritus, Astronomy & Astrophysics and Science Education, University of Toronto, and a former President (1978–1980) and Honorary President (2013–2017) of the RASC, and a charter and continuing member of CASCA.

Dish on the Cosmos

A Quenched Galaxy

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

The galaxies we see in the local Universe have been evolving steadily since the Big Bang. There are many different agents that drive galaxy evolution, but one of the most dramatic actors in evolution is the environment in clusters of galaxies. Galaxy clusters are the largest-known structures in the Universe, having huge masses and including hundreds or thousands of individual galaxies. Our current model of the Universe on the largest scales envisions a web of galaxies, and the galaxy clusters are found where the strands of the filamentary web intersect. The space between the galaxies of a cluster is hot and filled with a relatively dense million-degree plasma that is the product of the galaxies gathering. This hot bath of plasma shapes the cluster members, starving them of the cool gas that is required for the galaxies to grow. The most dramatic effects of this plasma on galaxies are seen when a galaxy gets drawn into a cluster for the first time. In this first passage into the cluster, a relatively normal star-forming galaxy has its cold gas stripped out as it fights the literal headwinds of the plasma. The details of this process are fascinating, and we can directly observe the process of galaxy "quenching" in clusters. New observations of the nearby galaxy NGC 4921 have captured images of a quenching system including the first evidence of displaced gas falling back into the galaxy, potentially keeping the galaxy forming stars for a little longer than expected.

Broadly, there are two types of galaxies in the Universe, which we have come to describe as either "star forming" or "quenched." Edwin Hubble originally classified galaxies based on their shapes on a scale ranging between elliptical galaxies and spiral galaxies. However, our continued study of galaxies has come to suggest that the main change that a galaxy experiences over its life is in how much star formation is happening within it. Galaxies grow their visible mass by forming stars, but at some point in their evolution, they appear to undergo a process of "quenching" where their star formation activity ceases, they continue to evolve passively, and their stellar population slowly ages.

To understand the evolution of galaxies, it is important to understand how stars form and evolve. Star formation occurs when cold clouds of molecular hydrogen gas collapse under the effects of gravity. The net effect of this complicated process yields young stars with a broad range of different masses, and the mass of a star sets its future. High mass stars (>10 times the mass of our Sun) consume their nuclear fuel quickly, shining bright and blue for just a short period of time. High-mass stars only live for a comparatively short time and end their lives in dramatic supernova explosions. Star formation forms relatively few high-mass stars, but these stars play an outsized role in setting the appearance of galaxies. Low-mass stars (<0.5 solar masses) are the opposites in almost every regard. These stars consume their fuel at a much slower pace and are individually faint and red. However, star formation produces many more low-mass stars compared to high-mass stars. They cannot compete with the brightness of the blue, high-mass stars. However, their long lives mean that they are what we see if there are no more high-mass (blue) stars in the galaxy. When we see a blue galaxy, we interpret that as a sign that the galaxy has had recent and usually continuous star formation. This also explains why we refer to red galaxies as "quenched" systems. Some physical effect has starved the quenched galaxy of the fuel that is required to star formation, so all we see is the low-mass stellar population that is slowly aging.

One way to quench a galaxy is to push its cold gas out of the system. We think this is what happens in galaxy clusters from the effects of the hot plasma that gathers in the clusters. Galaxy clusters develop where the dark matter of the Universe collects into large condensations because of dark matter's gravitational pull on itself. Ordinary matter, like the gas and stars in galaxies, follows the gravitational pull of the dark matter, falling into the forming cluster. When several galaxies fall into the cluster, they pass by each other and frequently collide with each other. These near misses and direct hits produce bursts of star formation, as well as stimulating jets from the central black holes in these systems. The supernova explosions from star formation and jets from the black holes fill the space between the clusters with the million-degree plasma that forms the intercluster medium (ICM).

The ICM is responsible for stripping the cold gas out of a galaxy that is falling into the cluster for the first time. In isolation, galaxies tend to form their stars continuously over their lifetime. This steady evolution slowly turns their cold gas into stars, and the cold gas is replenished slowly from the warm gas that is slowly raining onto the galaxy, leftover from the Big Bang. Thus, when a galaxy falls into a cluster, it usually has a fresh, blue appearance and a rich supply of cold gas that is actively forming stars. In falling into the cluster, the galaxy experiences a strong headwind as it gets pulled by gravity through the ICM. As the ICM blows through the galaxy, it meets the cold gas and steadily blows on the cold gas, heating and disrupting the star-forming clouds. The stars in the galaxy are essentially unaffected. Compared to the star-forming gas, the stars are much higher density and plough through the ICM with no changes. By means of analogy, the air from a box fan readily blows apart a smoke cloud (the gas clouds) but would not noticeably affect the motion of a bowling ball (the stars).

Figure 1 — Combined optical (background) and millimetre-wave (highlighted overlay) image of the nearby galaxy NGC 4921. The optical data are from the Hubble Space Telescope *and the millimetre-wave image is from the Atacama Large Millimetre/submillimetre Array. The image displays a galaxy in the process of having its cold, star-forming gas being stripped out by a headwind from the hot plasma in the galaxy cluster. The wind is blowing in from the upper-right corner of the image, stripping out the cold gas and concentrating it into an arc of gas visible in the ALMA map. Image credit: Credit: ALMA (ESO/NAOJ/NRAO)/S. Dagnello (NRAO), NASA/ESA/Hubble/K. Cook (LLNL), L. Shatz*

The recent observations of NGC 4921 catch this process in action (Figure 1). This galaxy is just entering the Coma cluster for the first time and clearly reveals the ICM stripping the cold gas from this galaxy. The image shows an optical image of the galaxy with visible dust lanes and new data from the Atacama Large Millimetre/submillimetre Array (ALMA) overlaid on top of the image. The ALMA data highlight where the star-forming molecular gas can be found. There are several galaxies visible in the image, some of which are members of the cluster, as well as some background galaxies. The dust that appears as dark features in the optical image is mixed in with the dense gas, giving some clue as to where the star-forming gas is usually found. Indeed, for most of the image, there is good agreement between where we see dust lanes and where ALMA reveals there to be molecular emission. The images made by ALMA do not cover the lower-left corner of the galaxy, so the lack of emission seen by ALMA in this part of the image is expected.

In this image, the ICM is blowing in from the direction of the upper-right corner, flowing toward the lower-left corner. Carefully examining the optical image reveals that the upper-right corner of the galaxy has no visible dust or molecular gas in that part of the galaxy. The ICM has blown all this star-forming material out toward the other corner. There are also very few young stellar clusters in the upper-right corner, which appear as bright dots elsewhere in the optical image, which also points toward in-progress quenching of star formation. The bright limb of molecular gas in the centre of the galaxy shows where the ICM has gathered and compressed the molecular gas, leading to a burst of star formation: a galactic going-out-of-business sale. Over time, the ICM will push all this cool material out of the galaxy, leading to the quenching of star formation.

The final noteworthy feature of the image are three clouds in the top of the image that are seen in the ALMA emission but do not have an associated dust feature in the optical image. These are peculiar, since usually the dust extinction and emission in ALMA are usually found together. The dark dust features happen because the dust is blocking bright starlight coming from behind the dust cloud. Since these clouds from ALMA have no associated extinction, these clouds are probably found behind the galaxy, where they have been blown out of the plane of the galaxy by the ICM. Given measurements of the cloud velocity from the Doppler shift of the ALMA emission, these clouds are expected to be falling back in toward the centre of the galaxy. This material is the first identified case of a gas cloud that has not been completely blown free of the galaxy by the ICM. The amount of such material helps provide limits on how long a galaxy can sustain star formation after entering a galaxy cluster.

While this is a nearly perfect case of a galaxy caught in the act of being quenched by entering a galaxy cluster, future work can help reveal different stages of the quenching process. The high resolution of the ALMA telescopes promises excellent opportunities for such gorgeous studies moving forward.

More information: https://arxiv.org/abs/2107.11731 ✶

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

Imager's Corner

Removing Background Banding

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

The idea for this edition's column came from a friend as we were discussing how to remove a brighter area in the image background. Let me say up front that it is much, much, much better to not have produced the problem in the first place, but if you make it to the final steps in your process and find that there are blotches in your background or some minor banding, then this technique could save you from going all the way back to the beginning of your workflow. This won't work on all types of images; you need an image where only the background is involved. The best subjects are star clusters or small galaxies where there is a lot of sky background visible in the image.

Let's start with an image of NGC 7331 I took a few years ago at the Nova East star party. My camera sat in my car all day and the temperature inside the vehicle climbed to well over 40 °C. As a result, when I started imaging, the camera produced quite a bit of banding and noise.

What we want to do here is to remove the banding and *blobs* in the background without making a mess of the stars and galaxies. The technique is a bit of a cheat and basically covers up the darker bands in the image. We start by sampling one of the brighter background blobs or bands in the image. Here I sampled the background just to the lower left of the main galaxy and it has an RGB intensity of 38, 50, 32. Now we

Figure 1 — Image of NGC 7331 with a substantial amount of banding.

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

Figure 2 — Fill layer, used to cover up imperfections in the background.

make a fill layer with a RGB value of 50, 50, 50, the brightest of the three values measured in the previous step, Figure 2.

The next step is to make a layer stack with the original, stretched image on the bottom and the fill layer on top. Set the blend mode to lighten as shown below using *Images Plus*, Figure 3.

The lighten combine covers up the darker background blobs and bands, producing an overly smooth background that looks a bit artificial as shown in Figure 4.

To improve the background and make it look more natural, just add a bit of noise to the fill layer. There is no rule of thumb as to how much noise to add so basically add enough so you

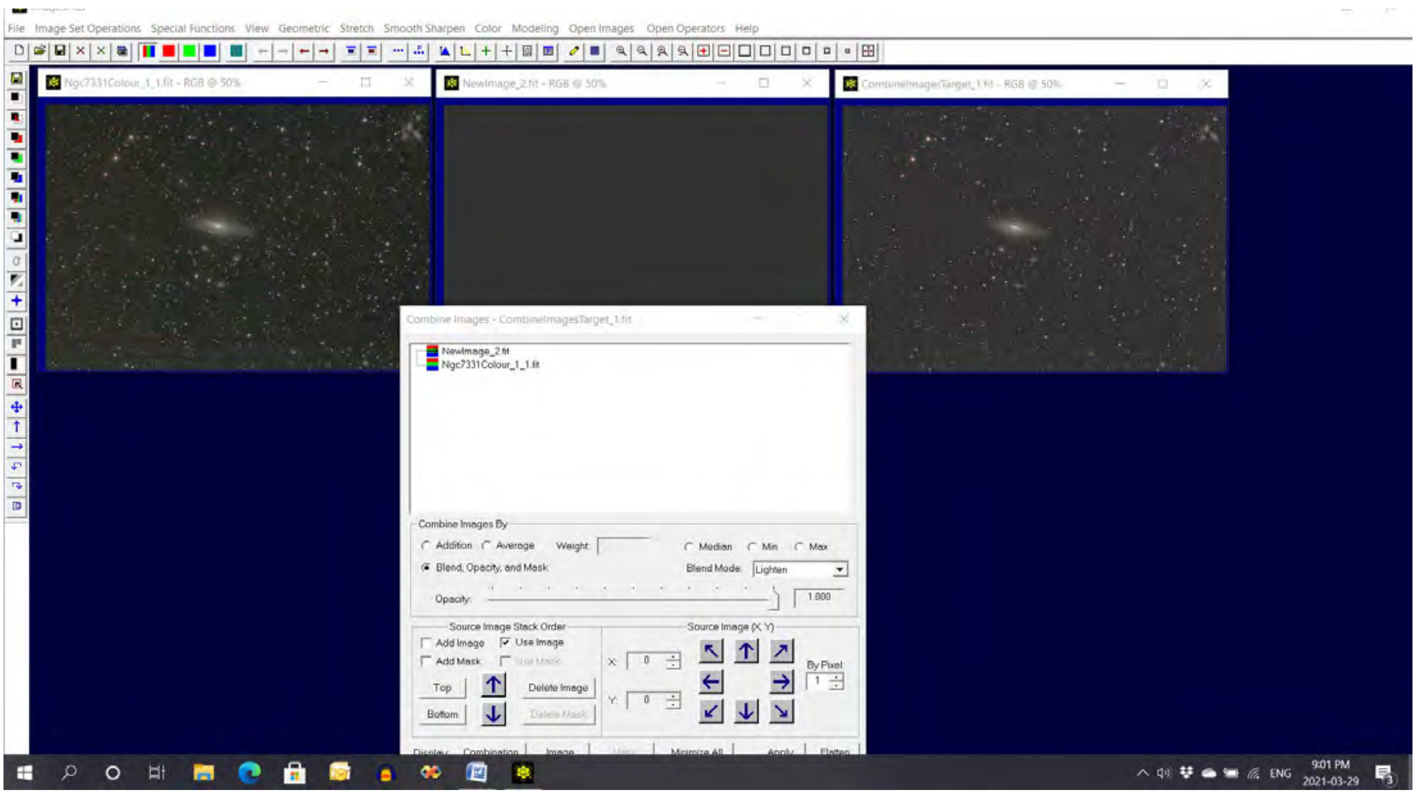


Figure 3 — Creating the image layer stack with a lighten blend mode set for the top layer

Figure 4 — Layer stack looks slightly unnatural due to the very flat background.

Figure 5 — Adding a little noise to the top layer improves the blend to produce a more normal looking background.

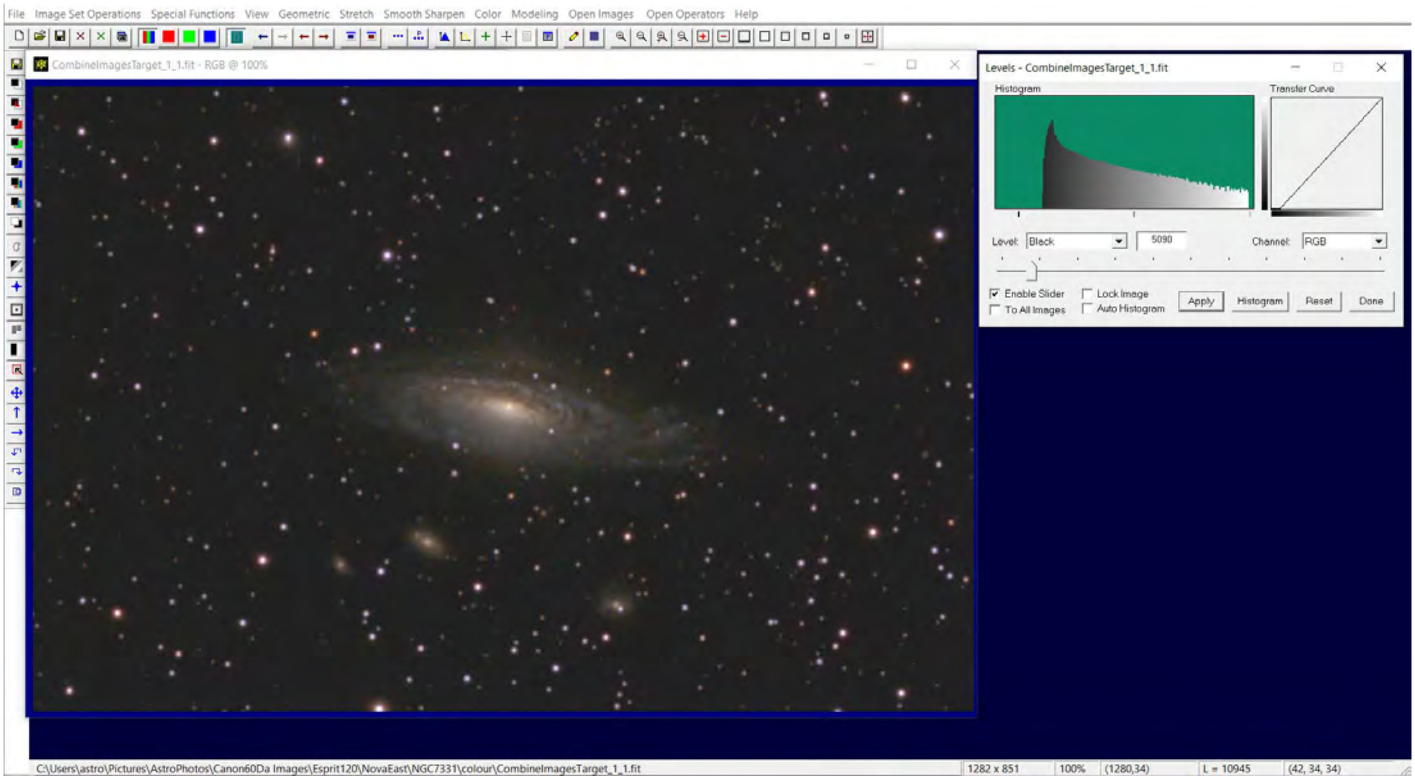


Figure 6 — Use your favourite stretch function to darken the background a bit. Here I used levels to set the black point.

Figure 7 — Original stretched image with lumpy, noisy and banded background.

Figure 8 — Processed image

are happy with the background and ensure that the galaxies and stars blend properly into the rest of the image. Here I used a standard deviation of 3 to add Gaussian noise to the fill layer.

With the background de-banded and much of the noise covered up with the fill layer, the stack is flattened and the final background level set using your favourite stretch. Here I used levels to set the black point for the image, Figure 6.

Compare a crop of the original stretched image in Figure 7 to the processed version in Figure 8 below and I think you will see the improvement.

Remember, this column will be based on your questions so keep them coming. You can send them 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.

RASC Awards for 2021

Chris Gainor, past president & chair, Awards Committee

Fellow of the RASC

This is the Society's most senior award and the highest honour the Society can pay to a member. A Fellow's service and contributions to the Society must have had a significant positive impact on the work of the Society over an extended period, beyond that of the Service Award. Fellows must have contributed to the Society's success in attaining its stated objectives, mission, and vision, with at least half of their service at the Society level, in addition to any contributions at the Centre level.

There are three outstanding individuals who are being recognized as Fellows of the RASC.

Roland Dechesne, Calgary Centre

Mr. Dechesne has been a member of the RASC since 1977 and has a long record of service at the national level and with the Calgary Centre. He has been involved in developing social media for both the Calgary Centre and the National RASC. At the National level, Mr. Dechesne served on National Council and as the longtime chair of the Membership and Promotion Committee. More recently, he became chair of the RASC Inclusivity and Diversity Committee. He has served three terms as Calgary Centre President, and won an RASC Service Award. Mr. Dechesne is also known as an active promoter of public outreach activities and for his work on Light Pollution Abatement in southern Alberta. He was instrumental in having the Ann and Sandy Cross Conservation Area recognized by the RASC in 2015 as the very first Nocturnal Preserve in Canada.

James Edgar, Regina Centre

As he was winding down a 40-year career with CN Rail around Western Canada, Mr. Edgar joined the RASC in 2000. A resident of Melville, Saskatchewan, Mr. Edgar didn't take long to make his presence felt at the national level when he became proofreader for the *Journal* of the RASC upon joining and for the *Observer's Handbook* in 2001. Four years later, he became Assistant Editor of the Handbook, and in 2016, he became the eighth editor of the Handbook, a position he still holds today. In 2006, he became production manager of the *Journal*, another job he still carries out today. Mr. Edgar also served on National Council, the RASC Board of Directors, two years as Recorder of National Council, National Secretary for seven years starting from 2007, and National President for two eventful years from 2014 through 2016. He already holds an RASC Service Award for his many contributions to the Society.

Michael Watson, National Member

Mr. Watson has been a highly active member of the RASC since he joined in May 1970. Before he became a National Member, Mr. Watson was a longtime active member of the Toronto Centre, and he has served the RASC at the national level in many capacities. He is currently serving as the Society's legal counsel and as Second Vice President for the second time as a member of the RASC Board of Directors. As chair of the Constitution Committee, he is continuing his work of improving the RASC's By-Laws and Policy Manual. He has also served as First Vice President and as the Society Treasurer, and he has been awarded the Society's Service Award, the Simon Newcomb Award, and the President's Award. Mr. Watson is also known as an outstanding observer and astroimager. As part of his love of chasing eclipses, Mr. Watson has played a key role in organizing many Society eclipse expeditions to various parts of the world.

Service Award

The RASC Service Award is a major award of the Society given to a member in recognition of outstanding service to the Society and/or a Centre, rendered over an extended time of at least 10 years.

Diane Bell, Victoria Centre

Ms. Bell spent a little over a decade as one of the Victoria Centre's most energetic and popular volunteers until her unexpected death late in 2020. Upon joining the Victoria Centre, she developed an encyclopedic knowledge of the sky that she happily shared with members of the public at Saturday night viewing events at the Dominion Astrophysical Observatory, observing at the Victoria Centre Observatory, Astronomy Cafés, and other centre events. Her fellow members benefitted from her skills as a photographer, sketcher, musician, quilter, crafter, baker, and observer. Her constellation blanket, eclipse and astronomical COVID masks will be long remembered. Ms. Bell will always be remembered as an astronomy cheerleader with boundless enthusiasm, a contagious smile, and ready hugs.

Andrew Bennett, Okanagan Centre

Mr. Bennett was a charter member of the RASC Okanagan Centre, joining the Society when the centre was established in 1996. He was quick to volunteer, using his tech skills to lead the Okanagan Centre in developing an online presence, later serving for many years as a co-webmaster. Mr. Bennett has been a regular at outreach events for many years, enthusiastically giving of his time and knowledge, and bringing a variety of telescopes—delighting the public with views of celestial wonders. He has given a variety of presentations as the featured speaker at club meetings over the years. He has donated financially on multiple occasions and given much time to the organizational committee of the Okanagan Observatory. Most recently, Mr. Bennett has been a strong advocate for the establishment of a robotic telescope at the observatory.

Zoltan Boda, Okanagan Centre

A former school teacher, principal, and administrator, Mr. Boda established himself quickly as an eloquent, thoughtful, and often humorous contributor to club discussions. He served as centre treasurer from 2006 to 2014, and proved himself both capable and dedicated. When accounting became more complex, requiring documentation of grant revenue, donations, and charitable receipts, Mr. Boda was equal to the task. When discussions began surrounding the creation of a new club observatory, he jumped in as a full participant and could be found on site in any of several roles: operating a diesel packer helping to level gravel, spreading ground cover, installing the entry gate, leading installation of amphitheatre seating, and lending a hand to various other maintenance tasks. Informally, the entranceway to the observatory became known as Zoli's Road, recognizing his astute input in the choice of an S-curved route joining the nearby secondary highway and the observing field.

Darrell Chatfield, Saskatoon Centre

Mr. Chatfield has been a member of the Saskatoon Centre since 1996. His contributions to the Centre have been invaluable. Darrell was a founder of, and has served on, the Saskatchewan Summer Star Party Committee every year since its inception in 1997. He is always present at Centre-sponsored public star-nights and events, almost never missing an opportunity to participate. Mr. Chatfield is also a founder and builder of the Sleaford Observatory and has provided yearly care, maintenance, and planning for the observatory's upkeep. He is also a fine observer, earning both the Herschel 400 and Herschel 400 II certificates from the Astronomical League, and the Messier and FNGC certificates from the RASC.

Paul Delaney, Toronto Centre

Dr. Delaney has arguably become the face of astronomy to the Canadian public. Since joining York University's Department of Physics and Astronomy in 1986, he has become a frequent television and radio commentator on astronomical events. Now a University Professor and Director of the Allan I. Carswell Astronomical Observatory at York, Dr. Delaney is a dedicated and enthusiastic astronomy educator. He has been a member of the RASC since 1980, and served as Toronto Centre's Vice-President for Programs from 2009 to 2020, where he arranged for regular speaker night presentations and gave many of them himself. Dr. Delaney is well known for his outreach activities, including anchoring the RASC's 150th Anniversary Star Party in 2018. He has won the Canadian Astronomical Society's Qilak Award, the 2017 Klumpke-Roberts Award of the Astronomical Society of the Pacific, and the 2010 Sanford Fleming Medal of the Royal Canadian Institute.

Ellen Dickson, Saskatoon Centre

Ms. Dickson has been active with the Saskatoon Centre since 1997 and became an associate member in 2013. Her contributions to the Centre have been invaluable. She was a founder of, and has served on, the Saskatchewan Summer Star Party Committee every year since its inception in 1997. Ms. Dickson is always present at Centre-sponsored public star-nights and events, almost never missing an opportunity to participate. Ms. Dickson has represented the Saskatoon Centre at Edmonton's Beaver Hills Dark Sky Preserve celebrations. She has also attended at least a dozen General Assemblies as an ambassador for the Saskatoon Centre.

Leslie (Les) Dickson, Saskatoon Centre

Mr. Dickson has been a member of the Saskatoon Centre since 1997. His contribution to the Centre has been invaluable. Mr. Dickson was a founder of, and has served on, the Saskatchewan Summer Star Party Committee every year since its inception in 1997 has held the position of rotating chair for the committee several times. He has also served as president of the centre for three terms. He is also a founder and builder of the Sleaford Observatory, helping to find the site and participate in the physical building. He is always present at centre-sponsored public star-nights and events, almost never missing an opportunity to participate. Mr. Dickson has represented the Saskatoon Centre at Edmonton's Beaver Hills Dark Sky Preserve celebrations. He has also been the Centre's National Council Representative for many years.

Blair MacDonald, Halifax Centre

As a member of the RASC for 30 years, Mr. MacDonald has become very well known at the Halifax Centre and around the Society for his expertise as an astroimager. He has become known as a mentor for many astroimagers in the Halifax Centre. His images and articles have appeared in many RASC publications, and he has served on the RASC Astroimaging Committee, and helped draw up criteria for RASC astroimaging certificates and the deep sky certificate. Mr. MacDonald has also been active in public outreach activities around Nova Scotia, and he has served on the executive of the Halifax Centre, chaired the Nova East Star Party for three years and assisted many other times.

Ronald (Ron) Waldron, Saskatoon Centre

Mr. Waldron has been a member of the Saskatoon Centre from 1970 to 1985, and again since he rejoined in 2002. As a teacher and planetarium operator, he has put stars in the eyes of countless students and trained many teachers. Even in retirement Mr. Waldron continues to be invited into schools to present star shows inside the travelling planetarium. He has held the positions of president and vice-president and has always participated in the long-term planning and welfare of the Saskatoon Centre. In retirement, he is acting as an aurora tour guide at the Churchill Northern Studies Centre in Churchill, Manitoba for fly-in visitors during aurora season.

Ian Wheelband, Toronto Centre

While Mr. Wheelband has been a member of the RASC for nearly 30 years, his energetic participation in Toronto Centre activities, particularly those involving public outreach, has grown in recent years prior to his retirement from his professional work. He is known for sharing the knowledge he has developed as an astroimager, leading imaging workshops and public outreach activities at the David Dunlap Observatory (DDO) and the E.C. Carr Astronomical Observatory (CAO). Mr. Wheelband has contributed to much of the work done at the CAO and the Sue-Lora Observatory. Many of his public outreach activities have taken place in the Durham Region east of the Greater Toronto area, as well as at his retreat in Nova Scotia. Mr. Wheelband has also helped keep the Toronto Centre's finances in good shape, and played a major role in returning the DDO to the Toronto Centre.

President's Award

This award is given at the President's discretion, usually once a year, to a member or members who has/have made an important contribution to the Society.

Renata Koziol, Society Office

Renata Koziol is a long-standing staff member of the Society Office who has recently retired as our Director of Finance. Her many contributions to the financial well-being of the Society and the many tasks she undertook related to our Operations, Publications, Budgets, and Audits to name a few, exemplify her dedication to the RASC. Renata has been the resident Book of Knowledge on everything financial for the Society through three Executive Directors, many Directors, at least seven Presidents, and numerous Treasurers. She was respected by our staff, our suppliers, our contractors, our members, and the past and present Board of Directors.

Qilak Award

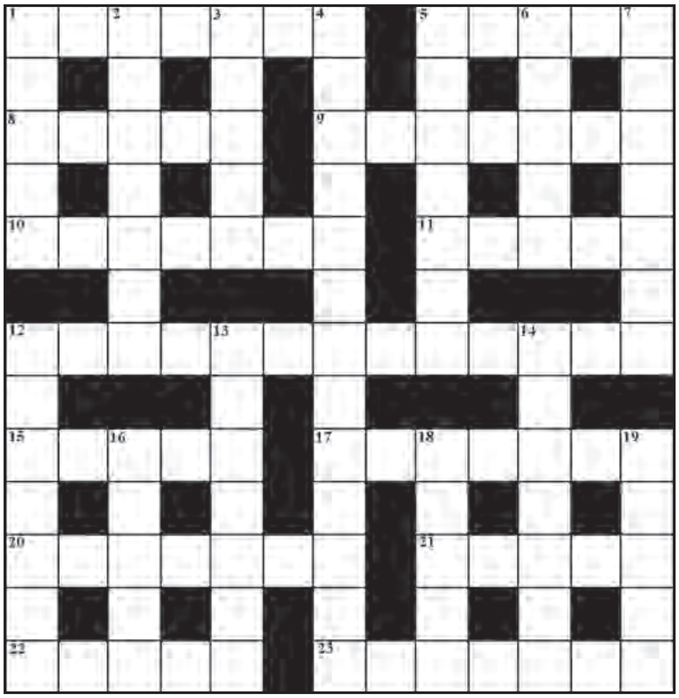
The RASC will not give out a Qilak Award this year.

Simon Newcomb Award

No RASC member was nominated this year.

Astrocryptic

by Curt Nason



ACROSS

1. Variable star around conjunction and Uranus (7)
5. The Beatles went halfway around Jupiter (5)
8. Drive part of first telescope in the backroom (5)
9. Henry Draper initially composed piece about variable star type (7)
10. Hubble successor extended the Universe in ages and ages (7)
11. Point your finger to a supplementary catalogue (5)
12. Driving Engels around to make a Barlow (9,4)
15. Cofounder of 26P with grand opening for avenging Diana (5)
17. They lived in water but one was seen around Neptune (7)
20. Left in a muddled queue, I relate to a little horse (7)
21. Dog star caught in a public harassment scandal (5)
22. Observing locations in south with backing from SETI program (5)
23. Shocked quartz mineral makes an unusual cot, I see (7)

DOWN

1. I'm up for more Spanish classes about Saturn (5)
2. A voter orbiting north star in a dolphin (7)
3. Woman or man turns in the Square (5)
4. Accredit sonic waves for black hole's surroundings (9,4)
5. Radio astronomer digitally keeping time to music (7)
6. Editor embraces fellows who correct the *Observer's Handbook* (5)
7. Early Solar System modeler is due back to hug and kiss us (7)
12. Professional astronomers have many measurements of freedom (7)
13. Little king sometimes called The Lionheart (7)
14. Ride in a whirling of the river (7)
16. Long-time aurora watchers one night in Quebec (5)
18. Outreach Chair with a stability limit (5)
19. Shatner's first word about capes (5)

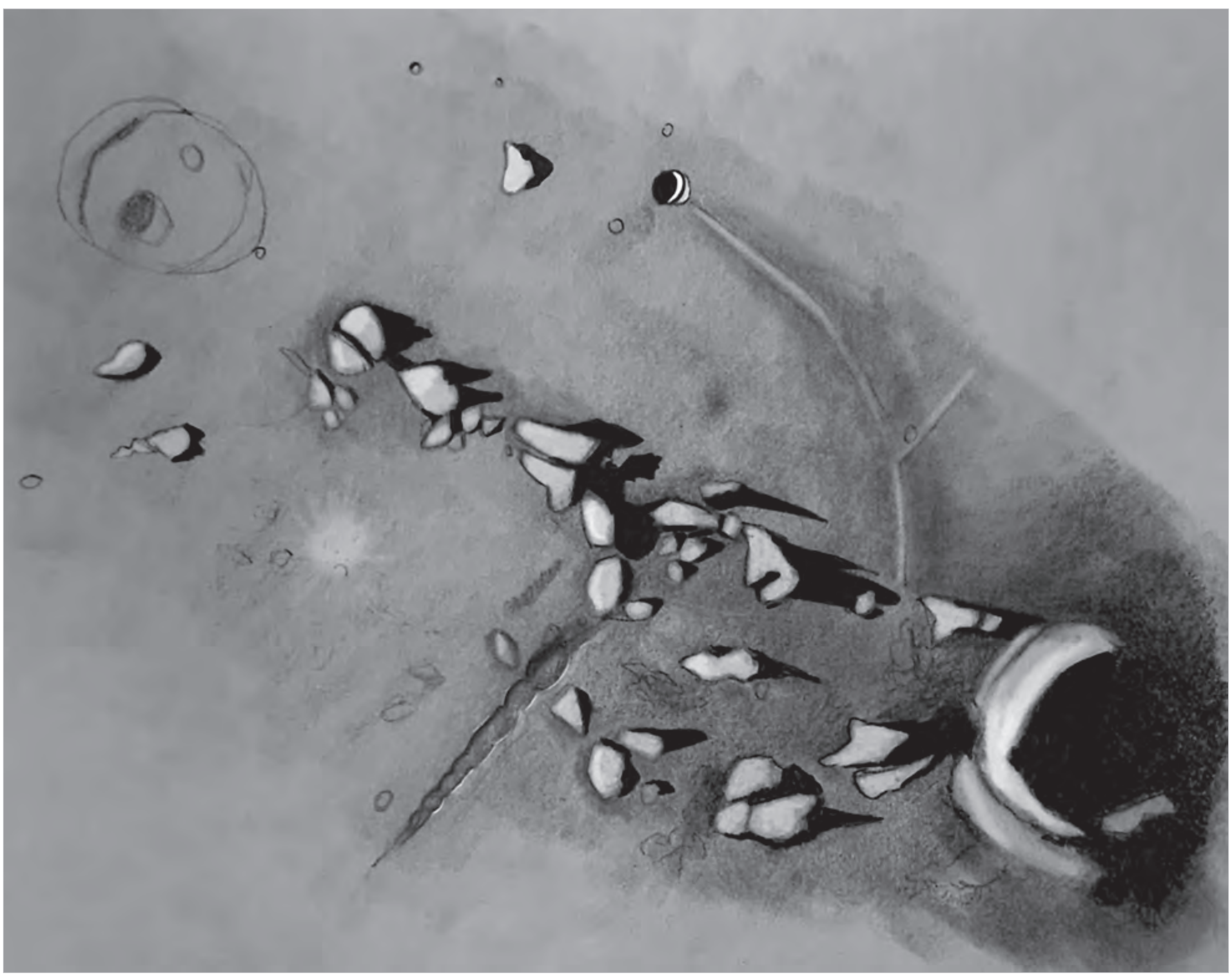
Answers to previous puzzle

Across: **1** ALRAKIS (anag); **5** RUPES (anag); **8** STILB S(rev)b; **9** UMBRIEL (anag); **10** AZIMUTH (2 def); **11** THEBE (T+Hebe); **12** NORTHERN CROSS (2 def+rev); **15** SET-UP (anag) **17** CALYPSO (c(anag)o); **20** ALBIREO (anag); **21** CRETE (hid); **2** AREND (anag); **24** STETSON (2 def)

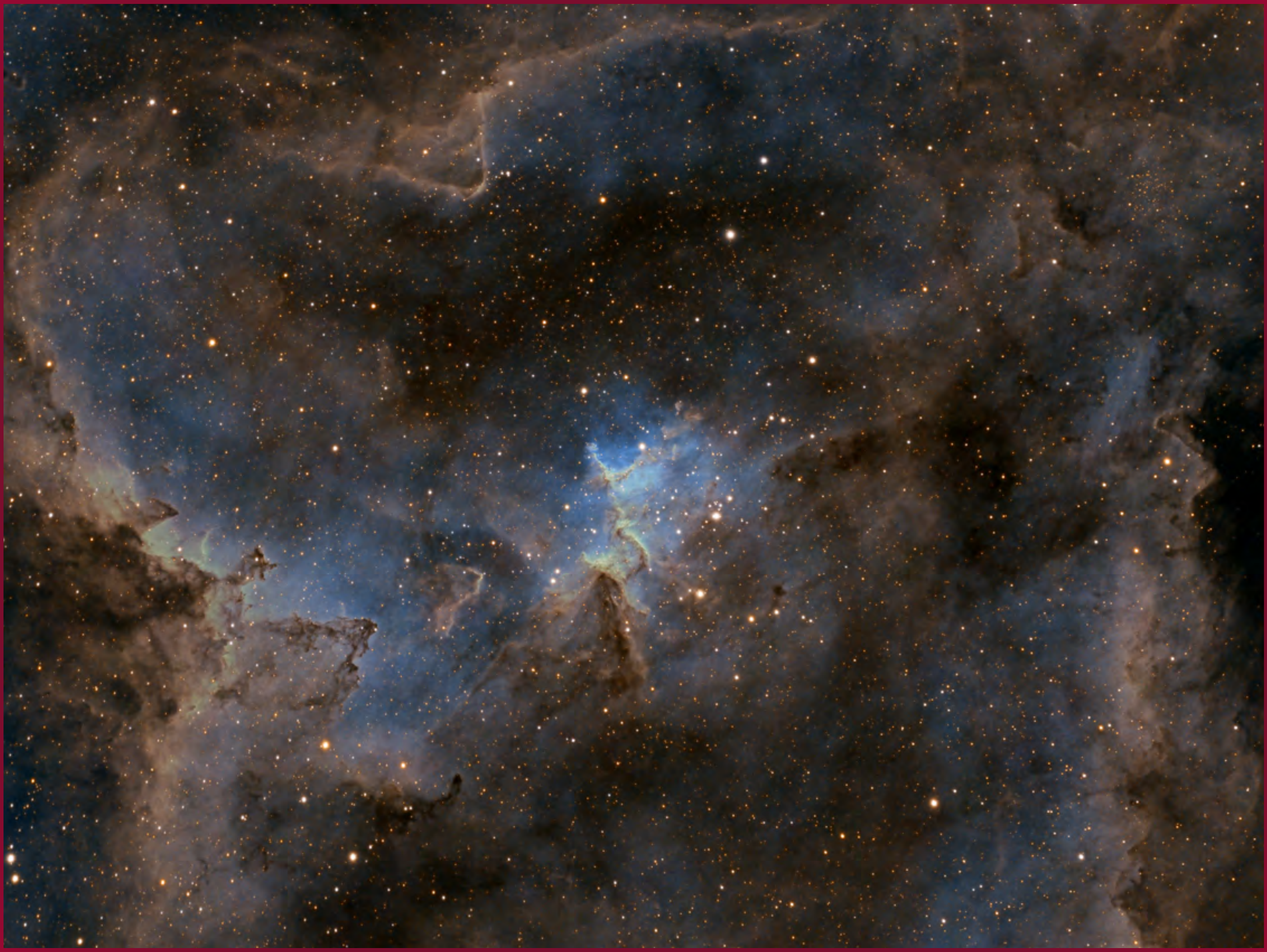
Down: **1** AT SEA (anag-ra); **2** RAINIER (hom); **3** KOBAU (2 def); **4** SOUTHERN CROSS (anag+2 def); **5** ROBOTIC (Rob+rev+IC); **6** PRIME (2 def); **7** SILVERS (2 def); **12** NUSHABA (anag); **13** HYPERED (hyper+red); **14** ORPHEUS (2 def, Lyra); **16** TABLE (2 def); **18** LOCKE (hid); **19** OCEAN (2 def)

Great Images

by Michael Gatto



Even under poor seeing conditions there is ample detail to be seen on the moon! Michael Gatto of the Halifax Centre sketched this view of the lunar landscape on 2021 March 21, at the eyepiece of his 8″ ƒ/7.5 reflector. The view is of the Alps mountains (Left to right) and the Alpine Valley (from centre to lower left), with Plato peeking out of the terminator at the bottom right. The seeing wasn't good enough to study the floor of the Alpine Valley, but still lots of interesting features to observe!



Journal

Dave Dev imaged Melotte 15 in 2019. He used an Orion 115mm APO with an ASI 1600 mono camera. Total exposure time was roughly 12 hours.